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MICROTCA BASED LLRF CONTROL SYSTEMS FOR TARLA AND NICA

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Abstract

The MicroTCA Technology Lab (A Helmholtz Innovation Lab) is preparing two turn-key Low Level RF control systems for facilities outside of DESY. The Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) is a 40 MeV electron accelerator with continuous wave (CW) RF operation. The MicroTCA based LLRF system controls the RF of two normal conducting and four superconducting cavities and cavity tuning via motors and piezo-actuators. The Light Ion Linac (LILAC) is one of the injectors for the Nuclotron-based Ion Collider Facility (NICA) in Dubna, Russia. It will provide a 7 MeV/u pulsed, polarized proton or deuteron beam. The MicroTCA based LLRF system will control five normal conducting cavities, consisting of one RFQ, one buncher, one debuncher and two IH-cavities. MicroTCA Technology Lab is cooperating with BEVATECH GmbH, Frankfurt, Germany, who designed the cavities.

This paper gives a brief overview of the design of both LLRF systems as well as the status of their assembly.

INTRODUCTION

MicroTCA is an open, modular hardware standard, based upon the Advanced Telecommunication Architecture (ATCA). It is regulated by the "PCI Industrial Computer Manufacturers Group" (PICMG), a non-profit consortium [1]. The crate standard MicroTCA.4 was developed to cater the needs of scientific equipment. It includes features, such as improved precision timing, enhanced rear connectivity and increased PCB area [2]. Low level RF control systems based on MicroTCA.4 is reliably operating in large-scale accelerator facilities, such as the European XFEL and the FLASH at DESY, Germany [3, 5].

The MicroTCA Technology Lab was founded to transfer the knowledge and expertise, gathered in decades of accelerator development and operation at DESY, to other scientific facilities as well as the industry. After its start-up phase, the MicroTCA Technology Lab is now in operation and working on various project, two of which concern the implementation of a MicroTCA-based LLRF control for installations outside of the Helmholtz Association.

THE TURKISH ACCELERATOR AND RADIATION LABORATORY IN ANKARA (TARLA)

TARLA is the first Turkish particle accelerator facility. The accelerator will deliver an electron beam to drive a free electron laser (FEL), which will generate mid to far infrared (3–250 µm) laser light. The electron beam parameters are listed in Table 1 [4]. Additionally, electron beam is provided for the production of Bremsstrahlung and fixed target experiments [6].

Table 1: TARLA Electron Beam Parameters

Parameter	Value	Unit
Beam Energy	0 – 40	MeV
Max. Average Beam Current	1.5	mA
Max. Bunch Charge	115	pC
Bunch Length	0.3 – 6	ps
Bunch Repetition Rate	0.001 – 52	MHz
Macro Pulse Duration	10 – cw	µs
Macro Pulse Repetition Rate	1 – cw	Hz
Horizontal Emittance	<15	mm mrad
Vertical Emittance	<12	mm mrad
Longitudal Emittance	<85	mm mrad

Overview of the LLRF System

The LLRF system at TARLA, similar to the system in Fig. 1, controls six cavities, two of which are normal conducting bunchers. The remaining four cavities are superconducting, Tesla-type 9-cell cavities [7], assembled pair-wise in two cryostats. One of the bunchers is subharmonic and will be operating at 260 MHz, while the remaining cavities are operated at 1.3 GHz. Additionally to the field control, the LLRF will also control the frequency tuning of all six cavities, as well as fast microphonics suppression via piezos for the superconducting cavities.

The LLRF system consists of six SIS-8300-L2 [8] digitizers, one of which will be paired with a DRTM-DS8VM1 direct sampling board for operation at 260 MHz. The remaining five boards (DRTM-DWC8VM1) will use down-mixing from 1.3 GHz to 54 MHz, which will then be sampled with 65 MS/s at a resolution of 16bits. Two DAMC-FMC25 carrier AMCs will carry two motor driver FMCs

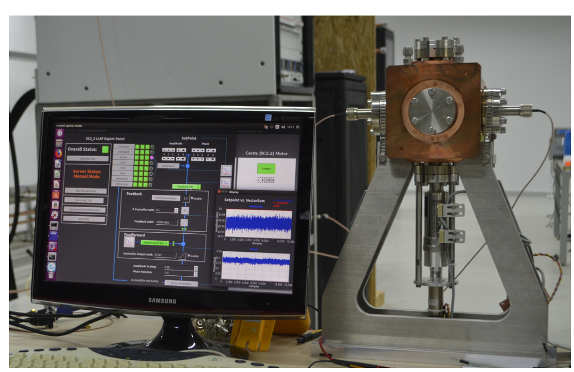

Figure 1: Controlling 1.3 GHz Buncher Cavity at TARLA.

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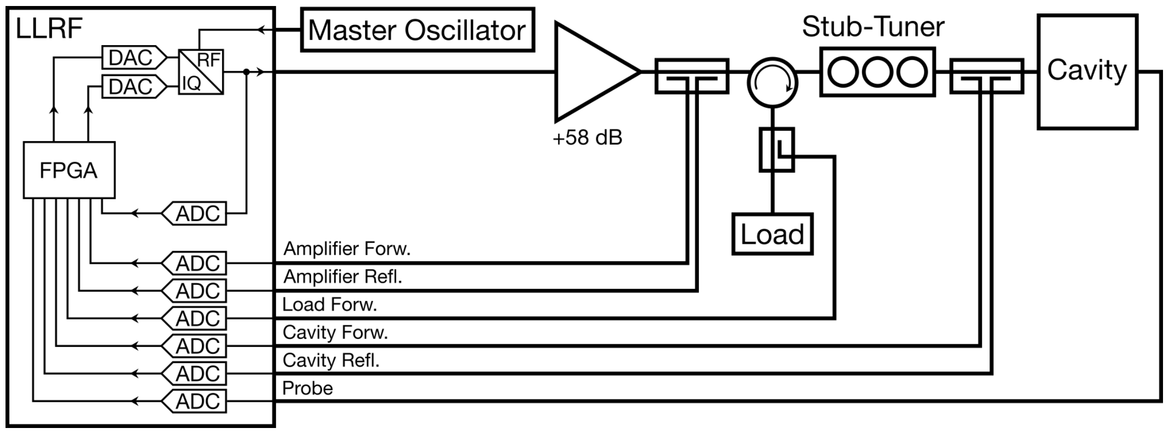

Figure 2: LLRF Setup for Commissioning at High Power.

(DFMC-MD22) each and will be paired with a DRTM-PZT4 piezo driver card.

Each cavity/control loop will have a dedicated software server, communicating directly via PCI Express with the LLRF hardware. The LLRF servers contain part of the advanced control algorithms, as well as providing access for the control system software (e.g. Control System Studio, jddd). As TARLA will use the "Experimantal Physics and Industrial Control System" (EPICS), the servers are implemented as EPICS Input/Output Controllers (IOCs), using the ChimeraTK tool kit [9]. With future upgrades and extensions in mind, instead of a crate mounted, embedded CPU card, it was decided to use a 19" industrial server, to provide enough computing resources. This "external CPU", will have its PCI Express bus extended via optical fiber to the MicroTCA.4 crate. This way, the hardware in the crate can be accessed just as it would on an embedded CPU, and the same software can be used for both solutions.

First Test Commissioning on Site

Additionally to the LLRF system, a MicroTCA.4 crate with minimum setup was assembled for LLRF development and testing. This crate was set up to conduct first tests with the MicroTCA.4–based LLRF system, and shipped to Ankara. There, the 1.3 GHz normal conducting buncher cavity was tested for the first time, using this crate. At first, the cavity was driven without amplification directly from the vector modulator of a DRTM-DWC8VM1 down convertion card.

The motor driver (DFMC-MD22) were tested by tuning the buncher, a "pillbox"-type cavity, to a fundamental mode at 1.3 GHz (see Figure 1). This was done by observing probe signal and adjusting tuner position from within the LLRF system. Technical features, like end switch functionality, were also tested during this time . During this test, stable feedback loop control was achieved.

After successfully tuning and operating the buncher at low power, high power operation was tested. Fig. 2 shows the setup for that purpose. Due to the high output power of the solid state amplifier, it was neccessary to isolate it from reflected high power due to a mismatched stub-tuner or cavity via a circulator with a water cooled load. The triple stub tuner was adjusted manually, until sufficient matching was achieved. During closed loop operation of the high power setup, a low power probe signal was observed. The source of this was later confirmed to be an issue with the probe antenna and coupler which would only be able to be solved by opening up the cavity under clean room conditions, concluding the first LLRF operation at TARLA.

THE LIGHT ION LINEAR ACCELERATOR (LILAC)@NICA

NICA is part of the "Joint Institute for Nuclear Research" (JINR) in Dubna, Russia. It conducts experiments in search of the mixed phase of barionic matter. The Nuclotron is a superconducting synchrotron, that accelerates light and heavy ion beams, alike. It is fed by two injectors, one for heavy ions, called HILAC, and one for light Ions, called LU-20. It will be replaced by LILAC, which will be constructed by BEVATECH GmbH, Germany [10].

The LILAC consists of two ion sources, one for polarized and non–polarized proton beam (see Table 2 [11]), and one for heavier elements, respectively. After a Low Energy Beam Transport (LEBT) section follows an RFQ, a Medium Energy Beam Transport Section MEBT with a buncher cavity, two IH-type accelerators and a debuncher cavity [11]. In cooperation with BEVATECH GmbH, the MicroTCA Technology Lab will deliver an LLRF system for those five cavities.

Table 2: LILAC Proton Beam Parameters

Parameter	**Value**	**Unit**
Beam Energy	7	MeV
Max. Beam Current	5	mA
Repetition Rate	5	Hz
RF Pulse Length	200	µs
Beam Pulse Length	30	µs

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Overview of the LLRF System for LILAC

All of the cavities are driven at 162.5 MHz, thus direct sampling without conversion to an intermediate frequency can be used for each cavity. The MicroTCA.4 12-slot crate is equipped with two 1000 W power supplies for redundancy. Every cavity will be controlled by a direct sampling card DRTM-DS8VM1 and a digitizer card SIS-8300-KU, equipped with an Ultrascale FPGA. As does the LLRF system of TARLA, this LLRF system will use an external CPU, too. Along the MicroTCA-based LLRF system, an off-the-shelf signal generator will be used as a master oscillator.

Status of the LLRF System for LILAC

All hardware components have been delivered to the MicroTCA Technology Lab and have been assembled in a rack. The external CPU has been set up and the PCI Express extension is working. The firmware development for the digitizer boards was recently finished and is being tested, at the moment.

Figure 3 shows the test assembly of the full LLRF system plus Master Oscillator at MicroTCA Technology Lab in Hamburg. In total the system integration is on schedule, and the LLRF system will be ready to be shipped to BEVATECH in Frankfurt am Main during Q3 this year.

Figure 3: LLRF System for LILAC, Assembled for Sytem Integration at MicroTCA Technology Lab, consisting of: 1) MicroTCA-Crate, 2) External CPU, 3) Master Oscillator.

CONCLUSION

The MicroTCA Techlab will deliver its first two turn-key LLRF systems to accelerator facilities outside of DESY, this year. The LLRF systems for TARLA and LILAC, and the status of their respective development, have been presented.

At TARLA in Ankara first tests at high power have been performed and showed promising results. The LLRF system for LILAC has been assembled and is in the process of system integration.

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