MTCA.4-based Digital LLRF Control System for CW SRF Linacs

Igor Rutkowski, Radosaw Rybaniec, Krzysztof Czuba, Lukasz Butkowski, Matthias Hoffmann, Frank Ludwig, Christian Schmidt, and Holger Schlarb

***Abstract*—The stable and reproducible generation of high average brilliance photon beam at Free Electron Lasers (FELs) requires a high-precision radio frequency (RF) regulation of the accelerating fields inside the cavities. High average power can be achieved with continuous wave (CW) operation, which minimizes Lorentz force detuning effects in superconducting resonant structures leaving microphonics and noise as the main sources of distortions.**

This paper describes the architecture of the low level radio frequency (LLRF) control system based on Micro-Telecommunications Computing Architecture (MTCA.4) platform developed by the PCI Industrial Computer Manufacturers Group (PICMG). This architecture offers manageability, reliability, and scalability which are crucial for high energy physics experiments. The hardware modules such as digitizers, down-converters (DWC), or vector modulators (VM) have been adopted from multi-channel, vector sum based systems and optimized. The field detection scheme utilizes the analog frequency shifting to an intermediate frequency (IF). Analog-to-digital conversion, and digital complex frequency down-conversion, is applied. The firmware has been optimized for minimal latency and includes programmable filters, fast proportional-integral (PI) controller for real-time suppression of distortions, set-point and feed-forward tables, and data acquisition module. The software communicates with the firmware, reads waveforms for diagnostic purposes, and abstracts hardware and firmware settings for the paneling system.

The system design process and important parameter value selection criteria are presented. The noise contribution of hardware subcomponents and other limitations of the field detection are analyzed. The digital signal processing path is split into atomic operations and inquired. The potential instability of the feedback loop due to unwanted fundamental modes of the TESLA type cavity is examined. Proposals of future developments are given, including two-tone calibration, drift calibration, and beam based feedbacks.

Manuscript received May 22,2012

I. Rutkowski, R. Rybaniec and K. Czuba are with Warsaw University of Technology (WUT), Warsaw, Poland.

L. Butkowski, M. Hoffmann, F. Ludwig, C. Schmidt and H. Schlarb are with Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany.