Migrating the LLRF controls from VME to µTCA hardware

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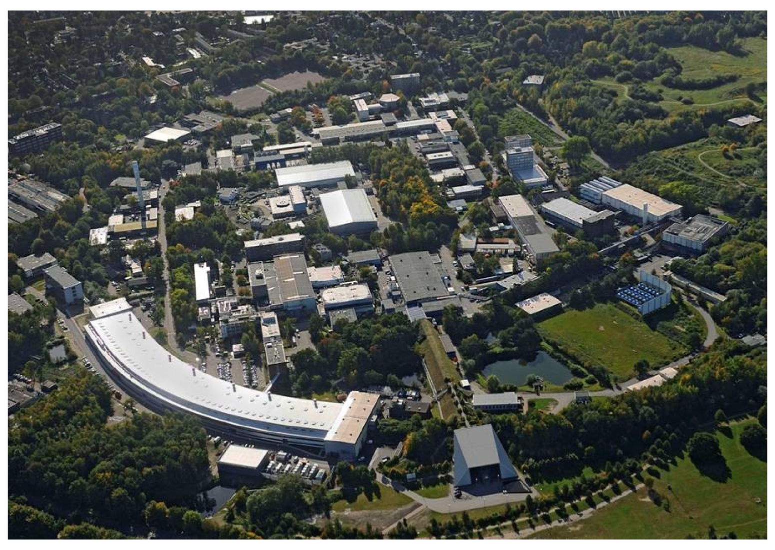
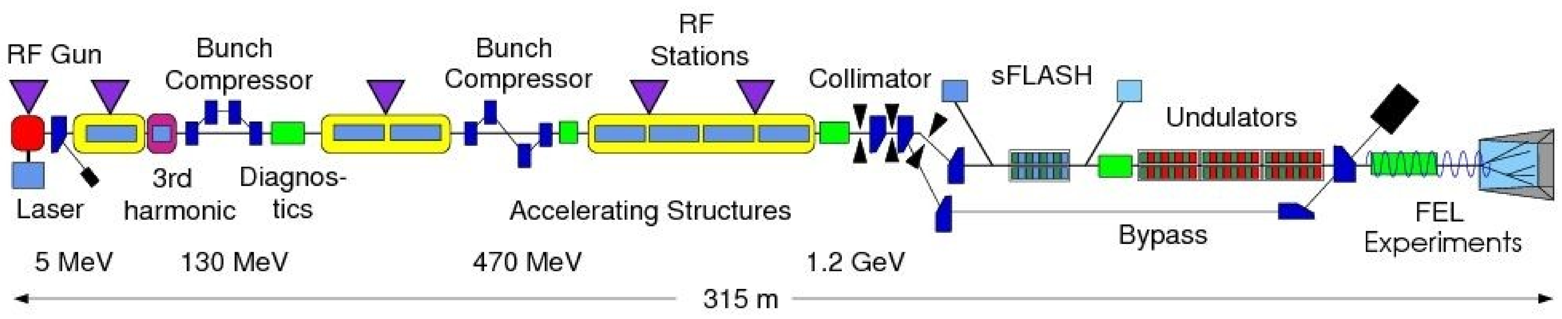
The Free electron LASer in Hamburg (FLASH)

FLASH the Free electron laser (FEL) in Hamburg at DESY (Germany) produces laser light of short wavelengths from the extreme ultraviolet down to soft X-rays. The reached peak brilliance is one billion times more intense than that of the best synchrotron light sources today.
FLASH is a high-gain FEL which achieves laser amplif cation and saturation within a single pass of the electron bunch through an undulator. The requirements for amplitude and phase stability to achieve lasing are very high, so precise LLRF regulation is needed.





Abstract

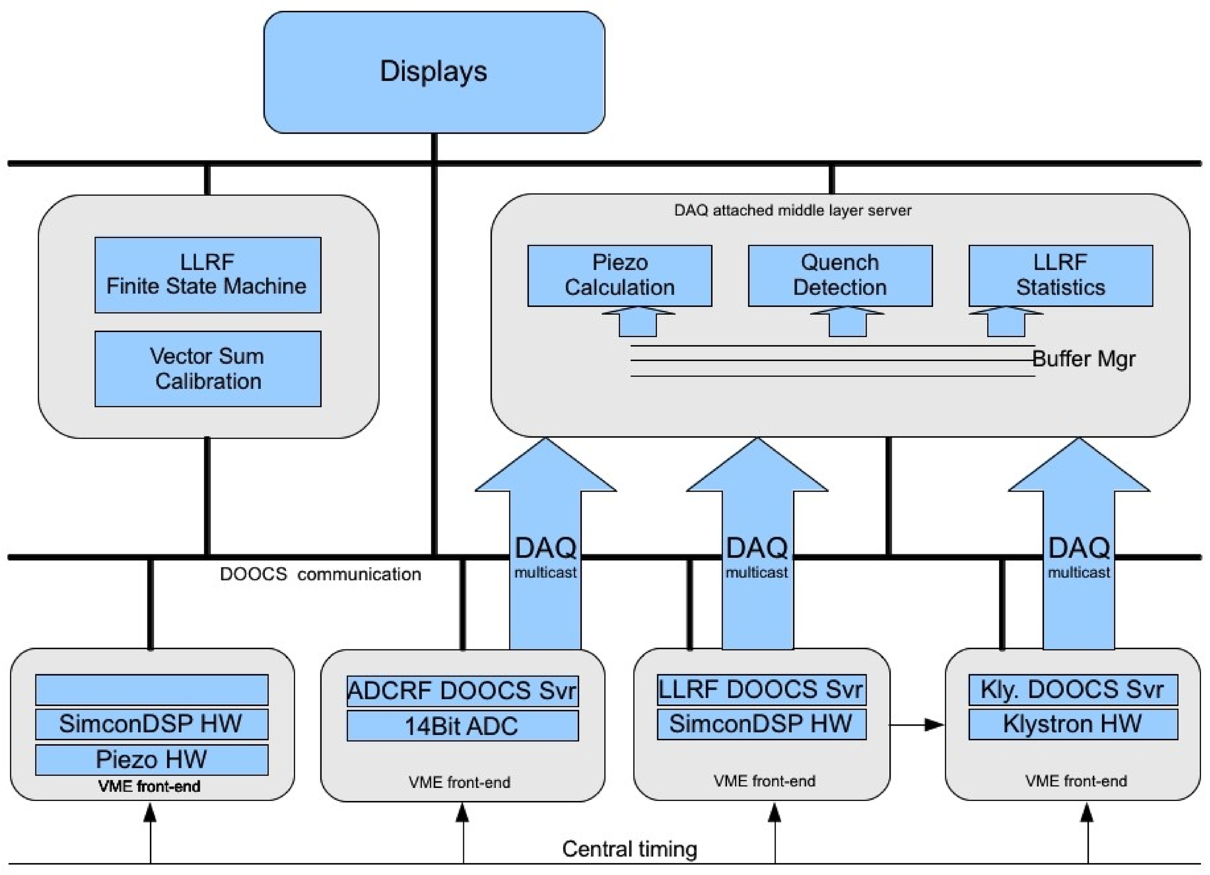
In order to operate the complex LLRF hardware and f rmware at FLASH and XFEL facilities successfully, a dedicated control system is required.
The software stack, based on the DOOCS control system, from the low level f rmware interface, front-end server and automation, up to high level calibration procedures and mass data storage will be presented. Additional attention will be given to the transition from VME to µTCA hardware.

Introduction

Over the period of the last 15 years, FLASH has evolved from a small test facility just with a Gun and one 8 cavity-accelerator module, running at about 100MeV to a photon science user facility. After the last shutdown, starting from September 2009, FLASH has been upgraded to 7 accelerator modules with eight 1.3GHz cavities each, plus a 3rd harmonic module with four 3.9GHz cavities. This set-up allows FLASH to run at a maximum beam energy of about 1.2GeV. Presently six RF stations are required to supply the gun, the 3.9GHz 3rd harmonic- and the seven 1.3GHz modules with RF.
Over this long period, the controls for the Low-Level RF (LLRF) developed with the changes of the accelerator. Many different f avors of LLRF controller hardware, starting from a pure analogue-based system for the f rst gun, a successfully used DSP system for the modules and different versions of Simcon and SimconDSP systems were developed.
A next step is now the development for a µTCA system, which is the new crate standard for the XFEL project. The migration of the DOOCS software have started about half a year ago and f rst tests were performed at FLASH at module ACC1 during August and September.

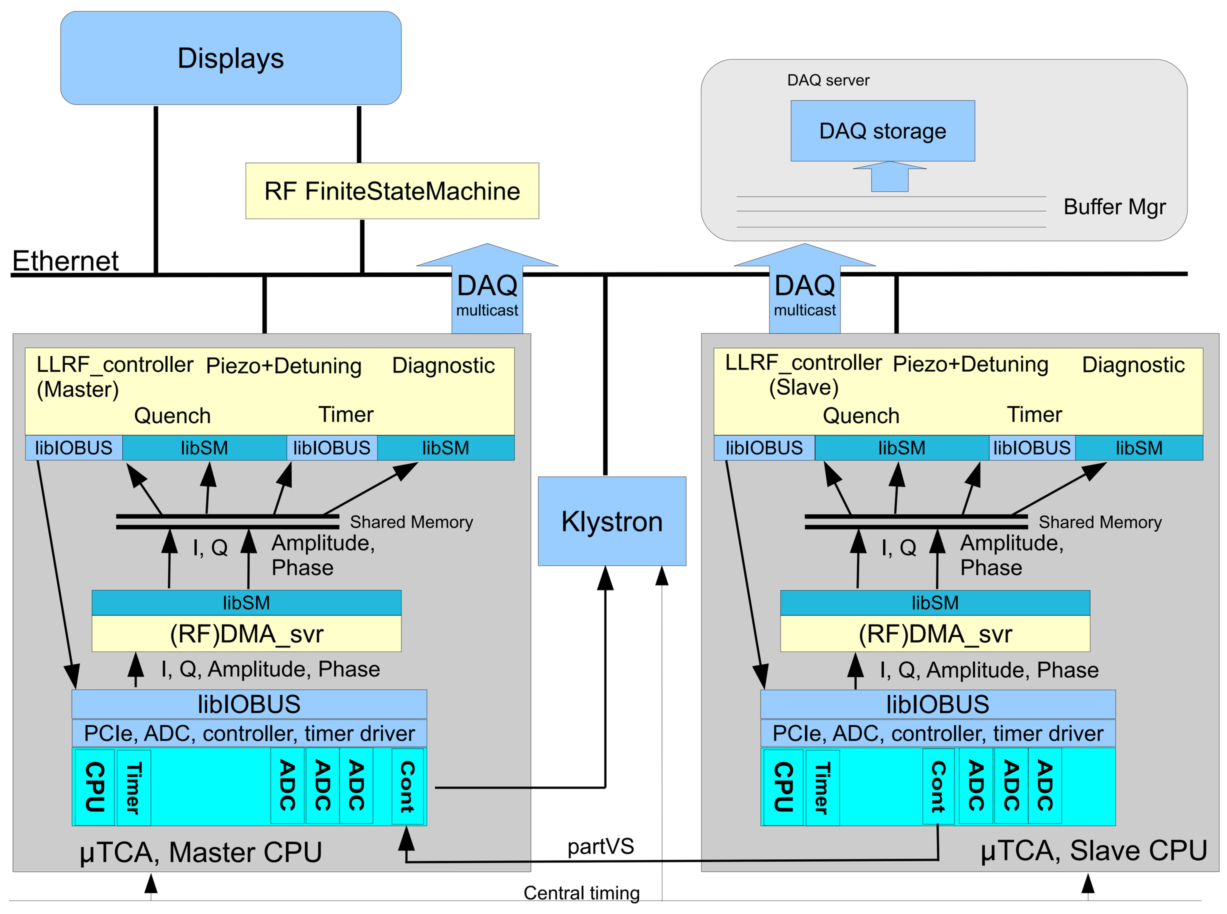
LLRF concept for VME

This picture show the overall concept for one RF station with all required front-end computer and the middle-layer server based on DAQ and standard communication. Currently 4 VME front-end computer are involved for 1 RF section for the klystron, LLRF control, LLRF monitoring and piezo controls.
Bunch-to-bunch data is send via DAQ multicast to a shared memory and used by middle layer server.
Automation server and display tool are communicating via DOOCS calls.



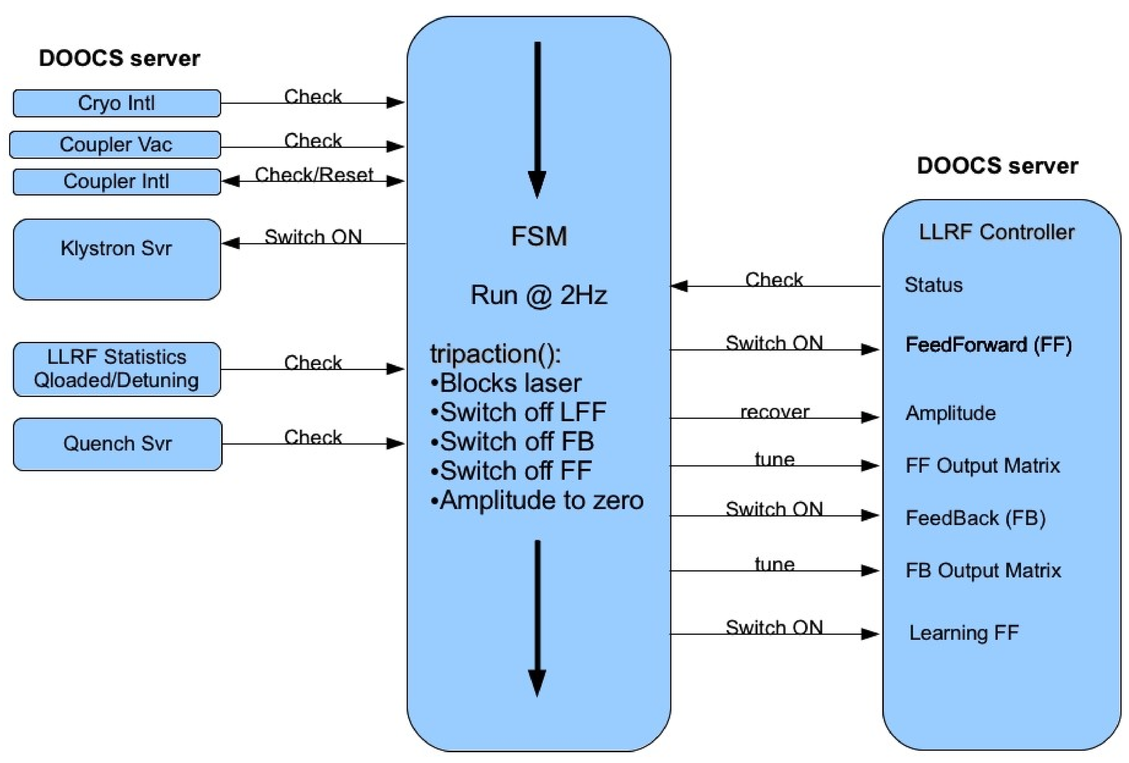
LLRF concept for µTCA

In this area, the concept for the XFEL µTCA setup is shown. It consist of two µTCA shelfs, with a CPU, a controller board, timer and several ADC cards each. To every shelf, up to 16 cavities are connected. The calculation from I/Q to amplitude and phase will be done already inside the FPGA's of the ADC. This idea and the better CPU allows to run several task, like quench-detection or diagnostics, locally on the font-end. A dedicated DMA server copies the data from the hardware to a shared memory to provide it other processes. DAQ middle-layer server are not needed anymore, but the DAQ is used for data storage.



Automation

The concept to automate the RF is based on a simple Finite State Machine FSM approach. The main purpose are to simplify the switching on/off procedure and faster recovery from trip.
This FSM is realized in the standard DOOCS server framework with the addition of the DOOCSdfsm library, which provides simple classes for monitoring f oat values, recover set-values or resetting interlocks. The FSM is the central server for the automation, it starts up or switches off the whole RF. All actions in other server are triggered by the FSM, giving the operator one central location to look for the status or problems of the RF system; no other software should switch the RF.
The FSM runs with a repetition rate of 2Hz, checking several things, like interlocks, coupler vacuum, klystron status or quenches. In case of a problem in a state, the so called tripaction() function is triggered to bring the system to a save condition. Then the FSM tries to recover the RF system.



Status

The transition of the LLRF control system is a still ongoing process, but first successful tests have been performed during the last FLASH run until mid of September. Accelerator module ACC1 was controlled by the µTCA system with beam, the feedback loop was closed and high level software,like LearningFeedForward LFF were running without problems.
Still, there are many things to be done, like firmware reloading or recovering of register settings.

This two pictures are showing the µTCA test setup for ACC1 and the jDDD control panel, which is created automatically by reading out the shelf via IPMI.