The LCLS-II Gun & Buncher LLRF Controller Upgrade

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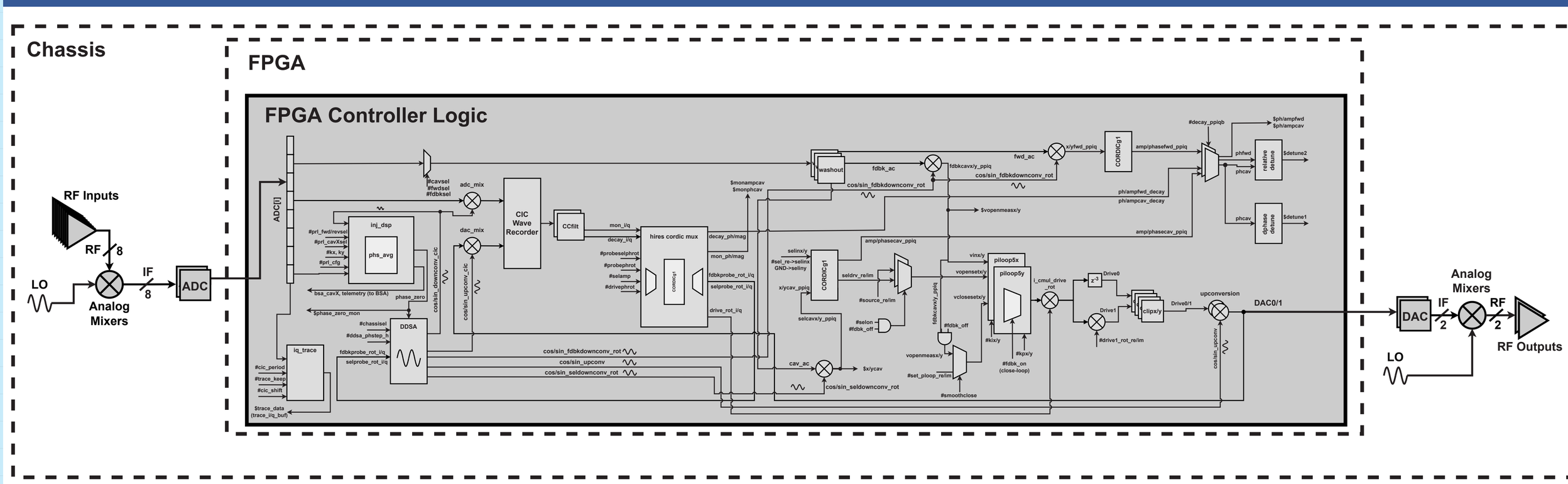
Abstract

LCLS-II is currently in its commissioning phase at SLAC. It is an X-ray FEL driven by a CW superconducting LINAC. The beam injector plays a crucial role in the overall performance of the accelerator, and is critical to the final electron beam performance parameters. The LCLS-II injector comprises of a $185.7\,\mathrm{MHz}$ VHF copper gun cavity, and a $1.3\,\mathrm{GHz}$ two-cell L-band copper buncher cavity. The FPGA-based controller employs feedback and Self-Excited Loop logic in order to regulate the cavity fields. It also features several other functionalities, such as live detune computation, active frequency tracking, and waveform recording. The LLRF system drives the cavities via two $60\,\mathrm{kW}$ SSAs through two power couplers, and thus stabilizes the fields inside the plant. This poster provides an outline of the general capabilities of the system, the functionality of the firmware and the software, before finalizing with the current status of the project alongside its future goals.

FPGA Controller Block Diagram



Outline

The challenge of the given design stems from its versatility requirements. Not only it has to serve as a controller for the gun and the buncher of LCLS-II, but it also has to operate the gun of the HiRES setup at LBNL. The fact that all aforementioned setups share the same hardware (in terms of controller electronics) as a foundation facilitates this endeavor greatly. Naturally, care was taken both in terms of the firmware and the software in order to achieve this as well. Besides some variations in terms of basic functions, what differentiates the setups is ADC channel mapping, and most importantly, upconversion and downconversion frequencies. During the development process, focus was given in having a single firmware flavor that can be dynamically configured during runtime in order to control the cavity at hand, while minimizing FPGA resource utilization.

Digital LLRF Chassis and EPICS GUI

Figure: Gun/Buncher Chassis Assembly

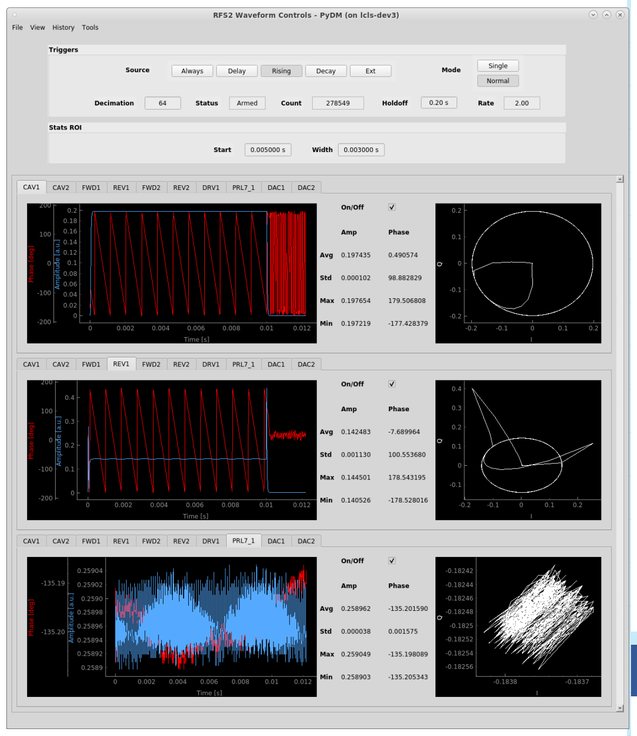


Figure: EPICS GUI during SEL operation

Highlights

- Based on the same hardware as the Superconducting RF Controller for LCLS-II
- Controls both the LCLS-II Gun and the Buncher
- Is also applied to the HiRES setup at LBNL
- Eight ADC channel inputs
- Two DAC channel outputs
- Several configurable modes of operation, such as open-loop, SEL, feedback
- Verilog-based cavity emulator for behavioral simulation purposes
- LCLS-II Timing and BSA/MPS support via fiber
- PRL tracking capabilities
- EPICS and various diagnostic software support and interfacing via GbE
- Extensive recording of RF input and output signals
- Cavity detune computation
- Fully open source, from hardware, firmware, to software design

Status

Currently, the design is able to control the gun cavity at HiRES, and can also support hardware-based cavity emulators that are within the frequency and bandwidth ranges of the LCLS-II gun and buncher. It is foreseen to deploy the system on the LCLS-II setup in the coming months. What is also in the works is the separation of chassis, based on whether they are involved in the downconversion or upconversion of the RF signals, in order to enhance channel separation and thus improve performance.

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