ACCEL LLRF Control Algorithm Design

Project: DARPA ACCEL

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U.S. DEPARTMENT OF ENERGY | Stanford University

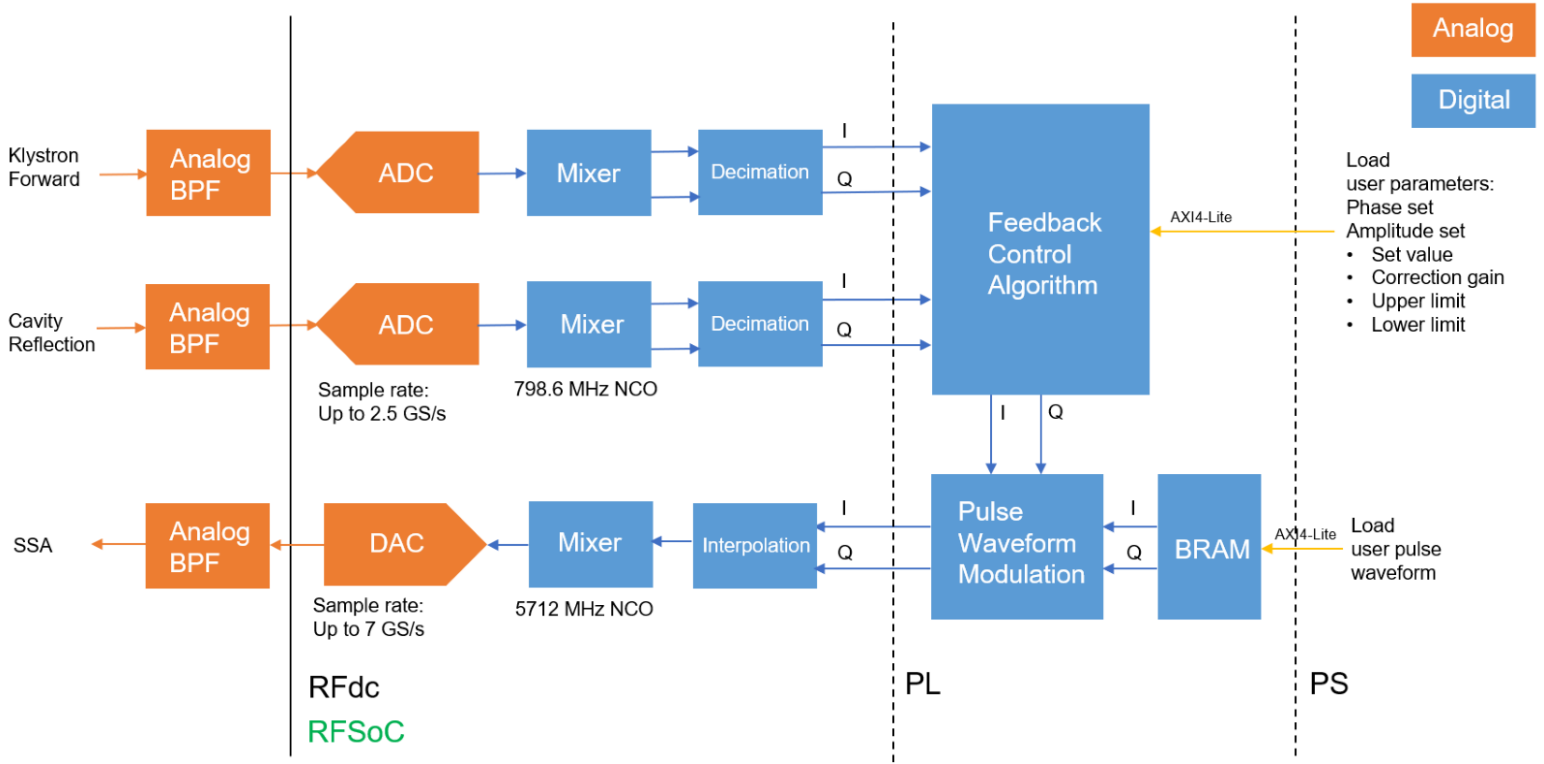
SLAC NATIONAL ACCELERATOR LABORATORY

LLRF Control Algorithm Specification for Phase 1.5

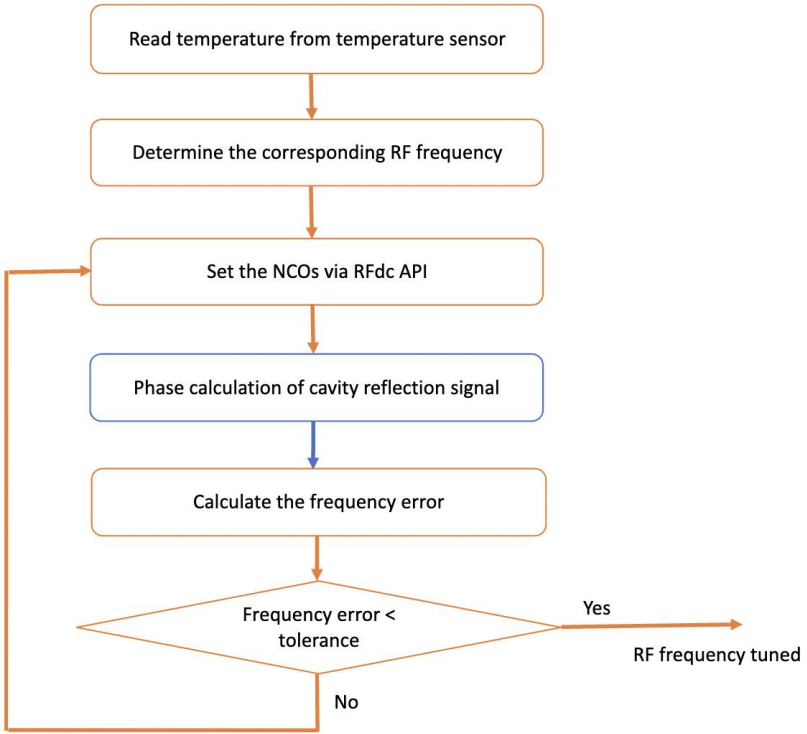
Parameters	Targets
RF frequency control	To be provided by RFAR
Pulse-top flatness Control	To be provided by RFAR
Amplitude and phase control	±1% and ±1 degree

- LLRF control algorithm specification drafted and shared with SLAC and Radiasoft
- Task division between SLAC and Radiasoft clarified
  - System architecture design lead by SLAC with input from Radiasoft
  - Firmware development by SLAC and software development by Radiasoft
- Functional and performance specifications iterated based on feedbacks
- Concerns and comments addressed between teams
- Still waiting for inputs for teams

Block Diagram of ACCEL LLRF Circuit

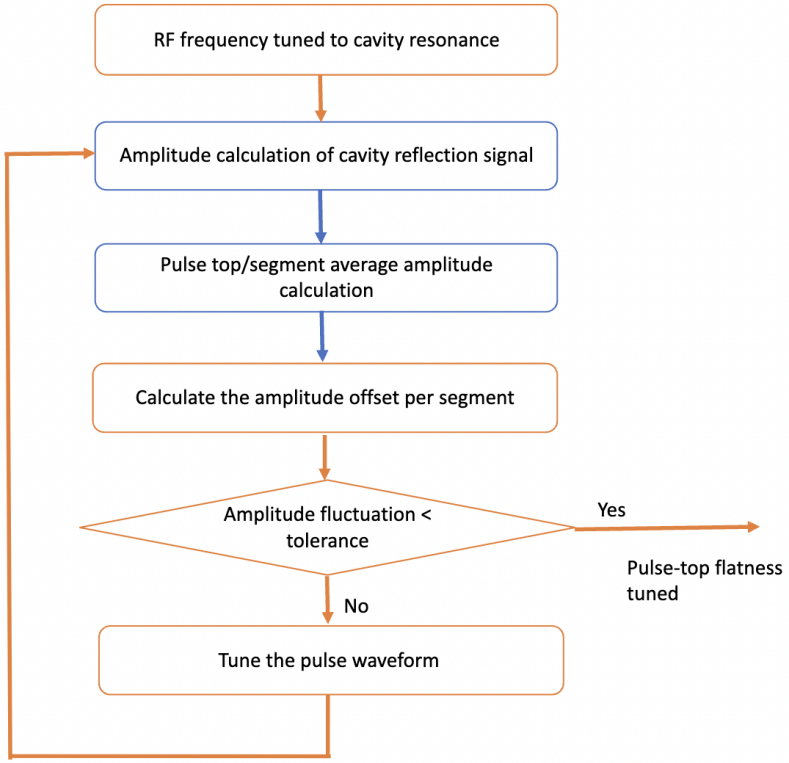


RF Frequency Control Flow



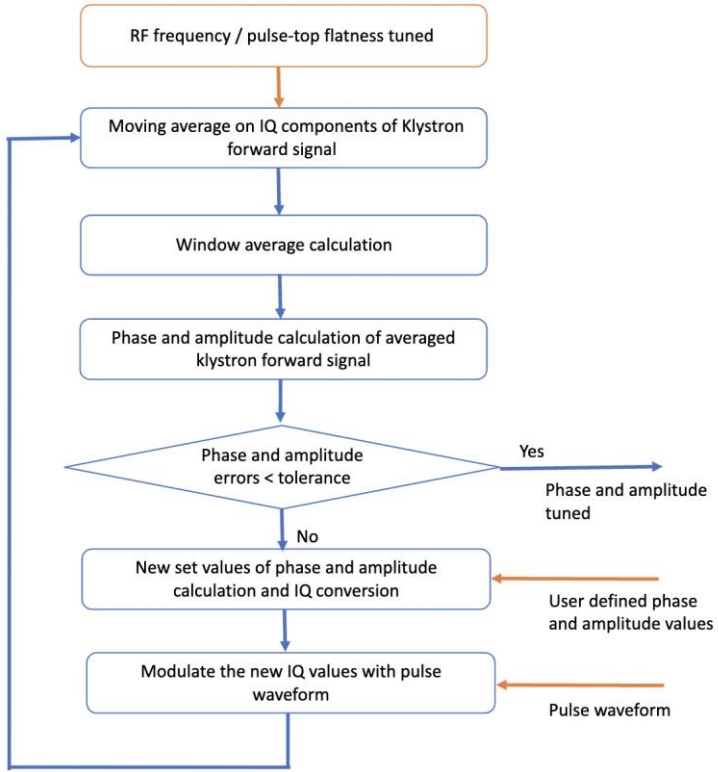
- Two-stage RF frequency control
  - Coarse frequency control – set the initial RF frequency based on the reading of a temperature sensor to enable the RF signal to be injected to the cavity
  - Fine frequency control – calculate the frequency error from the cavity reflection signal and then tune the RF frequency
- Implementation plan
  - Data samples to be collected from firmware
  - Control flow largely implemented in software
    - Initial RF frequency from LUT provided by RFAR team and RF frequency for fine-tunning calculated in software
    - RF frequency set via configuring the NCOs integrated in RFSoC by using API from Xilinx

Pulse-top Flatness Control Flow



- Pulse-top flatness control flow performed after the RF frequency control
- There are bunches over the entire RF pulse duration for ACCEL – the pulse-top flatness needs to be controlled to a desire level (the level to be confirmed by RFAR team)
- Implementation plan
  - Average values calculated in firmware
    - Streaming IQ samples of the cavity reflection signal are converted to amplitude and phase values in firmware
    - The entire pulse duration divided to a number of segments and average amplitude value per segment and over the whole pulse are calculated in firmware
  - Pulse waveform segments offset in software
    - The segment of waveform offset based on the average values calculated in firmware and then modulated with the new set values of IQ components

Amplitude and Phase Control



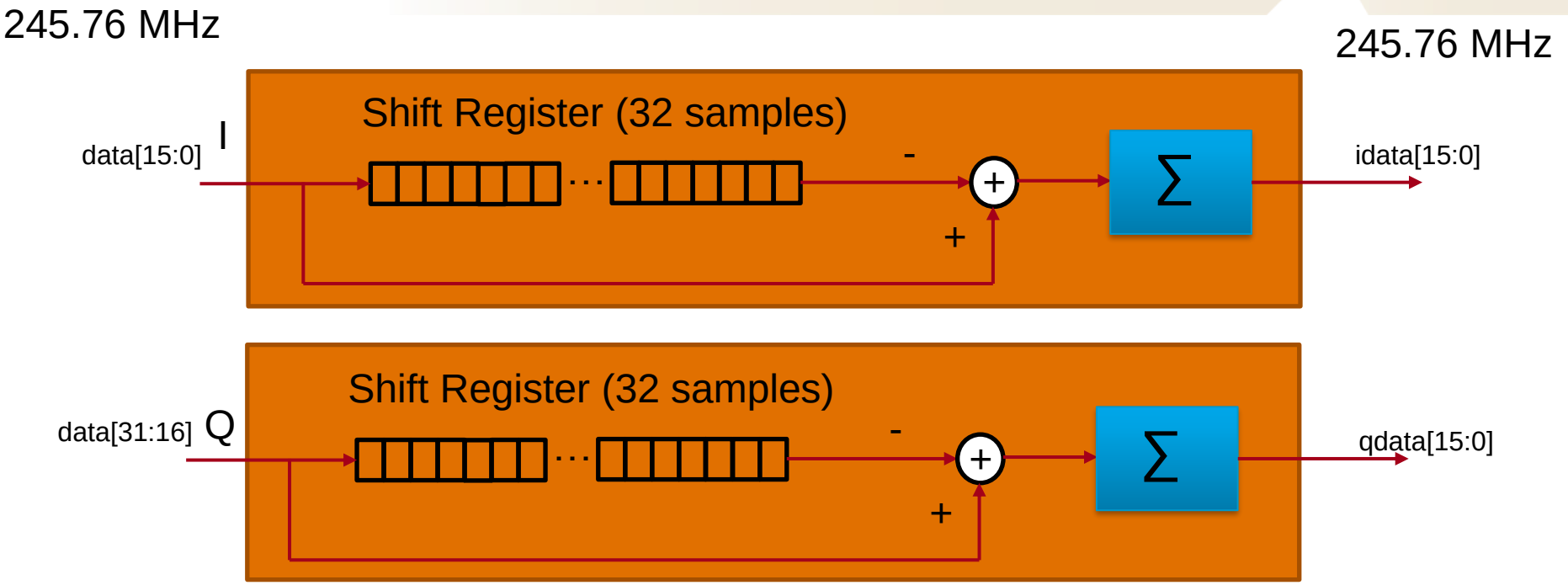
- Amplitude and phase control flow performed after the RF frequency and flatness control
- The phase and amplitude of the klystron forward signal are precisely controlled to user defined values with a real-time compensating loop
- Implementation plan
  - User defined values set in software
    - The target phase and amplitude values set in software
    - User defined waveform corrected by flatness control flow
  - Average values calculated in firmware
    - Streaming IQ samples of the cavity reflection signal are converted to amplitude and phase values in firmware
    - New set of phase and amplitude values calculated based on user defined steps and targets
    - New set values converted back to IQ and then modulated with pulse waveform from software

Task Allocation

- Lead the overall LLRF control firmware and software development
- Finalize the algorithms with RFAR team
- Interact with Radiasoft for detailed software development specification and interface
- Develop firmware for RF frequency and flatness control
- Lead the development of phase and amplitude control
- Possible tasks for experienced support engineers

Firmware Block	Hours
Moving average filter with parameterizable number of samples	20
Window average calculation with parameterizable length	30
Phase and amplitude calculation	30
Amplitude and phase to IQ conversion	20
Documentation, progress meetings and reports	20

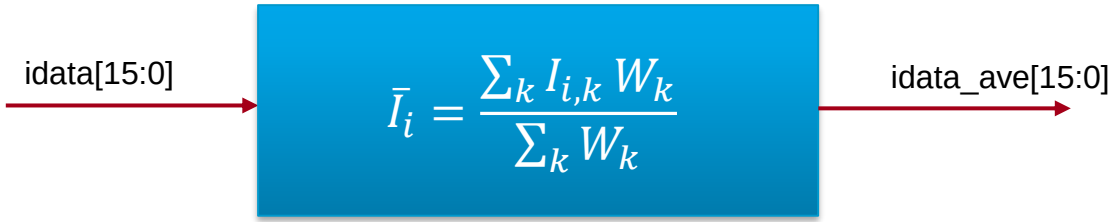
Moving Average with Parametrizable Number of Samples



Window Average Calculation

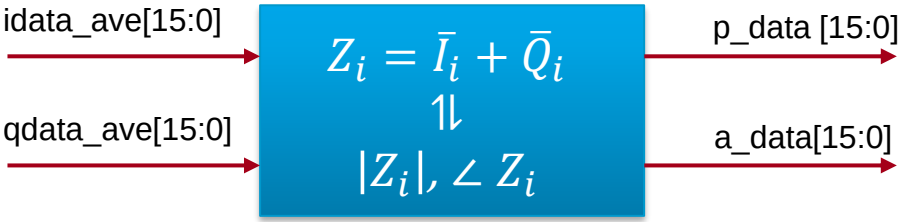
Window Average Calculation

245.76 MHz with AXIS interface



i: number of channel
k: number of samples

IQ to phase and amplitude conversion (and the other direction)



For phase 1.5, there will be only one channel.

Thank you!