RF Data Acquisition System for the APS Upgrade

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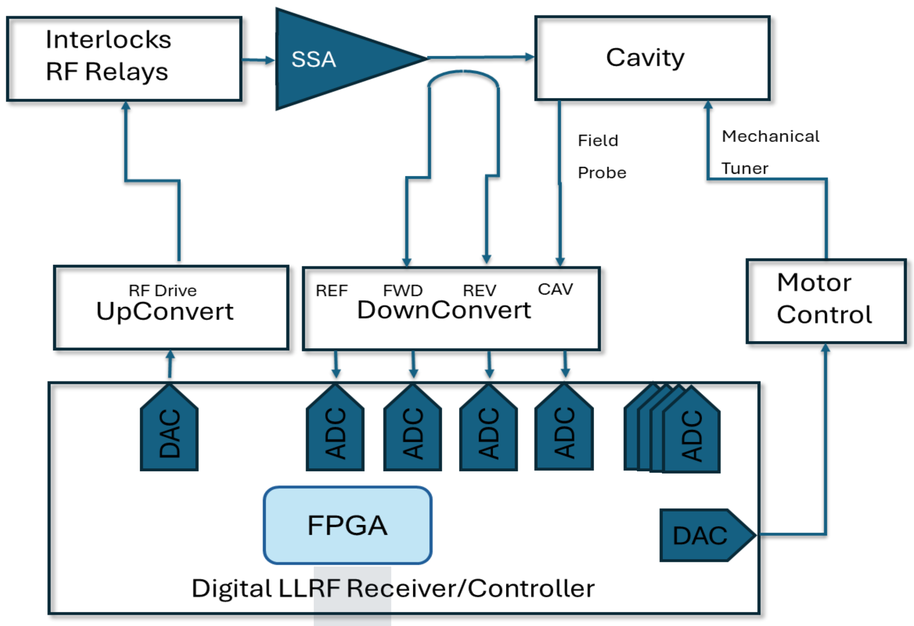
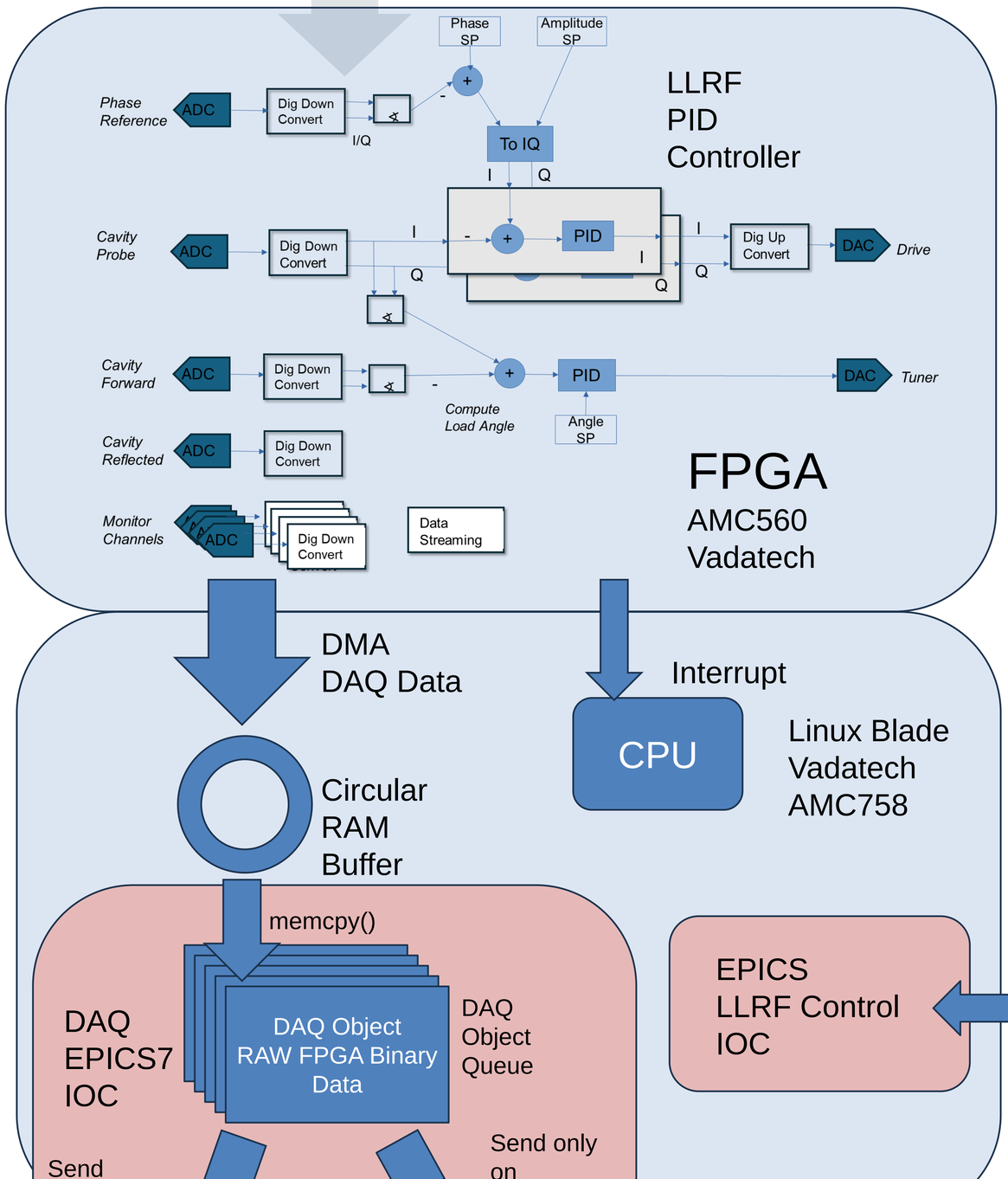
The RF systems at the Advanced Photon Source are being upgraded from analog LLRF systems to new Digital LLRF systems based upon Vadatech Micro-TCA Equipment [1,5]. To the right is a diagram of a Solid-State Amplifier System to be installed in the APS Storage Ring, utilizing a digital LLRF system [4]. The LLRF system features a Digital Receiver Controller, based upon an FPGA, D/A and A/D converters. The LLRF system runs at an Intermediate Frequency (IF) of 19.6MHz, which is converted to the 352MHz RF frequency used in the APS storage ring.

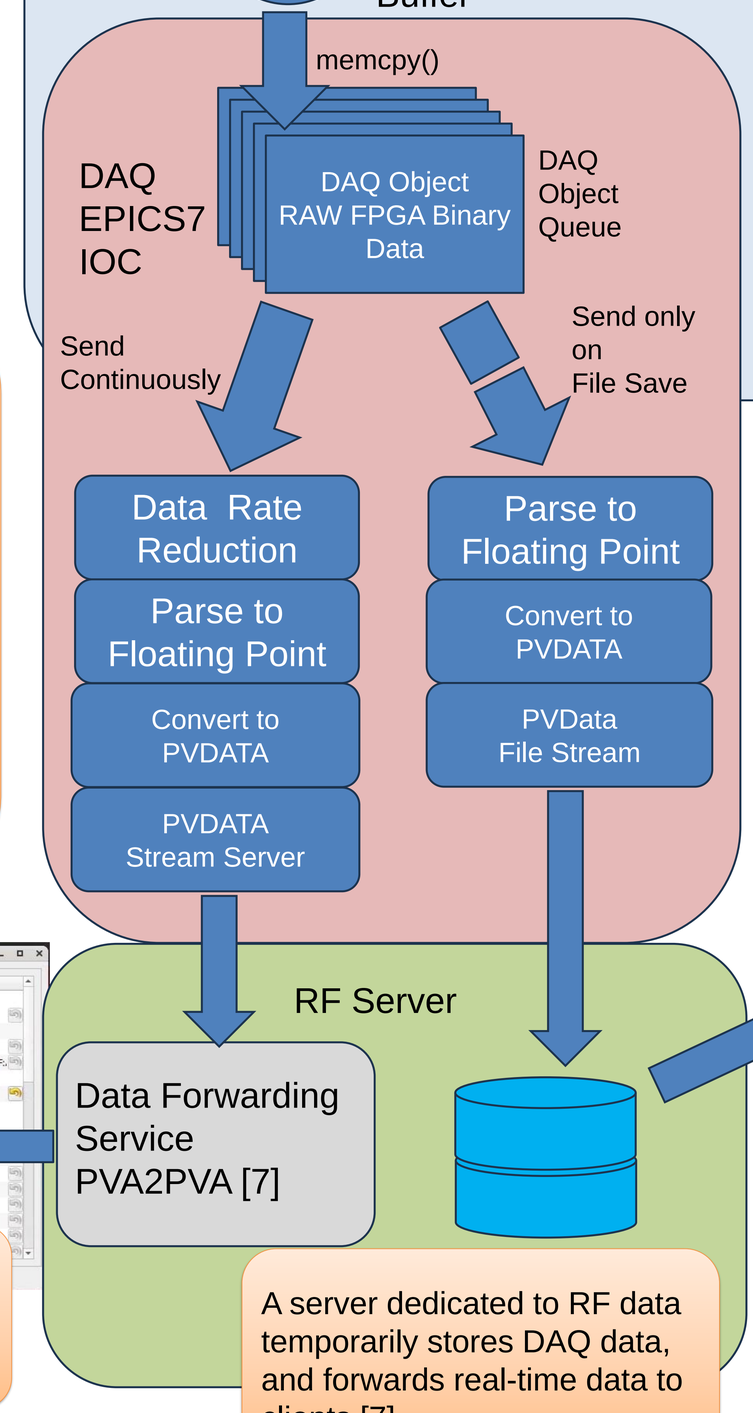


The LLRF controller is defined in the FPGA Firmware (Vadatech AMC560) and implements a PID controller to regulate Cavity RF field magnitude and phase. Also, the controller implements a PID controller to regulate the cavity tuner, assuring the cavity is at resonance.

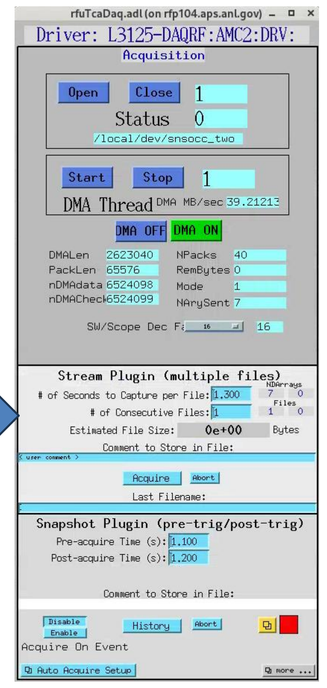
The FPGA firmware has taps at many points in the PID controllers to stream the IF waveforms to a real time DAQ system. Data is streamed in I/.Q space, and downstream software converts data to magnitude and phase.



RF waveform data is continuously streamed from the FPGA to a Linux blade (Vadatech AMC758) via the Micro-TCA crate backplane, running a PCIe buss. The FPGA initiates DMA transfers directly into the Linux Blade RAM, then interrupts the Linux CPU to notify software processes there is data available. The DAQ data is DMA'ed into a circular buffer which is continuously monitored for new data.



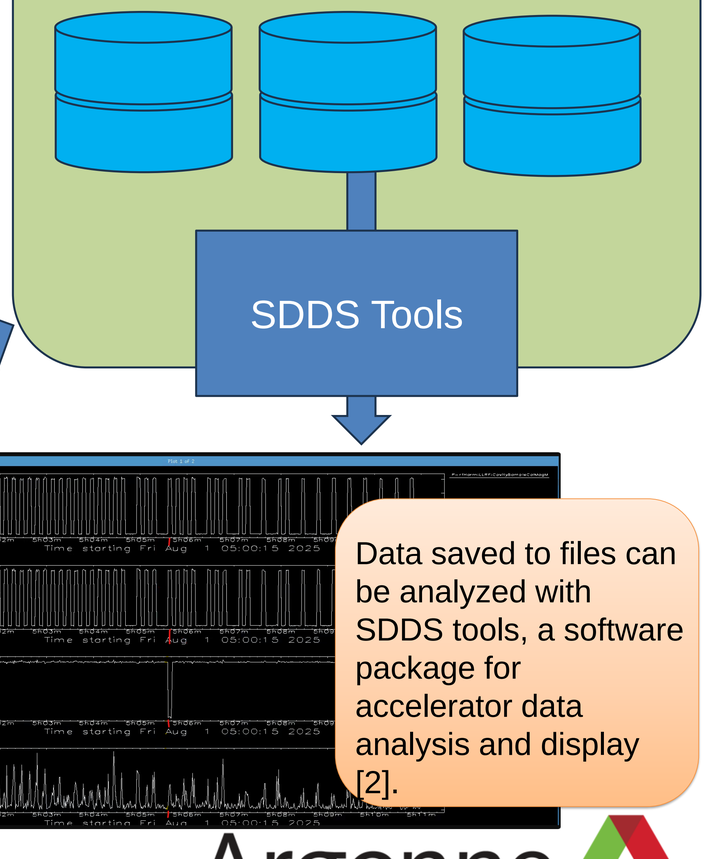
EPICS
LLRF Control
IOC

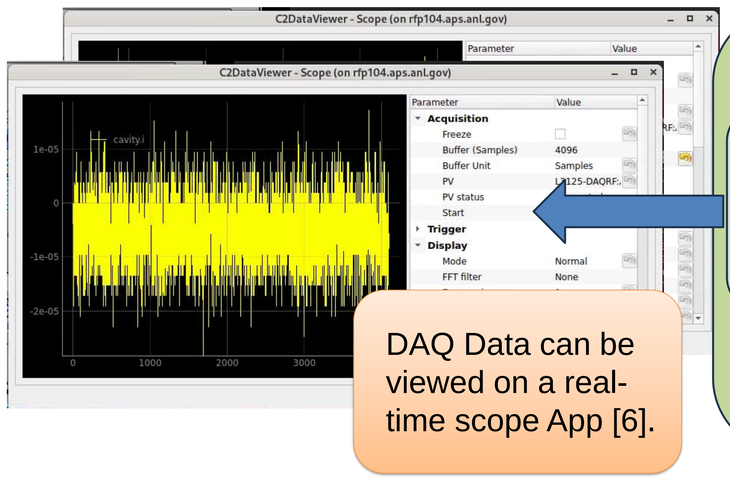


The Control IOC allows monitor and control of the LLRF system. Separating the DAQ and Control into two application improves reliability. User screens allow interface to the control IOC.

The Linux Blade runs two IOCs: A DAQ IOC for streaming real-time RF data, and a Control IOC for monitoring an controlling the LLRF system. The DAQ IOC gathers data from the circular buffer and assembles the RF data into a series of DAQ objects [2]. A plug-in software stack converts the raw binary data into floating point data in EPICS PVData format. This data is continuously streamed at 5-10MB/sec over the network. Further, high sample rate data can be saved in burst mode to a remote file system at 50MB/sec.

The Curzon Cluster is a permanent DAQ data repository at APS. Data is continuously transferred from the RF server to the Cluster.





DAQ Data can be viewed on a real-time scope App [6].

A server dedicated to RF data temporarily stores DAQ data, and forwards real-time data to clients [7].

Data saved to files can be analyzed with SDDS tools, a software package for accelerator data analysis and display [2].

[1] J. Galayda, "The Advanced Photon Source," *Proceedings Particle Accelerator Conference*, Dallas, TX, USA, 1995, pp. 4-8 vol.1, doi: 10.1109/PAC.1995.504556.
[2] S. Veseli *et. al.,* "Acquisition System for the APS Upgrade." *ICALEPCS 2019* (2019).
[3] T. Madden, *et. al.,* "Software Development for APS-Upgrade LLRF." *arXiv preprint arXiv:1910.04635* (2019).
[4] D. Horan, *et. al.*,"352-MHz Solid State RF System Development at the Advanced Photon Source." In *Proc. 12th Int. Particle Accel. Conf.(IPAC'21)*, pp. 2335-2338. 2021.
[5] Borland, Michael, et al. "The Upgrade of the Advanced Photon Source." 9th Int. Particle Accelerator Conf.(IPAC'18), Vancouver, BC, Canada, April 29-May 4, 2018. JACOW Publishing, Geneva, Switzerland, 2018.
[6] E. Chandler, G. Shen, S. Veseli, T. Fors, and T. Madden, "C2 Data Viewer: Visualization tool for EPICS7 Data Streaming," Presented at the EPICS Collaboration Meeting, Spring 2023
[7] R. Lange, *et. al.*, *PVA2PVA Website*, https://github.com/epics-base/pva2pva

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