Initial commissioning of the new beam control system of the Proton Synchrotron at CERN

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LOW LEVEL 2025 RADIO FREQUENCY Workshop

Motivation

The Proton Synchrotron (PS), CERN's first synchrotron, is in operation since 1959. With several upgrades over the years, today it delivers proton and heavy ion beams with charges ranging from 10^8 to $4{\cdot}10^{13}$ with an energy of up to 26 GeV. The ring has a circumference of 628 m and is equipped with six different RF systems in a frequency range from 0.4 to 200 MHz, driving in total 25 RF cavities [1].

The LLRF system can be divided in two main sub-systems: cavity controllers and beam control. The former are composed of multi-harmonic feedback loops [2] to control amplitude and phase of the RF signal being sent to the cavities. The latter implements phase, radial or synchronization loops to keep the required beam specifications and synchronize the injection and ejection processes.

The beam control is currently being renovated, and the new system is in the commissioning phase. The new beam control includes two VMEbus Switched Serial (VXS) crates performing digital demodulation of the beam loop inputs and one microTCA crate implementing the beam loops. These choices have been taken to reuse and standardize the elements used in different accelerators at CERN. In particular, VXS systems are currently in operation in several injectors at CERN: PSB, AD, ELENA, LEIR [3], whereas the beam loops implementation is inspired by the new beam control systems of SPS and LHC machines [4].

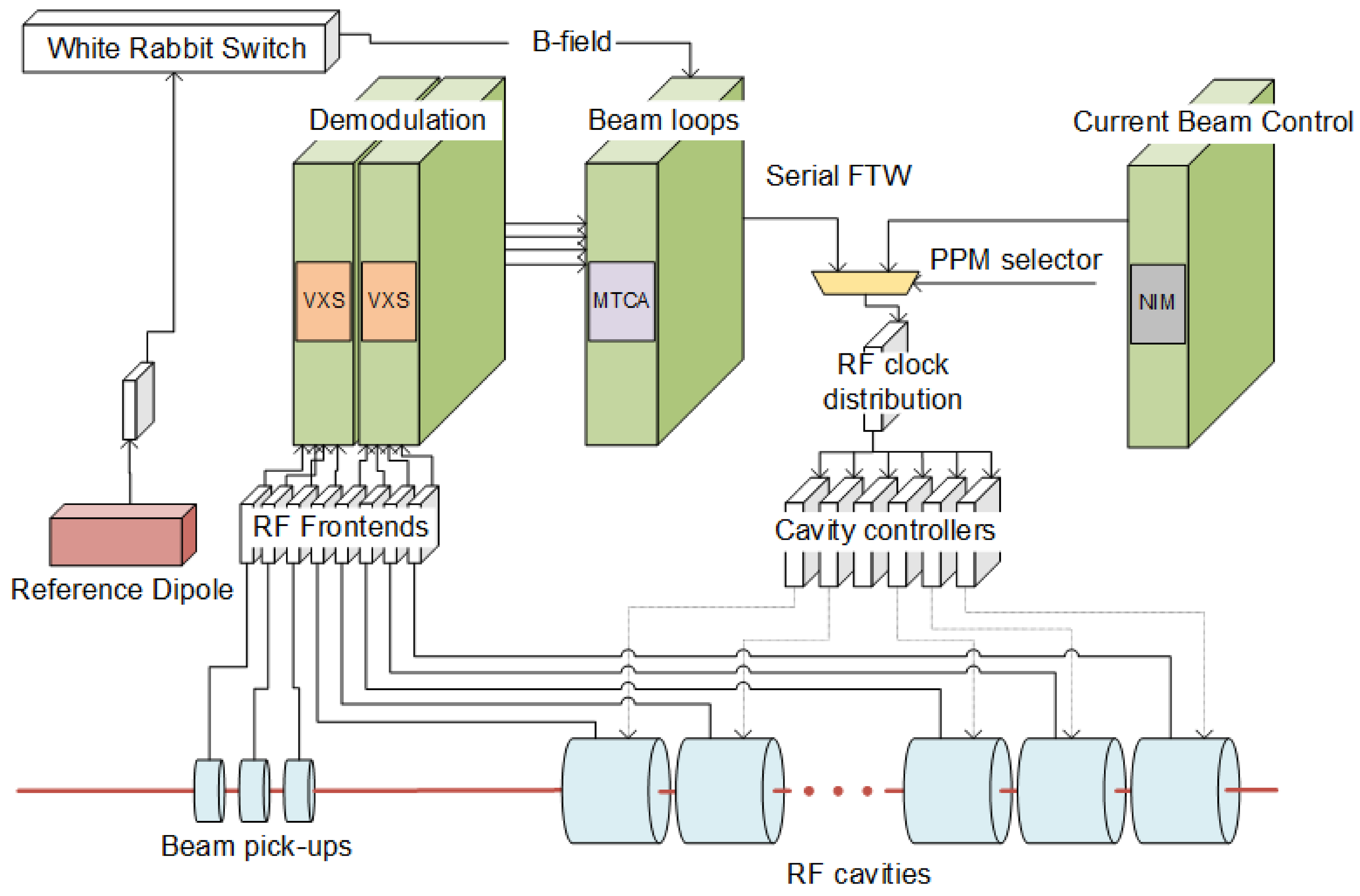

Figure 1 – PS beam control system layout for commissioning tests

Demodulation architecture

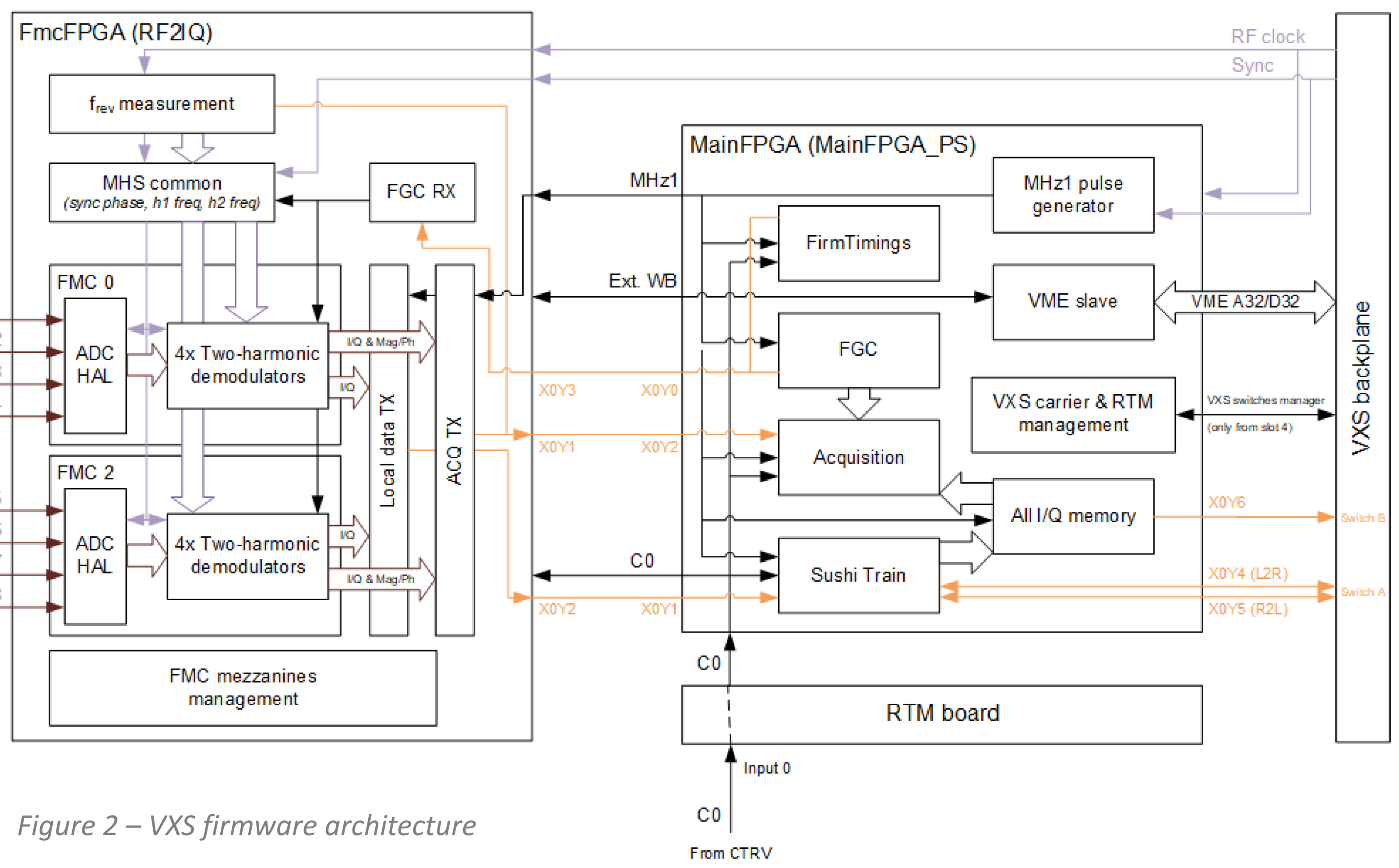

Figure 2 – VXS firmware architecture

Each VXS crate contains four VXS-DSP-FMC boards and two VXS switches [5]. The carrier boards include two FMC boards with 4-channel 125 MSPS ADCs. It also contains two FPGAs, one directly connected to the FMCs, in charge of the demodulation of the 8 input channels per board.

The demodulation is performed simultaneously using two harmonics of the revolution frequency, to allow a smooth harmonic change during the cycle in the beam loops. The harmonics are fully configurable via functions, as well as the azimuth of the NCOs. Other parameters, such as the phase offset or delay are configurable via registers.

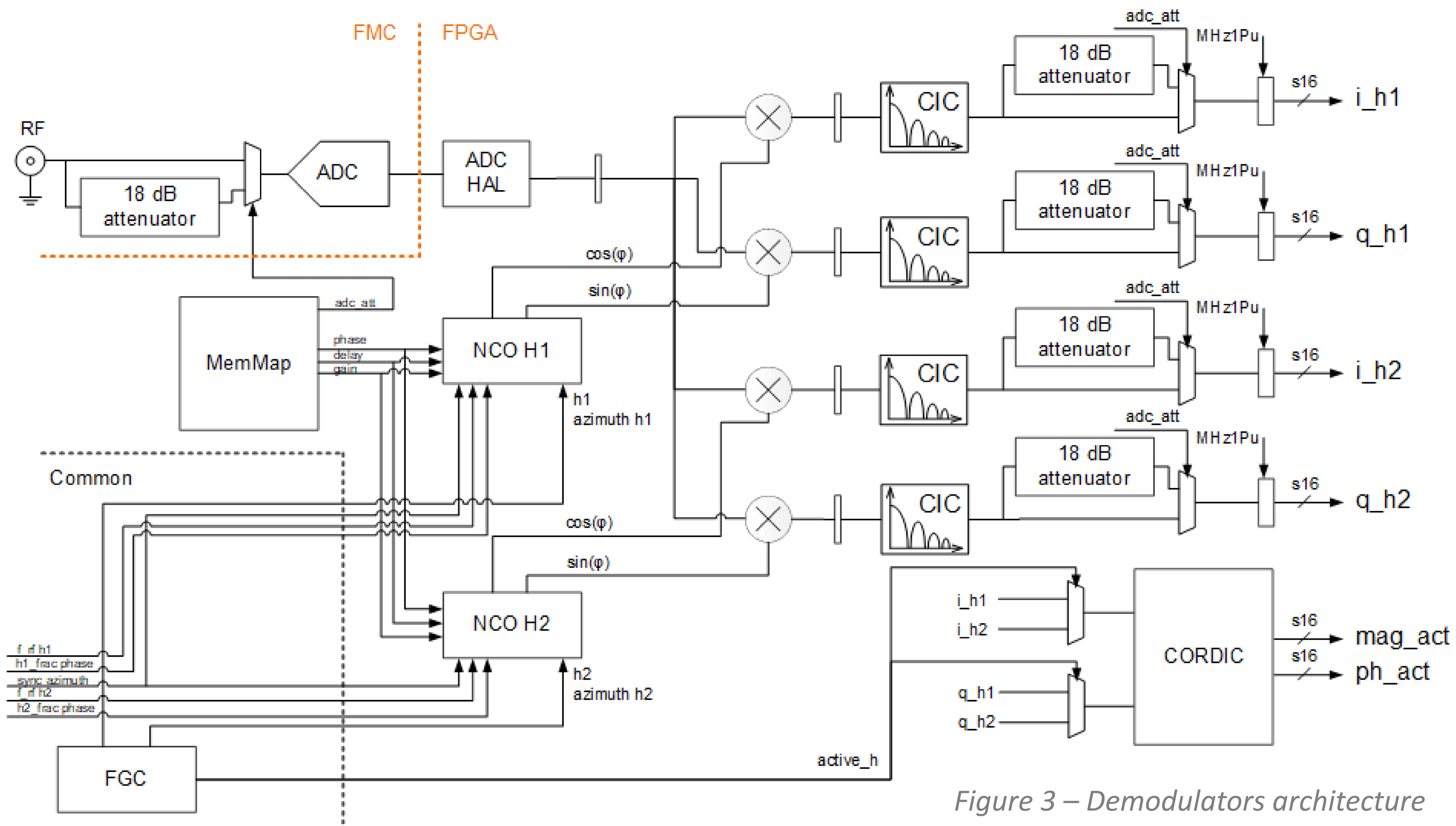

Figure 3 – Demodulators architecture

System validation and commissioning

Data streams (I/Q) are sent to the MainFPGA and synchronized between all boards in the VXS crate using the Sushi Train mechanism. Two high-speed serial links at 2 Gbps are used to exchange demodulated data from the 64 I/Q streams present in a single crate. New data are generated and synchronized every microsecond. When the data streams are synchronized, every board has access to the data streams of all boards. One of the boards is connected to the VXS switch in the crate, which routes the data stream to two SFPs. Two fiber connections per crate are then connected to the beam loops module in the microTCA crate, receiving I/Q streams for the two crates: 64 channels with 2 harmonics at 1 MSPS.

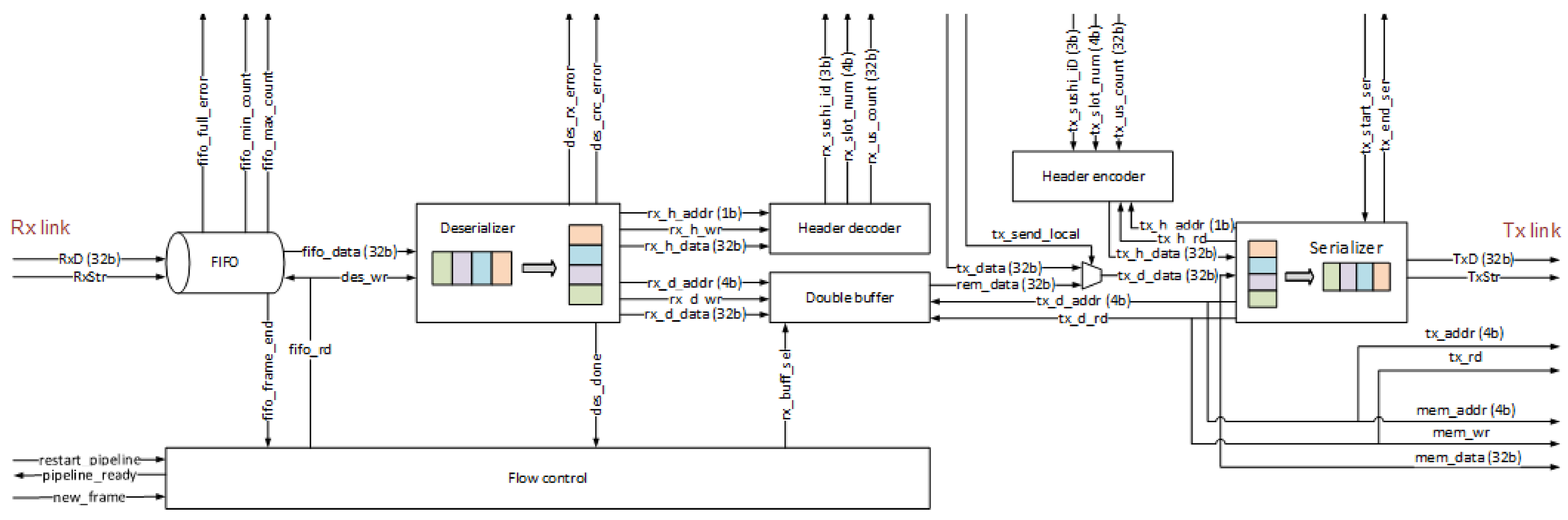

Figure 4 – Sushi Train datapath implementation details

As the PS delivers a wide variety of beam types to different extraction lines, the current beam control system is composed of a collection of independent systems being multiplexed according to the selected beam for each cycle.

Following the same principle, the new beam control system will include the digital multiplexing built-in to select the parameters for a given type of beam. For the initial commissioning, an external multiplexer will be used between the current and new beam control systems during Machine Development cycles.

The first VXS crates used for demodulation are currently being installed and cabled in the accelerator and beam tests are planned for next year.

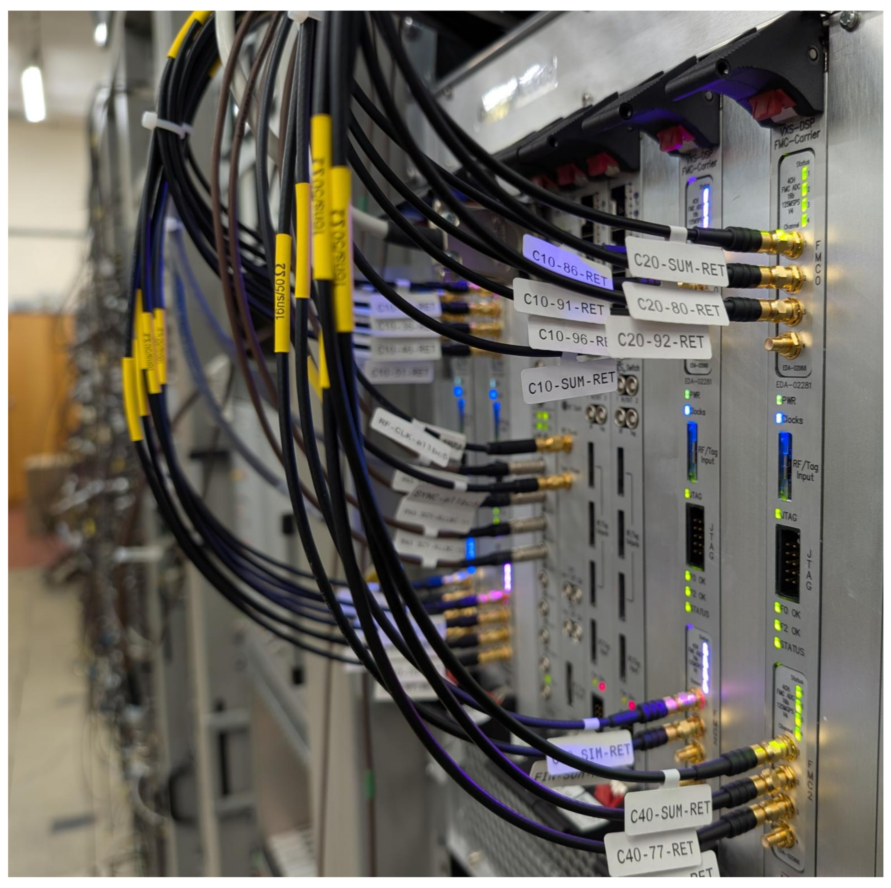

Figure 5 – VXS crate being commissioned for the new PS beam control

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REFERENCES
[1] H. Damerau, *PS LLRF upgrade. Functional specifications, cost, manpower and schedule*, September 2017.
[2] B. Woolley et al., *Digital cavity controller for the 20 MHz, 40 MHz and 80 MHz cavities in the CERN PS*, presented at LLRF Workshop 2022, Brugg-Windisch, Switzerland, October 2022.
[3] M. E. Angoletta et al., *Operation and new capabilities of CERN's digital LLRF family for injectors*, in Proc. IPAC'23, Venice, Italy, May 2023.
[4] A. Spierer et al., *The CERN SPS Low Level RF: The Beam-Control*, in Proc. IPAC'22, Bangkok, Thailand, June 2022.
[5] D. Barrientos et al., *Status of the beam control renovation of the Proton Synchrotron at CERN,* presented at LLRF Workshop 2023, Gyeongju, South Korea, October 2023.