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A Low-Level Radio Frequency (LLRF) Control System for Multiple Superconducting Cavities Based on MicroTCA.4*

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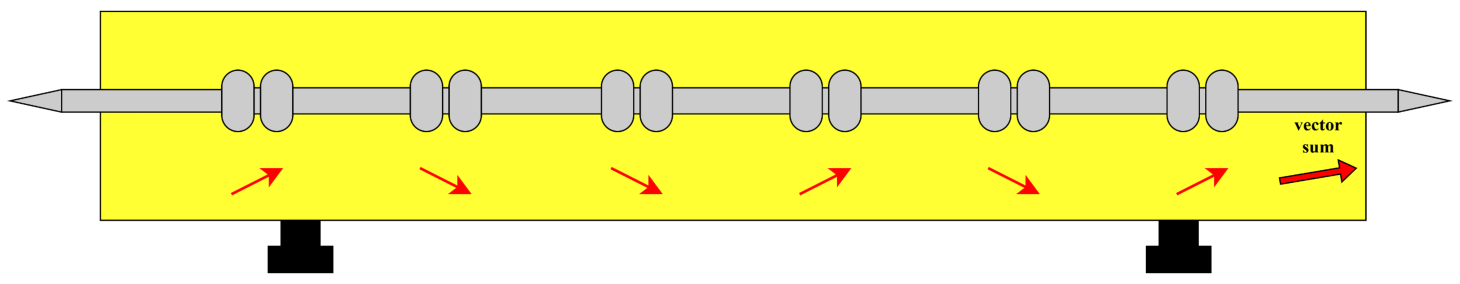
ABSTRACT

This poster presents a domestically developed LLRF control system for simultaneously driving six superconducting cavities with a single klystron. Based on a fully domestic MicroTCA.4 platform, the system employs vector-sum control, IQ sampling, and feedforward-feedback techniques. It ultimately achieves high-precision amplitude, phase, and frequency control for the six cavities, validating a key step for the CEPC project.

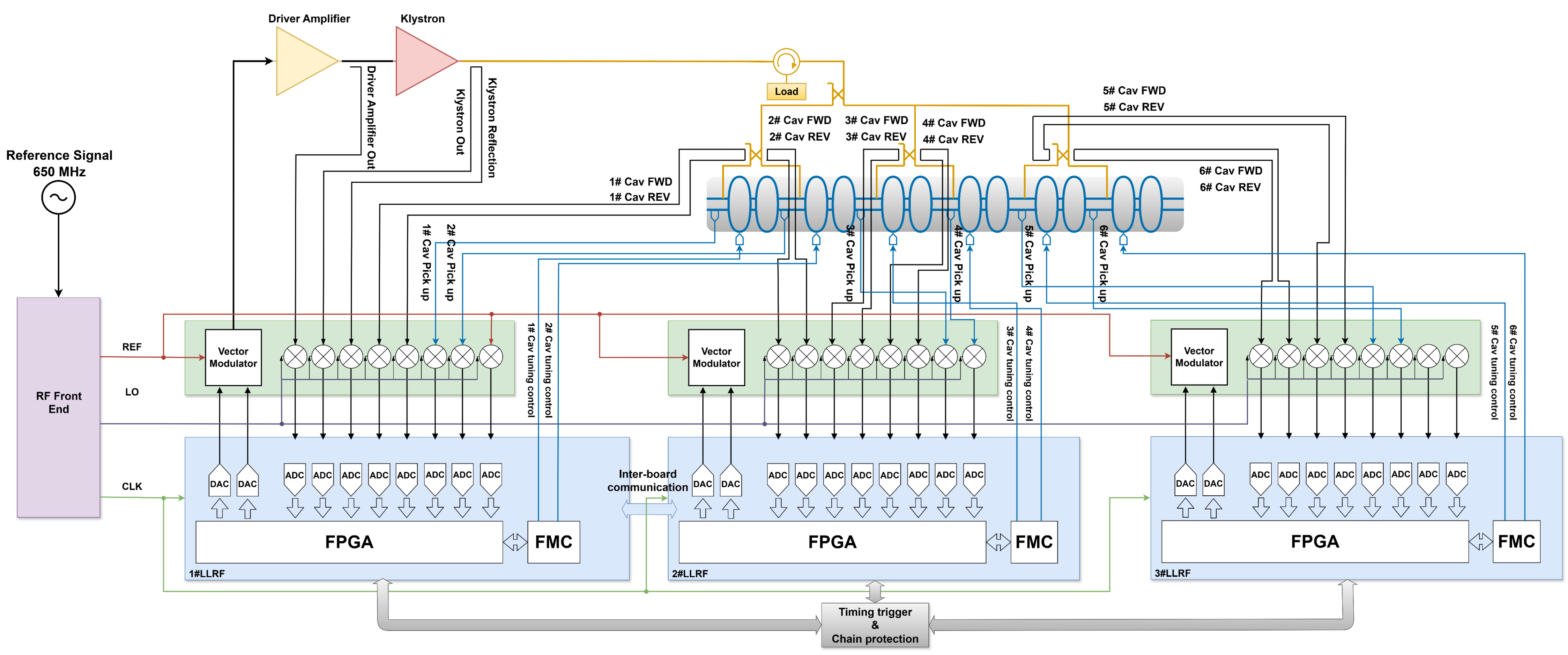
VECTOR-SUM CONTROL PRINCIPLE



The Vector Sum Control Principle

$$\sum_{i=1}^{n} \vec{V}_{cavity\_i} = \vec{V}_{cavities\_sum}$$

OVERVIEW OF THE LLRF FOR MULTI-CAVITY

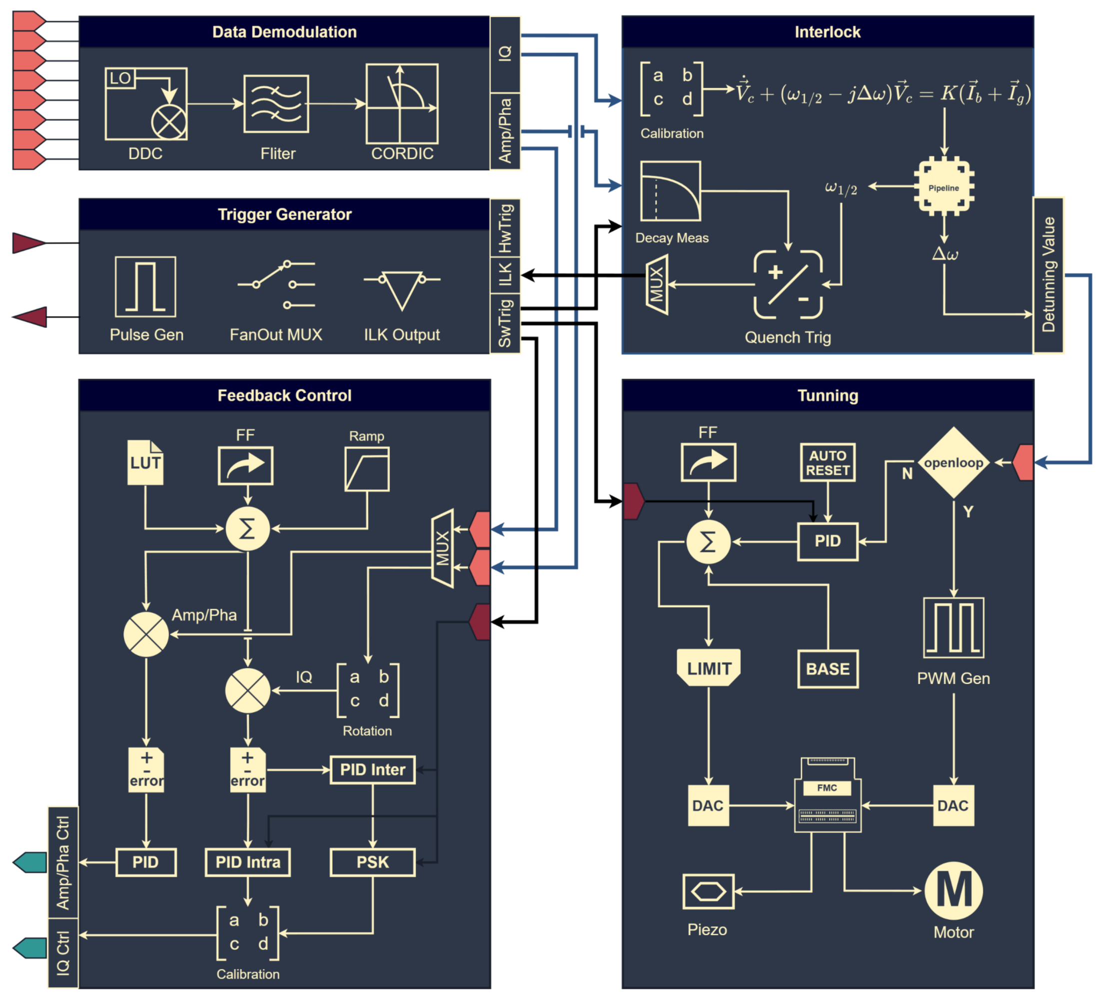


CEPC 650 MHz 6×2-cell superconducting module LLRF system design scheme

The system operates in a master-slave architecture, utilizing a unified vector-sum setpoint for global control, which eliminates per-cavity feedback loops to reduce cost and complexity. The tuning of individual cavities is achieved through a combination of feedforward and feedback control, ensuring precise adjustment.

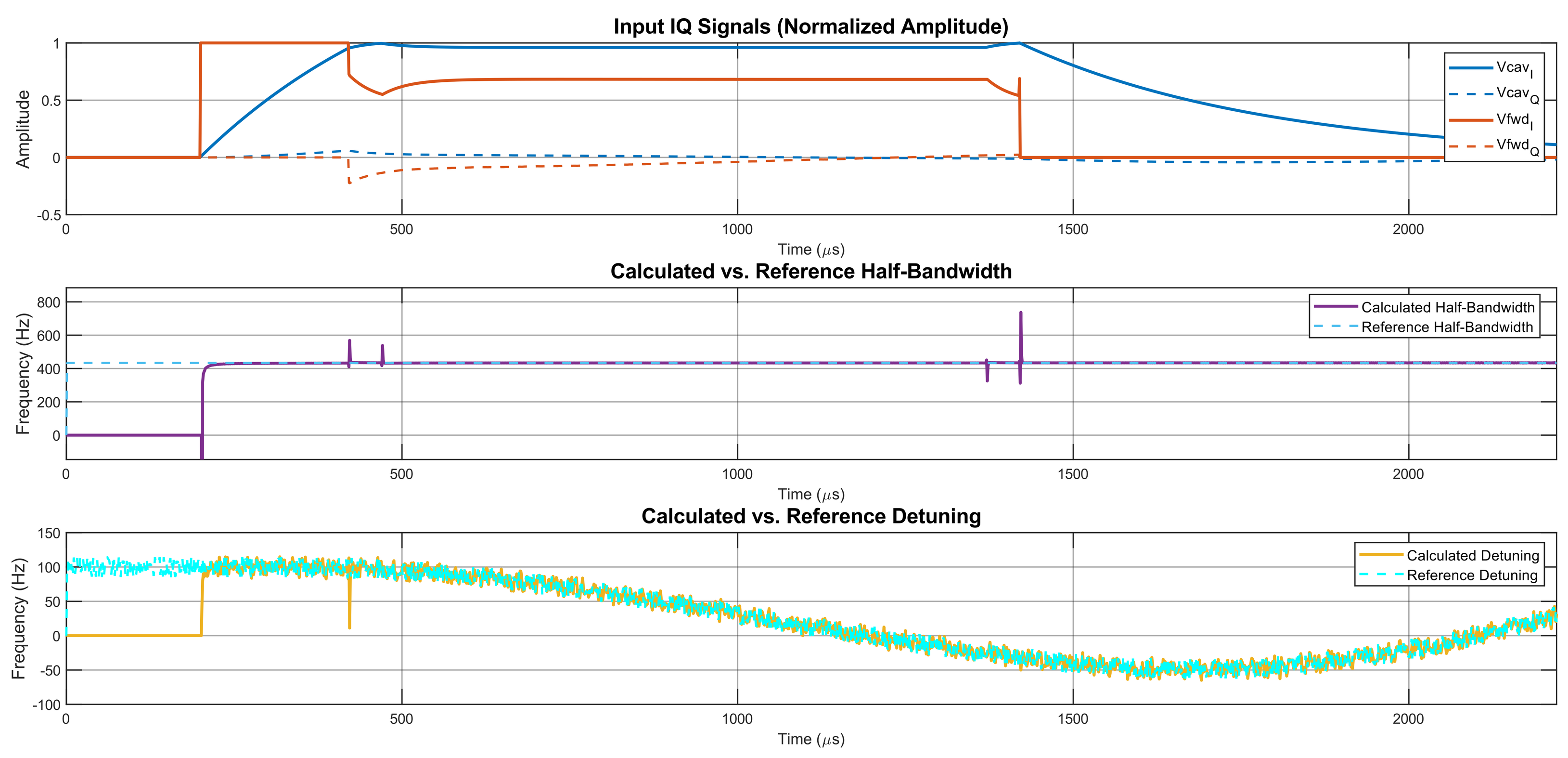
FIRMWARE OF THE LLRF

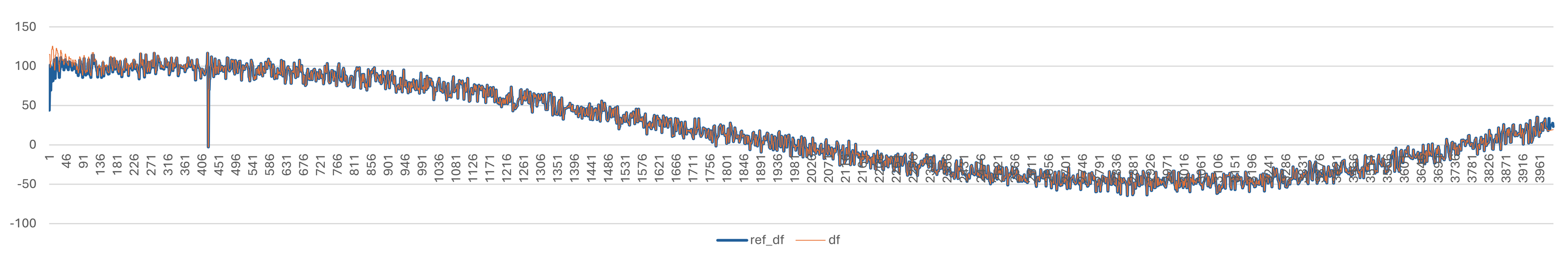
Each of the three board cards handles the complete processing for two cavities, including signal demodulation, local vector summation, tuning, and quench detection. These local vector sums are then sent to the main board, which consolidates them into a global vector sum and generates the final feedback signals.



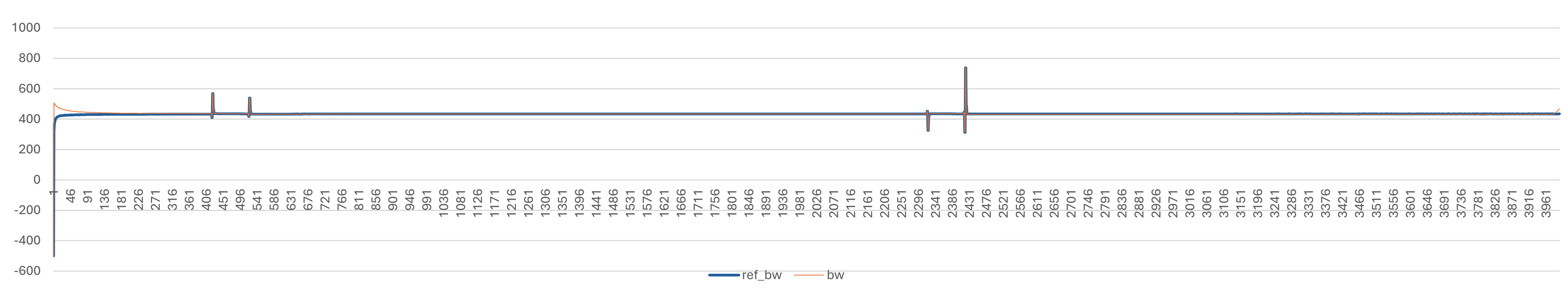
Firmware Architecture Diagram

DETUNING-CALCULATION FIRMWARE VERIFICATION



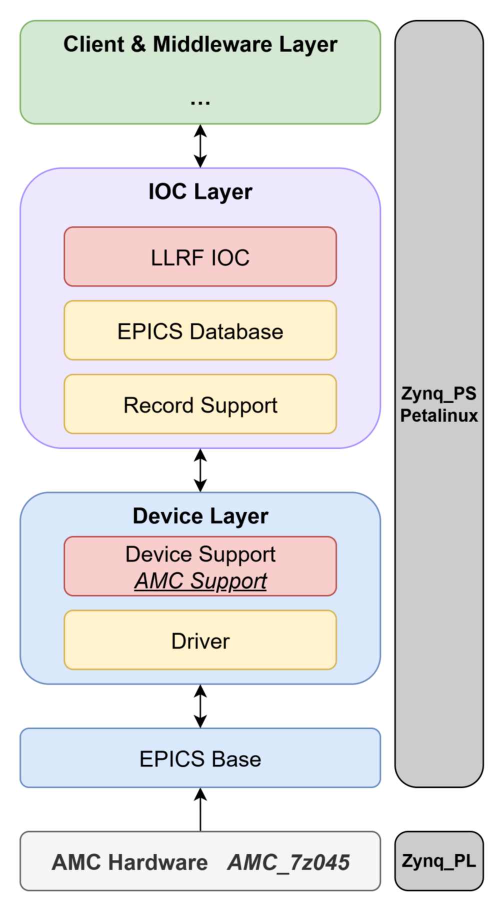


Detuning Fitting



Half bandwidth Fitting

SOFTWARE AND HARDWARE PLATFORM



PROGRESS

- **In Progress**
  Firmware integration and testing, calibration module development, upper-layer driver optimization, and EPICS applications are currently underway.
- **Future Plans**
  By June 2026, a horizontal test platform will be established in Huairou, Beijing for the installation and debugging of the LLRF control system.

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