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Design of an MTCA.4-Based LLRF tuning controller for cryomodules at S3FEL

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This report presents the design of an MTCA.4-based low-level radio frequency (LLRF) tuning controller for the Shenzhen Superconducting Soft X-ray Free Electron Laser (S3FEL). A standard 1.3 GHz cryomodule at S3FEL comprises eight superconducting cavities, each requiring one slow tuner motor control, two fast piezoelectric actuator (PZT) controls, and an additional motor control for high-power coupler antenna depth adjustment. To manage these requirements, two pairs of MTCA.4 control boards (each pair consisting of an AMC and an RTM connected via MTCA Zone3 D1.0 interface) are implemented per cryomodule. The controller's core processing utilizes a Kintex UltraScale KU040 FPGA on the AMC, which acquires cavity detuning data from four cavities through backplane peer-to-peer high-speed communication. An FMC mezzanine card interfacing with the AMC provides eight optically isolated motor control channels. The RTM board delivers eight channels of 16-bit high-precision DAC output for PZT control. Preliminary testing confirms that the developed tuning controller meets the operational requirements for S3FEL's standard superconducting cryomodules.

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Footnotes

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