NECQST: Novel Electronics for Cryogenic Quantum Sensors Technology

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FERMILAB-POSTER-19-132-QIS

- Development of low-noise cryogenic readout circuits for **SNSPDs** based on state-of-the-art, commercially available **SiGe HBT** technology, operating at a range of **1-4 Kelvin**.
- Targeting a **reduction of the timing jitter of SNSPDs** (from the current record of 2.7 ps FWHM at 400 nm), and a **reduction in the power dissipation** allowed by the development of **dedicated low-noise cryogenic amplifiers**, which will enable the scaling of ultra-low-jitter SNSPDs to large arrays
- Such performance advances will directly benefit the **Caltech/Fermilab INQNET** (Intelligent Quantum Networks & Technologies) program, which aims to demonstrate high-rate quantum communication at Fermilab.

SiGe Heterojunction bipolar transistor:

- SiGe Heterojunction Bipolar Transistors (HBTs) have **outstanding cryogenic capabilities**. When cooled, SiGe HBTs naturally exhibit improved frequency response, current gain, noise, bandwidth, output conductance and reliability.
- **BiCMOS** (SiGe HBT + Si CMOS) platform makes it an ideal mixed-signal technology that effectively marries high-performance SiGe HBTs for analog, RF, and microwave circuits, with on-board Si CMOS to support highly-integrated system functionality.
- Fabricated on large wafers (300 mm) at **high yield** and **low cost** using conventional silicon processing techniques and silicon economy-of-scale.

Cryogenic modelling of transistors and design optimization:

- The project requires modelling and characterization of transistors, with the creation of custom, EDA-ready functional level-0 models for operation at 4K.

Examples of future developments:

- scaling the readout circuit concept to large arrays of SNSPDs, which can enable ultra-high maximum count rates in addition to ultra-low-timing jitter;
- combine it with cryogenic CMOS electronics in the same device to implement complex post-detection electronics.

SQC-R&C: Superconducting quantum processor readout and control

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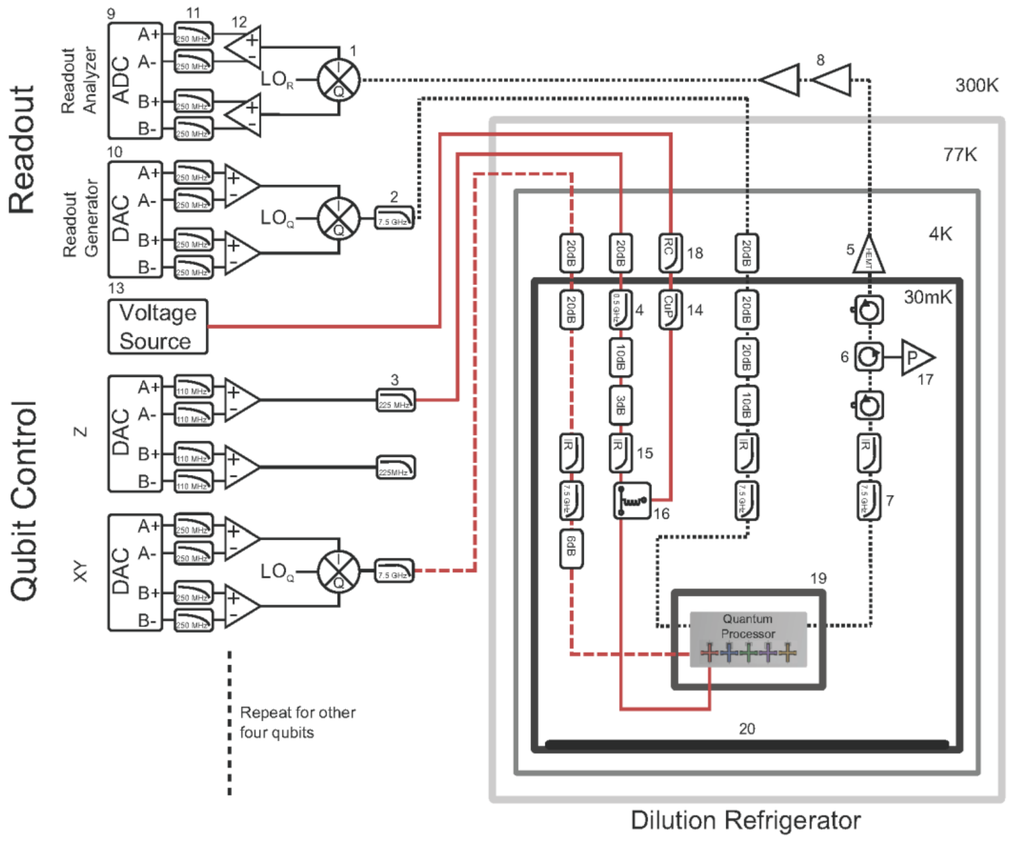
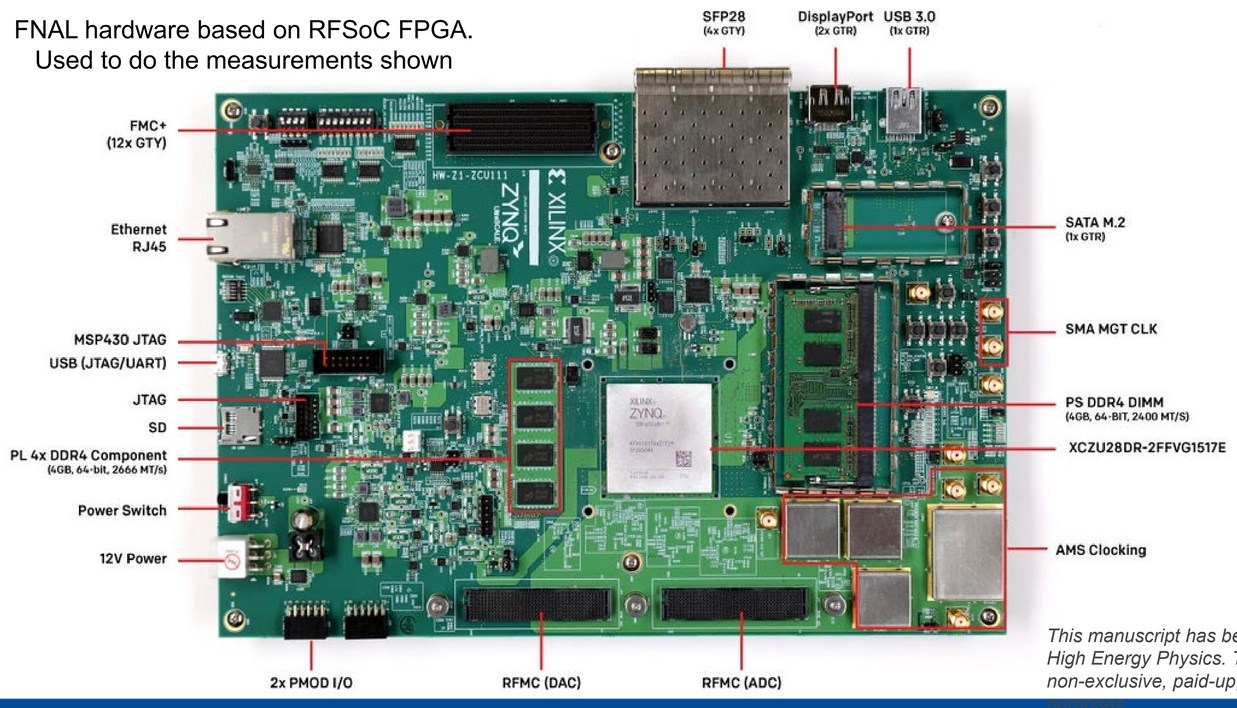


FNAL hardware based on RFSoC FPGA.
Used to do the measurements shown



- Fault tolerant quantum computers require a sophisticated readout and control electronics that includes RF hardware, high speed A/D and D/A electronics, FPGA signal processing, error detection and correction, flexible quantum program control, etc.
- Fermilab is leading an effort in R&C, with partners at UC and MIT.
- SQC-R&C developments have an important synergy with electronics for some of the main DOE Cosmology projects such as CMB-S4, ADMX, and MKIDs R&D.
- After only 2 months, we are already controlling qubits (Rabi & Ramsey oscillations).