Controlling a Quantum Processor with Customized FPGA Electronics

MSc Thesis @ Quantum Technology Laboratory FALL SEMESTER 2019

In the past 20 years, **superconducting circuits** have emerged as a leading architecture for quantum information processing [1], with prospected applications in the areas of computation, simulation, and communication. Our team is committed to develop a fully functioning superconducting quantum processor with 100 qubits in the next 10 years. Among other challenges, this will require dedicated hardware to interact with the quantum system and perform operations such as initialization, control, measurement, and feedback [2-4].

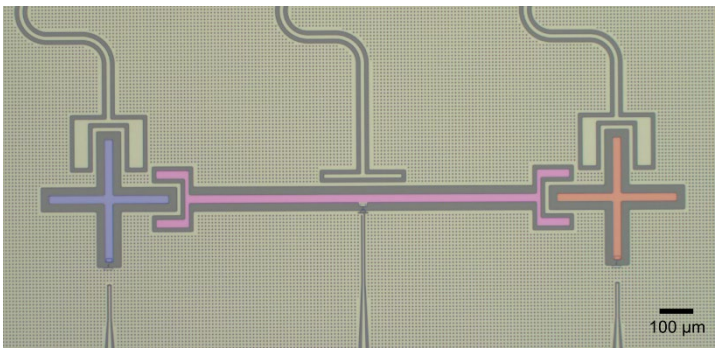
In this project, you will use a Radio Frequency System-on-Chip from Xilinx's Zynq® UltraScale+™ family to perform a set of measurements on state-of-the-art superconducting quantum bits (qubits). The relevant FPGA firmware (the softcore) is being developed as a collaboration between researchers at Chalmers and KTH. A key task within the project is to develop an intermediate layer between the softcore and the high-level software interface used to control our instruments. This will make it possible to run measurements such as qubit readout, Rabi and Ramsey oscillations, coherence measurements, and, ultimately, active feedback protocols.

You will: • Utilize an FPGA board running a custom softcore to perform qubit measurements. • Interact with the firmware developers to test and improve existing features. • Contribute to the development of new features, which may include feedback/feedforward, optimized readout, state discrimination based on template matching. • Integrate the Python code used to run the firmware in Labber, a software package with a high-end user interface which features a Python API.

What's in for you: • Work with cutting-edge microwave electronics with diverse applications in the industry, from wireless networks to radars. • Step into the emerging field of quantum information processing with superconducting circuits. • Interact on a daily basis with our diverse team comprising physicists, material scientists, engineers, programmers.

What we value: • Motivation, curiosity, independence, problem solving skills, ability to work in a team, creativity. • Good coding skills in Python are required. • Experience with digital signal processing is appreciated. • Experience with FPGA programming (VHDL, Verilog) is not required.

The Xilinx Zynq® UltraScale+™ Radio Frequency System-on-Chip (RFSoC) that you will use in this thesis.



Elementary quantum processor consisting of two superconducting qubits (blue, red) connected by a coupling element (purple). Micrograph courtesy of A. Bengtsson.

Contact information:

Simone Gasparinetti
+46 (0)723-92 56 97
simoneg@chalmers.se

Marina Kudra
kudra@chalmers.se

Further reading

[1] M. Devoret and R. J. Schoelkopf, Science, **339**, 1169 (2013)
[2] Y. Salathé *et al.*, Phys. Rev. Applied, **9**, 034011 (2018)
[3] D. Ristè *et al.*, Phys. Rev. Lett., **109**, 240502 (2012)
[4] L. Steffen *et al.*, Nature **500**, 319 (2013)