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Centro Nazionale HPC, Big Data e Quantum Computing

Missione 4, Componente 2, Investimento 1.4 – Spoke 10
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Università degli Studi di Napoli Federico II - Dipartimento di Fisica "Ettore Pancini"

Superconducting Quantum Processor for High Performance Quantum Computing

General Specifications:

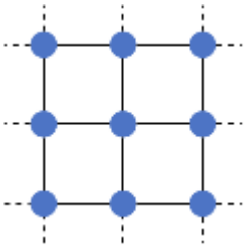
Superconducting Quantum Processor Unit (sQPU) for high-performance computing with a number of transmon qubits larger than 30.

It must include the Superconducting Quantum Processor Unit (sQPU), a suitable cryogenic packaging of the device, with a magnetic and radiative screening, and superconducting quantum-noise limited amplification chain for high-fidelity readout of the qubit state for high-performance quantum algorithms.

Detailed Specifications:

Specifications of Superconducting Quantum Processor Unit

- The device must include a number of flux-tunable coupled superconducting transmon qubits larger than 30, on a 2D square grid like in the schematic below:



- Connectivity between qubits, as outlined in the point above, must be guaranteed through high-frequency superconducting bus resonators, with a coupling strength > 5 MHz
- 90% of the qubits on chip must have a minimal relaxation time T_1 of 10 μs, while the average T_1 must be ≥ 20 μs
- Qubit frequencies must fall in the range between 4.5 and 7 GHz, compatible with the cryogenic and room-temperature electronics available in the superconducting High-performance

quantum computing laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II".

- Readout resonator frequencies must fall in the range between 6.5 and 8.5 GHz, compatible with the cryogenic and room-temperature electronics available in the superconducting High-performance quantum computing Laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II".
- The device must allow for multiplexed readout through the use of superconducting feedlines on chip (e.g., in a notch-geometry coupling). The number of feedlines must not exceed the number of readout input/output lines in a dilution Bluefors XLD1000 refrigerator, as well as the number of room-temperature electronics channels for readout, available at the superconducting High-performance quantum computing laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II", i.e. maximum 8 feedlines.
- The device must allow for simultaneous control of the qubit state through dedicated drive/control superconducting lines on chip.
- The device must allow for simultaneous flux biasing of the qubit frequencies through dedicated fast RF flux lines on chip.
- The 2D-square lattice grid connectivity must guarantee the possibility to work with fewer qubits than the maximum number of qubits available on chip (i.e., to work with sub-graphs for scalability validation), in terms of feedline numbers and coupling geometry.
- The superconducting wiring solutions for the sQPU must be well-matched to 50 Ω for control and feedline lines that allow for reduced cross-talk. Possible options include the use of superconducting Through-Substrate-Vias (TSVs).

Shielding and housing customized and configured for the Superconducting Quantum Processor Unit (sQPU)

- The device must be enclosed in a cryogenic housing that guarantees optimal radiative screening, low crosstalk between the control lines and reduction of the spurious microwave resonance modes above the readout and control frequency range.
- It is required a cold-finger that can mechanically and thermally anchor the sQPU sample holder to the coldest stage of a Bluefors XLD1000 dilution refrigerator, i.e. it must fit the anchoring screw grid of the mixing chamber plate of the cryostat.
- It is required a set of magnetic and radiative shielding compatible with the cold finger dimensions, and the available space on the mixing chamber plate in a Bluefors XLD1000 dilution refrigerator.
- The shielding and housing must be equipped with cryogenic microwave low-losses cables. The number of cables must be compatible with the total number of lines on chip. On the sQPU side, high-density and compact wiring solutions, such as Ardent connectors, are highly welcomed. The output connectors, on the other hand, must be male SMA connectors, in order to guarantee a ready-to-use system, compatible with cryogenic RF lines in a Bluefors XLD1000 dilution refrigerator, and the cryogenic electronics already available in the laboratory (standard isolator/circulators, low-pass filters, bias-tees, with female SMA connectors).

Quantum-noise limited superconducting Josephson amplifiers

- We request 8 Dispersion Engineered Josephson Travelling Wave Parametric Amplifiers (TWPAs), to be connected at the output of the readout feedlines for near-quantum-noise-limited amplification.

- The TWPAs must be delivered already bonded on a PCB (Printed-Chip-on-Board), compatible with dilution cryogenic temperatures, and enclosed in a cryogenic housing that guarantees optimal radiative screening (e.g. gold-plated copper housing).
- The TWPA housings must be equipped with one input female SMA connector and one output female SMA connector.
- The TWPAs must be functionally symmetric with no directional preference.
- The amplification band of TWPAs must be configured such that it is compatible with the readout resonator frequencies of the sQPU.
- The TWPAs must have a Lower Readout Band (LRB) and an Upper Readout Band (URB) ranging from 0.5 to 1 GHz at the optimal operating point.
- The average gain of the TWPA in the frequency range of the readout band of the sQPU must be ≥ 16 dB.
- The pump power of the TWPAs at the device must be in the range -70 dBm to -55 dBm, in order to comply with current room-temperature RF generators electronics and typical attenuation schemes in the available cryogenic setup at the superconducting High-performance quantum computing laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II".
- The pump frequency of the TWPAs must be in the range between 10 MHz to 12 GHz, in order to comply with current room-temperature RF generators electronics available at the superconducting High-performance quantum computing laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II".
- The TWPAs compression point must be above -110 dBm.
- The TWPAs ripple in LRB/HRB (2σ) must be below 5 dB.
- The TWPAs average insertion loss in the LRB/HRB must be below 10 dB**.**
- It is required a cold-finger that can mechanically and thermally anchor the TWPAs to the coldest stage of a Bluefors XLD1000 dilution refrigerator, and separately from the sQPU package.
- It is required a set of magnetic shielding (e.g. μ-metal, cryoperm) compatible with the cold finger for TWPAs and the standard dimensions of the mixing chamber plate in a Bluefors XLD1000 dilution refrigerator, i.e. it must fit the anchoring screw grid of the mixing chamber plate of the cryostat. The maximum space allowed for the TWPAs package must comply with the dimensions of the sQPU package.
- The shielding and housing must be equipped with cryogenic microwave low-losses cables. The number of cables must be compatible with the total number of input and output lines of the TWPAs in the package, i.e. 16 low-losses cables. The output connectors must be male SMA connectors, in order to guarantee compatibility with cryogenic RF lines in a Bluefors XLD1000 dilution refrigerator, and the cryogenic electronics available at the superconducting High-performance quantum computing laboratory at the Physics Department "E. Pancini" of the University of Napoli "Federico II" (standard isolator/circulators, low-pass filters, bias-tees, with female SMA connectors).

Hardware service: free for the first three (3) years after delivery.

Lead time: ten (10) months after order confirmation.

It is required to provide an sQPU with a number of qubits larger than 15, with the same specifics as reported above, before the ten (10) months lead time after order confirmation (between 5 and 7 months after order confirmation), in order to start setting up operations on the HPC quantum system. The sQPU must be compatible with the cold finger, housing and shielding of the sQPU with a number of qubits larger than 30, as reported above.