

Towards Cryogenic Superconductor Classical/Quantum Computing from a Computer Architecture Perspective

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Abstract—Moore’s Law, doubling the number of transistors in a chip every two years, has so far contributed to the evolution of computer systems. Unfortunately, we cannot expect sustainable transistors to shrink anymore, marking the beginning of the so-called post-Moore era. Therefore, it has become essential to explore emerging devices, and superconductor single-flux-quantum (SFQ) logic that operates in a 4.2 K environment is a promising candidate.

Josephson junctions (JJs) are used as switching elements in SFQ logic to compose a superconductor ring (SFQ ring) that can store (or trap) and transfer a single magnetic flux quantum. It fundamentally operates with the voltage pulse-driven nature that makes it possible to achieve extremely low-latency and low-energy JJ switching. This talk shares the history of our SFQ Research, e.g., revisiting microarchitecture and demonstrating over 30 GHz microprocessors, AI accelerator designs, and recently targeting quantum computers [ISLPED’17, ISSCC’19, VLSI Symposium’20, MICRO’20, IEEE Top Picks 2020, ISCA’22, ISCA’23, MICRO’24, MICRO’25]. Then, the role of computer architecture for such emerging device computing is discussed.

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