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Cryogenic Digital Electronics – Challenges for Practical Use –

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Superconductor-based cryogenic digital electronics has advanced much in the last decade. Single flux quantum (SFQ) circuits, in which an SFQ works as an information carrier, evolves from the rapid single flux quantum (RSFQ) logic circuit into several types of energy-efficient circuits such as the energy-efficient RSFQ circuit (ERSFQ, Hypres), the reciprocal quantum logic circuit (RQL, Northrop Grumman), the adiabatic quantum flux parametron circuit (AQFP, Yokohama Nat'l Univ.). The power consumption of these circuits is 1/10 or less compared to that of the RSFQ circuit with no or small reduction of operating frequencies. Our group has demonstrated an 8-bit-parallel RSFQ arithmetic logic unit (ALU) at 50 GHz by introducing the gate-level pipelining technique proposed by Kyushu University based on the Nb-based integrated circuit (IC) technology of the CRAVITY, AIST. The ALU has shown better performance in both the computing power defined as the number of million instructions per second (MIPS) and the power efficiency (MIPS/W) than the best semiconductor ALU, even if the cooling penalty is considered.

It is often said that difficulty of realization in large capacity cryogenic memories is an obstacle to practical applications of the SFQ ICs. However, nano-cryotrons (nTrons) invented by the MIT group showed a large output voltage up to 1 V. This device opened the way for directly driving a large capacity cryo-CMOS memory or other cryogenic memories including magnetic-Josephson-junction-based memories. Presently, we are struggling to drive a cryo-CMOS memory with an RSFQ decoder through NbN-based nTrons.

We already have a solution to all the obstacles. We believe that superconductor cryogenic digital electronics edges closer to practical use.

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