R&D Item

2. Advanced Qubit Control Front End

Progress until FY2024

1. Project Overview

This R&D project aims to enhance the performance and miniaturization of the front end (Figure 1) for qubit control and measurement, toward realizing a scalable and highly integrated quantum error correction system.

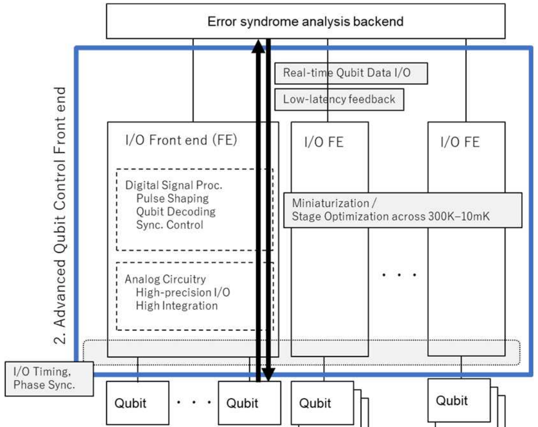

Figure 1: Role of the qubit control front end

Specifically, we addressed (1) system simplification and signal quality improvement using digital signal processing, (2) miniaturization through increased system integration, (3) improvement efficiency of clock distribution required for synchronizing multiple units, and (4) implementation of qubit measurement and feedback control for error correction, integrated with an error syndrome analysis backend.
The results of individual efforts on (1) feedback control implementation and (2) observation and error correction processing with the backend were integrated and evaluated using actual superconducting qubits. Additionally, we investigated a system architecture to apply the developed techniques to the control of non-superconducting qubits.

2. Progress to Date

To evaluate the technologies developed by FY2023 for 100-qubit control, a system composed of a signal processing board, control board, and chassis was developed (Photo 1).

Photo 1: Integrated system for ~100 qubits

Using the experimental board and integrated RF circuit modules developed by FY2023, we designed and built additional boards to adjust module dimensions and integrate them into a system for actual qubit control.
While these boards were developed for physical integration, the FPGA firmware for error syndrome measurement was independently extended to operate synchronously across multiple devices, enabling its use in a 100-qubit environment.
The firmware was successfully deployed on multiple controllers, demonstrating repeated error syndrome measurements with synchronization precision matching that of qubit control.
Furthermore, to extend the technology to quantum computers based on trapped ions and neutral atoms, we designed and implemented a prototype platform using a heterogeneous control system architecture (Figure 2).

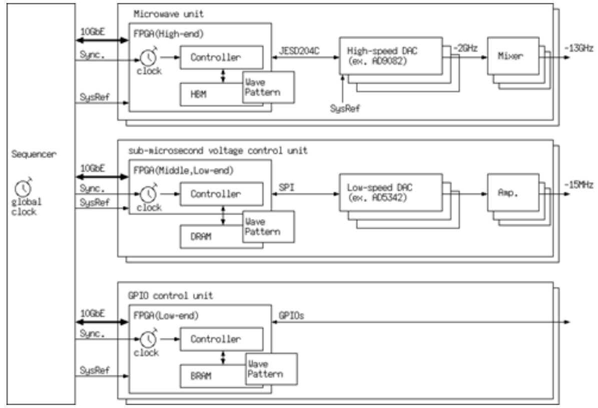

Figure 2: Heterogeneous Control System Architecture

3. Future Work

In FY2025, we will evaluate the 100-qubit controller by operating and measuring actual qubits, focusing on synchronization accuracy, signal quality, and feedback latency under realistic conditions.
We will also demonstrate error-correctable control using an error syndrome analysis backend and apply the architecture to other types of qubit-based quantum computers.