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Deltaflow.Control: A distributed control system architecture for large-scale ion trap and cold atom quantum computing

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A dedicated control system is pivotal for sophisticated experiments in atomic, molecular and optical (AMO) physics. In particular, large-scale ion-trap and neutral atom quantum computing will require some of the most complex control systems ever built. These will need to support measurement-heavy workflows, fast feedback with tight latency constraints, and be scalable in hardware and software. Here, we present the architecture of Deltaflow.Control, an FPGA-based control system designed with large-scale error-corrected quantum computing in mind. Its distributed architecture pushes processing out to all system components, reducing latency of feedback and feedforward loops. Modular atomic control units (ACUs) enable multi-tone generation of phase-coherent pulses with sub-nanosecond accuracy. We show bottleneck-free execution of instructions on all channels with scalability to multiple FPGAs and larger heterogeneous systems. Finally, we present an intuitive and deterministic programming model and a user interface for quick control, tune up and experiment orchestration crucial to saving time in the lab and enabling further advances. Our goal is to provide a powerful control system that can handle the growing list of requirements for error-corrected, large-scale quantum computing.

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