Scalable qubit control and readout with fast-scalable feedback

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Abstract
NISQ applications require improvements on gate fidelities, scalability and overcoming experimental overheads. Qblox's Cluster system is designed to support these efforts by providing fully-integrated, time-efficient and ultralow-noise control stacks. The Cluster control stacks incorporate Q1 advanced sequence processors capable of sequencing pulses and their parameters in real-time, and on-the-fly analysis of the readout signals (integration, averaging, binning and thresholding) [1]. Orders of magnitude speed-up is achieved by avoiding software-controlled loops [2,3]. While the system generates control pulses up to 18.5 GHz with ultra-low noise and drift, on the readout side, it allows both microwave and lockin measurements in the same device with frequency multiplexing, making it suitable for various qubit types and readout schemes. Qblox's fast scalable feedback distributes measurement outcomes with all-to-all connectivity to allow active-reset operations and error mitigation algorithms. Up to 80 control channels are linked to up to 40 input channels for feedback operations in a single device within 364 ns. This massively scalable approach brings qubit control and readout to a new level on the route to NISQ applications and further to fault tolerant quantum computing.

References

[1] W. Vlothuizen et al. (TU Delft, APS MM P48.014, 2016)
[2] Rol et al. PR App. 7, 041001 (2017)
[3] Koen et al. arXiv:2303.01450

Figures

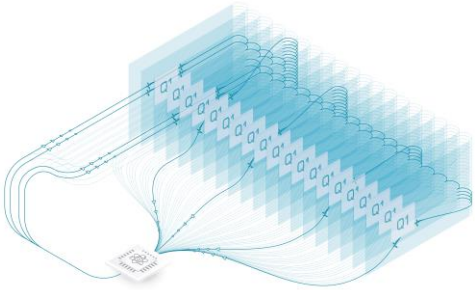

Figure 1: The fast scalable feedback is built on top Cluster's distributed intelligence consisting of 120 cores in a Cluster mainframe, working seamlessly synchronised thanks to proprietary SYNQ and LINQ protocols. The cluster mainframe distributes measurement outcomes with all-to-all connectivity, meaning that up to 80 control channels are linked to up to 40 input channels for feedback operations within 364 ns.

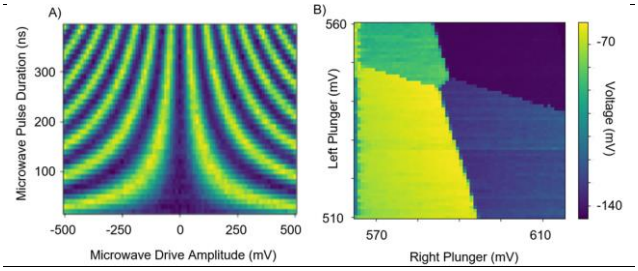

Figure 3: Examples where order-of-magnitude speed-ups are achieved through real-time on-board compiling and on-board data analysis. A) Chevron plot for tuning the pulse amplitudes and duration of a transmon qubit, measured in 23 seconds (IMPAQT consortium) B) Charge stability diagram for tuning a Si double-dot sample, measured in 180 ms (Qutech).