# Qblox Quantum Control Stacks: Accelerating Experiments, Reducing Error, and Enabling Large-Scale Quantum Computing

**Tahereh Niknejad**
Rohit Navarathna, Edgar Reehuis, Damaz de Jong, Marijn Tiggelman, Daniel Weigand, Edmundo Ferreira, Calin Sindile, Jordy Gloudemans, Wouter Vlothuizen, Jules van Oven, Christiaan Cornelis Bultink,

*Qblox BV, Delft, the Netherlands*

tniknejad@qblox.com

Abstract:

NISQ applications require improvements in 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 covering frequency range of DC to 18.5 GHz, making it suitable for various qubit types.

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. Orders of magnitude speed-up is achieved by avoiding software-controlled loops and fast scalable feedback operation.

RFSoC-based qubit control and readout modules generate RF signals directly on-chip, using double super-heterodyne approach, eliminating the need for mixer calibration. They are designed for scaling up control and readout systems with higher channel density, extended analog bandwidth up to 1.6 GHz, and multiplexing capability of up to 12 frequencies.

Additionally, a dedicated time-tagging module with digital I/O streamlines readout of single photon detectors for both time tagging and photon counting.

To minimise errors at the individual qubit level, the Qblox Cluster integrates real-time pre-distortion within the signal chain. This actively corrects pulse imperfections imposed by travelling through cables and cryogenic systems enabling repeatable and high-fidelity control pulses.

Finally, Qblox's fast scalable feedback distributes measurement outcomes with all-to-all connectivity to allow active-reset operations and error mitigation algorithms. 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.

For controlling the instrument, Qblox offers open-source Python-based software packages. The high-level software package, Quantify, simplifies complex quantum programming with libraries of pre-defined pulse schemes tailored to different qubit platforms.

For users requiring even greater control, the system allows programming the Q1 sequencer directly using assembly language for complex user-defined pulse sequences allowing unparalleled control. Additionally, Qblox integrates a Qiskit compiler enabling seamless execution of Qiskit experiments directly on the Qblox Cluster.

In this talk we will dive deep into the Qblox solution, from its hardware and software architecture to real-world applications.