Improving flux-based gates in superconducting QPUs through model learning of qubit and control stack parameters

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The flux-based controlled-phase (CZ) gate offers potential speed-ups for two-qubit entangling gates, by operating at the speed limit of the transverse coupling between the computational and non-computational states. The scheme entails flux control of transmon frequency using a unipolar or bipolar square pulse. While ideally, the population exchange between the |1,1> and |0,2> states near resonance should show symmetric chevron-like oscillation patterns around the target flux amplitude, experiments reveal asymmetries that impact fidelity of flux-based gates. Using a physics-informed machine learning model to minimize the Euclidean distance between experimental and simulated chevrons, we learnt pulse distortions occurring down the control line, besides learning some relevant system Hamiltonian parameters. Our framework complements the Cryoscope technique of measuring the step response of flux control lines, as we also model pulse distortions after digital-to-analog conversion in the control stack. The model achieves a 99.5% match with experimental chevron data for unipolar flux pulses and was validated for chevrons obtained for bipolar pulses. We shed light on the physical implication of the learnt parameters and lay out actionable insights about correcting the pulse distortions to improve fidelity of the flux-based gates.

References

[1] Wittler, et al., Physical Review Applied, 15(3), 2021

Figures

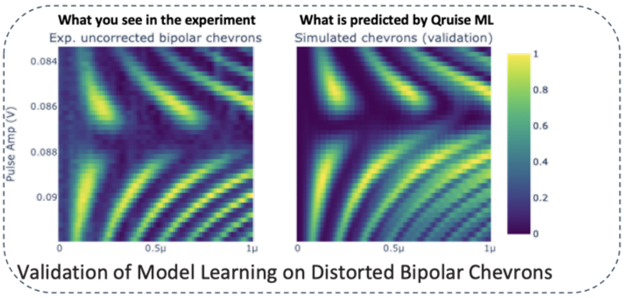

Figure 1: Validation of the Model Learning process through prediction of Bipolar CZ distorted chevrons from simulations.

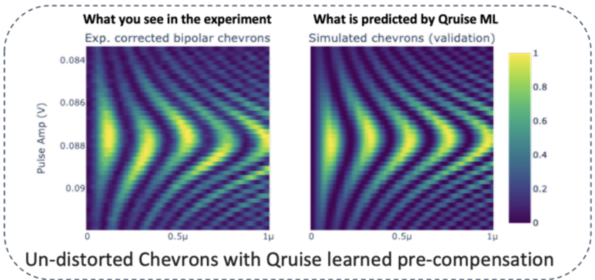

Figure 2: Application of Model Learning process to improve Bipolar CZ gates as demonstrated through correction of the chevron plots.