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**Progress towards a small-scale quantum annealer III: Device theory and modeling** DVIR KAFRI, Google Inc., CHRIS QUINTANA, Department of Physics, University of California, Santa Barbara, YU CHEN, ALIREZA SHABANI, VASIL DENCHEV, Google Inc., JOHN MARTINIS, Google Inc. and UCSB, HARTMUT NEVEN, Google Inc., QUANTUM A.I. LAB TEAM — Future superconducting quantum annealers will require precise calibration and control. This is especially difficult for systems with strong couplings and large Josephson nonlinearities, which are challenging to accurately model. In these regimes, linear (harmonic) approximations to circuit physics break down and phenomenological modeling is not practical because of the large number of control fields. Furthermore, such systems tend to have multiple interacting degrees of freedom, making numerical diagonalization of exact Hamiltonians exponentially inefficient. To overcome these difficulties, we develop an approximate, low dimensional theory equivalent to the Born-Oppenheimer Approximation in molecular physics. By effectively integrating out 'fast' degrees of freedom, this allows for efficient modeling of individual circuit components while including corrections due to interactions. Importantly, out theory is non-perturbative with respect to circuit interactions, making it applicable in the ultra-strong coupling regime. We apply these techniques to the precise calibration and control of coupled superconducting flux qubits.

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