# Characterization and Simulation of Quantum Gate Errors on IBM-Q Superconducting Devices

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Quantum computing holds the promise of revolutionizing fields such as quantum chemistry, material design, finance, and industrial management. However, the high error rates in near-term noisy intermediate-scale quantum (NISQ) devices have so far hindered these breakthroughs. Understanding the characteristics of quantum noise in NISQ devices is therefore crucial to developing hardware and software solutions for noise suppression. In this talk, I will present a general theoretical framework for noise characterization in quantum computers. This approach leverages a generic small error generator theory to comprehensively describe both coherent and incoherent quantum errors arising from quantum gate operations. Using this framework, we conducted extensive noise measurements on IBM-Q systems, including intrinsic qubit decoherence times (idle gates), as well as X, Y, Z, H, and CNOT gates. Our findings reveal significant differences in noise characteristics among these single-qubit gates, including a subtle rotation axis tilt that strongly influences the noise dynamics of gate operations. Notably, we observed that the noise is highly non-Gaussian, exhibits long-time correlations, and is strongly affected by state-preparation-and-measurement errors across all gates. Additionally, coherent errors dominate the noise for most gates, with the H gate being an exception. These noise characteristics offer valuable insights into the quantum noise and decoherence dynamics of IBM-Q superconducting devices. Furthermore, we demonstrated that these measured noise profiles enable accurate simulation of noisy gate operations on IBM-Q devices. We anticipate that this data will play a critical role in device calibration, error mitigation, and the development of error correction strategies for NISQ quantum computing systems.

**References**

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