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Hamiltonian Engineering for High Fidelity Quantum Operations

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— High-fidelity gates and operations are crucial to almost every aspect of quantum information processing. In recent experiments [1], fidelity is mostly limited by unwanted couplings with states living out of the logical subspace. This results in both leakage and phase errors. Here, we present a general method to deal simultaneously with both these issues and improve the fidelity of quantum gates and operations. Our method is applicable to a wide variety of systems. As an example, we can correct gates for superconducting qubits [1], improve coherent state transfer between a single NV centre electronic spin and a single nitrogen nuclear spin [2], improve control over a nuclear spin ensemble [3], etc. Our method is intimately linked to the Magnus expansion. By modifying the Magnus expansion of an initially given Hamiltonian H_{i}, we find analytically additional control Hamiltonians H_{ctrl} such that $H_{\mathrm{i}} + H_{\mathrm{ctrl}}$ leads to the desired gate while minimizing both leakage and phase errors.

[1] Zijun Chen, *et al.*, arXiv:1509.05470.
[2] G. D. Fuchs, *et al.*, Nat. Phys. **7**, 789793 (2011).
[3] Mathieu Munsch, *et al.*, Nat. Nano. 9, 671675 (2014).

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