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Architectural Design Issues for Reliable Trapped Ion Quantum Computers

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Central to the design of large-scale quantum computers is the fact that reliable quantum systems must explicitly and actively deal with relatively large component failure rates during operation. A quantum computing system must thus attain reliability by encoding operations with unreliable components such that faults can be detected and corrected, despite occasional failures induced by ubiquitous quantum noise. Accomplishing this requires more than just high gate fidelities, however, as two recent interesting results highlight. First, universal quantum computation on standard stabilizer quantum codes is impossible using only transversal gates, those which limit error propagation; it turns out non-transversal steps such as teleportation are necessary. Second, the overall reliability of trapped ion and other quantum computing schemes will ultimately be limited not by gate or measurement fidelities, but very likely, by the fidelity of movement and waiting operations, due to the necessity of non-transversal gates. These results are presented, together with implications for architectural design requirements.