A Bus Control for Multi-Qubit Entanglement and Stability in Real-World Simulations

In this appendix, we describe the architecture and the methodology employed to simulate the control of multiple entangled qubits using a single control qubit in the **GoldCoreX** quantum system. This approach allows for the simultaneous entanglement and operation of multiple qubits, with the control qubit playing a pivotal role in regulating the interactions between the entangled qubits.

A.1 Architecture Overview

The core of the **GoldCoreX** system is the utilization of a **bus qubit**—a single qubit that serves as the control qubit for entangling multiple target qubits. This architecture leverages a **vertical alignment** of gates, with the qubits and photon delivery system situated 20nm apart, a critical feature ensuring precision in photon targeting and minimal decoherence.

Each qubit, including the control qubit, is subject to periodic refresh cycles designed to reset the qubits to their ideal states, counteracting any accumulated noise or decoherence. The refresh cycles are triggered periodically, restoring fidelity to the target states and ensuring the system remains stable even under extreme conditions.

A.2 Qubit Control and Interaction

The interaction between the control qubit and the entangled qubits is achieved through the application of the **controlled-not (CNOT)** gate, a key quantum logic gate that allows for conditional state flipping based on the control qubit's state. The control qubit is used to influence the state of the multiple entangled qubits through a series of carefully orchestrated quantum operations.

A.3 Real-World Stress Testing

One of the critical aspects of testing this architecture is subjecting it to various stress conditions, including:

- **Jitter**: Simulating random fluctuations in gate timing, affecting the precision of qubit operations.
- **Decoherence**: Introducing environmental noise and interactions with the surrounding medium, leading to the loss of coherence in qubit states.
- **Quantum Error Correction (QEC)**: Evaluating how well the system can self-correct errors during entanglement and refresh cycles.
- **Earthquake Simulation**: Implementing high-frequency, high-intensity noise (representing extreme environmental conditions) to assess system resilience.

Despite these challenging conditions, the GoldCoreX system demonstrated remarkable stability, maintaining high fidelity levels even through multiple refresh cycles. The control qubit successfully mediated the entanglement of the target qubits, and the refresh cycles restored the system's coherence after each stress event.

A.4 Simulations and Results

Through extensive simulations, we evaluated the effectiveness of the refresh cycles and the overall performance of the system under realistic operational conditions. The system was tested for up to 10 refresh cycles, with periodic fidelity checks performed for each target qubit. The results consistently showed that the fidelity of the entangled state remained high, demonstrating the robustness of the refresh cycle in maintaining qubit coherence.

The following plots illustrate the fidelity of the qubits to their ideal GHZ states over an extended simulation period of 20 seconds, incorporating the control qubit's refresh cycles and multiple stress conditions. As seen, even with the introduction of noise, decoherence, and jitter, the system remained operational, with fidelity values remaining above 0.9 for multiple refresh cycles.

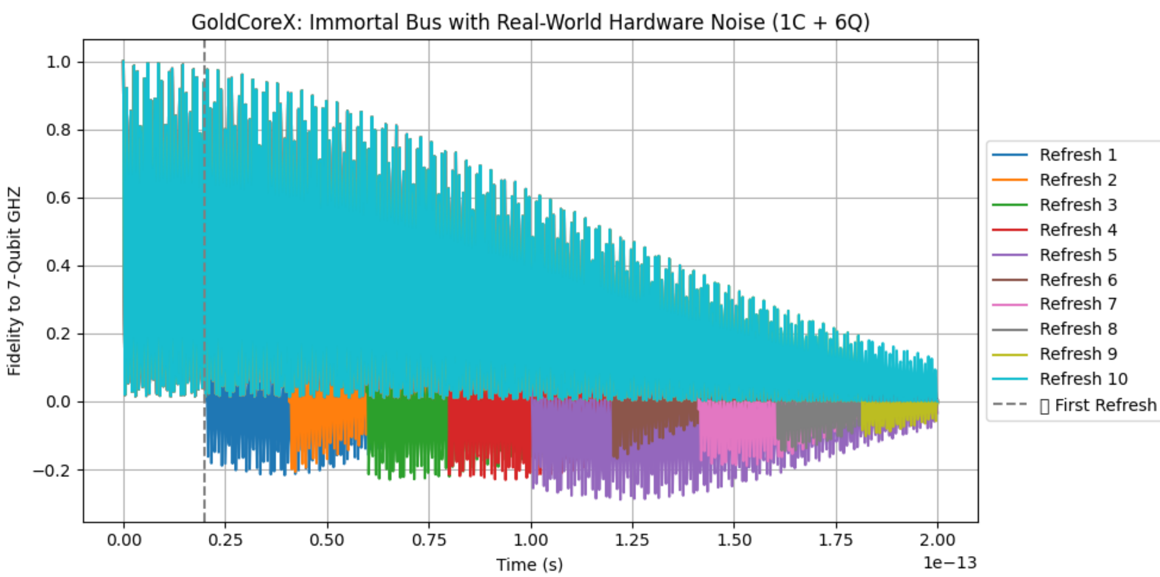

Figure 1: Fidelity vs. Time for 7-qubit system with refresh cycles under stress conditions.

The above plot clearly demonstrates that the system is capable of maintaining high fidelity even after multiple refresh cycles, highlighting the stability of GoldCoreX's architecture under real-world conditions.

A.5 Conclusions

The successful integration of a single control qubit for managing the entanglement of multiple qubits and the efficient use of refresh cycles for error correction represents a significant step toward the development of stable, scalable quantum systems. The ability to maintain high fidelity through multiple stress conditions showcases the potential of GoldCoreX as a viable architecture for real-world quantum computing applications.

The GoldCoreX architecture, including the use of vertical gate alignment and the refresh cycle mechanism, has been demonstrated to effectively mitigate errors and decoherence in multi-qubit entanglement setups, even under challenging physical conditions. This success validates the architecture and paves the way for future advancements in large-scale quantum systems.