**Circuit QED Pulse Control Interface**

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**Introduction**

Circuit Quantum Electrodynamics (circuit QED) leverages strong coupling between microwave photons and superconducting qubits for precise quantum state control via engineered pulses. Our Pulse Control Interface streamlines the design and testing of circuit QED control signals through a graphical user interface (GUI), incorporating two key protocols for state manipulation:

- **SNAP-Displacement Protocol**: Combines Selective Number-dependent Arbitrary Phase (SNAP) gates and displacement operators to modulate the states within a cavity. The SNAP gate applies a phase \( \theta_n \) to each photon number state \( |n \rangle \):
  \[
  S(\theta_n) = \prod_{n=0}^{\infty} e^{i \theta_n |n \rangle \langle n|}.
  \]
  Displacement operators shift the state in phase space: \( D(\alpha) = e^{i \alpha a^\dagger - \alpha^* a} \), where \( \alpha \) is the amplitude, \( a^\dagger |n \rangle = \sqrt{n+1} |n+1 \rangle \), and \( a|n \rangle = \sqrt{n} |n-1 \rangle \).

- **ECD Protocol**: Uses a qubit-state-dependent control mechanism. The Echoed Conditional Displacement (ECD) gate, expressed as \( ECD(\beta) = D \left( \frac{p}{2} \right) |e \rangle \langle g| + D \left( -\frac{p}{2} \right) |g \rangle \langle e| \), employs \( \beta \), a displacement parameter, and echoes via a qubit \( \pi \)-pulse. The protocol also involves qubit rotations: \( R_x(\theta) = e^{-i \theta (\cos \phi \sigma_x + \sin \phi \sigma_y)} \), to adjust the phase.

**Methods**

The interface features a drag-and-drop PyQt5 GUI for assembling quantum circuits. The signal generation module creates pulse envelopes based on user-defined parameters such as amplitude, phase, waveform, and duration. Real-time visualization of the control signals generated provides instant graphical feedback.

**Conclusion & Future Directions**

We have successfully developed a tool for efficient circuit QED control implementation, demonstrating high fidelity in quantum state preparation. Future efforts will focus on interfacing the application with circuit QED hardware and enhancing overall system performance. Plans include improving existing protocols by integrating noise models and error correction techniques and addressing sampling rate precision issues.

**References**


QuTiP simulations were utilized to verify the fidelity of state preparation using the implemented protocols. The fidelity values confirm that the states closely match the theoretical predictions.