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Enhancing Two-Qubit Gate Fidelity: Eliminating Phase Errors and Improving Performance

Technology Description

Our technology needs further improvements on the fidelity of two-qubit gates. The invention thus aims at such improvement by eliminating one of the most challenging and significant errors in the phase of qubit states that is always-on. By applying a fine-tuned cross-resonance (CR) pulse to the control qubit, the undesired phase errors can be significantly reduced and even ideally set to zero. The circuit includes two qubits with different frequencies and a coupler that connects them. Microwave pulses are used to drive the control qubit, and the amplitude of the CR pulse is adjusted to minimize the phase error. The method can be theoretically determined using circuit QED theory and experimentally verified using a modified version of quantum Hamiltonian tomography.

Problem

The previous state of the art in operating circuits with qubits faces several challenges. Quantum computers store and process information using qubits, which can exist in superposition states, unlike classical bits. However, maintaining superposition is challenging due to the short coherence time. Additionally, physical qubits have higher energy levels beyond the computational states, leading to unwanted interactions and phase errors. Unintended ZZ interactions between qubits, even in the absence of gates, accumulate phase errors. These issues hinder the performance of novel quantum computers. The new technology aims to address these problems by minimizing unwanted interactions and achieving a phase-error-free two-qubit state.

Solution

The invention provides a solution in order to modify the qubit parameters, coupling strength, and CR pulse amplitude to suppress undesired phase errors caused by computational energy level repulsion by non-computational levels.

By optimizing the frequency and anharmonicity in the qubits, the repulsion can be reduced to zero. However, applying the microwave-

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More Information
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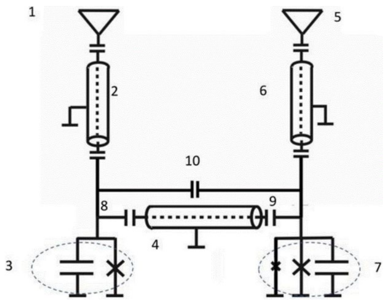
driven two-qubit gate, the Cross Resonance (CR) gate, re-establishes new repulsion. To improve fidelity of the gate the use of CR pulses in a specific amplitude range can effectively reduce the phase error and enhance gate fidelity. The control qubit can be a charge-sensitive flux qubit (CSFQ) while the qubits can also be of different types, such as qubits of the Transmon or CSFQ types, and their anharmonicity signs can be the same or opposite. The use of echo-CR pulses further reduces unwanted interactions.



Potential Use

The technology enables the creation of high-fidelity two-qubit gates, which are essential for various quantum sensing and quantum computing applications. The improved gate fidelity enhances the accuracy and reliability of quantum operations, leading to more robust quantum algorithms and error-correcting codes. The method can be applied to different types of qubits, allowing for flexibility in quantum hardware design. The precise control of qubit parameters and coupling strength opens up possibilities for advanced quantum information processing tasks, including quantum simulations and cryptographic protocols.

Development Status and Next Steps

Forschungszentrum Jülich has extensive expertise in this field and holds several patents. The technology described above has already been initially verified through prototypes and is continuously being developed further. The Peter Grünberg Institute (PGI-2) – Theoretical Nanoelectronics – already cooperates with numerous national and international companies and scientific partners. Forschungszentrum Jülich focuses on energy and cost-efficient devices, suitable for various emerging technologies. We are continuously seeking for cooperation partners and/or licensees in this and adjacent areas of research and applications.

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