A Toffoli Gate Using Dispersive Shifts Within Superconducting Circuits

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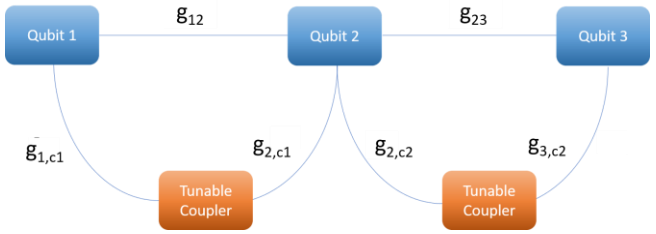
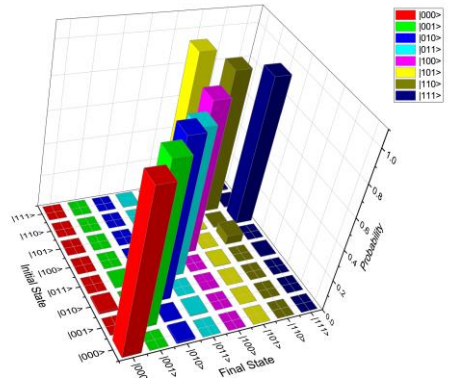
Abstract

Here, we propose a single shot method for executing a Toffoli gate using current superconducting hardware. We numerically show that this single shot gate can be run at a fidelity well over 97% and a gate time of ≈700ns. Our method can be extended to implement gates with more than two control qubits, e.g., controlled-controlled-controlled-not gates, with comparable fidelity and gate time.



a.)



b.)

a.) Simplified circuit diagram for our proposed circuit.
b.) Fidelity chart showing the overlap between the ideal Toffoli states and the measured Toffoli states. This shows an overall fidelity of >97% and a gate time of ~700ns.

Project Description

We propose a new way of performing multi qubit gates within superconducting circuits. We utilise ZZ couplings already present in current architecture used by Google, IBM etc. This ZZ coupling causes a shift in the transition frequency of a "Target" qubit causing the circuits energy levels to be individually addressable.

The individually adressable transition frequencies can be used to perform controlled Not gates by applying a microwave drive to the target qubit at the required frequency. This effectively causes a controlled Not gate to occur.

This system could be extended to perform Controlled arbitrary phase gates where off resonant driving is utilised in much the same way to accumulate phase on an individual energy level.

Key Results and Conclusions

- We have theoretically and numerically shown that a Single Shot Toffoli gate Is possible in Superconducting Circuits and shows the fidelity to be >97%.
- We have developed a mechanism to deal with any errors due to phase accumulation due to the Dispersive Shifts.
- This architecture can be used to perform Controlled-Controlled Phase gates as well when operating an off resonant drive
- We can also easily extend this circuit to Multi Control Not gates which are very useful in Quantum Error Correction and the same applies to the phase gates mentioned above