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FPGA Qubit Package

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ABSTRACT

FPGAs have wide-ranging applications across a multitude of disciplines, from bioinformatics to signal processing. In the field of quantum information and, specifically, quantum computing, FPGAs have unique application in being a fast classical interface for pre-processing quantum signals. FPGAs are useful for discriminating quantum states, binning these states, performing tomography, and enacting fast feedback schemes. As such, we propose to implement these features on an FPGA.

Specifically, we will begin by speeding up the qubit measurement process. This involves performing an FFT on microwave signals down-converted to 10 MHz, which will map a qubit state onto the complex (I-Q) plane. Next, we will load a linear discriminator onto our FPGA, which has been found using previous measurement data and machine learning (i.e. an SVM) to discriminate between the ground and excited state of our qubit. This linear classifier can then be used to perform a continuous binning of qubit data, over a series of a few thousand measurements. We will also consider reporting metrics such as the distance between the points and the classifier which can be used to assess how certain we are of our classification. This will allow us to determine the relative number of times our qubit collapses to the ground and excited state. We can use this information to implement quantum state tomography, a vital tool for the verification of quantum algorithms, which involves using techniques like maximum likelihood estimation to acquire more information about the qubit state and reconstruct the density matrix.

Lastly, we would like to explore the domain of real-time error correction. In a system of five qubits, we can use two as parity qubits to see if error has been introduced on any of our three data qubits. We propose using the measured values of the two parity qubits and a look-up table decoder to create a simple feedback scheme to correct errors in our three data qubits.