QCHACK 2021 - QCTRL
Robust Error Control

You must also write a 2-page report on how you used quantum control, with Q-CTRL's [BOULDER OPAL](), to discover and implement these pulses.

The start of our approach was to first **define our ideal gates** and then compare those definitions with the gates that we have proposed.These gates are rotations in the Bloch sphere, and are defined by sigma x, sigma y, sigma z (to represent the three coordinates axes of rotations).

To define any gate we needed a Hamiltonian of our system which contains information about the actual rotation we are trying to achieve with the gate and the noise that is present in our environment as the dephasing and the amplitude error.

The initial code cell used Boulder OPAL to generate the plots in our code and the main approach that we used to improve our qubits in the cloud was **Robust Control.** We used Linear Smoothing function over the Microwave pulses that were applied on our qubits and the pulses are chosen so that, *when smoothed by the filters in the system*, they will affect a high-quality gate.

The **Hamiltonian is divisible into controlled and noisy parts**, both of which are dependent on time. Discrete pulse segments are created in the ComplexSegmentInput in q-ctrl with the maximum value of the amplitude and a time duration. We use BOULDER OPAL to **approximate the values of the noisy environment to those of a classical process**. Our function takes in a small value of frequency cutoff against large power. This approximation when plotted shows that that lower frequency contributes to more dephasing.

We discover **that the trajectories of the real path diverges from an ideal one under the influence of noise.** The average gate infidelity is optimized to show average results through a stochastic simulation in BOULDER OPAL. Simulation of the noisy is done by using a **colored_noise_simulation** function and they are compared against the ideal simulation results.

By varying our angle by small values of theta, we study the average variation which at its finality gives us the infidelity for the proposed gate.

Additionally, we assume that the **noise within the Hamiltonian is constant**. We use the filter function as a Fourier transform on the noise hamiltonian , which allows us to quantify how noise affects our final input. By minimizing the infidelity we can create a robust function. We then compare the output of a standard not gate and a real gate at Low frequencies, making us realise the infidelity is low for small noises.

Inorder to have a robust design the infidelity of the noise and control should both be low, which in BOULDER OPAL, is optimized into the **obtaining the minimum value of the cost function**. Using the small cost values and the filter function we obtain a graph that almost entirely removes low frequency pulses.

Roadblocks encountered

The main problem that we encountered was the **calibration of our microwave pulses.** Given the time frame, although we generated a good approximation of the realistic qubits by simulation of noise on our systems, the actual measurement results were not acceptable due to the fact that Rabi rates of the qubits were not known to us.

We applied the same outline and principle to find a suitable microwave pulse for the Hadamard gate. However, we did not change the Hamiltonian we had previously used for the NOT gate due to time constraints. And thus the infidelity rates were beyond acceptable bounds.

Future Optimizations

- Since we were not able to figure out the Rabi rates for our qubit correctly given the time frame, we would like to be able to understand the format of that calculation.
- One other limitation in our approach was that the gate fidelity of our hadamard simulation was not perfect as we weren’t able to figure out the Hamiltonian to the best of our abilities.
- Last but not least, if given the time, we would surely be able to optimize our approach to realizing the general gates and help in producing better computations.