QCHACK 2021 Q-CTRL CHALLENGE

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1 Pulse optimization using optimal control

1.1 Control line characterization

To estimate the effect of the control lines on the pulses, we assumed a gaussian kernel of the line filter and probed its effect using gaussian pulses, according to the procedure described in https://docs.q-ctrl.com/boulder-opal/application-notes/control-hardware-system-identification#Characterizing-the-control-lines.

We use a total duration of 50, 256 segments and the same configuration of possible values for means and widths as in the tutorial. Only the maximum possible width is increased to 50/4.

Additionally, we need to find the optimal amplitude for each of the 24 possible probe pulses. To do that, we sweep the amplitude between 0 and 1 and pick the point that gives the maximal $|1\rangle$-probability as the optimal amplitude to be applied for the later characterization.

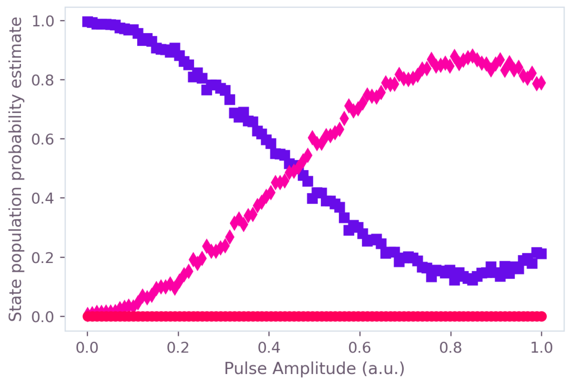

Figure 1: Probabilities of measuring a $|0\rangle, |1\rangle$ and $|2\rangle$ state for different pulse amplitudes but fixed mean and width.

The optimization process applied to our measured results is shown in Fig. 4, together with the extracted values in Table 1.

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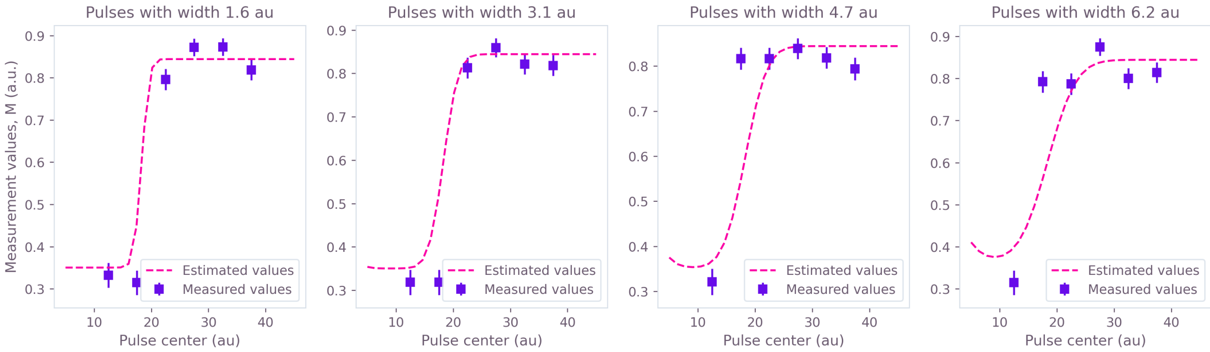

Figure 2: Filter optimization result for a duration of 50 units.

	estimated value
σ	(0.500 $\pm$ 0.381)
μ	(31.653 $\pm$ 0.147)
a	(-0.494 $\pm$ 0.016)
b	(0.844 $\pm$ 0.006)

Table 1: Estimated filter parameters in arbitrary units (relative to the total control duration).

1.2 Pulse optimization

We used the following Hamiltonian for the optimizer:

$$H = F\left[\frac{1}{2}\gamma(t)^{\dagger}b^{\dagger} + \frac{1}{2}\gamma(t)b\right] + \Omega_x\sigma_x + \Omega_y\sigma_y + \Omega_z\sigma_z \tag{1}$$

For the Noise channels:

$$\text{detuning: } a_{T2}\sigma_z \qquad \text{depolarisation: } a_{T1}b \tag{2}$$

For the values:

	estimated value
σ	(0.500 $\pm$ 0.381)
μ	(31.653 $\pm$ 0.147)
Ω_x	0.01
Ω_y	0.01
Ω_z	0.1
a_{T1}	0.01
a_{T2}	0.1

Table 2: Filter parameters used and guessed parameters for the noise model. Due to time constraints we weren't able to determine them using measurements and used educated guesses.

Using the above values we were able to get probability of achieving $|1\rangle$ when applying the

NOT gate to $|0\rangle$ - 0.96. For the Hadamard gate the measurement of the superposition state after applying the gate to $|0\rangle$ - 0.504. This sadly doesn't mean out H gate is that good, since applying HXH to $|0\rangle$, doesn't return $|0\rangle$. Most likely the phase noise values in the model are incorrect and the the phase of the state after applying the H gate is not correct.

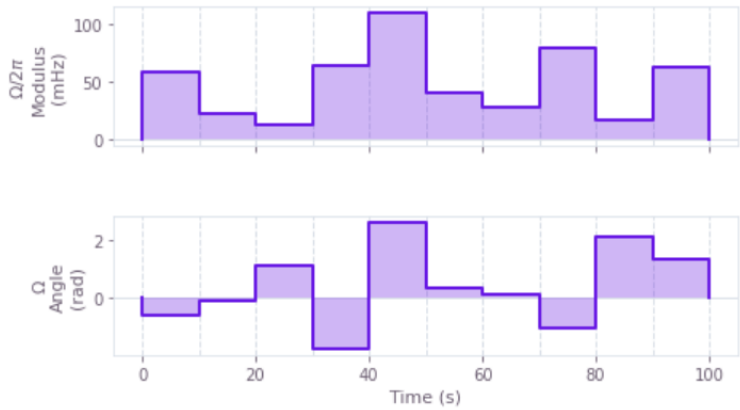

Figure 3: The pulses of the Hadamard gate

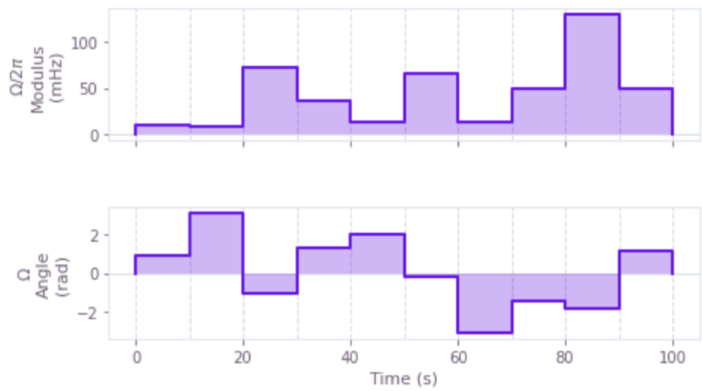

Figure 4: The pulses of the NOT gate