

Implementing Classical Logic in a Quantum Environment

Christopher T. Dunne
Capitol Technology University, USA
cdunne@captechu.edu

Abstract— This paper is meant to serve as an introductory guide on how to implement simple logic gates in a quantum environment. Uncompressed circuits for each statement can be found in the appendix.

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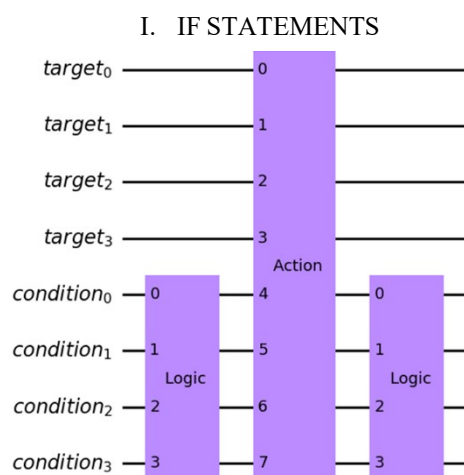


Fig. 1. The general structure of an IF statement in a quantum environment.

The target register in Fig. 1 will store the results of the Action gate and the condition register will be used in the Logic gate to determine if the Action gate runs. The Logic gates are used to set each qubit in the condition register to $|1\rangle$, or true.

A. LOGIC GATE EXAMPLE

If the Action gate is only supposed to run if a given value is 1001 the Logic gate would look like Fig. 2. This works by running an X-gate on each qubit that should be in the state $|1\rangle$ if the desired state was $|1001\rangle$. In this example, the qubits being set to $|1\rangle$ are qubits 1 and 2 of the condition register. The second Logic gate will then set the condition register back to its original value of $|1001\rangle$.

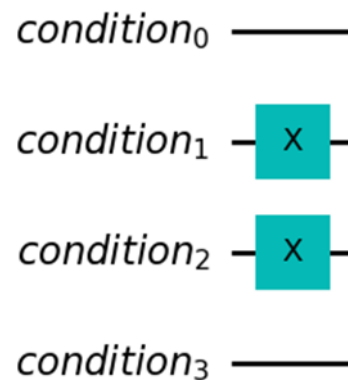


Fig. 2. An example of a Logic gate testing to see if the condition register is in the state $|1001\rangle$.

B. ACTION GATE EXAMPLE

The Action gate will consist of the normal gates one would use to reach a desired outcome but said gates will be modified to be controlled gates. Controlled gates are gates with a base gate and a control state, wherein the base gate will only run if the control is true (ControlledGate — Qiskit 0.36.1 documentation, 2021). Fig. 3 displays an example of this if one wanted to invert qubits 1 and 2 of the target register if the condition register was true.

In this scenario the Action gate consists of two controlled gates wherein a X-gate serves as the base gate and the condition register serves as the control state. This controlled gate is functionally identical to the MCX (multi-controlled X) gate (MCXGate — Qiskit 0.36.1 documentation, 2021). If a multi-controlled gate has multiple targets it will be referred to as a MCMT (multi-controlled multi-target) gate.

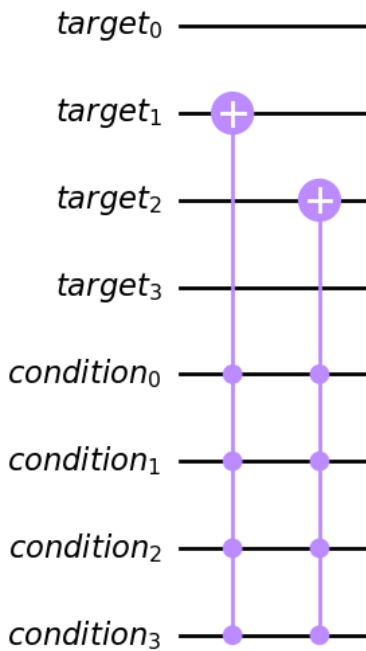


Fig. 3. An example of an Action gate that will invert qubits 1 and 2 of the target register.

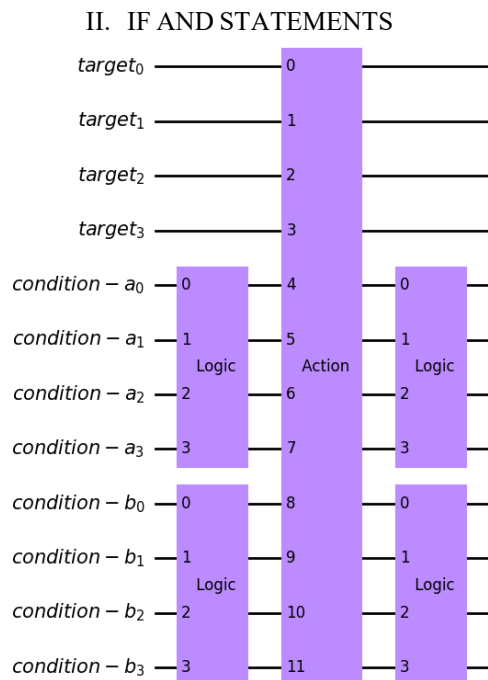


Fig. 4. The general structure of an IF AND statement in a quantum environment.

IF AND statements in a quantum environment are identical to IF statements, but the multi-controlled gates in the Action gate will use the qubits in both condition registers. This ensures that the Action gate will only run if the condition registers are in their desired state.

III. IF OR STATEMENTS

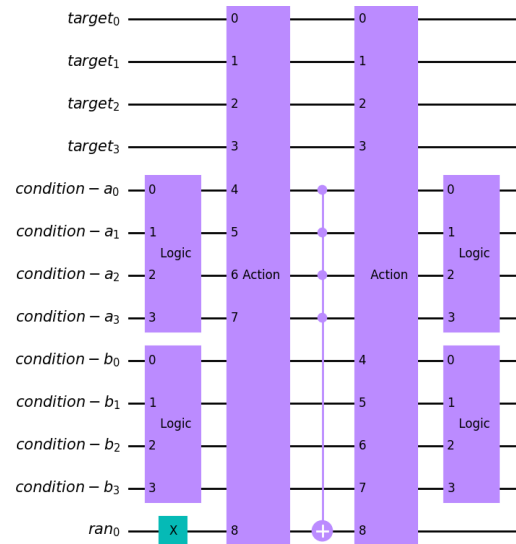


Fig. 5. The general structure of an IF OR statement in a quantum environment.

In an IF OR statement the Action gates will use the condition register as well as the ran register as the control state. The ran register is a single qubit register that is initialized to the state $|1\rangle$. After the first Action gate runs a MCX gate is used using the condition register for the first condition as its control state. This ensures that the Action gate will not be ran twice if both conditions are true.

IV. IF ELSE STATEMENTS

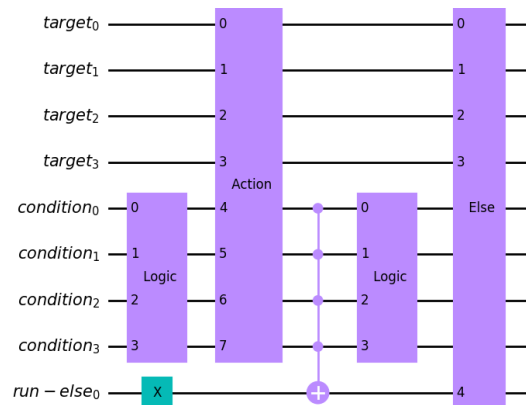


Fig. 6. The general structure of an IF ELSE statement in a quantum environment.

An IF ELSE statement uses an additional register (run-else) to determine whether to run the else condition. Similar to the ran register in the IF OR circuit, the run-else register is also initialized to the state $|1\rangle$. After the Action gate is ran a MCX gate is used using the condition register as the control state. Afterwards the Else gate will run if the run-else register is in the state $|1\rangle$.

V. APPENDIX

A. IF CIRCUIT

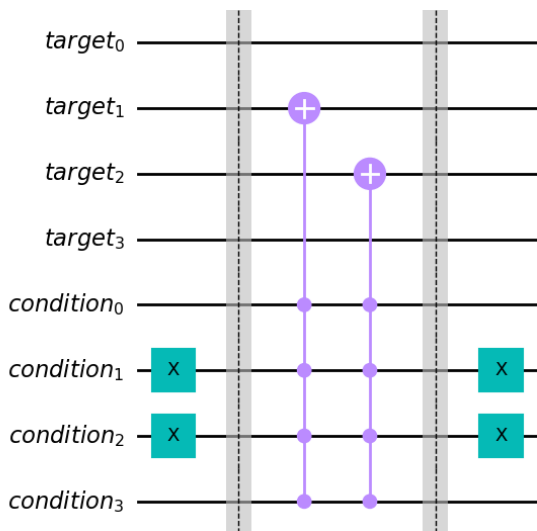


Fig. 7. A circuit that will invert qubits 1 and 2 of the target register if the condition register has the initial state $|1001\rangle$.

B. IF AND CIRCUIT

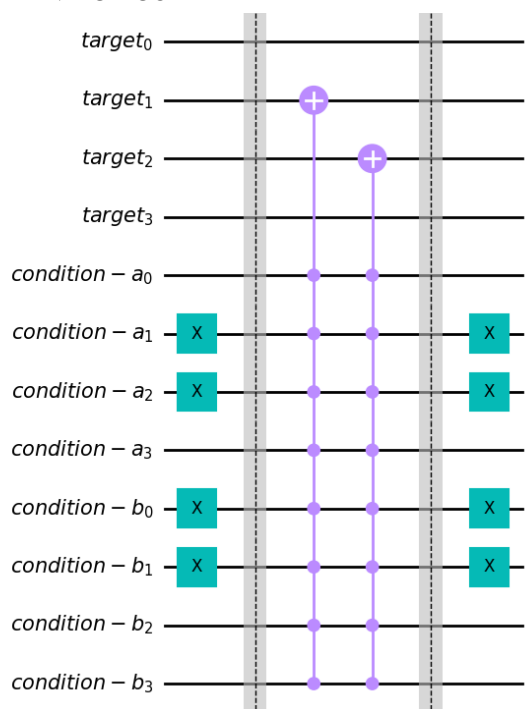


Fig. 8. A circuit that will invert qubits 1 and 2 of the target register if the condition registers have the initial states of $|1001\rangle$ and $|0011\rangle$.

C. IF OR CIRCUIT

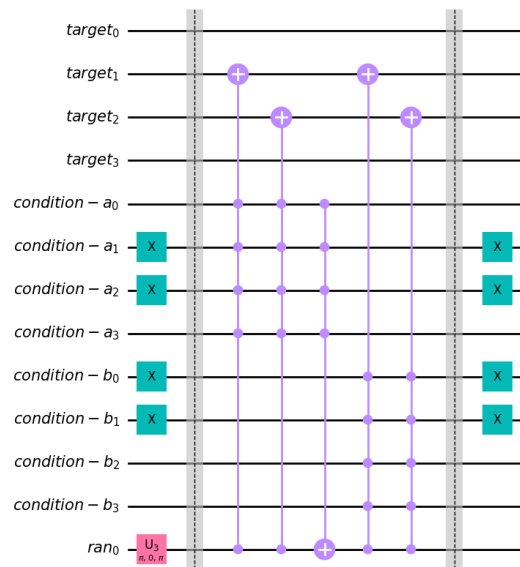


Fig. 9. A circuit that will invert qubits 1 and 2 of the target register if the condition registers have the initial states of $|1001\rangle$ or $|0011\rangle$.

D. IF ELSE CIRCUIT

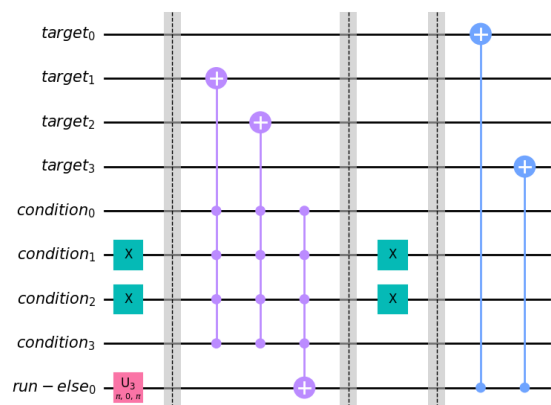


Fig. 10. A circuit that will invert qubits 1 and 2 of the target register if the condition register has the initial state $|1001\rangle$. Otherwise, it will invert qubits 0 and 3 of the target register.

REFERENCES

- ControlledGate — Qiskit 0.31.0 documentation, 2021, accessed October 8, 2021, at Qiskit.org at <https://qiskit.org/documentation/stubs/qiskit.circuit.ControlledGate.html>.
- MCXGate — Qiskit 0.31.0 documentation, 2021, accessed October 8, 2021, at Qiskit.org at <https://qiskit.org/documentation/stubs/qiskit.circuit.library.MCXGate.html>.