CMT304 Part3-Quantum Computing

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Task 1: Circuit Analysis

For analysing the behavior of the circuit I divided the circuit into two-part. Firstly the two controlled-NOT gates in the center and secondly, the F and $F^{\dagger}$ gate.

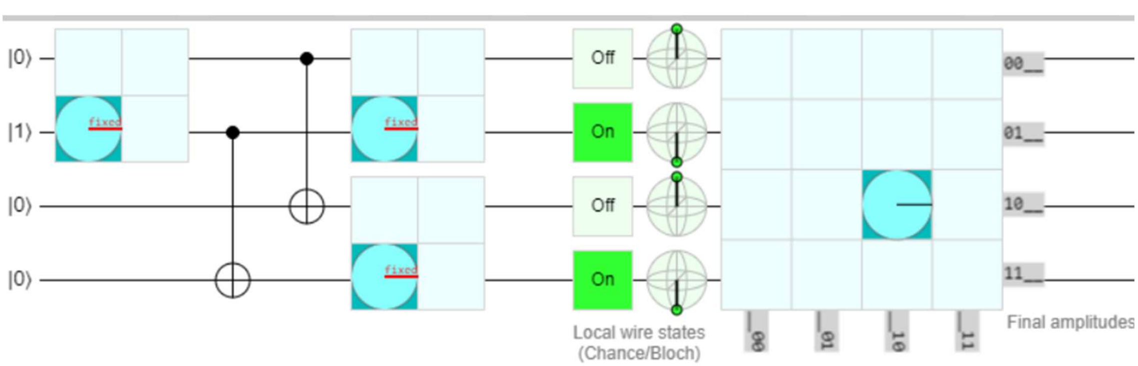
Two Controlled-NOTs:

The circuit consists of 4 qubits |Q0>, |Q1>, |Q2>, and |Q3>. The value of |Q0> and |Q1> are arbitrary whereas |Q2> and |Q3> are |0>. In the first and second CNOT, |Q0> represents the controlled bit whereas |Q2> represents the target bit, |Q1> represents the controlled bit whereas |Q3> represents the target bit respectively. The output of the CNOT at the target bit |Q2> would be |Q2⊕Q0> and for |Q3> output would be |Q3⊕Q1>. When |0> is provided as input to the controlled bit then the target bit will be unchanged and if |1> is passed as input then the target bit would be flipped. For example:-

|Q0>	|Q1>	|Q2>(Input)	|Q3>(Input)	|Q2⊕Q0> at |Q2>	|Q3⊕Q1> at |Q3>
|0>	|0>	|0>	|0>	|0>	|0>
|0>	|1>	|0>	|0>	|0>	|1>
|1>	|0>	|0>	|0>	|1>	|0>
|1>	|1>	|0>	|0>	|1>	|1>

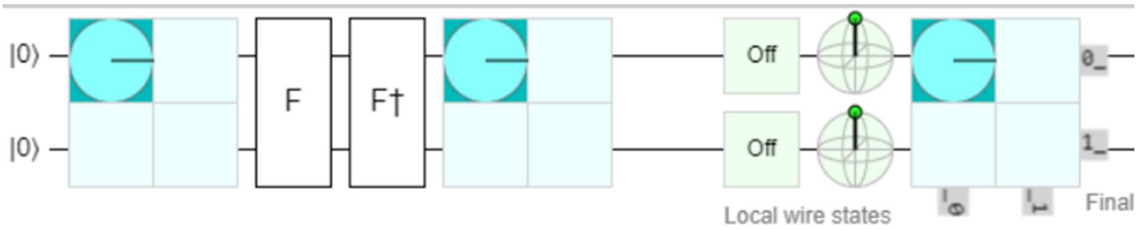
Input |Q0⊕Q1⊕Q2⊕Q3>	Output of CNOT |Q0⊕Q1⊕Q2⊕Q3>
|0000>	|0000>
|0100>	|0101>
|1000>	|1010>
|1100>	|1111>

The above tables show that when |Q2> and |Q3> are |0>, whatever the input is passed at |Q0> and |Q1> it is reflected at |Q2> and |Q3> respectively.|Q0>and|Q1> bit will remain the same at the input as well as output. In terms of qubits, the output would be incoherent.



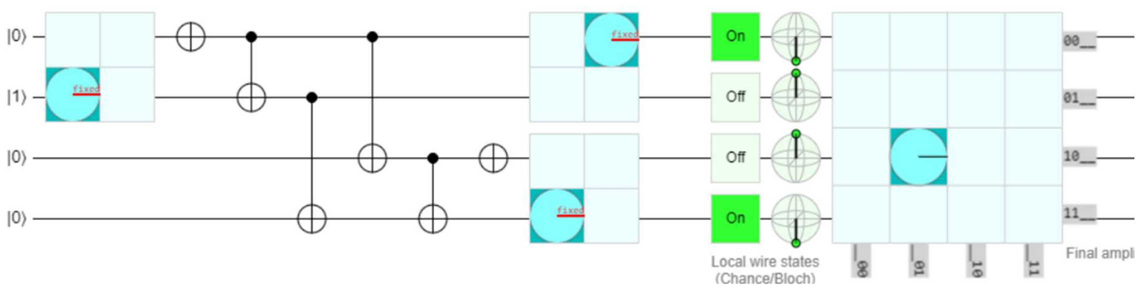
The F and F† gate:-

After understanding the functionality of the CNOT gates, the F and F† will just nullify each other and the input should be equal to the output. It uses this equation U*U†= I (Identity Metrix). For example, here F could be any gate.



In terms of classical-bits:-

The initial idea was that the circuit uses the concept of teleportation as it was able to teleport the classical bits. Whatever the input is passed from |x> the same output was observed at |B> and the value of |A> completely relies on the value of the F gate. For example, here F could be any classical gate

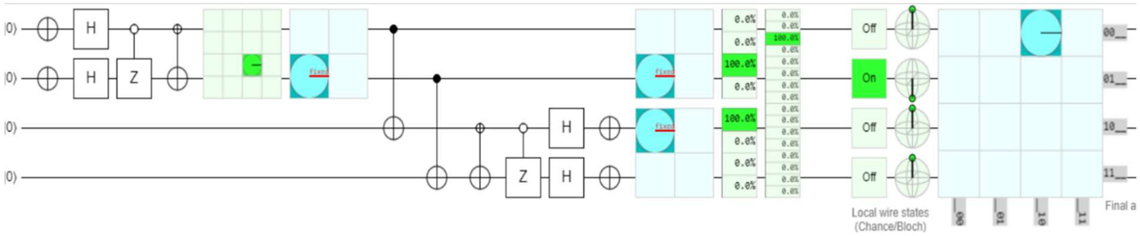


In terms of qubits:-

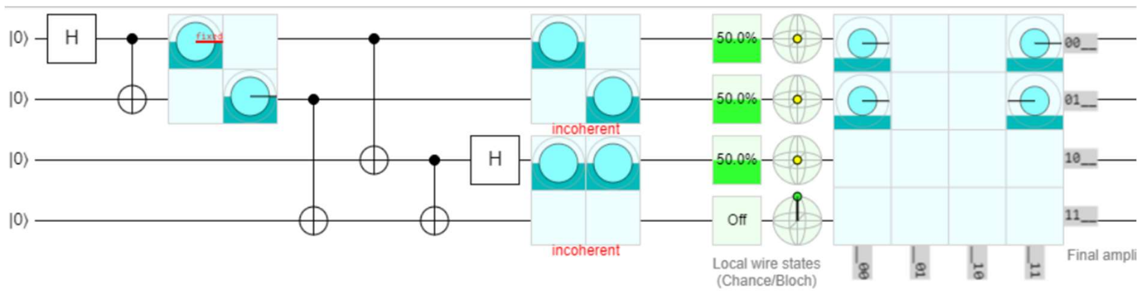
However, when qubits like |i>,|-i>,|+>, and |-> were passed from |X> or gates like Hadamard were applied, the same bits were not obtained at |B>. As the information was passed from |Q0> and |Q1> to |Q2> and |Q3> through entanglement, the information is lost into the environment during this transfer, and hence the output at both |A> and |B> are incoherent. Hence, the circuit uses the concept of teleportation if it is purely a classical circuit.

Task 2 Determining F-gate

For determining the functionality of the F gate, I tried applying 2 qubits Grover's search algorithm where the oracle bit was anti-controlled-Z (for finding |10>)(which could be any) and the inverse of Grover's search algorithm was taken for $F^{\dagger}$ gate.



The same nullifying effect was observed in this case as well as for applying Deutsch Jozsa algorithms. However, when provided a Hadamard followed by a CNOT gate(bell state) to two CNOTs in the center the circuit shows incoherence as discussed above and F and $F^{\dagger}$ did not nullify each other.



Quantum versus classical computing

1]. Through quantum computing, certain tasks could be performed within a blink of an eye like finding a secret number through the Bernstein-Vazirani algorithm in just one iteration, finding a number through Grover's search algorithms, finding prime factors of integer through Shor's algorithm, and many other fascinating things which could not be performed by classical computing as efficiently as a quantum computing could perform.

2]. My main concern is regarding debugging in quantum computing because of superposition as the developer would not be able to observe the data between input and output which might hinder the progress in the field of quantum computing whereas in classical computing debugging is not a big issue.