QACC – Quantum Experience Center

QACC Quantum Composer has a customizable set of tools that allow you to build, visualize, and run quantum circuits and algorithms on quantum systems or simulators.

What can the QACC composer do?

- **Visualize Qubit states**

Learn how changes to your circuit affect qubit states with probability Distribution, measurement probabilities, and state vector simulations.

- **Quantum Hardware**

Run your circuits on real quantum hardware to understand the effects of device noise with QPU.

- **Automatically generate code**

Instead of manually writing code, use QACC Composer to automatically generate OpenQASM or Python code in Qiskit that mimics your circuit.

QACC Menu Items:

File: This item has three sub-options mainly:

- New – This refers to a new circuit composer area opened in a new tab.
- Open Recent- This refers to opening any of the last five job circuits that a user is submitting.
- Make a Copy – This refers to opening a user's latest circuit copy.

View: This item provides the operation to close or open the Probability, Gate Matrix, and Last 5 Jobs sections.

Help: Contains two listed items:

- Documentation
- About QDE v1.0.0.

Gates Pallet/Catalog :

This section is a reference that defines the various classical and quantum operations you can use to manipulate qubits in the quantum circuit using the gates. Quantum operations include quantum gates, such as the Hadamard gate, and operations that are not quantum gates, such as the measurement operation, etc.

Each entry below provides details, gate matrix reference, and the OpenQASM reference for each gate operation.

Gates catalog/pallets: In quantum computing and specifically the quantum circuit model of computation, a quantum logic gate (or simply quantum gate) is a basic quantum circuit operating on a small number of qubits that are the building blocks of quantum circuits. Quantum gates operate on quantum bits (qubits). This means that quantum gates can leverage two key aspects of quantum mechanics that are entirely out of reach for classical gates: superposition and entanglement. Drag and drop these gates and other operations onto the graphical circuit editor/composer. Different types of gates are grouped by color. For example, classical gates are dark blue, phase gates are light blue, and non-unitary operations are grey. To learn about the available gates and operations, click on the gate and select Info(i) to read its definition or reference associated with it.

Hadamard Gate(H gate) :

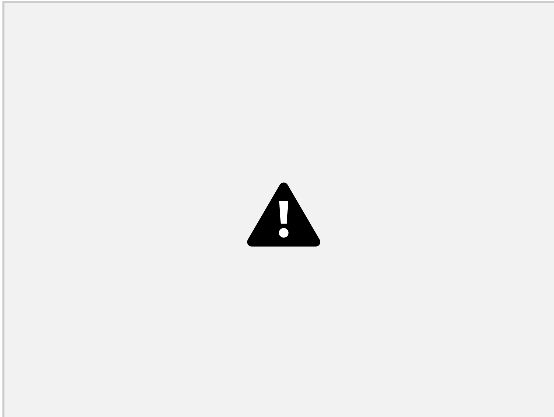
The H, or Hadamard, gate that rotates the states is useful for making superpositions. If you have a universal gate set on a classical computer and add the Hadamard gate, it becomes a universal gate set on a quantum computer.

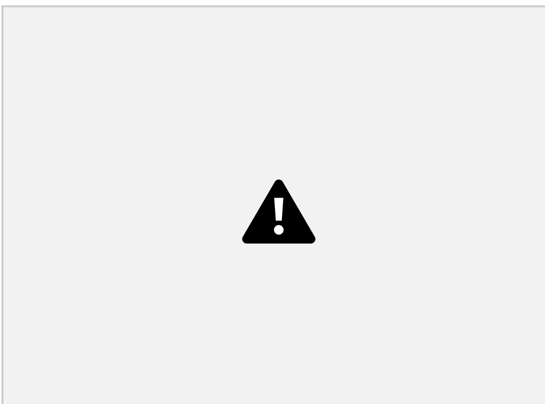
Open QASM reference code: h q[0];

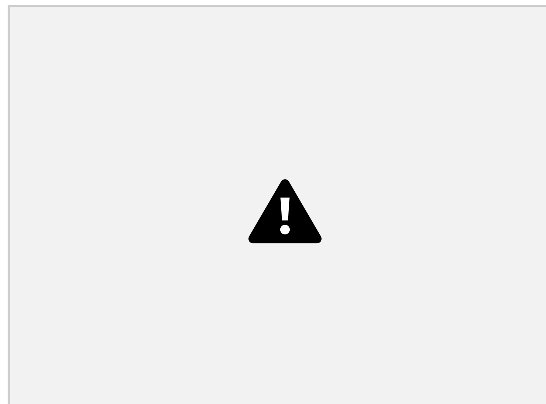
Gate Matrix reference:

X-Axis **Y-Axis**

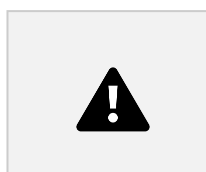
Z-Axis







Y gate:



Y-Gate Matrix

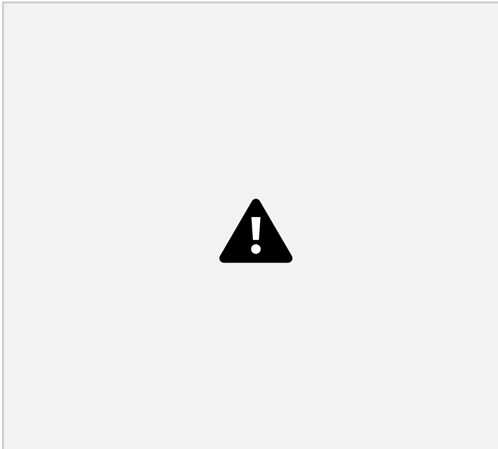
The Pauli Y gate is equivalent to Ry for the angle Π. It is equivalent to applying X and Z, to a global phase factor.

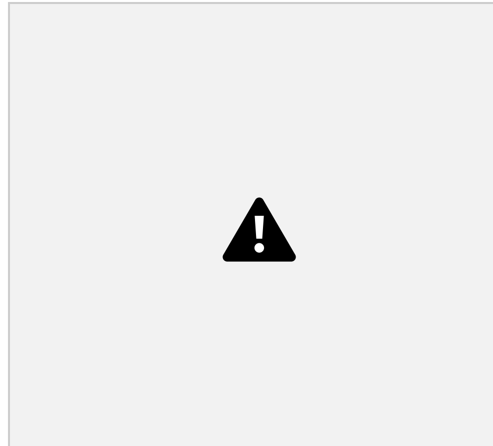
Open QASM reference code: y q[0];

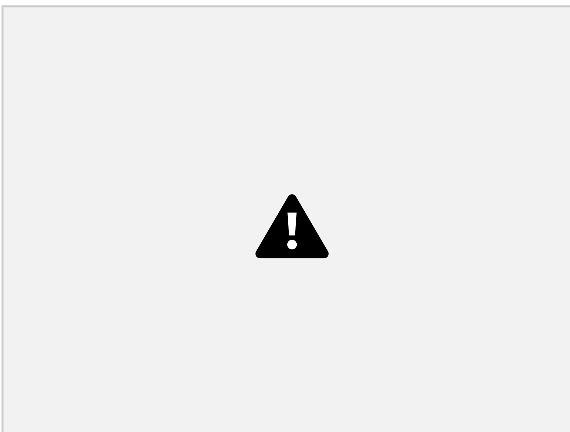
Gate Matrix reference:

X-Axis **Y-Axis**

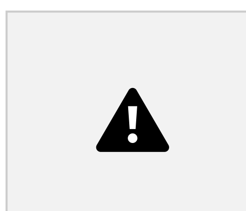
Z-Axis







Z gate:



Z-Gate Matrix

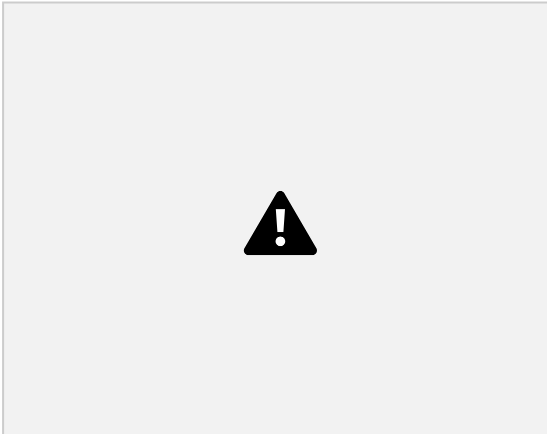
The Pauli Z gate acts as identity on the $|0\rangle$ state and multiplies the sign of the $|1\rangle$ state by -1. It therefore flips the $|+\rangle$ and $|-\rangle$ states. In the +/- basis, it plays the same role as the NOT gate in the $|0\rangle$ / $|1\rangle$ basis.

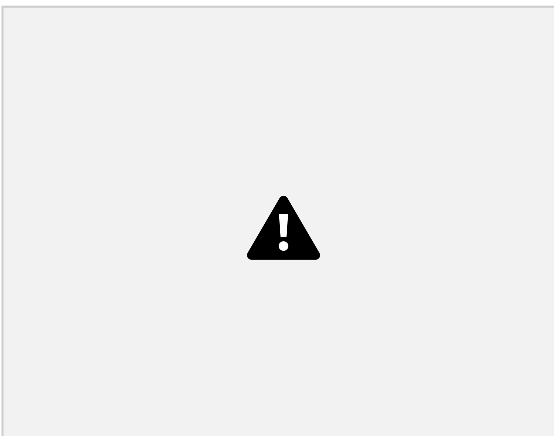
Open QASM reference code: z q[0];

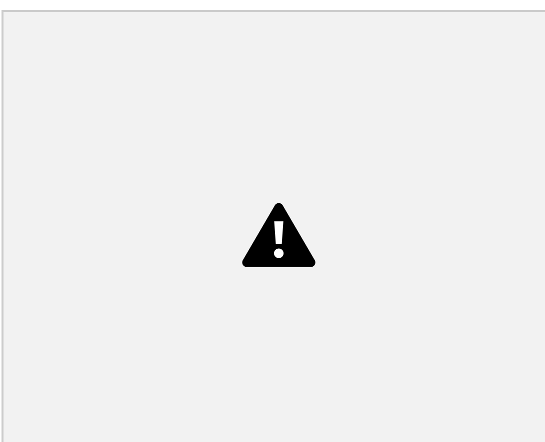
Gate Matrix reference:

X-Axis **Y-Axis**

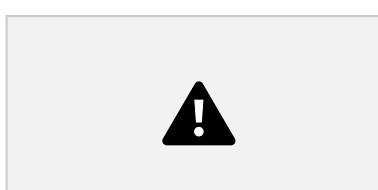
Z-Axis







T gate:

T-Gate Matrix

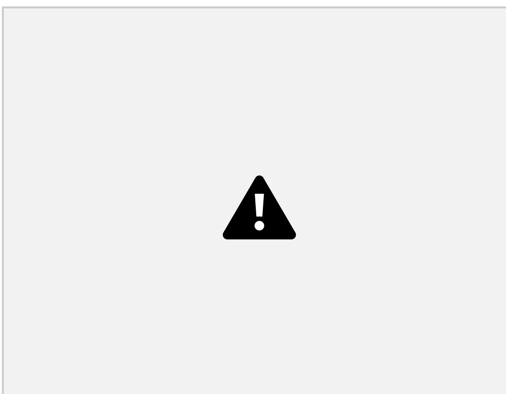
The T gate is equivalent to RZ for the angle π/4. In quantum computing, the T gate is a single-qubit gate that creates phase shifts. It’s also known as the π/4 gate.

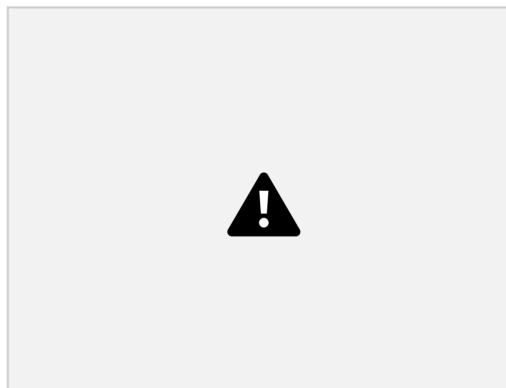
The T gate rotates the state of a qubit by an angle of π/4 radians. It applies a phase shift to the qubit’s state, specifically to the |1> state, while leaving the |0> state unchanged.
The T gate is also known as the π/8 gate because of how the RZ(π/4) matrix looks like. It’s also known as the fourth root of the Pauli Z gate because applying the T gate four times is equivalent to applying the Pauli Z gate.

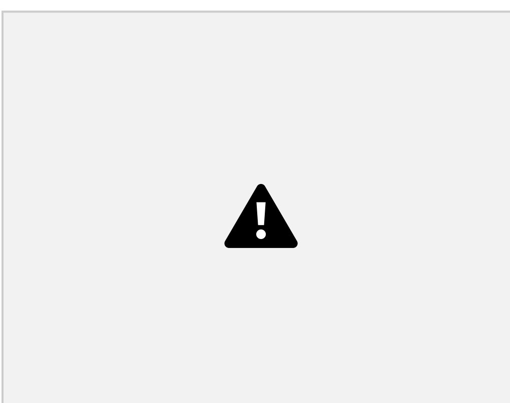
Open QASM reference code: t q[0];

Gate Matrix reference:

X-Axis **Y-Axis** **Z-Axis**







S gate:

S-Gate Matrix

The S gate applies a phase of i to the $|1\rangle$ state. It is equivalent to RZ for the angle π/2. Also S=P(π/2). Referring to quantum mechanics, the S gate is a 90-degree rotation around the z-axis. It is also known as the phase gate or the Z90 gate. The S gate is related to the T gate by the relationship S = T 2

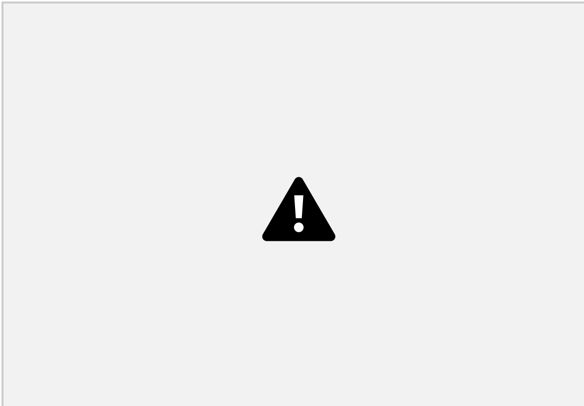
Open QASM reference code: s q[0];

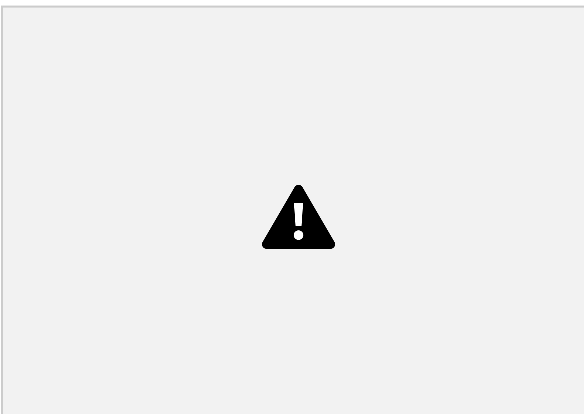
Gate Matrix reference:

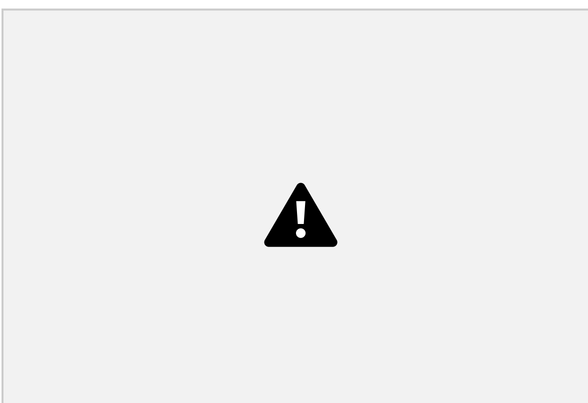
X-Axis

Y-Axis

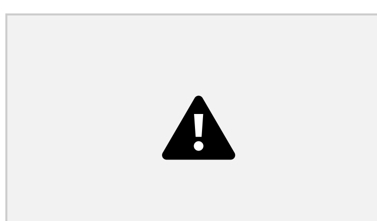
Z-Axis







P Gate:



P-Gate Matrix

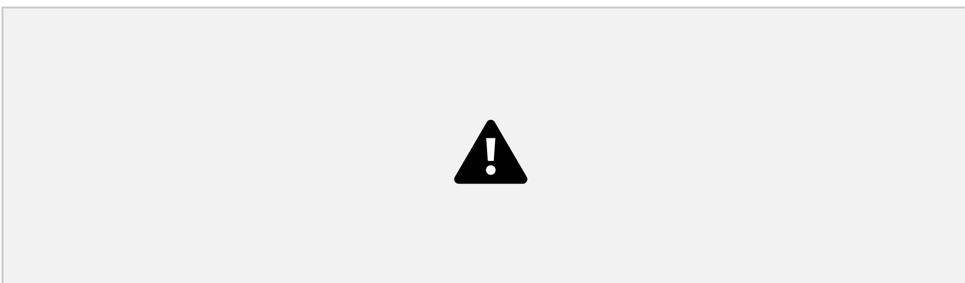
The phase gate (P-gate) is a gate. It is also known as the general phase shift operator in quantum computing.

In Qiskit, the phase gate can be applied to any qubit by calling the p() method on the Quantum Circuit. The p() method is parameterized, so the phase (in radians) that needs to be applied to the qubit must be passed to it.

Open QASM reference code: p(θ) q[0];

T† gate:

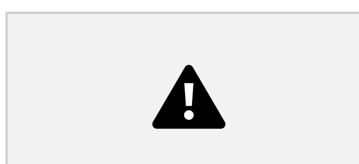
T† gate Matrix



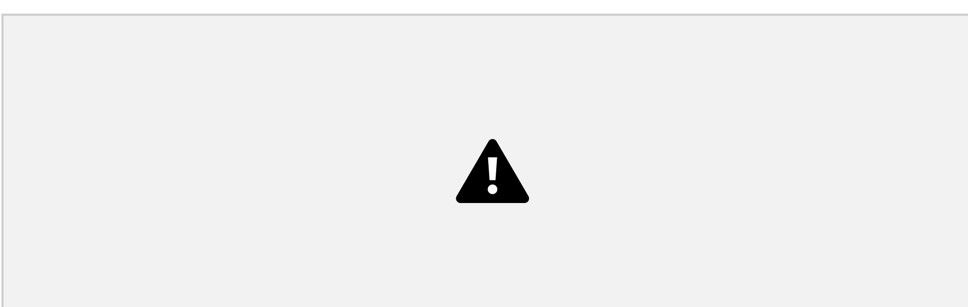
In quantum computing, the T gate is a single-qubit gate that creates phase shifts. It rotates the state of a qubit by an angle of π/4 radians. Also known as the Tdg or T-dagger gate. The T gate is also known as the π/4 gate. It is related to the S gate by the relationship S = T 2.

Open QASM reference code: tdg q[0];

S† gate:



S† gate Matrix



Also known as the Sdg or S-dagger gate. The inverse of the S gate.

Open QASM reference code: sdg q[0];

RZ gate:

RZ Gate Matrix, where ϕ = θ/2

The Rz-gate or the Rϕ-gate would be the first parametrized gate that will be introduced. By “parametrized” we mean that it accepts a parameter and performs an operation based on this parameter. The parameter accepted here is ϕ and the operation performed is rotation around the z-axis by ϕ radians. The matrix for this gate is given by

CZ gate:

CZ Gate Matrix

In quantum computing, a Cz gate, also known as a controlled-phase gate, is a two-qubit quantum gate that introduces a phase shift depending on the state of the control qubit.

The action of the Cz gate is to apply a phase shift of -1 to the $|11\rangle$ state while leaving the other basis states unchanged.

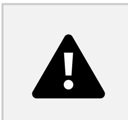
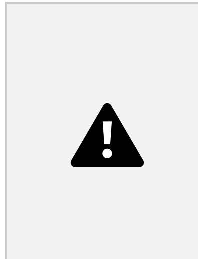
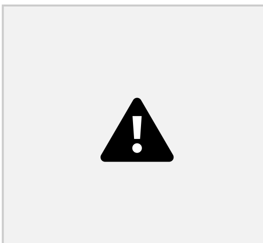
The mathematical operation of the Cz gate can be described as:

$Cz|00\rangle=|00\rangle$ $Cz|$

$01\rangle=|01\rangle$ $Cz|10\rangle=|10\rangle$ $Cz|11\rangle=-|11\rangle$

The Cz gate is a key component in quantum circuits and is used in various quantum algorithms and quantum error correction protocols. It is particularly important in constructing controlled gates and implementing certain quantum algorithms like quantum phase estimation and quantum teleportation.

NOT Gate(Pauli-X):

  **Pauli -X Gate Matrix**  **Pauli -Y Gate**  **Pauli -Z Gate**

The NOT gate, also known as the Pauli X gate, flips the $|0\rangle$ state to $|1\rangle$, and vice versa. The NOT gate is equivalent to RX for the angle π or 'HZH'.The quantum NOT gate is a fundamental quantum gate that plays a crucial role in quantum computing. It is the analog of the classical NOT gate and can be represented in a quantum circuit as a circle with a cross in it.

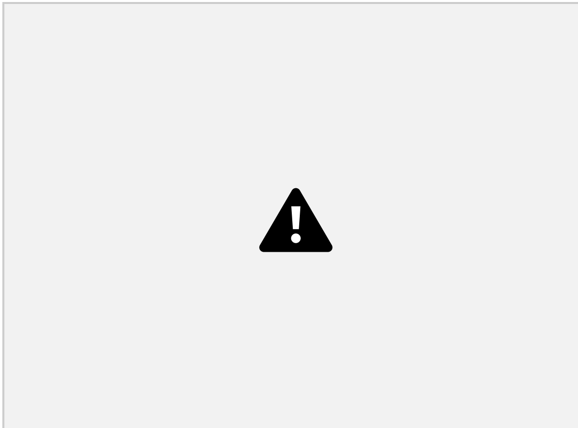
The NOT gate is reversible, meaning that if you apply a NOT gate twice to the same signal, you get out the same value you started with. The NOT gate is also known as an inverter because it gives a negative mathematical output.

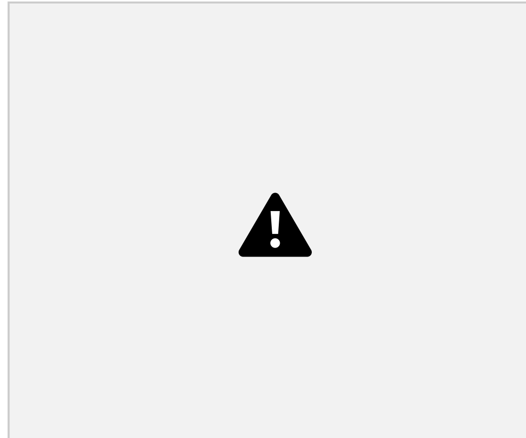
Open QASM reference code : x q[0];

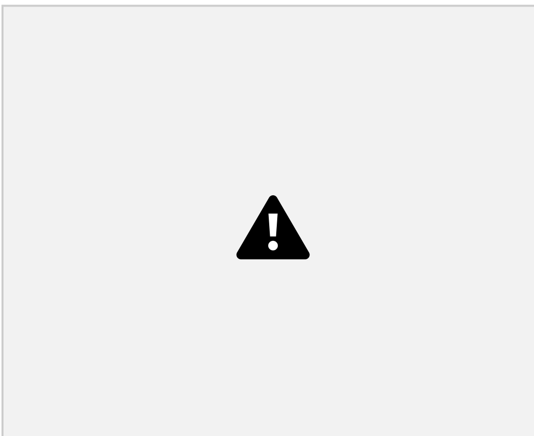
Gate Matrix reference:

X-Axis **Y-Axis**

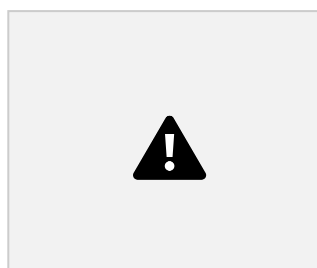
Z-Axis







CNOT Gate(CX):



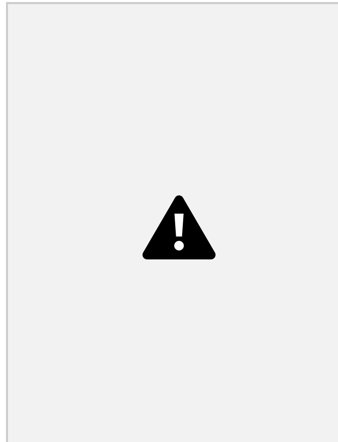
CNOT Gate Matrix

The controlled-NOT gate is also called the controlled-x (CX) gate. It operates on a pair of qubits, where one qubit acts as the ‘control’ and the other as the ‘target’. It executes a NOT operation on the target qubit if the control qubit is in the state $|1.\rangle$

If the control qubit is in a superposition, this gate creates entanglement.

Open QASM reference code : `cx q[0], q[1];`

Toffoli gate(CCX):

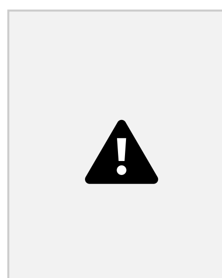


Toffoli Gate Matrix

The Toffoli gate, also known as the double controlled-NOT gate (CCX), has two control qubits and one target. It applies a NOT to the target only when both controls are in state $|1\rangle$. *Toffoli gate with the Hadamard gate is a universal gate set for quantum computing.*

Open QASM reference code : ccx q[0], q[1], q[2];

Identity gate:



Identity Gate Matrix

The I-gate does not do anything in particular. Its matrix is the Identity matrix itself. It is considered a gate because they are often useful in calculations. Also, they are significant in a way that they can be used to specify a “none” operation when considering real hardware. The identity gate is often used in quantum circuits for various purposes, such as padding or preparing qubits for subsequent operations without altering their states.

Open QASM reference code: id q[0];

Gate Matrix reference:

X-Axis **Y-Axis**

Z-Axis

SWAP gate:

Swap Gate Matrix

The Swap gate, often denoted as SWAP, is a two-qubit quantum gate used in quantum computing. As the name suggests, it swaps the states of two qubits.

Measurement:

Measurement in the standard basis, also known as the z basis or computational basis. Can be used to implement any kind of measurement when combined with gates. It is not a reversible operation. Quantum measurements are typically described as operations that collapse the quantum state to one of its basis states with certain probabilities.

In a quantum circuit, a measurement is represented by a measurement operator or a measurement gate. The most common type of measurement is the projective measurement, which projects the quantum state onto one of the basis states. The measurement outcomes are probabilistic, and the probabilities are determined by the magnitudes of the probability amplitudes associated with each basis state.

The measurement process is often denoted by the symbol **M** in quantum circuits.

Barrier operation:

In quantum computing, a barrier is a visualization tool used in quantum circuit diagrams. The barrier is not an actual quantum gate or operation but is employed to separate and group quantum gates within a circuit. It is represented by a double vertical line.

The barrier helps to organize and clarify the structure of a quantum circuit, especially when dealing with complex algorithms or when trying to highlight certain parts of the circuit for analysis. It does not affect the quantum computation itself and is purely a visual aid.

By inserting a barrier in a quantum circuit diagram, one can emphasize specific sections, making it easier to understand the logical structure of the algorithm or to isolate particular quantum operations. It is particularly useful in cases where different parts of the circuit are functionally distinct or are intended to be treated as separate entities.

Quantum Fourier Transform(QFT) :

QFT(Expanded view)

The Quantum Fourier Transform (QFT) is a fundamental operation in quantum computing that plays a pivotal role in various quantum algorithms, particularly those related to quantum cryptography and quantum simulation. It extends the classical Fourier Transform to quantum mechanics, enabling the manipulation of information encoded in the amplitudes of quantum states.

QFT transforms quantum states from one basis to another, specifically between the computational (Z) basis and the Fourier basis. While classical Fourier Transform operates on continuous functions, QFT operates on the amplitudes of quantum states, which can represent multiple possibilities simultaneously due to superposition.

In quantum circuits, the Hadamard gate (H-gate) acts as the single-qubit QFT, converting between the Z-basis and X-basis states. The QFT is also applicable to multi-qubit systems, where it transforms the entire quantum state from the computational basis to the Fourier basis and vice versa.

One of the most prominent applications of QFT is in Shor's algorithm, a quantum algorithm for integer factorization, where it enables efficient computation of the discrete Fourier transform, a crucial step in the algorithm's implementation. Additionally, QFT finds applications in quantum phase estimation, quantum error correction, and various quantum machine learning algorithms. Despite its significance, the implementation of QFT in large-scale quantum systems remains a challenge due to the sensitivity of quantum states to errors and decoherence.

Step 1: Apply a Hadamard gate (H-gate) to the first qubit.

- Apply controlled rotations (phase gates) on subsequent qubits, controlled by previous qubits.

Step 2: Controlled Rotations:

For each qubit j from 2 to n:

- Apply Hadamard gate (H-gate) to qubit j.
- Apply controlled rotations (phase gates) on qubit j, controlled by qubits 1 to j-1.
- Our phases will increase π/2**1, π/2**2, till the number of qubits j-1.

Step 3: Swap Gates

- Perform swap gates to reverse the order of the qubits.