Como programar em Qiskit – Parte 2

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Glauco Reis
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IBM Qiskit Developer Certified

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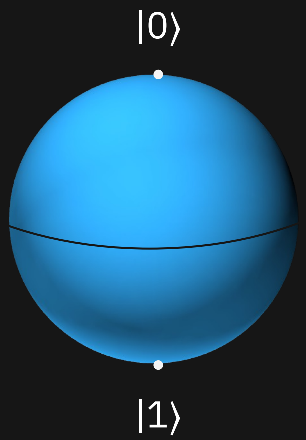
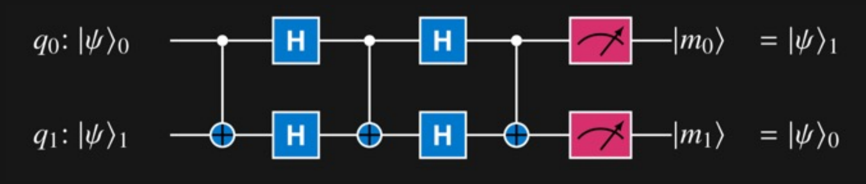
Quantum bits (qubits) and quantum circuits

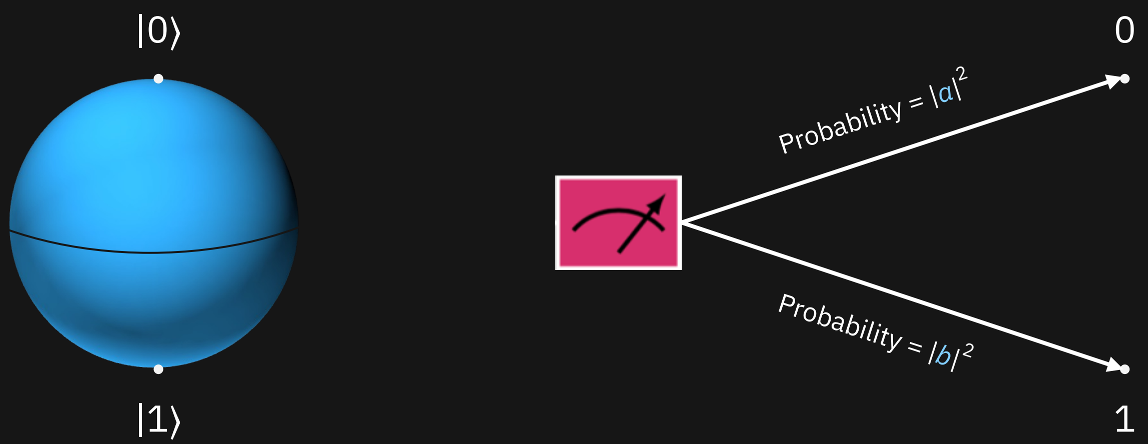


A quantum bit or qubit is a controllable quantum object that is the unit of information



A quantum circuit is a set of quantum gate operations on qubits and is the unit of computation

Bits and qubits



A qubit's state is a combination of |0⟩ and |1⟩:

$$a\,|0\rangle + b\,|1\rangle$$

This means that a single qubit contains two pieces of information.

When we measure a qubit, it becomes **0** or **1** based on probability.

Bits and qubits: the effect of the X gate on |0⟩

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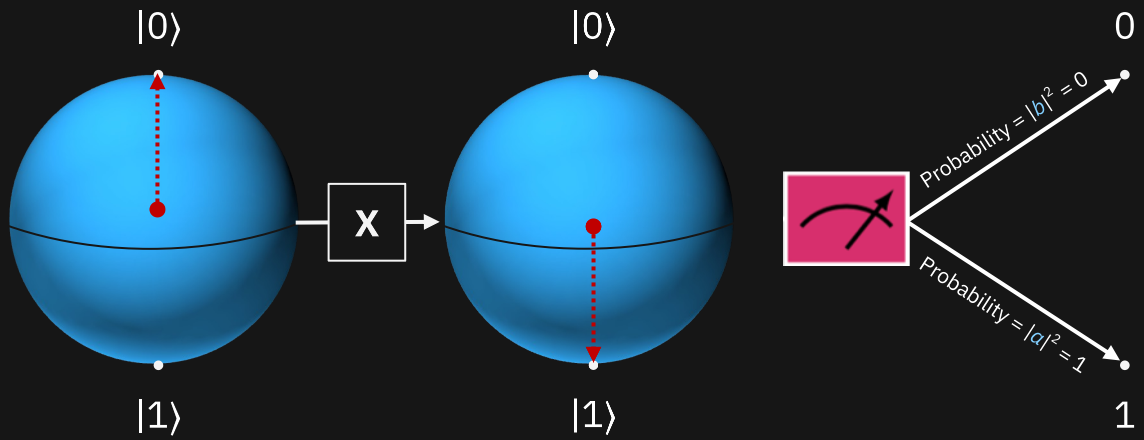


The **X** gate reverses |0⟩ and |1⟩:

$$a\,|0\rangle + b\,|1\rangle \;\mapsto\; b\,|0\rangle + a\,|1\rangle$$

$a = 1$ and $b = 0$, so |0⟩ is mapped to |1⟩.

When measured, the result is **1** with 100% probability.

Quantum computing uses essential ideas from quantum mechanics

Superposition

$|0\rangle$ and $|1\rangle$ are vectors in the two-dimensional complex vector space $\mathbf{C}^2$:

$$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad \text{and} \quad |1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

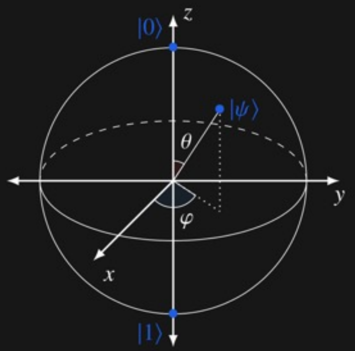
So we can write any vector in $\mathbf{C}^2$ as

$$a\,|0\rangle + b\,|1\rangle$$

We pronounce $|0\rangle$ and $|1\rangle$ as "ket zero" and "ket one." These are called the *computational basis*.

Quantum computing uses essential ideas from quantum mechanics

Superposition



Superposition is creating a quantum state that is a combination of |0⟩ and |1⟩

$$a\,|0\rangle + b\,|1\rangle$$

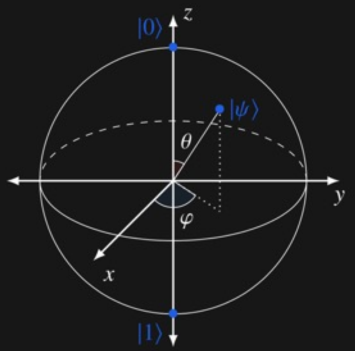
These conditions allow us to map the qubit onto the *Bloch Sphere*.

Note that if a and b are non-zero, then the qubit's state contains both |0⟩ and |1⟩.

This is what people mean when they say that a qubit can be "0 and 1 at the same time."

Quantum computing uses essential ideas from quantum mechanics

Measurement



Measurement is forcing the qubit's state

$$a\,|0\rangle + b\,|1\rangle$$

to $|0\rangle$ or $|1\rangle$ by observing it, where

- $|a|^2$ is the probability we will get $|0\rangle$ when we measure
- $|b|^2$ is the probability we will get $|1\rangle$ when we measure

For example,

$$\frac{\sqrt{2}}{2}\,|0\rangle + \frac{\sqrt{2}}{2}\,|1\rangle$$

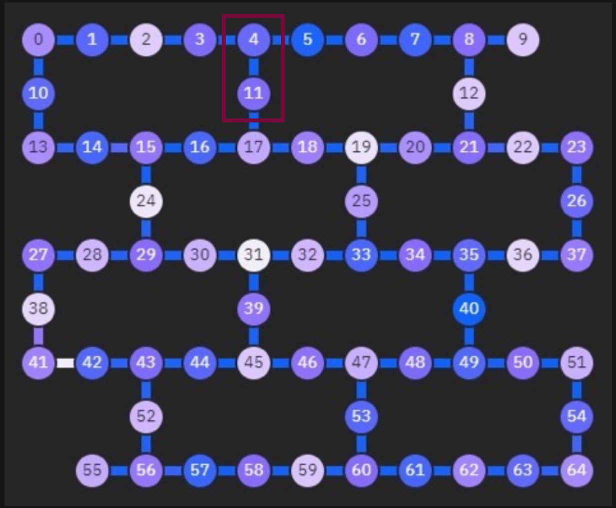
has an equal probability of becoming $|0\rangle$ or $|1\rangle$, and

$$\frac{\sqrt{3}}{2}\,|0\rangle - \frac{1}{2}\,i\,|1\rangle$$

has a 75% chance of becoming $|0\rangle$.

Quantum computing uses essential ideas from quantum mechanics

Entanglement



With two qubits we get combinations like

$$a\,|00\rangle + b\,|01\rangle + c\,|10\rangle + d\,|11\rangle$$

where

$|01\rangle$ means the first qubit is $|0\rangle$ and the second is $|1\rangle$

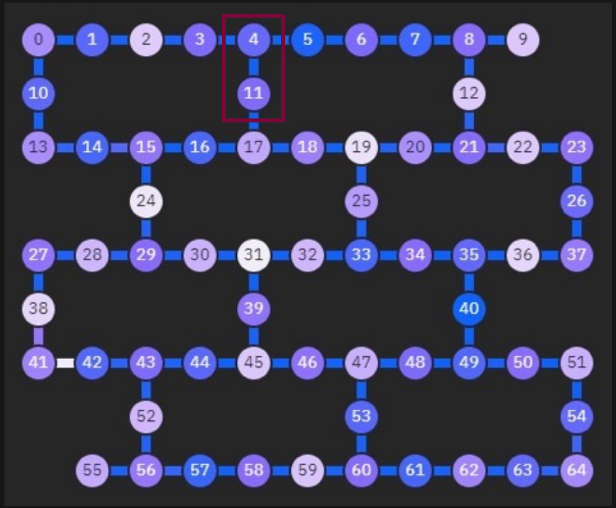
a, b, c, and d are complex numbers and

$$|a|^2 + |b|^2 + |c|^2 + |d|^2 = 1$$

If two or more of the a, b, c, and d are non-zero, and we cannot separate the qubits, they are entangled with perfect correlation and are no longer independent.

Quantum computing uses essential ideas from quantum mechanics

Entanglement



For example,

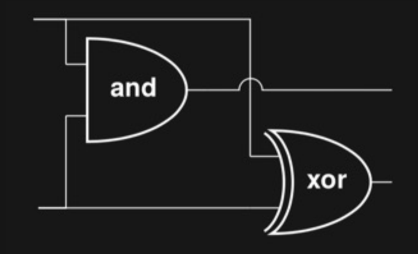
$$\frac{\sqrt{2}}{2}|00\rangle + \frac{\sqrt{2}}{2}|01\rangle$$ not entangled

$$\frac{\sqrt{2}}{2}|01\rangle - \frac{\sqrt{2}}{2}|10\rangle$$ entangled

$$\frac{\sqrt{2}}{2}|00\rangle + \frac{\sqrt{2}}{2}|11\rangle$$ entangled

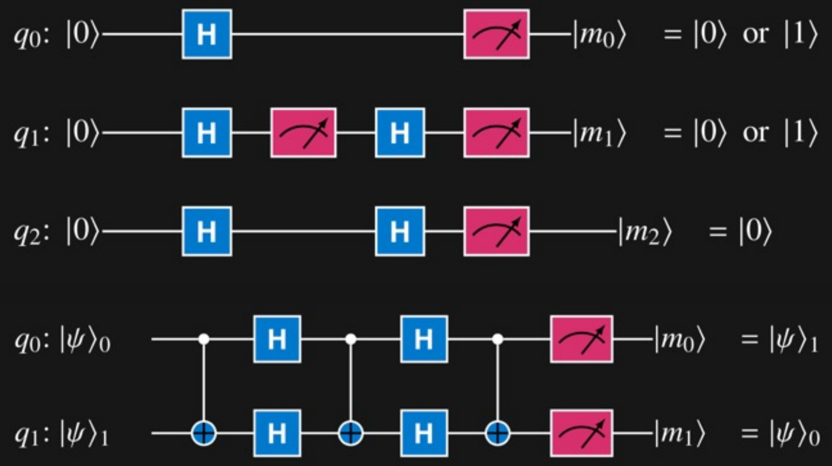
Quantum computing uses essential ideas from quantum mechanics

Gates / operations



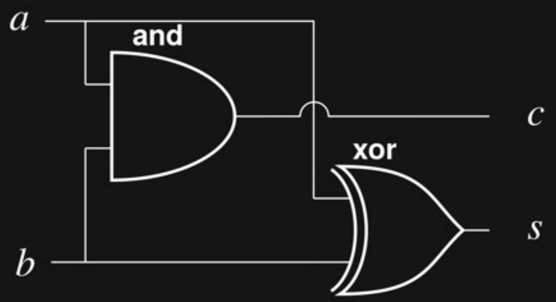
Classical logical circuits use operations like and, or, not, nand, and xor. We also call these gates.

Quantum circuits use reversible gates that change the quantum states of one, two , or more qubits.



Bits and classical logic circuits

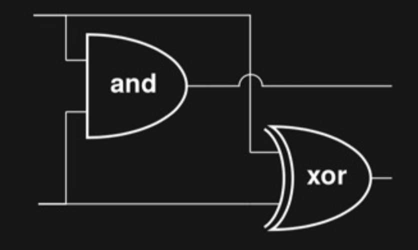
A bit is a controllable classical object that is the unit of information



A classical logic circuit is a set of gate operations on bits and is the unit of computation

Quantum computing uses essential ideas from quantum mechanics

Gates / operations



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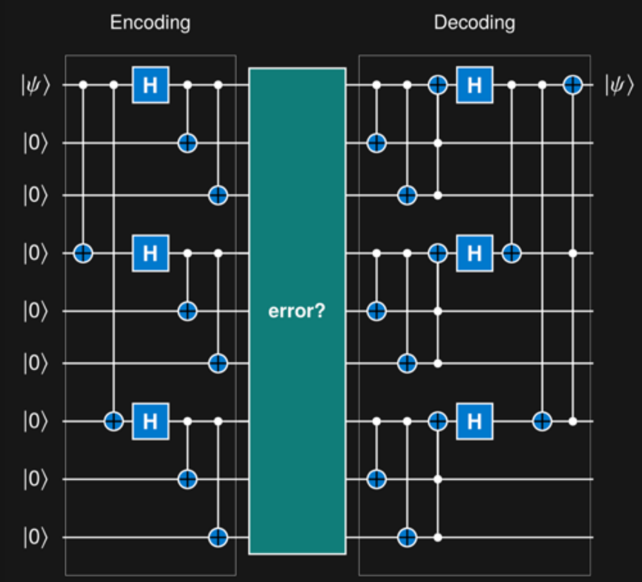
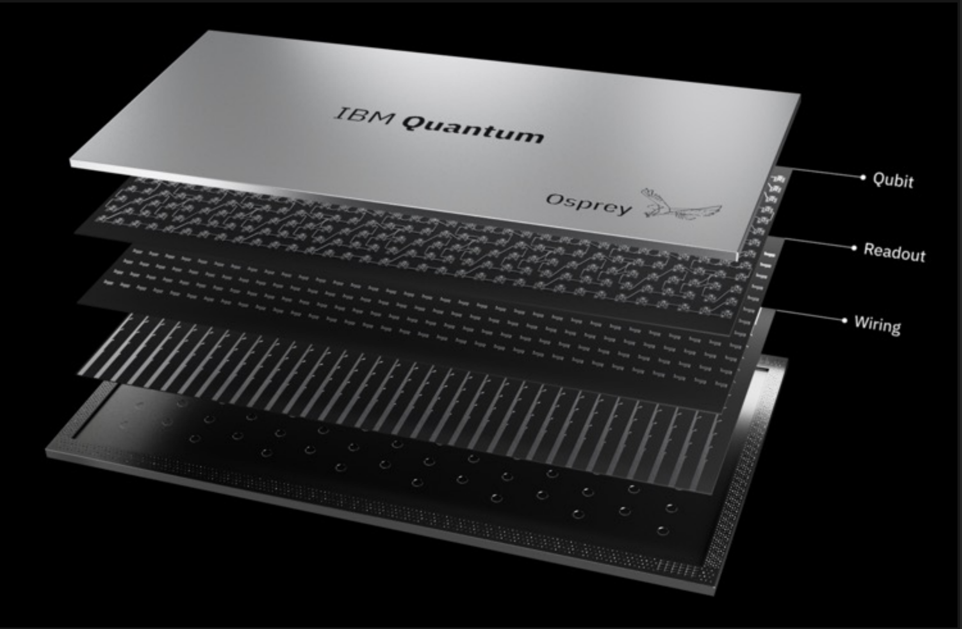


Osprey – 433 Qubits



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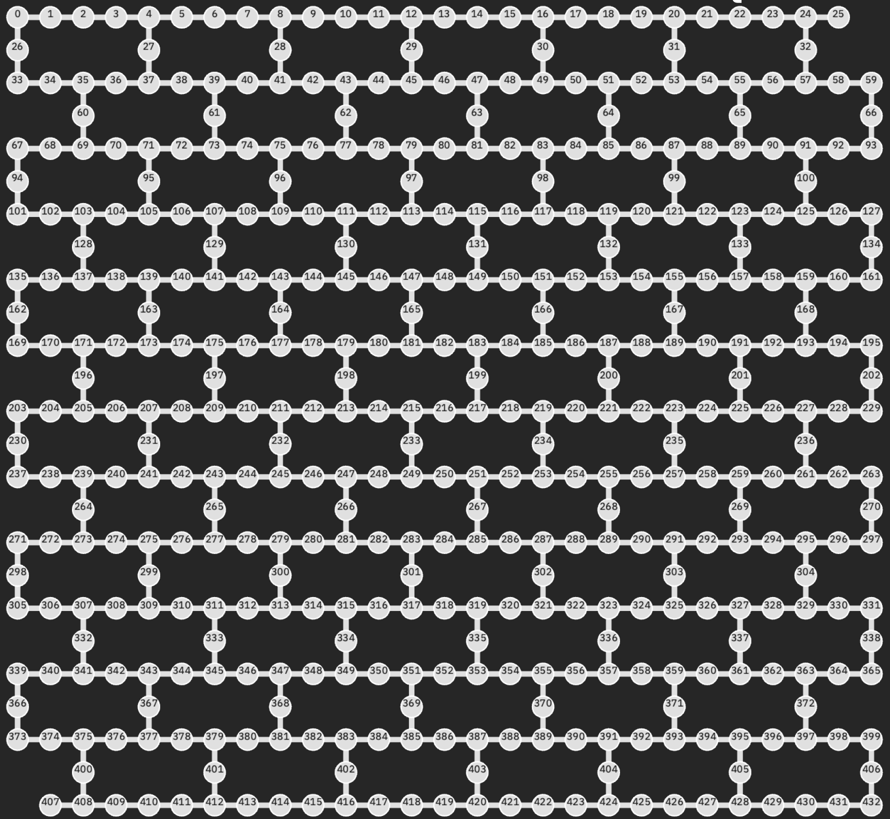

Osprey connectivity map

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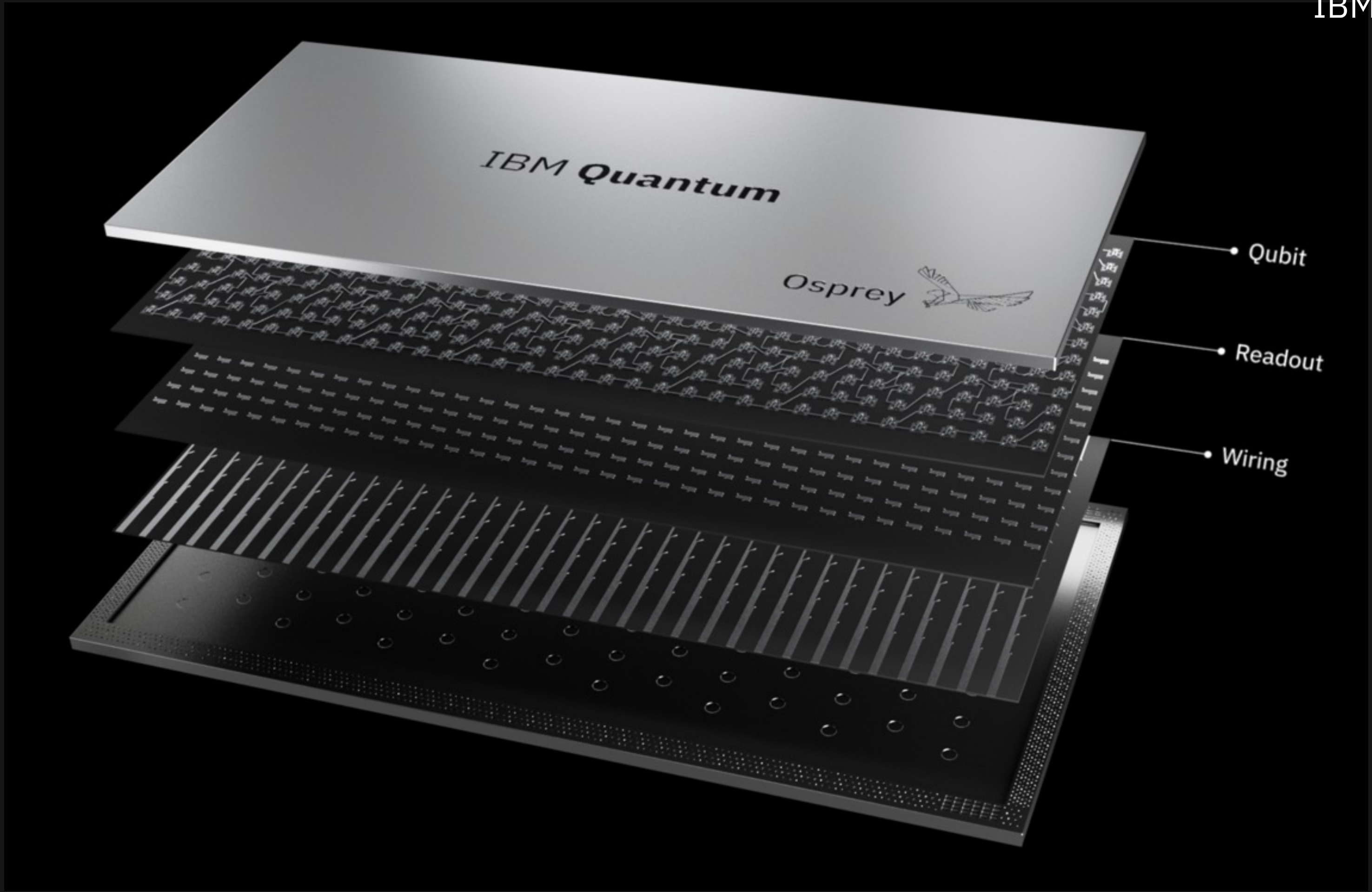

Near-time classical: Qiskit Runtime

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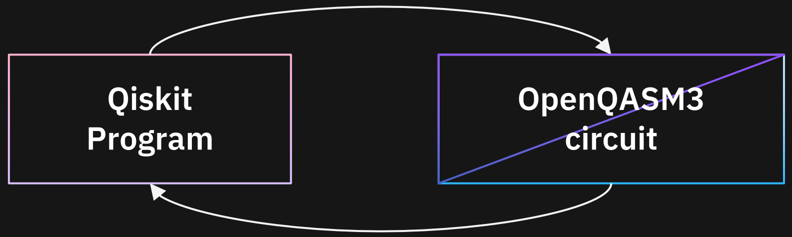

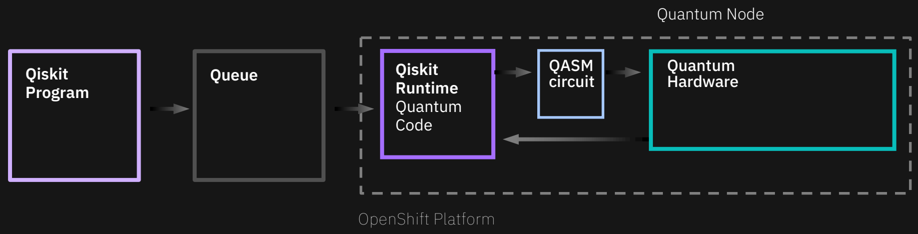

A high-performance system also requires low-latency interaction to generic classical compute.

Near-time classical: Qiskit Runtime

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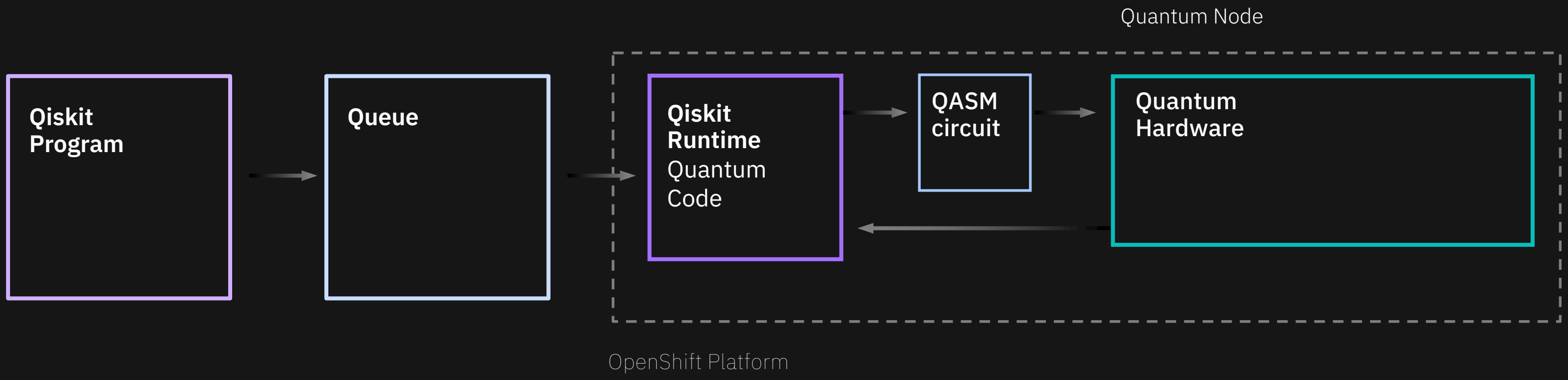

A high-performance system also requires low-latency interaction to generic classical compute.

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