```
backend = provider.get_backend('ibmq_qasm_simulator')

q = QuantumRegister(5,'q')
c = ClassicalRegister(5,'c')

circuit = QuantumCircuit(q,c)

circuit.x(q[4])
circuit.x(q[2])
circuit.x(q[0])
circuit += QFT(num_qubits=5, approximation_degree=0, do_swaps=False, inverse=Fal
circuit.measure(q,c)
circuit.draw(output='mpl', filename = 'qft1.png'
print(circuit)

job = execute(circuit, backend, shots=1000)

job_monitor(job)
```

Interested in learning how to program quantum computers? Then check out our Qiskit textbook **Introduction to Quantum Computing with Qiskit** (https://quantumcomputinguk.org/shop/introduction-to-quantum-computing-with-qiskit-ebook-1).

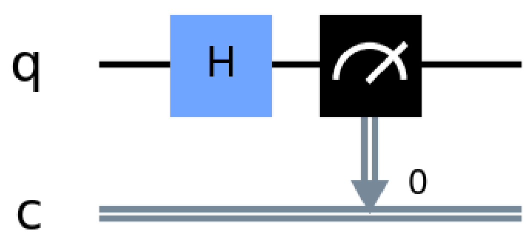
Introduction

In this tutorial we will explore the Quantum Fourier transform and how to implement it in Qiskit.

What is the Quantum Fourier Transform?

The Quantum Fourier Transform (QFT) is a circuit that transforms the state of the qubit from the computational basis to the Fourier basis. Note that the Fourier basis is just another term for the Hadamard basis. As such the easiest way to implement a QFT is with Hadamard gates and Controlled U1 gates.

Note: A Controlled U1 gate is just a gate that implements a single rotation around the Z-axis (phase) of the target qubit if the control qubit is 1.



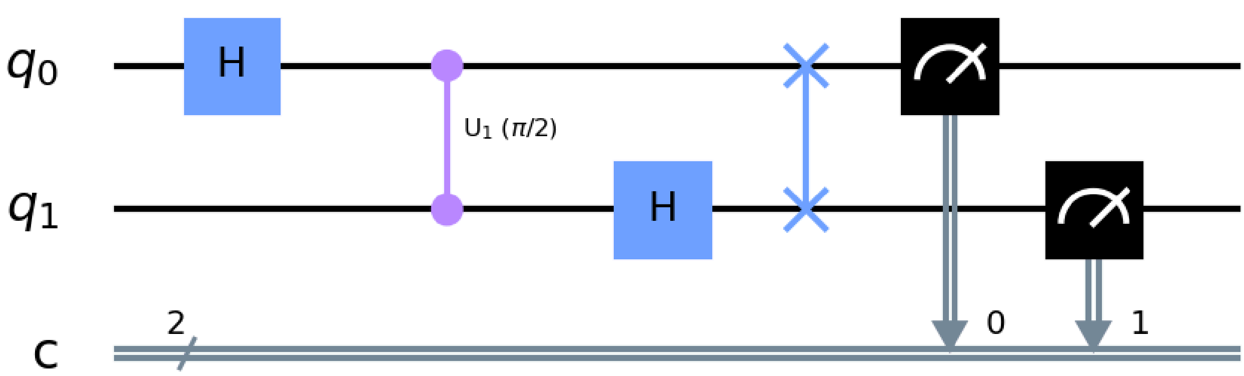
Circuit diagram of a 1 qubit QFT

For more information on phase and its relationship with Hadamard gates see our tutorial below:

https://quantumcomputinguk.org/tutorials/z-gate (https://quantumcomputinguk.org/tutorials/z-gate)

The simplest QFT is a 1 qubit QFT which just implements a Hadamard gate.

However if we implement a 2 qubit QFT then you can see how the controlled U1 are used:



2 qubit QFT

First we implement a Hadamard gate which puts q0 in to superposition. Next we apply a controlled U1 gate with a rotation of pi/2 to q1. After this a Hadamard gate is applied to q1. Next we apply a swap gate to q0 and q1.

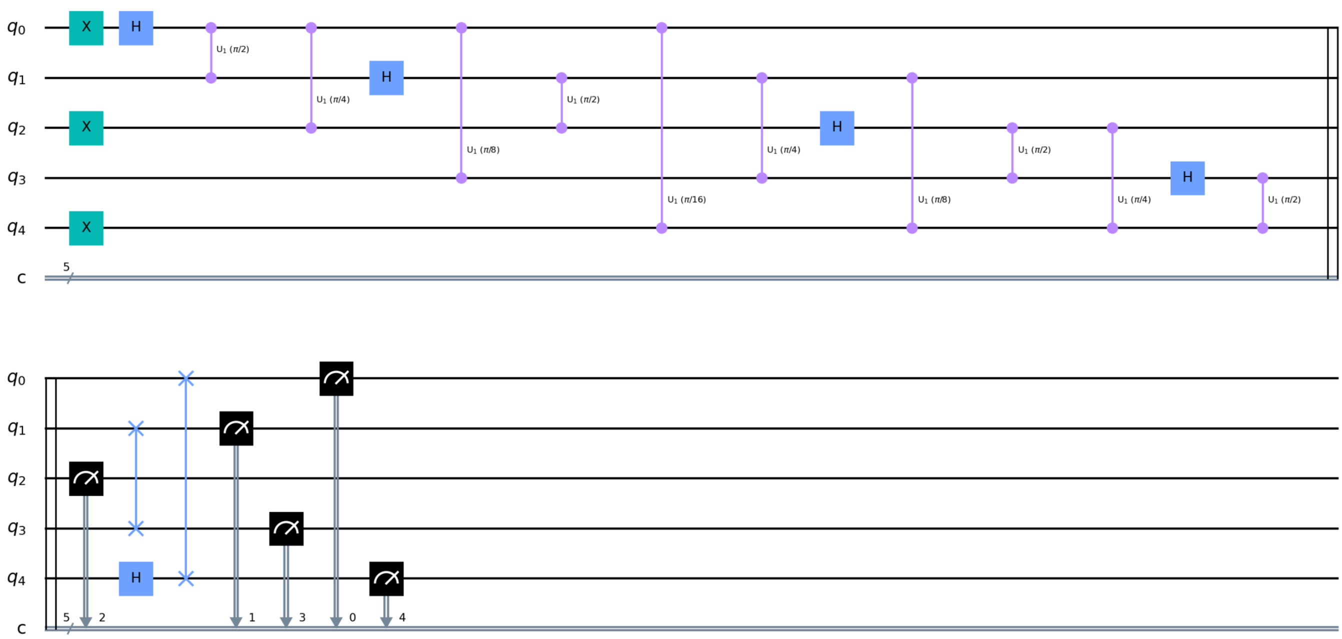
Note that these swap gates are not needed if the QFT is implemented at the end of your circuit.

After this both qubits will be in superposition but whatever computational value (1 or 0) will be encoded in to the Hadamard basis of the qubit.

To encode values on N qubits we have to double the rotation value of each qubit. For example the diagram below shows a 5 qubit QFT.

Notice how for q0 it applies a rotation of pi/2 for q1 then pi/4 for q2 then pi/8 for q3 and so on. This pattern repeats for each qubit. When all rotations have been applied to a qubit it is put in to superposition using a Hadamard gate. Then it can be used as a control qubit to apply rotations to target qubits below it.

Implementation



Circuit diagram of a 5 qubit QFT

Implementing a 5 qubit Quantum Fourier Transform in qiskit

In qiskit we could implement the 5 qubit QFT by implementing all the gates in the diagram above.Thankfully qiskit has a QFT function that we can use to make everything simpler!

In qiskit you can use the QFT() function as follows:

```
QFT(num_qubits=None, approximation_degree=0, do_swaps=True, inverse
```

Where:

- num_qubits: The number of qubits we want to add to the QFT (in our case it is 5)
- approximation_degree: This allows us to reduce circuit depth by ignoring phase rotations under a certain value
- do_swaps: If set to true then we use swap gates in the QFT
- inverse: If set to true we implement the inverse QFT
- insert barrier: If set to true then we insert barriers

For example in our 5 qubit QFT we implement the following:

```
QFT(num_qubits=5, approximation_degree=0, do_swaps=True,
inverse=False, insert_barriers=True, name='qft')
```

If we encode 1010 on to a QFT and then measure it we will get random values since the qubits have been put in to superposition and the values we encoded in to the computational basis are now encoded in the Hadamard basis of each qubit via the controlled U1 gates.

Inverse Quantum Fourier Transform

To get our values back we can use the inverse QFT. This reverses all the rotations done in the QFT above.

For example is there was a rotation of Pi in the QFT then the inverse QFT will do a rotation of -Pi.

In qiskit we can get the values back by implementing an inverse QFT by setting inverse to true.

For example:

```
QFT(num_qubits=5, approximation_degree=0, do_swaps=True,
inverse=True, insert_barriers=True, name='qft')
```

How to run the program

1. Copy and paste the code below in to a python file
2. Enter your API token in the IBMQ.enable_account('Insert API token here') part
3. Save and run

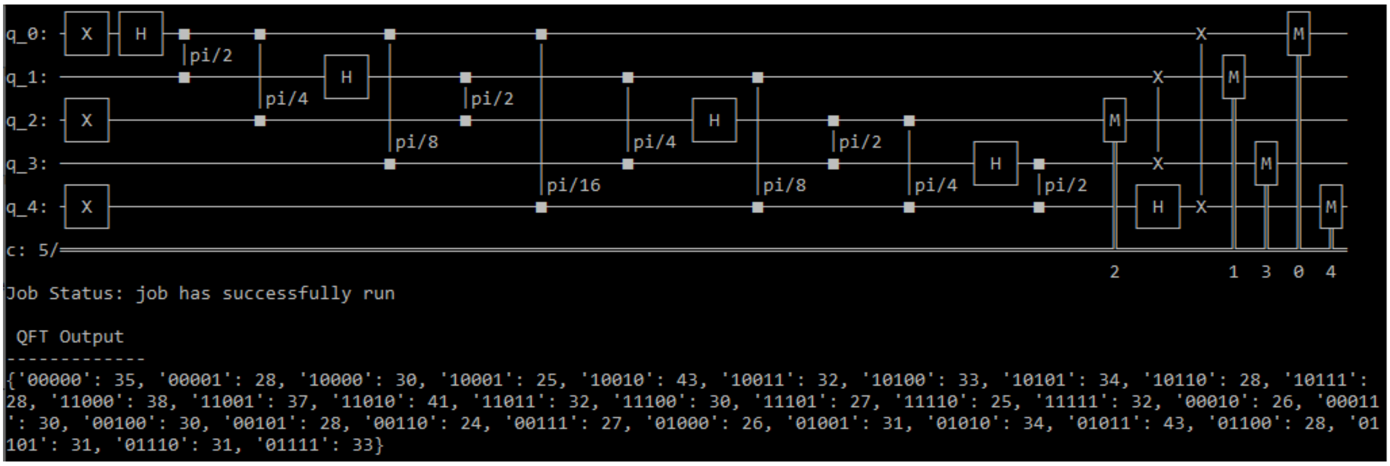
Code

```
from qiskit import QuantumRegister, ClassicalRegister
from qiskit import QuantumCircuit, execute,IBMQ
from qiskit.tools.monitor import job_monitor
from qiskit.circuit.library import QFT
import numpy as np

pi = np.pi

IBMQ.enable_account(‘ENTER API KEY HERE’)
provider = IBMQ.get_provider(hub='ibm-q')

backend = provider.get_backend('ibmq_qasm_simulator')

q = QuantumRegister(5,'q')
c = ClassicalRegister(5,'c')

circuit = QuantumCircuit(q,c)

circuit.x(q[4])
circuit.x(q[2])
circuit.x(q[0])
circuit += QFT(num_qubits=5, approximation_degree=0,
do_swaps=True, inverse=False, insert_barriers=False, name='qft')
circuit.measure(q,c)
circuit.draw(output='mpl', filename='qft1.png')
print(circuit)

job = execute(circuit, backend, shots=1000)

job_monitor(job)

counts = job.result().get_counts()

print("\n QFT Output")
print("-------------")
print(counts)
input()

q = QuantumRegister(5,'q')
c = ClassicalRegister(5,'c')

circuit = QuantumCircuit(q,c)

circuit.x(q[4])
circuit.x(q[2])
circuit.x(q[0])
circuit += QFT(num_qubits=5, approximation_degree=0,
```

```
do_swaps=True, inverse=False, insert_barriers=True, name='qft')
circuit += QFT(num_qubits=5, approximation_degree=0,
do_swaps=True, inverse=True, insert_barriers=True, name='qft')
circuit.measure(q,c)
circuit.draw(output='mpl',filename='qft2.png')

print(circuit)

job = execute(circuit, backend, shots=1000)

job_monitor(job)

counts = job.result().get_counts()

print("\n QFT with inverse QFT Output")
print("------------------------------")
print(counts)
input()
```

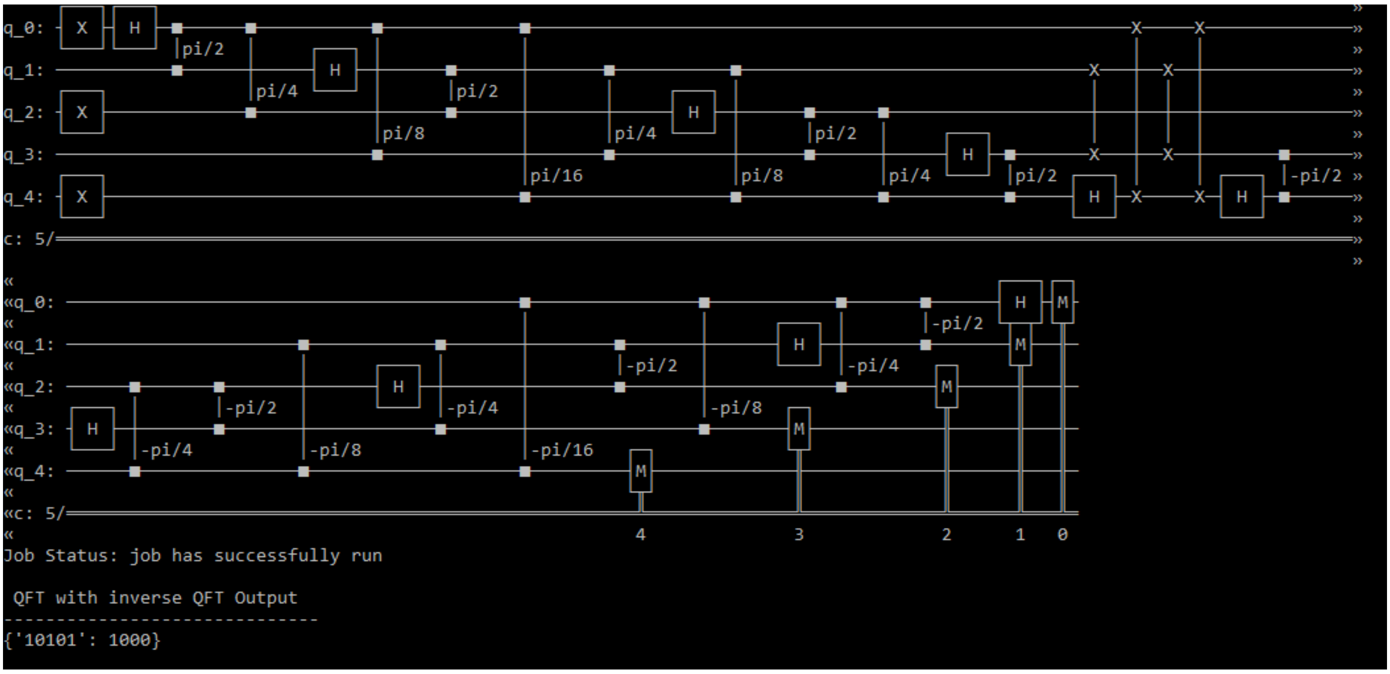
Output

Here is the output when running the QFT:



Output when running the 5 qubit QFT. Notice how we get multiple values back since the qubits are in superposition and the value is encoded in the Hadamard basis.

Here is the output when running the QFT with the inverse QFT.



Here the output when running the QFT with the inverse QFT. Notice how we get the 1010 back!

Tagged: Quantum Computing (/tutorials/tag/Quantum+Computing), Qiskit (/tutorials/tag/Qiskit), quantum fourier transform (/tutorials/tag/quantum+fourier+transform), 0 (/tutorials/tag/0)

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Tanmoy 5 years ago · 0 Likes

Nice to see thatQiskit has come up with QFT function..which simplifies the coding. Just one request, please include introduction of QFT with 2-3 quibit, so that the operation of QFT function can be understand by first time user.

Thanks for youreffort and simplifies our learning.

Macauley Coggins 5 years ago · 0 Likes

Thank you Tanmoy, I'll try to update the tutorial with a 2-3 qubit QFT example as soon as I can. In the meantime if you just use the code and initialise a QFT with 2 or 3 qubits you will be able to see the printed circuit.

Sina Sheikholeslami (https://www.inceptionq.com) 5 years ago · 0 Likes
(https://www.inceptionq.com)

Remarkable description and implementation of the QFT algorithm!

Kapil Rathore 5 years ago · 0 Likes

Well explained the QFT in easiest way

himel101 5 years ago · 0 Likes

One more thing, are you planning to demonstrate Quantum approximate counting as well? I want to see how that looks like. If you are doing that can you let me know? Email: himel101@yahoo.com

Macauley Coggins 5 years ago · 0 Likes

Hi himel101,

No problem, if you follow us on linkedin you can see our updates on new tutorials:

https://www.linkedin.com/company/28812155

Hopefully we'll have a tutorial on approximate counting up soon.

---

himel101 5 years ago · 0 Likes

Hi, I am wondering how to run any quantum circuit dynamically. I mean are there anyways to put a circuit in For/while loop and to figure out results from each count of the loop? Say if I want to run this QFT 3 times, I need to run this code thrice, what I want is: looking for a way to run this circuit as many times as I want by running code once. Is it possible?

Macauley Coggins 5 years ago · 0 Likes

You can just put it in a for loop like this:

```
from qiskit import QuantumRegister, ClassicalRegister
from qiskit import QuantumCircuit, execute,IBMQ
from qiskit.tools.monitor import job_monitor
from qiskit.circuit.library import QFT
import numpy as np

pi = np.pi

IBMQ.enable_account('Enter key')
provider = IBMQ.get_provider(hub='ibm-q')
```

```
backend = provider.get_backend('ibmq_qasm_simulator')

q = QuantumRegister(5,'q')
c = ClassicalRegister(5,'c')

for i in range(0, 3):
circuit = QuantumCircuit(q,c)
```

```
circuit.x(q[4])
circuit.x(q[2])
circuit.x(q[0])

circuit += QFT(num_qubits=5, approximation_degree=0,
do_swaps=True, inverse=False, insert_barriers=True,
name='qft')
circuit += QFT(num_qubits=5, approximation_degree=0,
do_swaps=True, inverse=True, insert_barriers=True,
name='qft')

circuit.measure(q,c)

job = execute(circuit, backend, shots=1000)
job_monitor(job)

counts = job.result().get_counts()

print(&quot;\n QFT with inverse QFT Output&quot;)
print(&quot;------------------------------&quot;)
print(counts)
```

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Older Post
Quantum Error Correction: Phase flip code in Qiskit (/tutorials/quantum-error-correction-phase-flip-code-in-qiskit)

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