

# T3 - Exercise Deutsch

December 11, 2024

## 1 Deutsch Algorithm

```
[1]: %pip install qiskit[visualization]
```

```
Requirement already satisfied: qiskit[visualization] in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages
(1.3.0)
Requirement already satisfied: rustworkx>=0.15.0 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (0.15.1)
Requirement already satisfied: numpy<3,>=1.17 in /opt/conda/lib/python3.11/site-
packages (from qiskit[visualization]) (1.26.4)
Requirement already satisfied: scipy>=1.5 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (1.14.1)
Requirement already satisfied: sympy>=1.3 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (1.13.3)
Requirement already satisfied: dill>=0.3 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (0.3.9)
Requirement already satisfied: python-dateutil>=2.8.0 in
/opt/conda/lib/python3.11/site-packages (from qiskit[visualization]) (2.9.0)
Requirement already satisfied: stevedore>=3.0.0 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (5.4.0)
Requirement already satisfied: typing-extensions in
/opt/conda/lib/python3.11/site-packages (from qiskit[visualization]) (4.12.2)
Requirement already satisfied: symengine<0.14,>=0.11 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (0.13.0)
Requirement already satisfied: matplotlib>=3.3 in
/opt/conda/lib/python3.11/site-packages (from qiskit[visualization]) (3.9.3)
Requirement already satisfied: pydot in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit[visualization]) (3.0.3)
Requirement already satisfied: Pillow>=4.2.1 in /opt/conda/lib/python3.11/site-
packages (from qiskit[visualization]) (11.0.0)
```

Requirement already satisfied: pylatexenc>=1.4 in  
/opt/.qbraid/environments/qbraid\_000000/pyenv/lib/python3.11/site-packages (from  
qiskit[visualization]) (2.10)

Requirement already satisfied: seaborn>=0.9.0 in  
/opt/.qbraid/environments/qbraid\_000000/pyenv/lib/python3.11/site-packages (from  
qiskit[visualization]) (0.13.2)

Requirement already satisfied: contourpy>=1.0.1 in  
/opt/conda/lib/python3.11/site-packages (from  
matplotlib>=3.3->qiskit[visualization]) (1.3.1)

Requirement already satisfied: cycycler>=0.10 in /opt/conda/lib/python3.11/site-  
packages (from matplotlib>=3.3->qiskit[visualization]) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in  
/opt/conda/lib/python3.11/site-packages (from  
matplotlib>=3.3->qiskit[visualization]) (4.55.2)

Requirement already satisfied: kiwisolver>=1.3.1 in  
/opt/conda/lib/python3.11/site-packages (from  
matplotlib>=3.3->qiskit[visualization]) (1.4.7)

Requirement already satisfied: packaging>=20.0 in  
/opt/conda/lib/python3.11/site-packages (from  
matplotlib>=3.3->qiskit[visualization]) (24.0)

Requirement already satisfied: pyparsing>=2.3.1 in  
/opt/conda/lib/python3.11/site-packages (from  
matplotlib>=3.3->qiskit[visualization]) (3.2.0)

Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.11/site-  
packages (from python-dateutil>=2.8.0->qiskit[visualization]) (1.16.0)

Requirement already satisfied: pandas>=1.2 in /opt/conda/lib/python3.11/site-  
packages (from seaborn>=0.9.0->qiskit[visualization]) (2.2.3)

Requirement already satisfied: pbr>=2.0.0 in  
/opt/.qbraid/environments/qbraid\_000000/pyenv/lib/python3.11/site-packages (from  
stevedore>=3.0.0->qiskit[visualization]) (6.1.0)

Requirement already satisfied: mpmath<1.4,>=1.1.0 in  
/opt/.qbraid/environments/qbraid\_000000/pyenv/lib/python3.11/site-packages (from  
sympy>=1.3->qiskit[visualization]) (1.3.0)

Requirement already satisfied: pytz>=2020.1 in /opt/conda/lib/python3.11/site-  
packages (from pandas>=1.2->seaborn>=0.9.0->qiskit[visualization]) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in /opt/conda/lib/python3.11/site-  
packages (from pandas>=1.2->seaborn>=0.9.0->qiskit[visualization]) (2024.2)

Note: you may need to restart the kernel to use updated packages.

First we'll define a quantum circuit that implements a query gate for one of the four functions  $f_1$ ,  $f_2$ ,  $f_3$ , or  $f_4$  from one bit to one bit: -  $f_1$ : constant function that maps 0 and 1 to 0. -  $f_2$ : function that maps 0 to 0 and 1 to 1. -  $f_3$ : function that maps 0 to 1 and 1 to 0. -  $f_4$ : constant function that maps 0 and 1 to 1.

As was discussed, the implementation of query gates is not really a part of Deutsch's algorithm itself — here we're essentially just showing one way to prepare the input (in the form of a circuit implementation of a query gate).

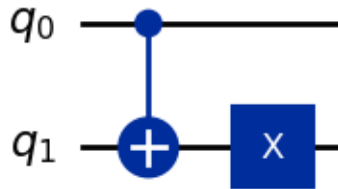
```
[2]: from qiskit import QuantumCircuit

def deutsch_function(case: int):
    """
    Generate a valid Deutsch function as a `QuantumCircuit`.
    """
    if case not in [1, 2, 3, 4]:
        raise ValueError("`case` must be 1, 2, 3, or 4.")

    f = QuantumCircuit(2)
    if case in [2, 3]:
        f.cx(0, 1)
    if case in [3, 4]:
        f.x(1)
    return f
```

We can see what each circuit looks like using the draw method.

```
[3]: display(deutsch_function(3).draw('mpl'))
```



Next we will create the actual quantum circuit for Deutsch's algorithm, substituting the query gate with a quantum circuit implementation given as an argument. Shortly we'll plug in one of the four circuits defined by the function `deutsch_function` we defined earlier. Barriers are included to show the visual separation between the query gate implementation and the rest of the circuit, but they aren't necessary and can safely be removed.

```
[4]: def compile_circuit(function: QuantumCircuit):
    """
    Compiles a circuit for use in Deutsch's algorithm.
    """
    n = function.num_qubits - 1
    qc = QuantumCircuit(n + 1, n)

    qc.x(n)
    qc.h(range(n + 1))
```

```

qc.barrier()
qc.compose(function, inplace=True)
qc.barrier()

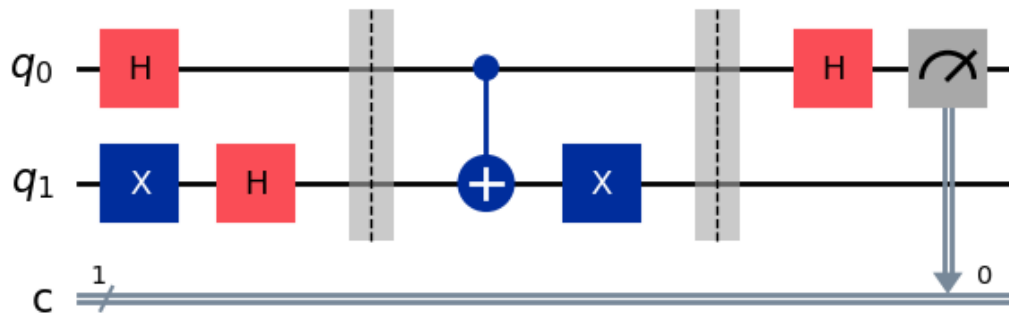
qc.h(range(n))
qc.measure(range(n), range(n))

return qc

```

Again we can see what the circuit looks like using the draw method.

```
[5]: display(compile_circuit(deutsch_function(3)).draw('mpl'))
```



Finally, we'll create a function that runs the circuit just defined one time and outputs the appropriate result: "constant" or "balanced."

```
[6]: %pip install qiskit_aer
```

```

Requirement already satisfied: qiskit_aer in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages
(0.15.1)
Requirement already satisfied: qiskit>=1.1.0 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit_aer) (1.3.0)
Requirement already satisfied: numpy>=1.16.3 in /opt/conda/lib/python3.11/site-
packages (from qiskit_aer) (1.26.4)
Requirement already satisfied: scipy>=1.0 in
/opt/.qbraided/environments/qbraided_000000/pyenv/lib/python3.11/site-packages (from
qiskit_aer) (1.14.1)
Requirement already satisfied: psutil>=5 in /opt/conda/lib/python3.11/site-
packages (from qiskit_aer) (5.9.8)
Requirement already satisfied: rustworkx>=0.15.0 in

```

```

/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
qiskit>=1.1.0->qiskit_aer) (0.15.1)
Requirement already satisfied: sympy>=1.3 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
qiskit>=1.1.0->qiskit_aer) (1.13.3)
Requirement already satisfied: dill>=0.3 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
qiskit>=1.1.0->qiskit_aer) (0.3.9)
Requirement already satisfied: python-dateutil>=2.8.0 in
/opt/conda/lib/python3.11/site-packages (from qiskit>=1.1.0->qiskit_aer) (2.9.0)
Requirement already satisfied: stevedore>=3.0.0 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
qiskit>=1.1.0->qiskit_aer) (5.4.0)
Requirement already satisfied: typing-extensions in
/opt/conda/lib/python3.11/site-packages (from qiskit>=1.1.0->qiskit_aer)
(4.12.2)
Requirement already satisfied: symengine<0.14,>=0.11 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
qiskit>=1.1.0->qiskit_aer) (0.13.0)
Requirement already satisfied: six>=1.5 in /opt/conda/lib/python3.11/site-
packages (from python-dateutil>=2.8.0->qiskit>=1.1.0->qiskit_aer) (1.16.0)
Requirement already satisfied: pbr>=2.0.0 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
stevedore>=3.0.0->qiskit>=1.1.0->qiskit_aer) (6.1.0)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/opt/.qbraidd/environments/qbraidd_000000/pyenv/lib/python3.11/site-packages (from
sympy>=1.3->qiskit>=1.1.0->qiskit_aer) (1.3.0)
Note: you may need to restart the kernel to use updated packages.

```

```

[7]: from qiskit_aer import AerSimulator

def deutsch_algorithm(function: QuantumCircuit):
    """
    Determine if a Deutsch function is constant or balanced.
    """
    qc = compile_circuit(function)

    result = AerSimulator().run(qc, shots=1, memory=True).result()
    measurements = result.get_memory()
    if measurements[0] == "0":
        return "constant"
    return "balanced"

```

The following code cell runs Deutsch's algorithm on any one of the four functions defined above.

```

[9]: # Replace ?
f = deutsch_function(1)
display(f.draw('mpl'))

```

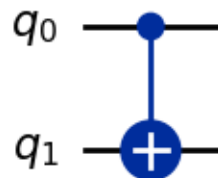
```
display(deutsch_algorithm(f))
```

$q_0$  —

$q_1$  —

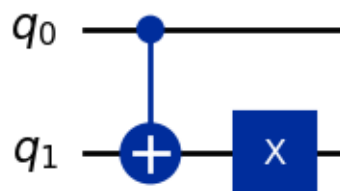
'constant'

```
[10]: f = deutsch_function(2)
      display(f.draw('mpl'))
      display(deutsch_algorithm(f))
```



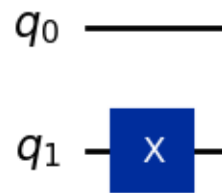
'balanced'

```
[11]: f = deutsch_function(3)
      display(f.draw('mpl'))
      display(deutsch_algorithm(f))
```



'balanced'

```
[12]: f = deutsch_function(4)
      display(f.draw('mpl'))
      display(deutsch_algorithm(f))
```



'constant'

## 2 End of Notebook