

Quantum Circuit

```
In[*]:= Quit[]

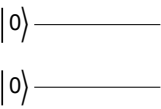
In[*]:= << Q3`

In[*]:= Let[Qubit, S]
```

Input

```
In[*]:= qc = QuantumCircuit[Ket[S@{1, 2}]]

Out[*]=
```



```
In[*]:= Elaborate[qc]

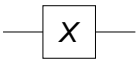
Out[*]=
```



Single-Qubit Operators

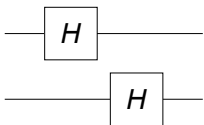
```
In[*]:= qc = QuantumCircuit[S[1, 1]]

Out[*]=
```



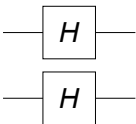
```
In[*]:= qc = QuantumCircuit[S[1, 6], S[2, 6]]

Out[*]=
```



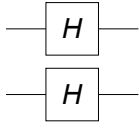
```
In[*]:= qc = QuantumCircuit[{S[1, 6], S[2, 6]}]

Out[*]=
```



```
In[*]:= qc = QuantumCircuit[S[{1, 2}, 6]]
```

```
Out[*]:=
```



```
In[*]:= op = Elaborate[qc]
```

```
Out[*]:=
```

$$\frac{1}{2} S_1^x S_2^x + \frac{1}{2} S_1^x S_2^z + \frac{1}{2} S_1^z S_2^x + \frac{1}{2} S_1^z S_2^z$$

```
In[*]:= S[1, 6] ** S[2, 6]
```

```
Out[*]:=
```

$$S_1^H S_2^H$$

```
In[*]:= mat = Matrix[qc];
MatrixForm[mat]
```

```
Out[*]//MatrixForm=
```

$$\begin{pmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \frac{1}{2} & -\frac{1}{2} & \frac{1}{2} & -\frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \\ \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & \frac{1}{2} \end{pmatrix}$$

```
In[*]:= out = qc ** Ket[]
```

```
Out[*]:=
```

$$\frac{1}{2} |0_{S_1} 0_{S_2}\rangle + \frac{1}{2} |0_{S_1} 1_{S_2}\rangle + \frac{1}{2} |1_{S_1} 0_{S_2}\rangle + \frac{1}{2} |1_{S_1} 1_{S_2}\rangle$$

```
In[*]:= Basis[S@{1, 2}]
```

```
Out[*]:=
```

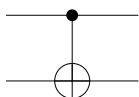
$$\{|0_{S_1} 0_{S_2}\rangle, |0_{S_1} 1_{S_2}\rangle, |1_{S_1} 0_{S_2}\rangle, |1_{S_1} 1_{S_2}\rangle\}$$

Two-Qubit Operators

CNOT (Controlled-NOT)

```
In[*]:= qc = QuantumCircuit[CNOT[S[1], S[2]]]
```

```
Out[*]:=
```



```
In[*]:= in = Basis[S@{1, 2}]
```

```
Out[*]:=
```

$$\{|0_{S_1} 0_{S_2}\rangle, |0_{S_1} 1_{S_2}\rangle, |1_{S_1} 0_{S_2}\rangle, |1_{S_1} 1_{S_2}\rangle\}$$

```
In[*]:= out = qc ** in
Out[*]:= { |0S10S2⟩, |0S11S2⟩, |1S11S2⟩, |1S10S2⟩ }
```

```
In[*]:= Thread[in → out] // TableForm
```

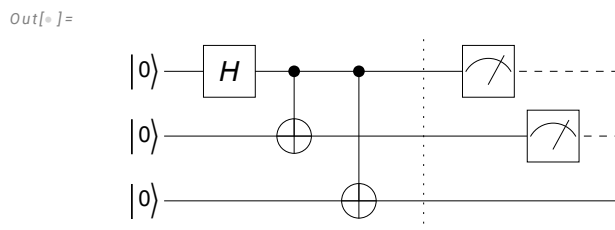
```
Out[*] // TableForm =
|0S10S2⟩ → |0S10S2⟩
|0S11S2⟩ → |0S11S2⟩
|1S10S2⟩ → |1S11S2⟩
|1S11S2⟩ → |1S10S2⟩
```

```
In[*]:= Matrix[qc] // MatrixForm
```

```
Out[*] // MatrixForm =
( 1 0 0 0
  0 1 0 0
  0 0 0 1
  0 0 1 0 )
```

Measurements

```
In[*]:= qc = QuantumCircuit[Ket[S@{1, 2, 3}],
  S[1, 6], CNOT[S[1], S[2]], CNOT[S[1], S[3]], "Separator",
  Measurement[S[1, 3]], Measurement[S[2, 3]]]
```



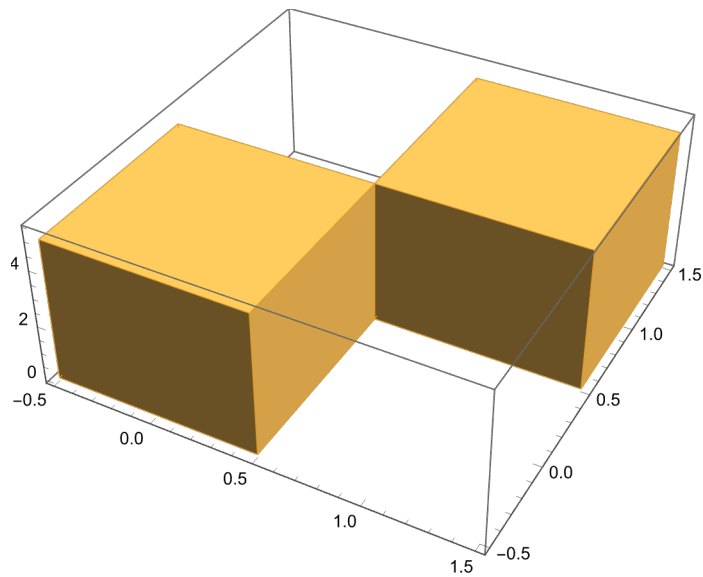
```
In[*]:= out = Elaborate[qc]
```

```
Out[*] = |0S10S20S3⟩
```

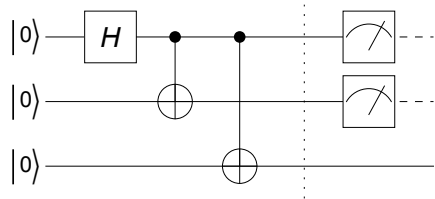
```
In[*]:= data = Table[Elaborate[qc]; Readout[S[{1, 2}, 3]], 10]
```

```
Out[*] = {{1, 1}, {0, 0}, {0, 0}, {0, 0}, {1, 1}, {1, 1}, {1, 1}, {0, 0}, {0, 0}, {1, 1}}
```

```
In[ ]:= Histogram3D[data]
Out[ ]:=
```



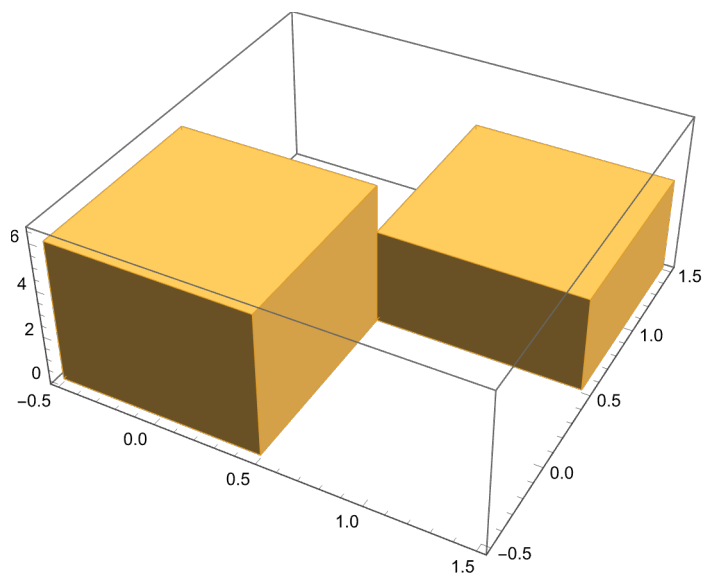
```
In[ ]:= qc = QuantumCircuit[Ket[S@{1, 2, 3}],
  S[1, 6], CNOT[S[1], S[2]], CNOT[S[1], S[3]], "Separator",
  Measurement[S[{1, 2}, 3]]]
Out[ ]:=
```



```
In[ ]:= data = Table[Elaborate[qc]; Readout[S[{1, 2}, 3]], 10]
Out[ ]:=
```

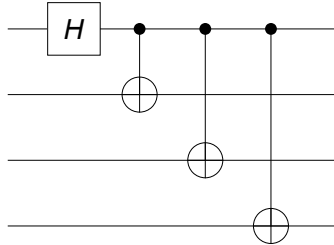
```
{ {1, 1}, {0, 0}, {0, 0}, {1, 1}, {0, 0}, {0, 0}, {0, 0}, {0, 0}, {1, 1}, {1, 1} }
```

```
In[ ]:= Histogram3D[data]
Out[ ]:=
```



List vs Sequence

We want to generate the following quantum circuit for different numbers of target qubits.



What should we do?

```
In[*]:= Let[Qubit, S, T]

In[*]:= $n = 3;
        TT = T[Range[$n], $]

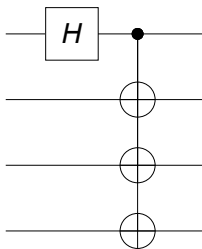
Out[*]:= {T1, T2, T3}
```

```
In[*]:= cn = Table[CNOT[S[1], q], {q, TT}];
        cn // TableForm

Out[*]//TableForm=
  CNOT[{S1} → {1}, {T1}]
  CNOT[{S1} → {1}, {T2}]
  CNOT[{S1} → {1}, {T3}]
```

```
In[*]:= qc = QuantumCircuit[S[1, 6], cn]

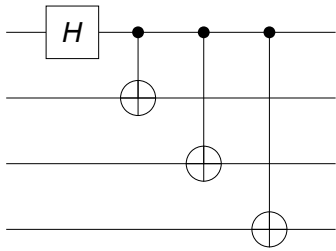
Out[*]=
```



```
In[*]:= cn

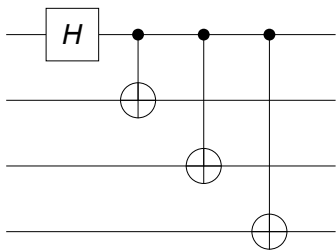
Out[*]=
  {CNOT[{S1} → {1}, {T1}], CNOT[{S1} → {1}, {T2}], CNOT[{S1} → {1}, {T3}]}
```

```
In[*]:= QuantumCircuit[S[1, 6], CNOT[S[1], T[1]], CNOT[S[1], T[2]], CNOT[S[1], T[3]]]
Out[*]=
```



Is there any simpler way?

```
In[*]:= qc = QuantumCircuit[S[1, 6], Sequence @@ cn]
Out[*]=
```



List, Sequence, and @@.

Summary

Functions

- QuantumCircuit
- Elaborate, ExpressionFor
- Matrix, MatrixForm
- Apply

Related Links

- Chapter 2 of the Quantum Workbook (2022, 2023).
- Tutorial: “Quantum Computation: Overview”