

The tikz-quantumgates Package: Drawing quantum circuits with TikZ

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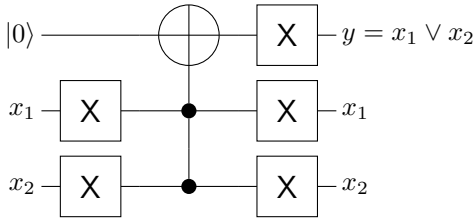
BTU Cottbus-Senftenberg

November 3, 2018

See <https://github.com/matthias-wolff/tikz-quantumgates/blob/master/tikz-quantumgates.pdf> for the latest version of this document.

Abstract

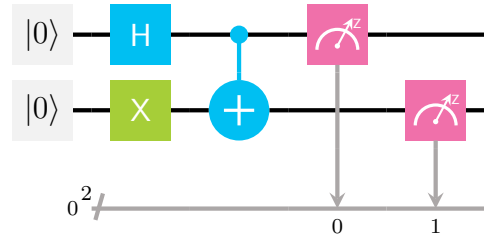
This package provides macros for drawing quantum gates and circuits with TikZ [1].



```

1 \documentclass{standalone}
2 \usepackage{tikz-quantumgates}
3 \begin{document}
4   \centering
5   \begin{tikzpicture}
6     \node[anchor=west] at (-0.6,2) {$|0\rangle$};
7     \node[anchor=west] at (-0.6,1) {$x_1$};
8     \node[anchor=west] at (-0.6,0) {$x_2$};
9     \qwire{0}{2}\qgateX{0}{1}\qgateX{0}{0}
10    \qgateCNC{b}{1}{2}\qgateCNC{b}{1}{1}\qgateCNC{t}{1}{0}
11    \qgateX{2}{2}\qgateX{2}{1}\qgateX{2}{0}
12    \node[anchor=west] at (3.2,2) {$y=x_1\vee x_2$};
13    \node[anchor=west] at (3.2,1) {$x_1$};
14    \node[anchor=west] at (3.2,0) {$x_2$};
15  \end{tikzpicture}
16 \end{document}

```



```

1 \documentclass{standalone}
2 \usepackage{tikz-quantumgates}
3 \begin{document}
4   \centering
5   \begin{tikzpicture}
6     \node[anchor=west] at (0.6,-0.3) {\footnotesize 0};
7     \qzero[ibmqx]{0}{2}\qzero[ibmqx]{0}{1}
8     \qgateH[ibmqx]{1}{2}\qgateX[ibmqx]{1}{1}\qmeasBh[ibmqx]{2}{1}{0}
9     \qgateCNC[ibmqx]{b}{2}{2}\qgateCNC[ibmqx]{t}{2}{1}\qmeasB[ibmqx]{2}{0}
10    \qmeasM[ibmqx]{3}{2}\qmeasR[ibmqx]{3}{1}\qmeasMB[ibmqx]{0}{3}{0}
11    \qwire[ibmqx]{4}{2}\qmeasM[ibmqx]{4}{1}\qmeasMB[ibmqx]{1}{4}{0}
12  \end{tikzpicture}
13 \end{document}


































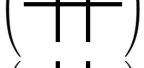








```

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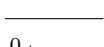



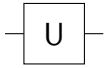

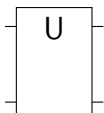
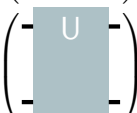
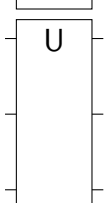
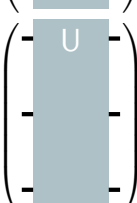
1 Overview

1.1 List of Circuit Symbols

Standard	Option ibmqx	Command
		<code>\qwire[option]{x}{y}</code>
$ 0\rangle$		<code>\qzero[option]{x}{y}</code>
		<code>\qgateID[option]{x}{y}</code>
		<code>\qgateX[option]{x}{y}</code>
		<code>\qgateY[option]{x}{y}</code>
		<code>\qgateZ[option]{x}{y}</code>
		<code>\qgateH[option]{x}{y}</code>
		<code>\qgateS[option]{x}{y}</code>
		<code>\qgateSi[option]{x}{y}</code>
		<code>\qgateT[option]{x}{y}</code>
		<code>\qgateTi[option]{x}{y}</code>
		<code>\qgateUa[option]{x}{y}</code>
		<code>\qgateUb[option]{x}{y}</code>
		<code>\qgateUc[option]{x}{y}</code>
		<code>\qgateCNX[option]{cwires}{x}{y}</code>
		<code>\qgateCNR[option]{x}{y}</code>
		<code>\qgateCNC[option]{cwires}{x}{y}</code>
		<code>\qgateSWt[option]{x}{y}</code> (not an “official” IBM QX symbol)
		<code>\qgateSWR[option]{x}{y}</code> (not an “official” IBM QX symbol)
		<code>\qgateSWb[option]{x}{y}</code> (not an “official” IBM QX symbol)
		<code>\qmeasM[option]{x}{y}</code>
		<code>\qmeasR[option]{x}{y}</code>

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Standard	Option <code>ibmqx</code>	Command
		<code>\qmeasMB[option]{b}{x}{y}</code>
		<code>\qmeasB[option]{x}{y}</code>
		<code>\qmeasBh[option]{b}{x}{y}</code>
		<code>\qgateU[option]{x}{y}{label}</code> (not an “official” IBM QX symbol)
		<code>\qgateUu[option]{x}{y}{label}</code> (not an “official” IBM QX symbol)
		<code>\qgateUuu[option]{x}{y}{label}</code> (not an “official” IBM QX symbol)

1.2 Installation

Download `tikz-quantumgates.sty` from [2] file into your project folder and include the package with `\usepackage{tikz-quantumgates}`.

2 Documentation of Commands

2.1 Wire and State Preparation Symbols

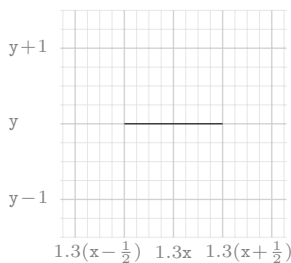
`\qwire[option]{x}{y}`

Draws a wire.

Parameters

- `option` Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- `x, y` Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x, y)`.

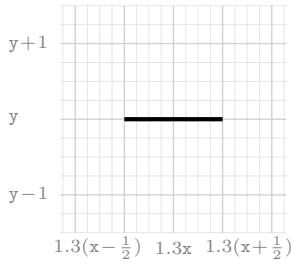
Examples



```

1 \begin{tikzpicture}
2   \qScalePaper
3   \qwire{0}{0}
4 \end{tikzpicture}

```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qwire[ibmqx]{0}{0}
4 \end{tikzpicture}
```

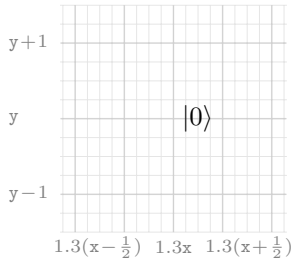
`\qzero[option]{x}{y}`

Draws the zero-state preparator.

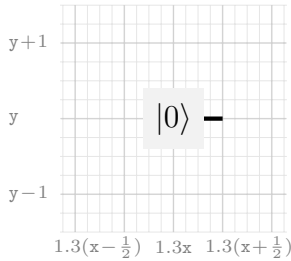
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qzero{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qzero[ibmqx]{0}{0}
4 \end{tikzpicture}
```

2.2 Single-Qubit Gate Symbols

`\qgateU[option]{x}{y}{label}`

Draws a general single-qubit quantum gate.

Parameters

- option** Omit for standard circuit styling or `ibmqxA, ..., ibmqxH` for IBM Q Experience circuit styling. The last letter of `ibmqx*` defines the color of the gate symbol:

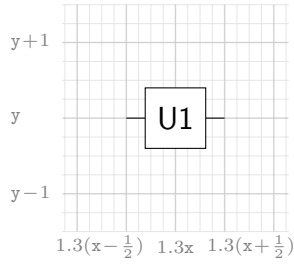
A B C D E F G H

If `ibmqx` is passed, `ibmqxG` will be used.

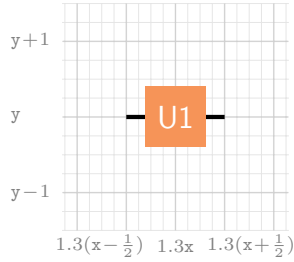
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

- label** Gate label.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateU{0}{0}{U1}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateU[ibmqxA]{0}{0}{U1}
4 \end{tikzpicture}
```

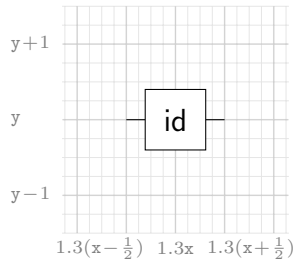
`\qgateID[option]{x}{y}`

Draws the identity gate.

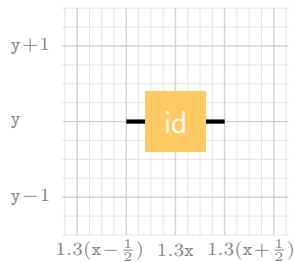
Parameters

- `option` Omit for standard circuit styling or `ibmqxA` for IBM Q Experience circuit styling.
- `x, y` Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateID{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateID[ibmqxA]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$I \doteq \left(\begin{array}{c|cc} & \langle 0| & \langle 1| \\ \hline |0\rangle & 1 & 0 \\ |1\rangle & 0 & 1 \end{array} \right) \quad \text{\texttt{\$}\displaystyle I\texttt{\$}} \quad \text{\texttt{\$}\displaystyle I\texttt{\$}}$$

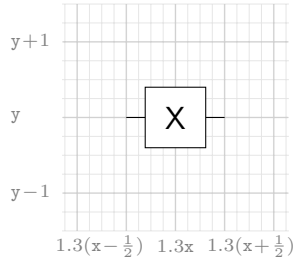
`\qgateX[option]{x}{y}`

Pauli-X gate.

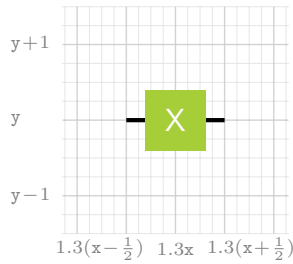
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateX{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateX[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$X \doteq \begin{pmatrix} & | & \langle 0| & \langle 1| \\ \hline |0\rangle & 0 & 1 \\ |1\rangle & 1 & 0 \end{pmatrix}$$

1 `\displaystyle X\doteq\qgateOX`

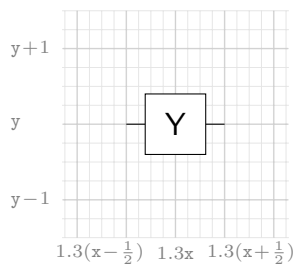
`\qgateY[option]{x}{y}`

Pauli-Y gate.

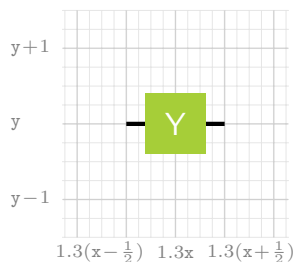
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateY{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateY[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$Y \doteq \begin{pmatrix} & | & \langle 0| & \langle 1| \\ \hline |0\rangle & 0 & -i \\ |1\rangle & i & 0 \end{pmatrix} \quad \text{1} \quad \text{\texttt{\$}\displaystyle Y\doteq\qgateOY \$}$$

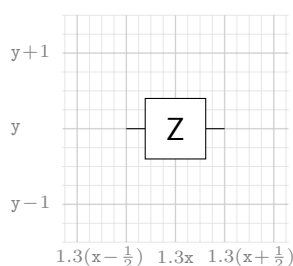
`\qgateZ[option]{x}{y}`

Pauli-Z gate.

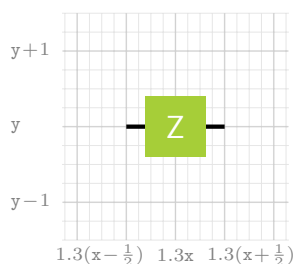
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateZ{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateZ[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$Z \doteq \begin{pmatrix} & | & \langle 0| & \langle 1| \\ \hline |0\rangle & 1 & 0 \\ |1\rangle & 0 & -1 \end{pmatrix} \quad \text{1} \quad \text{\texttt{\$}\displaystyle Z\doteq\qgateOZ \$}$$

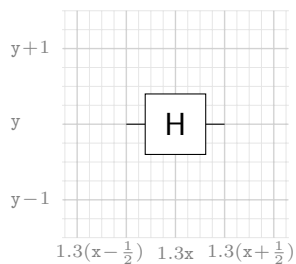
`\qgateH[option]{x}{y}`

Hadamard gate.

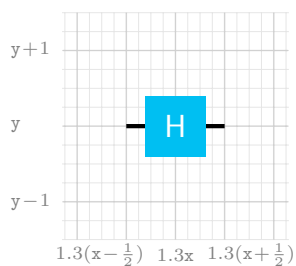
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateH{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateH[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$H \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} & \langle 0| & \langle 1| \\ |0\rangle & 1 & 1 \\ |1\rangle & 1 & -1 \end{pmatrix}$$

```
1 $\displaystyle H\dotseq\qgateOH$
```

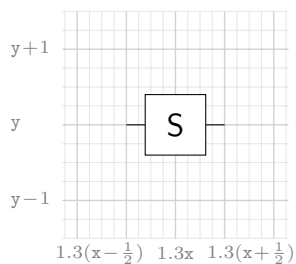
`\qgateS[option]{x}{y}`

S phase gate.

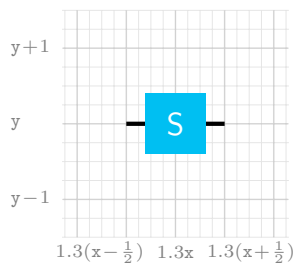
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are (`\qgateSx*x, y`).

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateS{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateS[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$S = \sqrt{Z} \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} | & \langle 0| & \langle 1| \\ |0\rangle & 1 & 0 \\ |1\rangle & 0 & i \end{pmatrix}$$

```
1  $\displaystyle S=\sqrt{Z}\doteq\qgate{0}{0}$ 
```

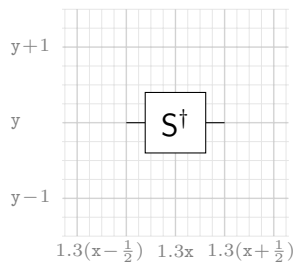
`\qgateSi[option]{x}{y}`

Inverse S phase gate.

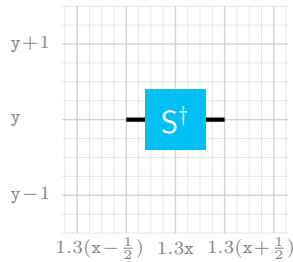
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSi{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSi[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$S^\dagger \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} | & \langle 0| & \langle 1| \\ |0\rangle & 1 & 0 \\ |1\rangle & 0 & -i \end{pmatrix}$$

```
1  $\displaystyle S^\dagger\doteq\qgate{0}{Si}$ 
```

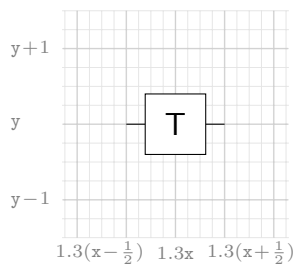
`\qgateT[option]{x}{y}`

T phase gate.

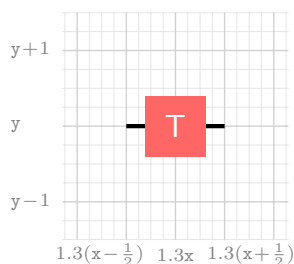
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateT{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateT[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$T = \sqrt{S} \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} & \langle 0| & \langle 1| \\ |0\rangle & 1 & 0 \\ |1\rangle & 0 & \frac{1}{\sqrt{2}}(1+i) \end{pmatrix}$$

```
1 $\displaystyle T=\sqrt{S}\doteq\qgateOT$
```

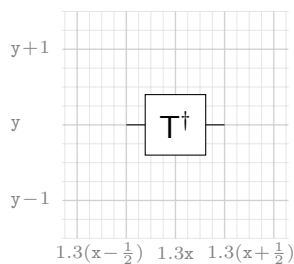
`\qgateTi[option]{x}{y}`

Inverse T phase gate.

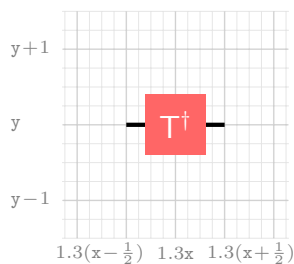
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateTi{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateTi[ibmqx]{0}{0}
4 \end{tikzpicture}
```

Gate Operator

$$T^\dagger \doteq \frac{1}{\sqrt{2}} \left(\begin{array}{c|cc} & \langle 0| & \langle 1| \\ \hline |0\rangle & 1 & 0 \\ |1\rangle & 0 & \frac{1}{\sqrt{2}}(1-i) \end{array} \right)$$

2.3 Single-Qubit Physical Gate of IBM Q Experience

$$\backslash\mathrm{qgateUa}[\mathrm{option}]\{x\}\{y\}$$

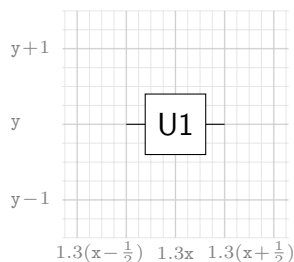
$$\backslash\mathrm{qgateUa}^*[\mathrm{option}]\{x\}\{y\}\{\mathrm{sublabel}\}$$

U1 gate of IBM Q Experience.

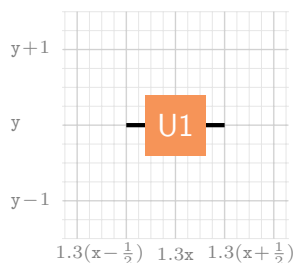
Parameters

option	Omit for standard circuit styling or <code>ibmqx</code> for IBM Q Experience circuit styling.
x, y	Position of symbol in schematic. The actual TikZ coordinates are <code>(\qgateSx*x,y)</code> .
sublabel	Sub-label, e.g. for gate parameters (starred version only)

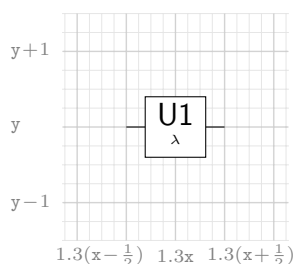
Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUa{0}{0}
4 \end{tikzpicture}
```



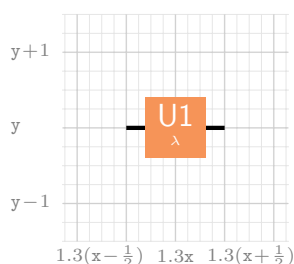
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUa[ibmqx]{0}{0}
4 \end{tikzpicture}
```



```

1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUa*{0}{0}{{\lambda$}}
4 \end{tikzpicture}

```



```

1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUa*[ibmqx]{0}{0}{$\lambda$}
4 \end{tikzpicture}

```

Gate Operator

$$U1_\lambda \doteq \begin{pmatrix} & \langle 0| & \langle 1| \\ |0\rangle & 1 & 0 \\ |1\rangle & 0 & e^{i\lambda} \end{pmatrix} \quad \text{\texttt{\textbackslashdisplaystyle U1_{\lambda}\doteq\qgateOUa \$}}$$

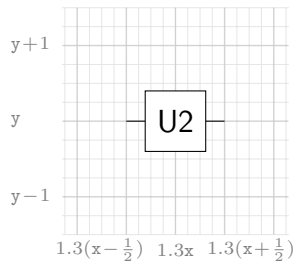
`\qgateUb[option]{x}{y}`
`\qgateUb*[option]{x}{y}{sublabel}`

U2 gate of IBM Q Experience.

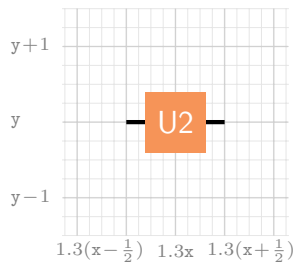
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.
- sublabel** Sub-label, e.g. for gate parameters (starred version only)

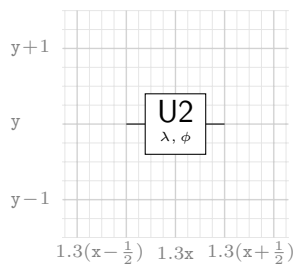
Examples



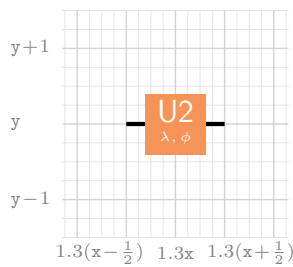
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUb{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUb[ibmqx]{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUb*{0}{0}{\lambda,\phi}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUb*[ibmqx]{0}{0}{\lambda,\phi}
4 \end{tikzpicture}
```

Gate Operator

$$U_{2,\lambda,\phi} \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} & \langle 0| & \langle 1| \\ |0\rangle & 1 & -e^{i\lambda} \\ |1\rangle & e^{i\phi} & e^{(\lambda+\phi)i} \end{pmatrix}$$

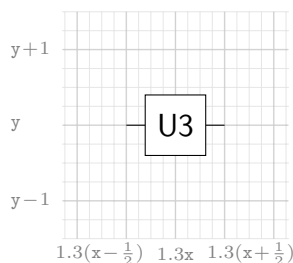
```
\qgateUc[option]{x}{y}
\qgateUc*[option]{x}{y}{sublabel}
```

U3 gate of IBM Q Experience.

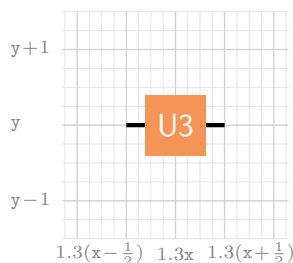
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.
- sublabel** Sub-label, e.g. for gate parameters (starred version only)

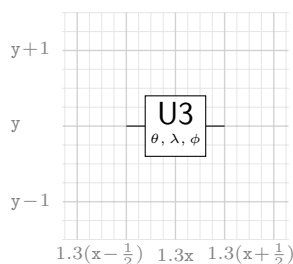
Examples



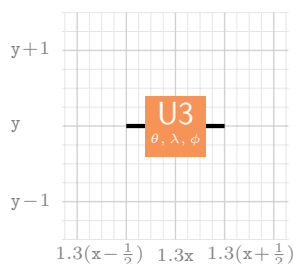
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUc{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUc[ibmqx]{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUc*[0]{0}{\theta,\lambda,\phi}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUc*[ibmqx]{0}{0}{\theta,\lambda,\phi}
4 \end{tikzpicture}
```

Gate Operator

$$U_{3\lambda,\phi,\theta} \doteq \left(\begin{array}{c|cc} & \langle 0| & \langle 1| \\ \hline |0\rangle & \cos(\frac{\theta}{2}) & -\sin(\frac{\theta}{2})e^{\lambda i} \\ |1\rangle & \sin(\frac{\theta}{2})e^{\phi i} & \cos(\frac{\theta}{2})e^{(\lambda+\phi)i} \end{array} \right) \quad \text{\texttt{\textbackslash displaystyle U3_{\lambda,\phi,\theta}\doteq\qgateUc}}$$

2.4 Multiple-Qubit Gate Symbols

`\qgateUu[option]{x}{y}{label}`

General three-qubit gate.

Parameters

option Omit for standard circuit styling or `ibmqxA`, ..., `ibmqxH` for IBM Q Experience circuit styling. The last letter of `ibmqx*` defines the color of the gate symbol:

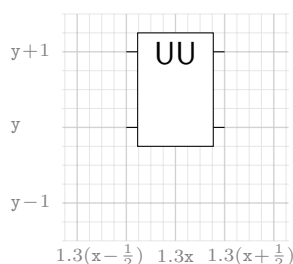
A B C D E F G H

If `ibmqx` is passed, `ibmqxG` will be used.

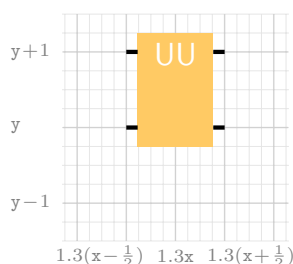
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x, y)`.

label Gate label.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUu{0}{0}{UU}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUu[ibmqxB]{0}{0}{UU}
4 \end{tikzpicture}
```

`\qgateUuu[option]{x}{y}{label}`

General three-qubit gate.

Parameters

option Omit for standard circuit styling or `ibmqxA`, ..., `ibmqxH` for IBM Q Experience circuit styling. The last letter of `ibmqx*` defines the color of the gate symbol:

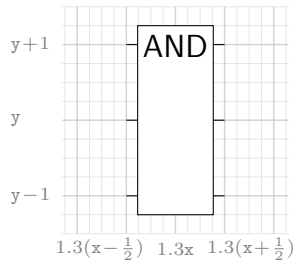
A B C D E F G H

If `ibmqx` is passed, `ibmqxG` will be used.

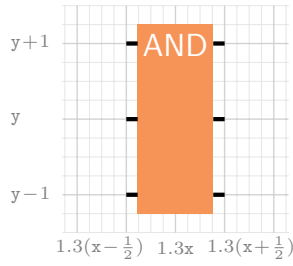
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x, y)`.

label Gate label.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUuu{0}{0}{AND}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUuu[ibmqxA]{0}{0}{AND}
4 \end{tikzpicture}
```

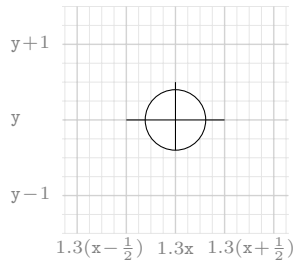
`\qgateCNX[option]{cwires}{x}{y}`

XOR symbol of controlled-NOT gate.

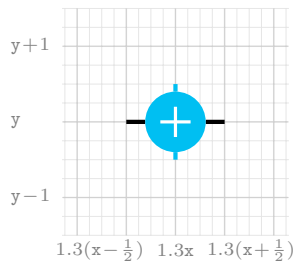
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- cwires** Control wires, `t` for top, `b` for bottom, and `tb` for both sides.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNX{t}{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNX[ibmqx]{tb}{0}{0}
4 \end{tikzpicture}
```

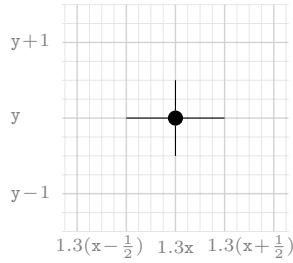
`\qgateCNC[option]{cwires}{x}{y}`

Control qubit symbol of controlled-NOT gate.

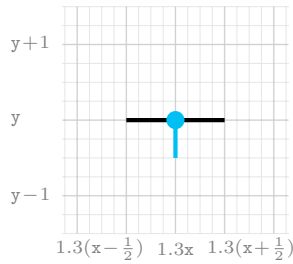
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- cwires** Control wires, `t` for top, `b` for bottom, and `tb` for both sides.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNC{bt}{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNC[ibmqx]{b}{0}{0}
4 \end{tikzpicture}
```

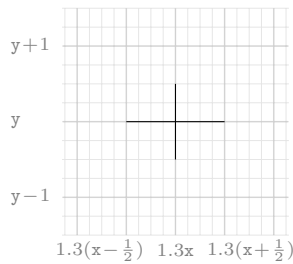
`\qgateCNR[option]{x}{y}`

Run-through qubit symbol of controlled-NOT gate.

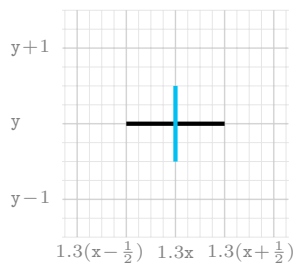
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNR{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateCNR[ibmqx]{0}{0}
4 \end{tikzpicture}
```

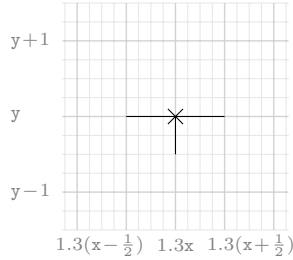
`\qgateSwT[option]{x}{y}`

Top qubit of a SWAP gate.

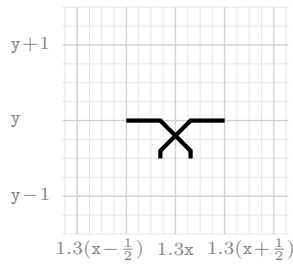
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWt{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWt[ibmqx]{0}{0}
4 \end{tikzpicture}
```

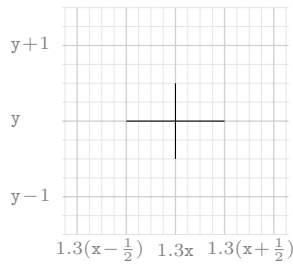
$\backslash\text{qgateSWR}[\text{option}]{x}{y}$

Run-through qubit of a SWAP gate.

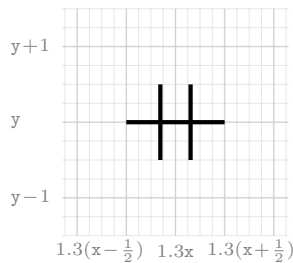
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWR{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWR[ibmqx]{0}{0}
4 \end{tikzpicture}
```

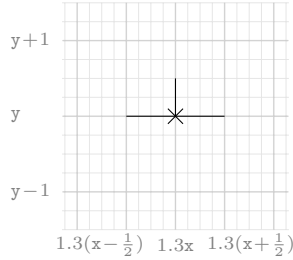
$\backslash\text{qgateSWb}[\text{option}]{x}{y}$

Bottom qubit of a SWAP gate.

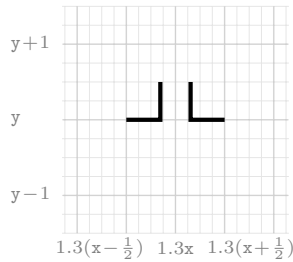
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWb{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateSWb[ibmqx]{0}{0}
4 \end{tikzpicture}
```

2.5 Measurement Symbols

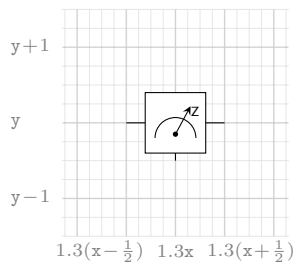
`\qmeasM[option]{x}{y}`

Measurement symbol.

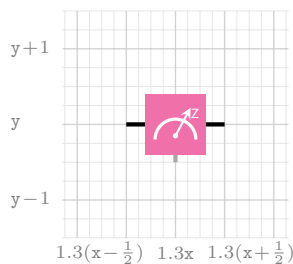
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasM{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasM[ibmqx]{0}{0}
4 \end{tikzpicture}
```

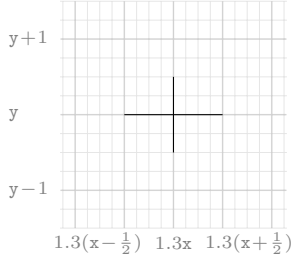
`\qmeaR[option]{x}{y}`

Measurement run-through qubit symbol.

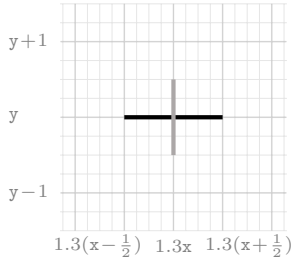
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasR{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasR[ibmqx]{0}{0}
4 \end{tikzpicture}
```

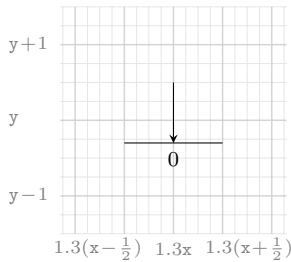
`\qmeasMB[option]{b}{x}{y}`

Measurement-joins-bus symbol.

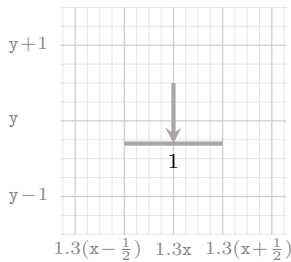
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
- b** Bit identifier on conventional bits bus.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasMB{0}{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasMB[ibmqx]{1}{0}{0}
4 \end{tikzpicture}
```

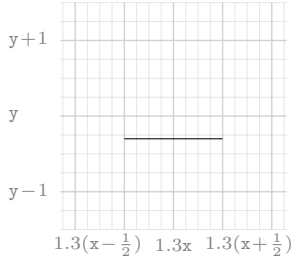
`\qmeaB[option]{x}{y}`

Measurement bus symbol.

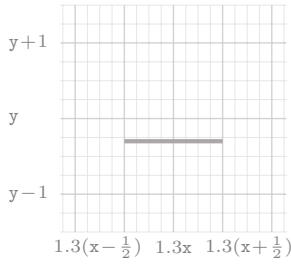
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasB{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasB[ibmqx]{0}{0}
4 \end{tikzpicture}
```

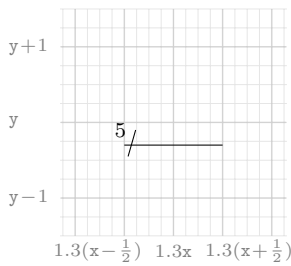
`\qmeaBh[option]{b}{x}{y}`

Measurement bus header symbol.

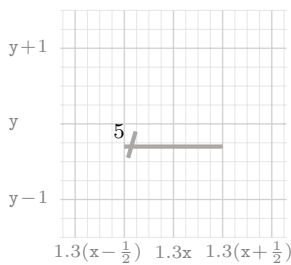
Parameters

- option** Omit for standard circuit styling or `ibmqx` for IBM Q Experience circuit styling.
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x,y)`.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasBh{5}{0}{0}
4 \end{tikzpicture}
```



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasBh[ibmqx]{5}{0}{0}
4 \end{tikzpicture}
```

2.6 Further Gate Operators

CNOT Gate Operator

$$CNOT \doteq \left(\begin{array}{c|cccc} & \langle 00 | & \langle 01 | & \langle 10 | & \langle 11 | \\ \hline |00\rangle & 1 & 0 & 0 & 0 \\ |01\rangle & 0 & 1 & 0 & 0 \\ |10\rangle & 0 & 0 & 0 & 1 \\ |11\rangle & 0 & 0 & 1 & 0 \end{array} \right) \quad \text{\texttt{\textbackslash displaystyle CNOT\dotseq\qgateOCNOT \$}}$$

Toffoli (CCNOT) Gate Operator

$$CCNOT \doteq \left(\begin{array}{c|cccccccc} & \langle 000 | & \langle 001 | & \langle 010 | & \langle 011 | & \langle 100 | & \langle 101 | & \langle 110 | & \langle 111 | \\ \hline |000\rangle & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ |001\rangle & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ |010\rangle & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ |101\rangle & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ |100\rangle & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ |101\rangle & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ |110\rangle & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ |111\rangle & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{array} \right) \quad \text{\texttt{\textbackslash displaystyle CCNOT\dotseq\qgateOCCNOT \$}}$$

2.7 Auxiliary Commands

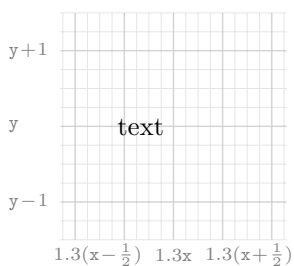
`\qnode[style]{x}{y}{label}`

TikZ node in schematics coordinates.

Parameters

- style** TikZ node style.
- x, y** Position of symbol in schematic. The actual TikZ coordinates are (`\qgateSx*x, y`).
- label** Node label.

Examples



```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qnode[anchor=east]{0}{0}{text}
4 \end{tikzpicture}
```

3 The Package Source Code

```
1 %% == LaTeX PACKAGE tikz-quantumgates ==
2 %%   Drawing quantum circuits with TikZ
3 %%
4 %% Matthias Wolff, BTU Cottbus-Sentenberg
5 %% August 20, 2018
6 %%
7 %% References:
8 %% [1] T. Tantau. TikZ & PGF - Manual for Version 3.0.1a. 2015.
9 %%   http://mirror.ctan.org/graphics/pgf/base/doc/pgfmanual.pdf Retrieved
10 %%   July 22, 2018.
```

```

11 %%
12 %% TODO:
13 %% - Barrier symbols: \qbarrX
14
15 %% == REQUIRED PACKAGES =====
16
17 \RequirePackage{xifthen}
18 \RequirePackage{tikz}
19
20 %% == DEFINITIONS AND COLORS =====
21 \def\qgateSx{1.3}
22
23 \definecolor{ibmqxA}{HTML}{F69458} % IBM QX Ux gate
24 \definecolor{ibmqxB}{HTML}{FFCA64} % IBM QX id gate
25 \definecolor{ibmqxC}{HTML}{A6CE38} % IBM QX Pauli gates
26 \definecolor{ibmqxD}{HTML}{00BFF2} % IBM QX H, S, S' und CNOT gates
27 \definecolor{ibmqxE}{HTML}{FF6666} % IBM QX T und T' gates
28 \definecolor{ibmqxF}{HTML}{F070AA} % IBM QX measurement and if
29 \definecolor{ibmqxG}{HTML}{ADC1C6} % IBM QX barrier
30 \definecolor{ibmqxH}{HTML}{F2F2F2} % IBM QX |0> state
31 \definecolor{ibmqxI}{HTML}{ABA7A7} % IBM QX measurement wire
32
33 %% == COMMANDS =====
34
35 % Wire
36 \newcommand{\qwire}[3][]{\{
37   \pgfmathsetmacro\x{\qgateSx*(#2)}
38   \pgfmathsetmacro\y{(#3)}
39   \ifthenelse{\isin{ibmqx}{#1}}{\{
40     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
41   }\{
42     \tikzset{lstyle/.style={}}
43   }\}
44   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
45 }}
46
47 % Zero state preparator
48 \newcommand{\qzero}[3][]{\{
49   \pgfmathsetmacro\x{\qgateSx*(#2)}
50   \pgfmathsetmacro\y{(#3)}
51   \ifthenelse{\isin{ibmqx}{#1}}{\{
52     \draw[ultra thick,line cap=butt] (\x+0.4,\y) -- (\x+\qgateSx/2,\y);
53     \draw[draw=none,fill=ibmqxH] (\x-0.4,\y-0.4) rectangle (\x+0.4,\y+0.4);
54     \node at (\x,\y){\large $|0\rangle$};
55   }\{
56     \node[anchor=east] at (\x+\qgateSx/2,\y){\large $|0\rangle$};
57   }\}
58 }}
59
60 % General single-qubit gate
61 \newcommand{\qgateU}[4][]{\{
62   \pgfmathsetmacro\x{\qgateSx*(#2)}
63   \pgfmathsetmacro\y{(#3)}
64   \ifthenelse{\isin{ibmqx}{#1}}{\{
65     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
66     \ifthenelse{\equal{ibmqx}{#1}}{\{
67       \tikzset{rstyle/.style={draw=none,fill=ibmqxG}}
68     }\{
69       \tikzset{rstyle/.style={draw=none,fill=#1}}
70     }\}
71     \tikzset{tstyle/.style={white}}
72   }\{
73     \tikzset{lstyle/.style={}}
74     \tikzset{rstyle/.style={fill=white}}
75     \tikzset{tstyle/.style={}}
76   }\}
77   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.4,\y);
78   \draw[lstyle] (\x+0.4,\y) -- (\x+\qgateSx/2,\y);
79   \draw[rstyle] (\x-0.4,\y-0.4) rectangle (\x+0.4,\y+0.4);
80   \node[tstyle] at (\x,\y){\sf\large #4};
81 }}
82

```

```

83 % Identity gate
84 \newcommand\qgateID[3][]{%
85   \ifthenelse{\isin{ibmqx}{#1}}{%
86     \qgateU[ibmqxB]{#2}{#3}{id}
87   }{%
88     \qgateU{#2}{#3}{id}
89   }%
90 }
91 \newcommand\qgateOID{%
92   \def\ket##1{\scriptstyle|##1\rangle}
93   \def\bra##1{\scriptstyle\langle ##1|}
94   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
95     & \bra{0} & \bra{1} \\ \hline
96     \ket{0} & 1 & 0 \\
97     \ket{1} & 0 & 1
98   \end{array}\!\!\right)
99 }}
100
101 % Pauli-X gate
102 \newcommand\qgateX[3][]{%
103   \ifthenelse{\isin{ibmqx}{#1}}{%
104     \qgateU[ibmqxC]{#2}{#3}{X}
105   }{%
106     \qgateU{#2}{#3}{X}
107   }%
108 }
109 \newcommand\qgateOX{%
110   \def\ket##1{\scriptstyle|##1\rangle}
111   \def\bra##1{\scriptstyle\langle ##1|}
112   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
113     & \bra{0} & \bra{1} \\ \hline
114     \ket{0} & 0 & 1 \\
115     \ket{1} & 1 & 0
116   \end{array}\!\!\right)
117 }}
118
119 % Pauli-Y gate
120 \newcommand\qgateY[3][]{%
121   \ifthenelse{\isin{ibmqx}{#1}}{%
122     \qgateU[ibmqxC]{#2}{#3}{Y}
123   }{%
124     \qgateU{#2}{#3}{Y}
125   }%
126 }
127 \newcommand\qgateOY{%
128   \def\ket##1{\scriptstyle|##1\rangle}
129   \def\bra##1{\scriptstyle\langle ##1|}
130   \def\j{\mathrm{i}}
131   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
132     & \bra{0} & \bra{1} \\ \hline
133     \ket{0} & 0 & -\j \\
134     \ket{1} & \j & 0
135   \end{array}\!\!\right)
136 }}
137
138 % Pauli-Z gate
139 \newcommand\qgateZ[3][]{%
140   \ifthenelse{\isin{ibmqx}{#1}}{%
141     \qgateU[ibmqxC]{#2}{#3}{Z}
142   }{%
143     \qgateU{#2}{#3}{Z}
144   }%
145 }
146 \newcommand\qgateOZ{%
147   \def\ket##1{\scriptstyle|##1\rangle}
148   \def\bra##1{\scriptstyle\langle ##1|}
149   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
150     & \bra{0} & \bra{1} \\ \hline
151     \ket{0} & 1 & 0 \\
152     \ket{1} & 0 & -1
153   \end{array}\!\!\right)
154 }}

```



```

155
156 % Hadamard gate
157 \newcommand\qgateH[3][]{%
158 \ifthenelse{\isin{ibmqx}{#1}}{%
159 \qgateU[ibmqxD]{#2}{#3}{H}
160 }{%
161 \qgateU{#2}{#3}{H}
162 }%
163 }
164 \newcommand\qgateOH{%
165 \def\ket##1{\scriptstyle|##1\rangle}
166 \def\bra##1{\scriptstyle\langle ##1|}
167 \dfrac{1}{\sqrt{2}}\!
168 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
169 & \bra{0} & \bra{1} \\ \hline
170 \ket{0} & 1 & 1 \\
171 \ket{1} & 1 & -1
172 \end{array}\!\right)
173 }}
174
175 % S phase gate
176 \newcommand\qgateS[3][]{%
177 \ifthenelse{\isin{ibmqx}{#1}}{%
178 \qgateU[ibmqxD]{#2}{#3}{S}
179 }{%
180 \qgateU{#2}{#3}{S}
181 }%
182 }
183 \newcommand\qgateOS{%
184 \def\ket##1{\scriptstyle|##1\rangle}
185 \def\bra##1{\scriptstyle\langle ##1|}
186 \def\j{\mathrm{i}}
187 \dfrac{1}{\sqrt{2}}\!
188 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
189 & \bra{0} & \bra{1} \\ \hline
190 \ket{0} & 1 & 0 \\
191 \ket{1} & 0 & \j
192 \end{array}\!\right)
193 }}
194
195 % Inverse S phase gate
196 \newcommand\qgateSi[3][]{%
197 \ifthenelse{\isin{ibmqx}{#1}}{%
198 \qgateU[ibmqxD]{#2}{#3}{S$^\dagger$}
199 }{%
200 \qgateU{#2}{#3}{S$^\dagger$}
201 }%
202 }
203 \newcommand\qgateOSi{%
204 \def\ket##1{\scriptstyle|##1\rangle}
205 \def\bra##1{\scriptstyle\langle ##1|}
206 \def\j{\mathrm{i}}
207 \dfrac{1}{\sqrt{2}}\!
208 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
209 & \bra{0} & \bra{1} \\ \hline
210 \ket{0} & 1 & 0 \\
211 \ket{1} & 0 & -\j
212 \end{array}\!\right)
213 }}
214
215 % T phase gate
216 \newcommand\qgateT[3][]{%
217 \ifthenelse{\isin{ibmqx}{#1}}{%
218 \qgateU[ibmqxE]{#2}{#3}{T}
219 }{%
220 \qgateU{#2}{#3}{T}
221 }%
222 }
223 \newcommand\qgateOT{%
224 \def\ket##1{\scriptstyle|##1\rangle}
225 \def\bra##1{\scriptstyle\langle ##1|}
226 \def\j{\mathrm{i}}

```

```

227 \dfrac{1}{\sqrt{2}}\!
228 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
229 & \bra{0} & \bra{1} \\ \hline
230 \ket{0} & 1 & 0 \\
231 \ket{1} & 0 & \frac{1}{\sqrt{2}}(1\!+\!\mathrm{j})
232 \end{array}\!\!\right)
233 }}
234
235 % Inverse T phase gate
236 \newcommand\qgateTi[3][]{%
237 \ifthenelse{\isin{ibmqx}{#1}}{%
238 \qgateU[ibmqxA]{#2}{#3}{T$^\dagger$}
239 }{%
240 \qgateU{#2}{#3}{T$^\dagger$}
241 }%
242 }
243 \newcommand\qgateOTi{%
244 \def\ket##1{\scriptstyle|##1\rangle}
245 \def\bra##1{\scriptstyle\langle ##1|}
246 \def\j{\mathrm{j}}
247 \dfrac{1}{\sqrt{2}}\!
248 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
249 & \bra{0} & \bra{1} \\ \hline
250 \ket{0} & 1 & 0 \\
251 \ket{1} & 0 & \frac{1}{\sqrt{2}}(1\!-\!\mathrm{j})
252 \end{array}\!\!\right)
253 }}
254
255 % U1 gate of IBM Q Experience
256 \makeatletter
257 \newcommand\qgateUa{\@ifstar\qgateUaS\qgateUaN}
258 \makeatother
259 \newcommand\qgateUaN[3][]{% unstarred version
260 \ifthenelse{\isin{ibmqx}{#1}}{%
261 \qgateU[ibmqxA]{#2}{#3}{U1}
262 }{%
263 \qgateU{#2}{#3}{U1}
264 }%
265 }
266 \newcommand\qgateUaS[4][]{% starred version
267 \ifthenelse{\isin{ibmqx}{#1}}{%
268 \qgateU[ibmqxA]{#2}{#3}{\begin{tabular}{c}U1\\[-0.6em]\tiny #4\end{tabular}}
269 }{%
270 \qgateU{#2}{#3}{\begin{tabular}{c}U1\\[-0.6em]\tiny #4\end{tabular}}
271 }%
272 }
273 \newcommand\qgateOUa{%
274 \def\ket##1{\scriptstyle|##1\rangle}
275 \def\bra##1{\scriptstyle\langle ##1|}
276 \def\ee{\mathrm{e}}
277 \def\j{\mathrm{j}}
278 \left(\hspace*{-0.4ex}\begin{array}{c|cc}
279 & \bra{0} & \bra{1} \\ \hline
280 \ket{0} & 1 & 0 \\
281 \ket{1} & 0 & \mathrm{e}^{-\mathrm{j}\lambda\mathrm{da}}
282 \end{array}\!\!\right)
283 }}
284
285 % U2 gate of IBM Q Experience
286 \makeatletter
287 \newcommand\qgateUb{\@ifstar\qgateUbS\qgateUbN}
288 \makeatother
289 \newcommand\qgateUbN[3][]{% unstarred version
290 \ifthenelse{\isin{ibmqx}{#1}}{%
291 \qgateU[ibmqxA]{#2}{#3}{U2}
292 }{%
293 \qgateU{#2}{#3}{U2}
294 }%
295 }
296 \newcommand\qgateUbS[4][]{% starred version
297 \ifthenelse{\isin{ibmqx}{#1}}{%
298 \qgateU[ibmqxA]{#2}{#3}{\begin{tabular}{c}U2\\[-0.6em]\tiny #4\end{tabular}}

```

```

299 }{%
300   \qgateU{#2}{#3}{\begin{tabular}{c}U2\\[-0.6em]\tiny #4\end{tabular}}
301 }%
302 }
303 \newcommand\qgateUUb{%
304   \def\ket##1{\scriptstyle|##1\rangle}
305   \def\bra##1{\scriptstyle\langle ##1|}
306   \def\mathrm{e}{\mathrm{e}}
307   \def\mathrm{j}{\mathrm{j}}
308   \renewcommand\arraystretch{1.4}
309   \dfrac{1}{\sqrt{2}}\!
310   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
311     & \bra{0} & \bra{1} \\ \hline
312     \ket{0} & 1 & -e^{-i\lambda j} \\
313     \ket{1} & e^{-i\phi j} & e^{-i(\lambda+\phi)j}
314   \end{array}\!\right)
315 }%
316
317 % U3 gate of IBM Q Experience
318 \makeatletter
319 \newcommand\qgateUc{\@ifstar\qgateUcS\qgateUcN}
320 \makeatother
321 \newcommand\qgateUcN[3][]{%
322   \ifthenelse{\isin{ibmqx}{#1}}{% unstarred version
323     \qgateU[ibmqxA]{#2}{#3}{U3}
324   }{%
325     \qgateU{#2}{#3}{U3}
326   }%
327 }
328 \newcommand\qgateUcS[4][]{% starred version
329   \ifthenelse{\isin{ibmqx}{#1}}{% unstarred version
330     \qgateU[ibmqxA]{#2}{#3}{\begin{tabular}{c}U3\\[-0.6em]\tiny #4\end{tabular}}
331   }{%
332     \qgateU{#2}{#3}{\begin{tabular}{c}U3\\[-0.6em]\tiny #4\end{tabular}}
333   }%
334 }
335 \newcommand\qgateUUb{%
336   \def\ket##1{\scriptstyle|##1\rangle}
337   \def\bra##1{\scriptstyle\langle ##1|}
338   \def\mathrm{e}{\mathrm{e}}
339   \def\mathrm{j}{\mathrm{j}}
340   \renewcommand\arraystretch{1.4}
341   \left(\hspace*{-0.4ex}\begin{array}{c|cc}
342     & \bra{0} & \bra{1} \\ \hline
343     \ket{0} & \cos(\frac{\theta}{2}) & -\sin(\frac{\theta}{2})e^{-i\lambda j} \\
344     \ket{1} & \sin(\frac{\theta}{2})e^{-i\phi j} & \cos(\frac{\theta}{2})e^{-i(\lambda+\phi)j}
345   \end{array}\!\right)
346 }%
347
348 % General two-qubit gate
349 \newcommand\qgateUu[4][]{%
350   \pgfmathsetmacro\x{\qgateSx*(#2)}
351   \pgfmathsetmacro\y{(#3)}
352   \ifthenelse{\isin{ibmqx}{#1}}{%
353     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
354     \ifthenelse{\equal{ibmqx}{#1}}{%
355       \tikzset{rstyle/.style={draw=none,fill=ibmqxG}}
356     }{%
357       \tikzset{rstyle/.style={draw=none,fill=#1}}
358     }
359     \tikzset{tstyle/.style={white}}
360   }{%
361     \tikzset{lstyle/.style={}}
362     \tikzset{rstyle/.style={fill=white}}
363     \tikzset{tstyle/.style={}}
364   }%
365   \draw[rstyle] (\x-0.5,\y-0.25) rectangle (\x+0.5,\y+1.25);
366   \draw[lstyle] (\x-\qgateSx/2,\y+1) -- (\x-0.5,\y+1);
367   \draw[lstyle] (\x+0.5,\y+1) -- (\x+\qgateSx/2,\y+1);
368   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.5,\y);
369   \draw[lstyle] (\x+0.5,\y) -- (\x+\qgateSx/2,\y);
370   \node[anchor=north,tstyle] at (\x,\y+1.25){\sf\large #4};

```

```

371 }}
372
373 % General three-qubit gate
374 \newcommand{\qgateUuu}[4] [] {{%
375   \pgfmathsetmacro\x{\qgateSx*(#2)}
376   \pgfmathsetmacro\y{(#3)}
377   \ifthenelse{\isin{ibmqx}{#1}}{%
378     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
379     \ifthenelse{\equal{ibmqx}{#1}}{%
380       \tikzset{rstyle/.style={draw=none,fill=ibmqxG}}
381     }{%
382       \tikzset{rstyle/.style={draw=none,fill=#1}}
383     }
384     \tikzset{tstyle/.style={white}}
385   }{%
386     \tikzset{lstyle/.style={}}
387     \tikzset{rstyle/.style={fill=white}}
388     \tikzset{tstyle/.style={}}
389   }%
390   \draw[rstyle] (\x-0.5,\y-1.25) rectangle (\x+0.5,\y+1.25);%
391   \draw[lstyle] (\x-\qgateSx/2,\y+1) -- (\x-0.5,\y+1);%
392   \draw[lstyle] (\x+0.5,\y+1) -- (\x+\qgateSx/2,\y+1);%
393   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.5,\y);%
394   \draw[lstyle] (\x+0.5,\y) -- (\x+\qgateSx/2,\y);%
395   \draw[lstyle] (\x-\qgateSx/2,\y-1) -- (\x-0.5,\y-1);%
396   \draw[lstyle] (\x+0.5,\y-1) -- (\x+\qgateSx/2,\y-1);%
397   \node[anchor=north,tstyle] at (\x,\y+1.25){\sf\large #4};%
398 }}
399
400 % CNOT gate XOR symbol
401 \newcommand{\qgateCNX}[4] [] {{%
402   \pgfmathsetmacro\x{\qgateSx*(#3)}
403   \pgfmathsetmacro\y{(#4)}
404   \ifthenelse{\isin{ibmqx}{#1}}{%
405     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
406     \tikzset{cstyle/.style={ibmqxD,ultra thick,line cap=butt}}
407     \tikzset{rstyle/.style={draw=none,fill=ibmqxD}}
408     \tikzset{tstyle/.style={very thick,white}}
409   }{%
410     \tikzset{lstyle/.style={}}
411     \tikzset{cstyle/.style={}}
412     \tikzset{rstyle/.style={fill=white}}
413     \tikzset{tstyle/.style={}}
414   }%
415   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.4,\y);
416   \draw[lstyle] (\x+0.4,\y) -- (\x+\qgateSx/2,\y);
417   \draw[rstyle] (\x,\y) circle (0.4);
418   \ifthenelse{\isin{ibmqx}{#1}}{%
419     \draw[tstyle] (\x-0.2,\y) -- (\x+0.2,\y);
420     \draw[tstyle] (\x,\y-0.2) -- (\x,\y+0.2);
421   }{%
422     \draw[lstyle] (\x-0.4,\y) -- (\x+0.4,\y);
423     \draw[lstyle] (\x,\y-0.4) -- (\x,\y+0.4);
424   }
425   \ifthenelse{\isin{t}{#2}}{%
426     \draw[cstyle] (\x,\y+0.4) -- (\x,\y+0.5);
427   }{}
428   \ifthenelse{\isin{b}{#2}}{%
429     \draw[cstyle] (\x,\y-0.4) -- (\x,\y-0.5);
430   }{}
431 }}
432
433 % CNOT gate control qubit symbol
434 \newcommand{\qgateCNC}[4] [] {{%
435   \pgfmathsetmacro\x{\qgateSx*(#3)}
436   \pgfmathsetmacro\y{(#4)}
437   \ifthenelse{\isin{ibmqx}{#1}}{%
438     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
439     \tikzset{cstyle/.style={ibmqxD,ultra thick,line cap=butt}}
440     \tikzset{rstyle/.style={draw=none,fill=ibmqxD}}
441     \tikzset{tstyle/.style={white}}
442   }{\def\r{0.12}}

```

```

443 }{%
444   \tikzset{lstyle/.style={}}
445   \tikzset{cstyle/.style={}}
446   \tikzset{rstyle/.style={draw=none,fill=black}}
447   \tikzset{tstyle/.style={}}
448   \def\r{0.1}
449 }%
450 \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
451 \draw[rstyle] (\x, \y) circle (\r);
452 \ifthenelse{\isin{t}{#2}}{%
453   \draw[cstyle] (\x,\y+0.1) -- (\x,\y+0.5);
454 }{}
455 \ifthenelse{\isin{b}{#2}}{%
456   \draw[cstyle] (\x,\y-0.1) -- (\x,\y-0.5);
457 }{}
458 }}
459
460 % CNOT gate run-through qubit symbol
461 \newcommand\qgateCNR[3][]{%
462   \pgfmathsetmacro\x{\qgateSx*(#2)}
463   \pgfmathsetmacro\y{(#3)}
464   \ifthenelse{\isin{ibmqx}{#1}}{%
465     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
466     \tikzset{cstyle/.style={ibmqxD,ultra thick,line cap=butt}}
467   }{%
468     \tikzset{lstyle/.style={}}
469     \tikzset{cstyle/.style={}}
470   }%
471   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
472   \draw[cstyle] (\x, \y-0.5) -- (\x, \y+0.5);
473 }}
474
475 % Swap gate top qubit symbol
476 \newcommand\qgateSWt[3][]{%
477   \pgfmathsetmacro\x{\qgateSx*(#2)}
478   \pgfmathsetmacro\y{(#3)}
479   \ifthenelse{\isin{ibmqx}{#1}}{%
480     \draw[ultra thick,line cap=butt]
481       (\x-\qgateSx/2,\y) -- (\x-0.2,\y) -- (\x+0.2,\y-0.4) -- (\x+0.2,\y-0.5);
482     \draw[ultra thick,line cap=butt]
483       (\x+\qgateSx/2,\y) -- (\x+0.2,\y) -- (\x-0.2,\y-0.4) -- (\x-0.2,\y-0.5);
484   }{%
485     \pgfmathsetmacro\w{0.1}
486     \draw(\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
487     \draw(\x-\w, \y-\w) -- (\x+\w, \y+\w);
488     \draw(\x-\w, \y+\w) -- (\x+\w, \y-\w);
489     \draw(\x, \y) -- (\x, \y-0.5);
490   }%
491 }}
492
493 % Swap gate run-through qubit symbol
494 \newcommand\qgateSWR[3][]{%
495   \pgfmathsetmacro\x{\qgateSx*(#2)}
496   \pgfmathsetmacro\y{(#3)}
497   \ifthenelse{\isin{ibmqx}{#1}}{%
498     \draw[ultra thick,line cap=butt] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
499     \draw[ultra thick,line cap=butt] (\x-0.2, \y+0.5) -- (\x-0.2, \y-0.5);
500     \draw[ultra thick,line cap=butt] (\x+0.2, \y+0.5) -- (\x+0.2, \y-0.5);
501   }{%
502     \draw(\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
503     \draw(\x, \y-0.5) -- (\x, \y+0.5);
504   }%
505 }}
506
507 % Swap gate bottom qubit symbol
508 \newcommand\qgateSWb[3][]{%
509   \pgfmathsetmacro\x{\qgateSx*(#2)}
510   \pgfmathsetmacro\y{(#3)}
511   \ifthenelse{\isin{ibmqx}{#1}}{%
512     \draw[ultra thick,line cap=butt]
513       (\x-\qgateSx/2,\y) -- (\x-0.2,\y) -- (\x-0.2,\y+0.5);
514     \draw[ultra thick,line cap=butt]

```

```

515 (\x+\qgateSx/2,\y) -- (\x+0.2,\y) -- (\x+0.2,\y+0.5);
516 }{%
517 \pgfmathsetmacro\w{0.1}
518 \draw(\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
519 \draw(\x-\w,\y-\w) -- (\x+\w,\y+\w);
520 \draw(\x-\w,\y+\w) -- (\x+\w,\y-\w);
521 \draw(\x,\y) -- (\x,\y+0.5);
522 }%
523 }}
524
525 % Measurement symbol
526 \newcommand\qmeasM[3][]{%
527 \pgfmathsetmacro\x{\qgateSx*(#2)}
528 \pgfmathsetmacro\y{(#3)}
529 \ifthenelse{\isin{ibmqx}{#1}}{%
530 \tikzset{lstyle/.style={ultra thick,line cap=butt}}
531 \tikzset{rstyle/.style={draw=none,fill=ibmqxF}}
532 \tikzset{tstyle/.style={white,very thick,line cap=butt}}
533 \tikzset{pstyle/.style={->,>=stealth,white,thick,line cap=butt}}
534 \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
535 }{%
536 \tikzset{lstyle/.style={}}
537 \tikzset{rstyle/.style={fill=white}}
538 \tikzset{tstyle/.style={}}
539 \tikzset{pstyle/.style={->,>=stealth,line cap=butt}}
540 \tikzset{cstyle/.style={}}
541 }%
542 \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.4,\y);
543 \draw[lstyle] (\x+0.4,\y) -- (\x+\qgateSx/2,\y);
544 \draw[rstyle] (\x-0.4,\y-0.4) rectangle (\x+0.4,\y+0.4);
545 \draw[tstyle] (\x+0.27,\y-0.2) arc (0:180:0.27);
546 \draw[pstyle] (\x,\y-0.15) -- (\x+0.2,\y+0.22);
547 \node[pstyle] at (\x+0.26,\y+0.15) {\tiny\sf Z};
548 \fill[pstyle] (\x,\y-0.15) circle (0.035);
549 \draw[cstyle] (\x,\y-0.4) -- (\x,\y-0.5);
550 }}
551
552 % Measurement run-through qubit symbol
553 \newcommand\qmeasR[3][]{%
554 \pgfmathsetmacro\x{\qgateSx*(#2)}
555 \pgfmathsetmacro\y{(#3)}
556 \ifthenelse{\isin{ibmqx}{#1}}{%
557 \tikzset{lstyle/.style={ultra thick,line cap=butt}}
558 \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
559 }{%
560 \tikzset{lstyle/.style={}}
561 \tikzset{cstyle/.style={}}
562 }%
563 \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
564 \draw[cstyle] (\x,\y-0.5) -- (\x,\y+0.5);
565 }}
566
567 % Measurement-joins-bus symbol
568 \newcommand\qmeasMB[4][]{%
569 \pgfmathsetmacro\x{\qgateSx*(#3)}
570 \pgfmathsetmacro\y{(#4)}
571 \ifthenelse{\isin{ibmqx}{#1}}{%
572 \tikzset{cstyle/.style={>=stealth,ibmqxI,ultra thick,line cap=butt}}
573 }{%
574 \tikzset{cstyle/.style={>=stealth}}
575 }%
576 \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
577 \draw[cstyle,->] (\x,\y+0.5) -- (\x,\y-0.3)
578 node[anchor=north,black] {\footnotesize #2};
579 }}
580
581 % Measurement bus symbol
582 \newcommand\qmeasB[3][]{%
583 \pgfmathsetmacro\x{\qgateSx*(#2)}
584 \pgfmathsetmacro\y{(#3)}
585 \ifthenelse{\isin{ibmqx}{#1}}{%
586 \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}

```

```

587 }{%
588   \tikzset{cstyle/.style={}}
589 }%
590 \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
591 }}
592
593 % Measurement bus head symbol
594 \newcommand\qmeasBh[4] [] {%
595   \pgfmathsetmacro\x{\qgateSx*(#3)}
596   \pgfmathsetmacro\y{(#4)}
597   \ifthenelse{\isin{ibmqx}{#1}}{%
598     \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
599   }{%
600     \tikzset{cstyle/.style={}}
601   }%
602   \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
603   \draw[cstyle] (\x-\qgateSx/2+0.05,\y-0.45) -- (\x-\qgateSx/2+0.15,\y-0.1)
604     node[anchor=east,black] {\footnotesize #2};
605 }}
606
607 %% == OTHER GATE OPERATORS =====
608
609 \newcommand\qgateOCNOT{%
610   \def\ket##1{\scriptstyle\ket{##1}}
611   \def\bra##1{\rotatebox{90}{\scriptstyle\bra{##1}}}
612   \left(\hspace*{-0.4ex}\begin{array}{c|cccc}
613     & \ket{00} & \ket{01} & \ket{10} & \ket{11} \\ \hline
614     \ket{00} & 1 & 0 & 0 & 0 \\
615     \ket{01} & 0 & 1 & 0 & 0 \\
616     \ket{10} & 0 & 0 & 0 & 1 \\
617     \ket{11} & 0 & 0 & 1 & 0
618   \end{array}\right)
619 }}
620
621 \newcommand\qgateOCCNOT{%
622   \def\ket##1{\scriptstyle\ket{##1}}
623   \def\bra##1{\rotatebox{90}{\scriptstyle\bra{##1}}}
624   \left(\hspace*{-0.4ex}\begin{array}{c|cccccccc}
625     & \ket{000} & \ket{001} & \ket{010} & \ket{011} & \ket{100} & \ket{101} & \ket{110} & \ket{111} \\ \hline
626     \ket{000} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
627     \ket{001} & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
628     \ket{010} & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
629     \ket{011} & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
630     \ket{100} & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
631     \ket{101} & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
632     \ket{110} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
633     \ket{111} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
634   \end{array}\right)
635 }}
636
637 %% == AUXILIARY COMMANDS =====
638
639 % TikZ node in circuit coordinate system
640 \newcommand\qnode[4] [] {%
641   \pgfmathsetmacro\x{\qgateSx*(#2)}
642   \pgfmathsetmacro\y{(#3)}
643   \node[#1] at (\x,\y) {#4};
644 }
645
646 \newcommand\qScalePaper{%
647   \draw[help lines,xstep=\qgateSx/8,ystep=0.25,opacity=0.2] (-1.5,-1.5) grid (1.5,1.5);
648   \draw[help lines,line width=.6pt,xstep=\qgateSx/2,ystep=1,opacity=0.2] (-1.49,-1.5) grid (1.49,1.5);
649   \node[anchor=west,color=gray] at (-1,-1.7) {\scriptsize $\texttt{x} \leftarrow \frac{1}{2}$};
650   \node[anchor=west,color=gray] at (0,-1.7) {\scriptsize $\texttt{x}$};
651   \node[anchor=west,color=gray] at (1,-1.7) {\scriptsize $\texttt{x} \leftarrow \frac{1}{2}$};
652   \node[anchor=west,color=gray] at (-2.3,-1) {\scriptsize $\texttt{y} \leftarrow 1$};
653   \node[anchor=west,color=gray] at (-2.3,0) {\scriptsize $\texttt{y}$};
654   \node[anchor=west,color=gray] at (-2.3,1) {\scriptsize $\texttt{y} \leftarrow 1$};
655 }
656
657 %% == EOF =====

```

References

- [1] Till Tantau. Tikz & pgf - manual for version 3.0.1a. <http://mirror.ctan.org/graphics/pgf/base/doc/pgfmanual.pdf>, 2015. Retrieved: July 27, 2018.
- [2] Matthias Wolff. The `tikz-quantumgates` package: Drawing quantum circuits with TikZ. <https://github.com/matthias-wolff/tikz-quantumgates>, 2018. Retrieved: August 20, 2018.