

The tikz-quantumgates Package: Drawing quantum circuits with TikZ

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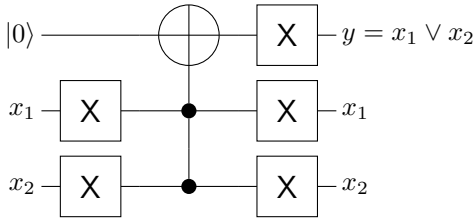
BTU Cottbus-Senftenberg

November 15, 2018

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

Abstract

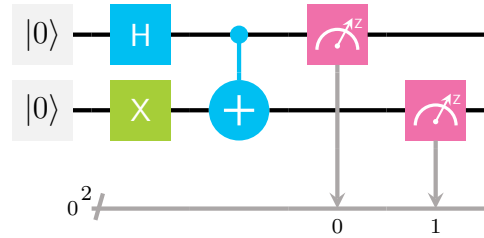
This package provides macros for drawing quantum gates and circuits with TikZ [1].



```

1 \documentclass{standalone}
2 \usepackage{tikz-quantumgates}
3 \begin{document}
4   \centering
5   \begin{tikzpicture}
6     \node[anchor=east] at (-0.6,2) {$|0\rangle$};
7     \node[anchor=east] at (-0.6,1) {$x_1$};
8     \node[anchor=east] at (-0.6,0) {$x_2$};
9     \qwire{0}{2}\qgateX{0}{1}\qgateX{0}{0}
10    \qgateCNC{b}{1}{2}\qgateCNC{bt}{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=east] 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}\qgateCNCX[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$	$ 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>\qgateUa*[option]{x}{y}{sublabel}</code>
		<code>\qgateUb*[option]{x}{y}{sublabel}</code>
		<code>\qgateUc*[option]{x}{y}{sublabel}</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)

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Standard	Option <code>ibmqx</code>	Command
		<code>\qmeasM[option]{x}{y}</code>
		<code>\qmeasM*[option]{x}{y}{axis}{wires}</code>
		<code>\qmeasR[option]{x}{y}</code>
		<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

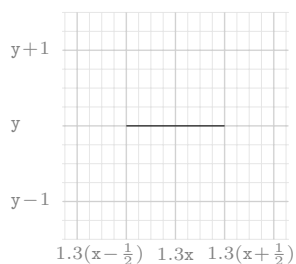
`\qwire[option]{x}{y}`

Draws a wire.

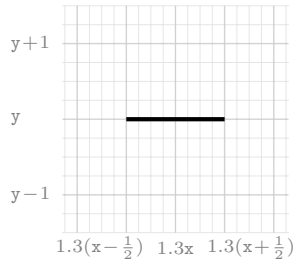
Parameters

`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 $(\backslash\text{qgateSx}*\text{x}, \text{y})$.

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}
```

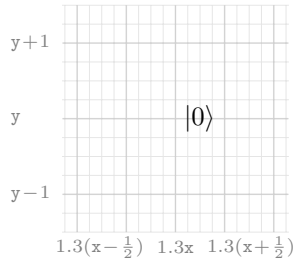
`\qzero[option]{x}{y}`

Draws the zero-state preparator.

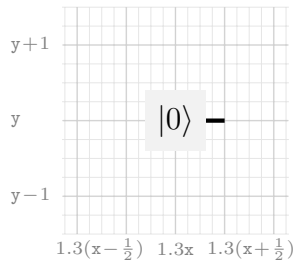
Parameters

- 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

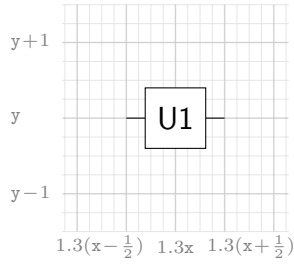
`\qgateU[option]{x}{y}{label}`

Draws a general single-qubit quantum gate.

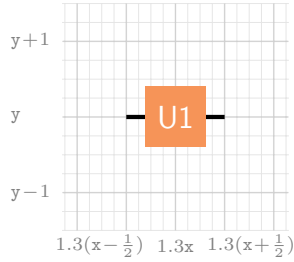
Parameters

- 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}
```

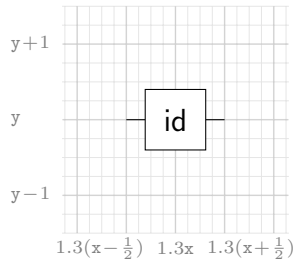
`\qgateID[option]{x}{y}`

Draws the identity gate.

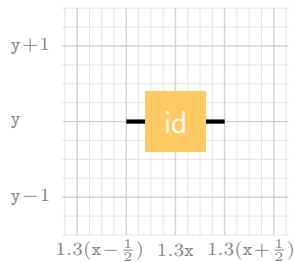
Parameters

- `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

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

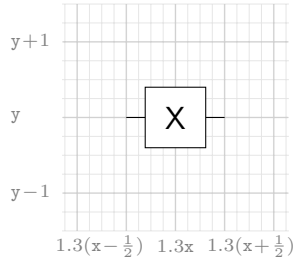
`\qgateX[option]{x}{y}`

Pauli-X gate.

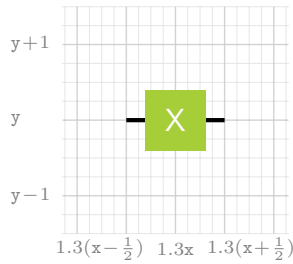
Parameters

- 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`

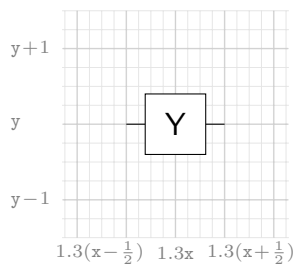
`\qgateY[option]{x}{y}`

Pauli-Y gate.

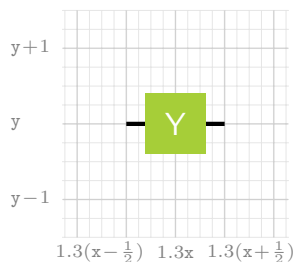
Parameters

- 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

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

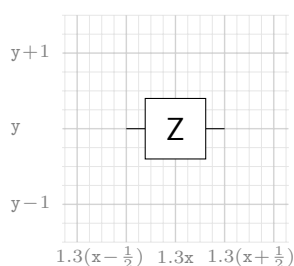
`\qgateZ[option]{x}{y}`

Pauli-Z gate.

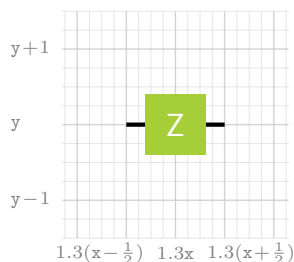
Parameters

- 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

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

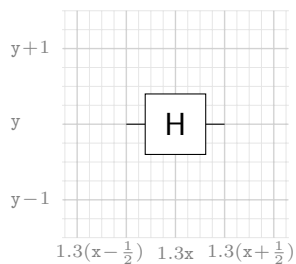
`\qgateH[option]{x}{y}`

Hadamard gate.

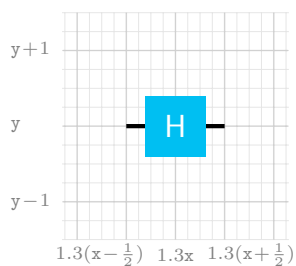
Parameters

- 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 $\displaystyle H\dot{eq}\qgateOH$
```

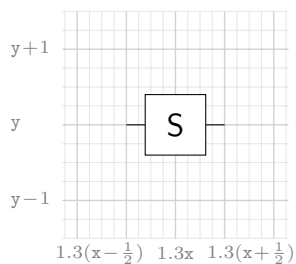
`\qgateS[option]{x}{y}`

S phase gate.

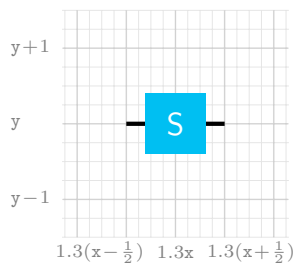
Parameters

- 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\qgateOS`

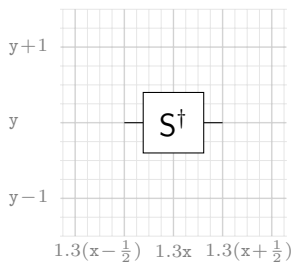
`\qgateSi[option]{x}{y}`

Inverse S phase gate.

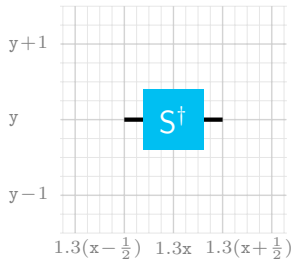
Parameters

- `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\qgateOSi`

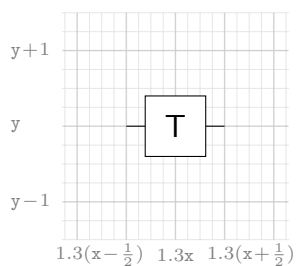
`\qgateT[option]{x}{y}`

T phase gate.

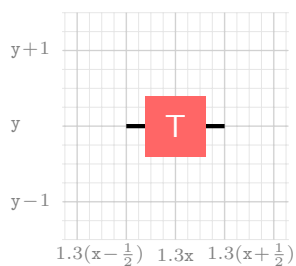
Parameters

- `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

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

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

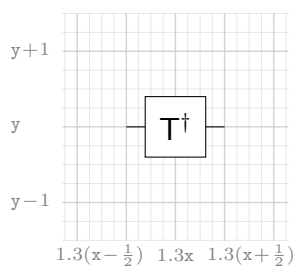
`\qgateTi[option]{x}{y}`

Inverse T phase gate.

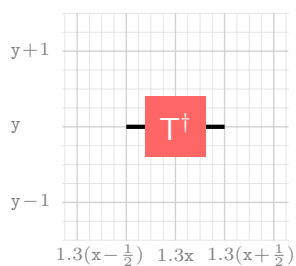
Parameters

- 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

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

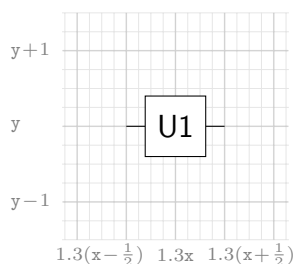
$$\backslash\mathrm{qgateUa}^*[\mathrm{option}]\{x\}\{y\}\{\mathrm{sublabel}\}$$

U1 gate of IBM Q Experience.

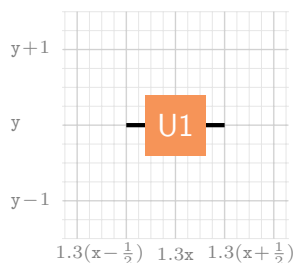
Parameters

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)

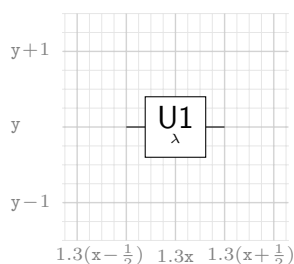
Examples



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



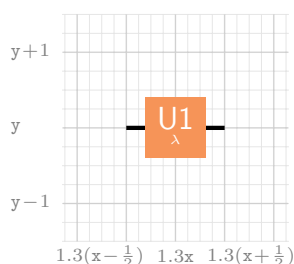
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUa[ibmqx]{0}{0}
4 \end{tikzpicture}
```



```

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

$$U1_{\lambda} \doteq \begin{pmatrix} & \langle 0| & \langle 1| \\ |0\rangle & 1 & 0 \\ |1\rangle & 0 & e^{i\lambda} \end{pmatrix} \quad \text{\texttt{\$}\displaystyle U1_{\{\lambda\}}\doteq\qgate0Ua \$}$$

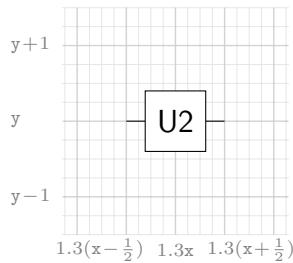
```
\qgateUb[option]{x}{y}
\qgateUb*[option]{x}{y}{sublabel}
```

U2 gate of IBM Q Experience.

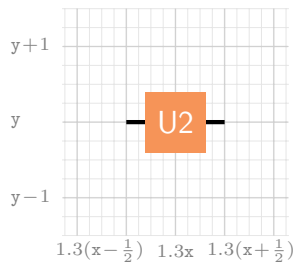
Parameters

- 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)

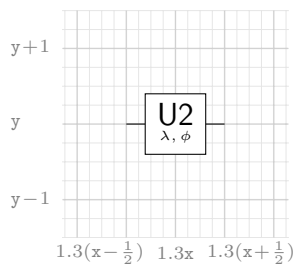
Examples



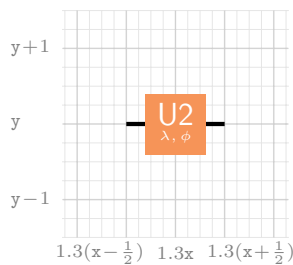
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUb{0}{0}
4 \end{tikzpicture}
```



```
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

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

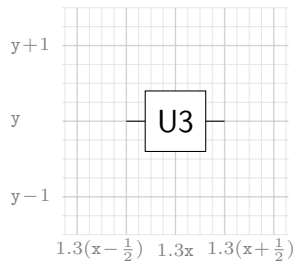
```
\qgateUc[option]{x}{y}
\qgateUc*[option]{x}{y}{sublabel}
```

U3 gate of IBM Q Experience.

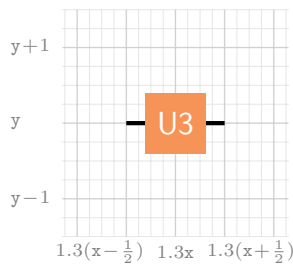
Parameters

- 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)

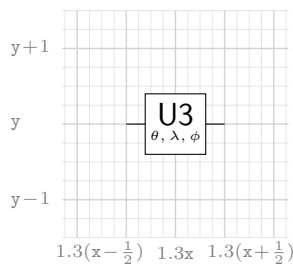
Examples



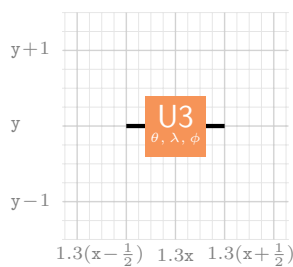
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qgateUc{0}{0}
4 \end{tikzpicture}
```



```
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

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

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:

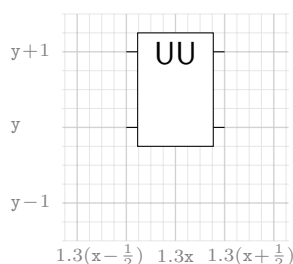
A B C D E F G H

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

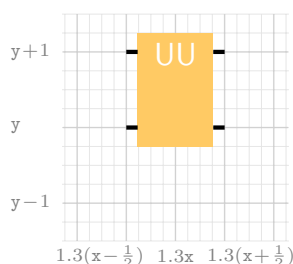
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x, y)`.

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:

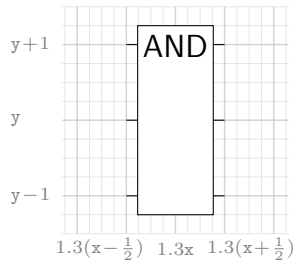
A B C D E F G H

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

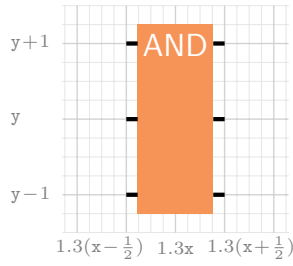
x, y Position of symbol in schematic. The actual TikZ coordinates are `(\qgateSx*x, y)`.

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}
```

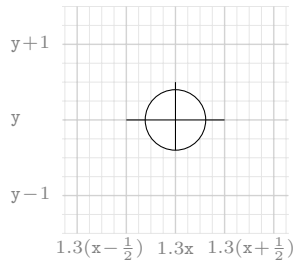
`\qgateCNX[option]{cwires}{x}{y}`

XOR symbol of controlled-NOT gate.

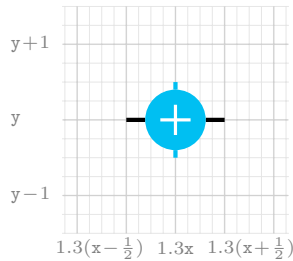
Parameters

- 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}
```

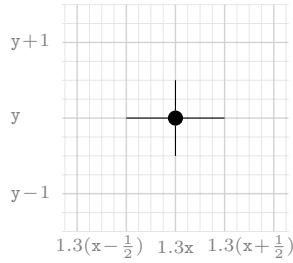
`\qgateCNC[option]{cwires}{x}{y}`

Control qubit symbol of controlled-NOT gate.

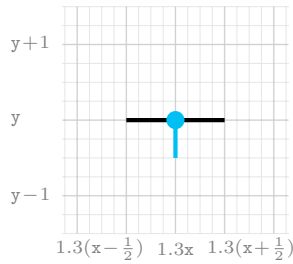
Parameters

- 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}
```

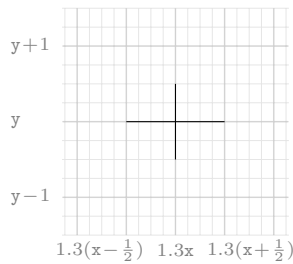
`\qgateCNR[option]{x}{y}`

Run-through qubit symbol of controlled-NOT gate.

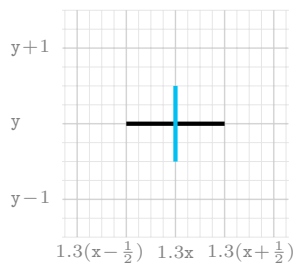
Parameters

- 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}
```

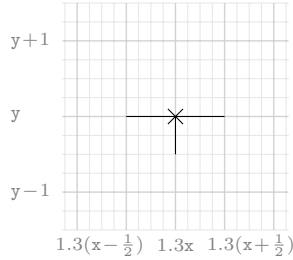
`\qgateSwT[option]{x}{y}`

Top qubit of a SWAP gate.

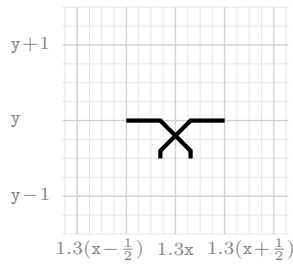
Parameters

- 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}
```

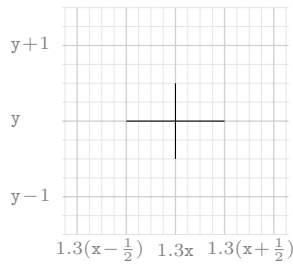
`\qgateSWR[option]{x}{y}`

Run-through qubit of a SWAP gate.

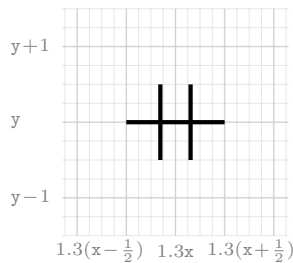
Parameters

- 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}
```

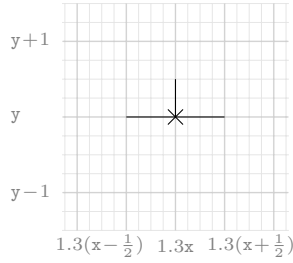
`\qgateSWb[option]{x}{y}`

Bottom qubit of a SWAP gate.

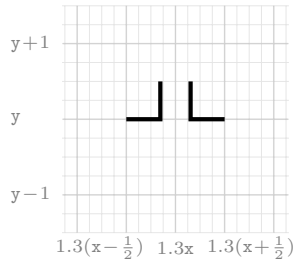
Parameters

- 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

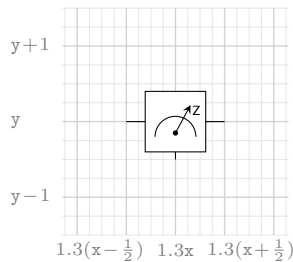
```
\qmeasM[option]{x}{y}
\qmeasM*[option]{x}{y}{axis}{wires}
```

Measurement symbol.

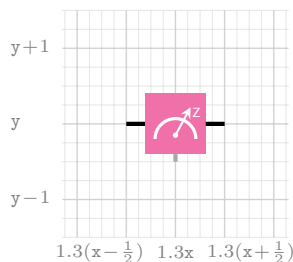
Parameters

- 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 $(\backslash\text{qgateSx}*x, y)$.
- axis** Axis of measurement: X, Y, or Z (starred version only).
- wires** Wires, b for bottom, r for right, and br for both (starred version only).

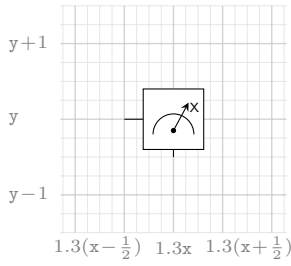
Examples



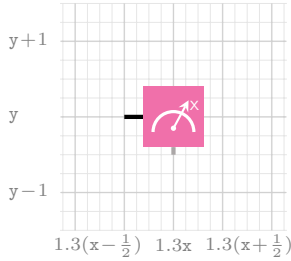
```
1 \begin{tikzpicture}
2   \qScalePaper
3   \qmeasM{0}{0}
4 \end{tikzpicture}
```



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



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



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

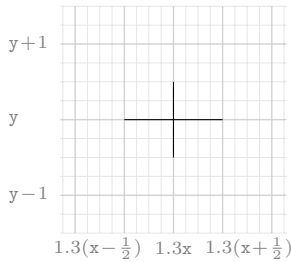
`\qmeasR[option]{x}{y}`

Measurement run-through qubit symbol.

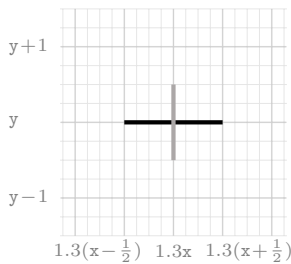
Parameters

- 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}
```

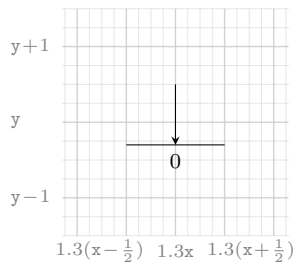
`\qmeasMB[option]{b}{x}{y}`

Measurement-joins-bus symbol.

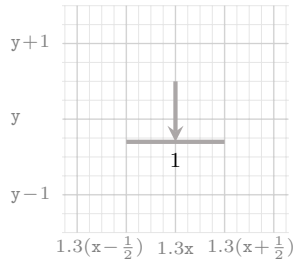
Parameters

- 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}
```

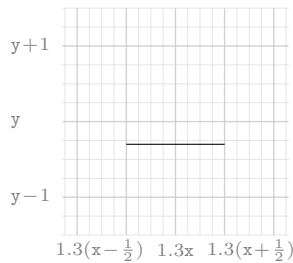
`\qmeaB[option]{x}{y}`

Measurement bus symbol.

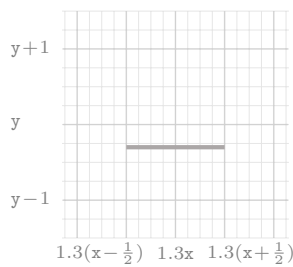
Parameters

- `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}
```

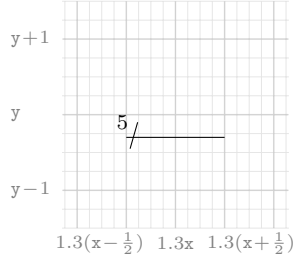
`\qmeaBh[option]{b}{x}{y}`

Measurement bus header symbol.

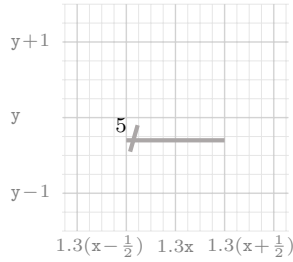
Parameters

- 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 $(\backslash\text{qgateSx}*x, y)$.

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

$$CNOT \doteq \left(\begin{array}{c|cccc} & \langle 00 | & \langle 01 | & \langle 10 | & \langle 11 | \\ \hline |00\rangle & 1 & 0 & 0 & 0 \\ |01\rangle & 0 & 1 & 0 & 0 \\ |10\rangle & 0 & 0 & 0 & 1 \\ |11\rangle & 0 & 0 & 1 & 0 \end{array} \right)$$

```
1 $\displaystyle CNOT\dotseq\qgateOCNOT $
```

Toffoli (CCNOT) Gate Operator

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

```
1 $\displaystyle CCNOT\dotseq\qgateOCCNOT $
```

2.7 Auxiliary Commands

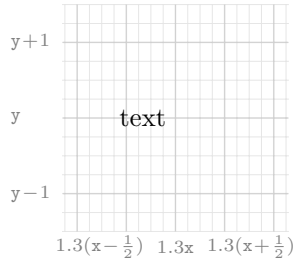
```
\qnode[style]{x}{y}{label}
```

TikZ node in schematics coordinates.

Parameters

<code>style</code>	TikZ node style.
<code>x, y</code>	Position of symbol in schematic. The actual TikZ coordinates are $(\backslash\text{qgateSx}*x, y)$.
<code>label</code>	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}
24 \definecolor{ibmqxB}{HTML}{FFCA64}
25 \definecolor{ibmqxC}{HTML}{A6CE38}
26 \definecolor{ibmqxD}{HTML}{00BFF2}
27 \definecolor{ibmqxE}{HTML}{FF6666}
28 \definecolor{ibmqxF}{HTML}{F070AA}
29 \definecolor{ibmqxG}{HTML}{ADC1C6}
30 \definecolor{ibmqxH}{HTML}{F2F2F2}
31 \definecolor{ibmqxI}{HTML}{ABA7A7}
32
33 %% == COMMANDS =====
34
35 % Wire
36 \newcommand{\qwire}[3]{}{
37   \pgfmacthsetmacro\x{\qgateSx*(#2)}
38   \pgfmacthsetmacro\y{(#3)}
39   \ifthenelse{\isin{ibmqx}{#1}}{
40     \tikzset{style/.style={ultra thick,line cap=butt}}
41   }{
42     \tikzset{style/.style={}}
43   }
44   \draw[style] (\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 $\lvert 0 \rangle$};
55   }{%
56     \node[anchor=east] at (\x+\qgateSx/2,\y){$\lvert 0 \rangle$};
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\lvert##1\rangle}
93   \def\bra##1{\scriptstyle\langle##1\lvert}
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\lvert##1\rangle}
111   \def\bra##1{\scriptstyle\langle##1\lvert}
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\qgate0Si{\%
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\qgate0T{\%
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\!+\!\j)
232 \end{array}\!\right)
233 }}
234
235 % Inverse T phase gate
236 \newcommand\qgateTi[3][]{\%
237 \ifthenelse{\isin{ibmqx}{#1}}{\%
238 \qgateU[ibmqxE]{#2}{#3}{T$^\dagger$}
239 }{\%
240 \qgateU{#2}{#3}{T$^\dagger$}
241 }%
242 }
243 \newcommand\qgate0Ti{\%
244 \def\ket##1{\scriptstyle|##1\rangle}
245 \def\bra##1{\scriptstyle\langle ##1|}
246 \def\j{\mathrm{i}}
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\!-\!\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}{\qgateSublabel{U1}{#4}}
269 }{%
270 \qgateU{#2}{#3}{\qgateSublabel{U1}{#4}}
271 }%
272 }
273 \newcommand\qgateOUa{%
274 \def\ket##1{\scriptstyle|##1\rangle}
275 \def\bra##1{\scriptstyle\langle ##1|}
276 \def\mathrm{e}{}
277 \def\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 & e^{-\lambda\mathrm{j}}
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}{\qgateSublabel{U2}{#4}}
299 }{%
300 \qgateU{#2}{#3}{\qgateSublabel{U2}{#4}}
301 }%
302 }
303 \newcommand\qgateOUb{%
304 \def\ket##1{\scriptstyle|##1\rangle}
305 \def\bra##1{\scriptstyle\langle ##1|}
306 \def\mathrm{e}{}
307 \def\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^{-\lambda\mathrm{j}} \\
313 \ket{1} & e^{-\phi\mathrm{j}} & e^{-(\lambda+\phi)\mathrm{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}{\qgateSublabel{U3}{#4}}
331 }{%
332 \qgateU{#2}{#3}{\qgateSublabel{U3}{#4}}
333 }%
334 }
335 \newcommand\qgateOUc{%

```

```

336 \def\ket##1{\scriptstyle|##1\rangle}
337 \def\bra##1{\scriptstyle\langle ##1|}
338 \def\mathrm{e}{\mathrm{e}}
339 \def\mathrm{i}{\mathrm{i}}
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 % Sawp 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 \makeatletter
527 \newcommand\qmeasM{\@ifstar\qmeasMS\qmeasMN}
528 \makeatother
529 \newcommand\qmeasMN[3][]{
530 \qmeasMS[#1]{#2}{#3}{Z}{br}
531 }
532 \newcommand\qmeasMS[5][]{\%
533 \pgfmathsetmacro\x{\qgateSx*(#2)}
534 \pgfmathsetmacro\y{(#3)}
535 \ifthenelse{\isin{ibmqx}{#1}}{\%
536 \tikzset{lstyle/.style={ultra thick,line cap=butt}}
537 \tikzset{rstyle/.style={draw=none,fill=ibmqxF}}
538 \tikzset{tstyle/.style={white,very thick,line cap=butt}}
539 \tikzset{pstyle/.style={->,>=stealth,white,thick,line cap=butt}}
540 \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
541 }{%
542 \tikzset{lstyle/.style={}}
543 \tikzset{rstyle/.style={fill=white}}
544 \tikzset{tstyle/.style={}}
545 \tikzset{pstyle/.style={->,>=stealth,line cap=butt}}
546 \tikzset{cstyle/.style={}}
547 }%
548 \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x-0.4,\y);
549 \draw[rstyle] (\x-0.4,\y-0.4) rectangle (\x+0.4,\y+0.4);
550 \draw[tstyle] (\x+0.27,\y-0.2) arc (0:180:0.27);
551 \draw[pstyle] (\x,\y-0.15) -- (\x+0.2,\y+0.22);

```

```

552 \node[pstyle] at (\x+0.28,\y+0.15) {\tiny\sffamily #4};
553 \fill[pstyle] (\x, \y-0.15) circle (0.035);
554 \ifthenelse{\isin{r}{#5}}{%
555   \draw[lstyle] (\x+0.4,\y) -- (\x+\qgateSx/2,\y);%
556 }{}
557 \ifthenelse{\isin{b}{#5}}{%
558   \draw[cstyle] (\x,\y-0.4) -- (\x,\y-0.5);%
559 }{}
560 }}
561
562 % Measurement run-through qubit symbol
563 \newcommand\qmeasR[3][]{\{
564   \pgfmathsetmacro\x{\qgateSx*(#2)}
565   \pgfmathsetmacro\y{(#3)}
566   \ifthenelse{\isin{ibmqx}{#1}}{%
567     \tikzset{lstyle/.style={ultra thick,line cap=butt}}
568     \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
569   }{%
570     \tikzset{lstyle/.style={}}
571     \tikzset{cstyle/.style={}}
572   }%
573   \draw[lstyle] (\x-\qgateSx/2,\y) -- (\x+\qgateSx/2,\y);
574   \draw[cstyle] (\x, \y-0.5) -- (\x, \y+0.5);
575 }
576
577 % Measurement-joins-bus symbol
578 \newcommand\qmeasMB[4][]{\{
579   \pgfmathsetmacro\x{\qgateSx*(#3)}
580   \pgfmathsetmacro\y{(#4)}
581   \ifthenelse{\isin{ibmqx}{#1}}{%
582     \tikzset{cstyle/.style={>stealth,ibmqxI,ultra thick,line cap=butt}}
583   }{%
584     \tikzset{cstyle/.style={>stealth}}
585   }%
586   \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
587   \draw[cstyle,->] (\x,\y+0.5) -- (\x,\y-0.3)
588   node[anchor=north,black] {\footnotesize #2};
589 }
590
591 % Measurement bus symbol
592 \newcommand\qmeasB[3][]{\{
593   \pgfmathsetmacro\x{\qgateSx*(#2)}
594   \pgfmathsetmacro\y{(#3)}
595   \ifthenelse{\isin{ibmqx}{#1}}{%
596     \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
597   }{%
598     \tikzset{cstyle/.style={}}
599   }%
600   \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
601 }
602
603 % Measurement bus head symbol
604 \newcommand\qmeasBh[4][]{\{
605   \pgfmathsetmacro\x{\qgateSx*(#3)}
606   \pgfmathsetmacro\y{(#4)}
607   \ifthenelse{\isin{ibmqx}{#1}}{%
608     \tikzset{cstyle/.style={ibmqxI,ultra thick,line cap=butt}}
609   }{%
610     \tikzset{cstyle/.style={}}
611   }%
612   \draw[cstyle] (\x-\qgateSx/2,\y-0.3) -- (\x+\qgateSx/2,\y-0.3);
613   \draw[cstyle] (\x-\qgateSx/2+0.05,\y-0.45) -- (\x-\qgateSx/2+0.15,\y-0.1)
614   node[anchor=east,black] {\footnotesize #2};
615 }
616
617 %% == OTHER GATE OPERATORS =====
618
619 \newcommand\qgateOCNOT{\{
620   \def\ket##1{\scriptstyle|#1\rangle}
621   \def\bra##1{\rotatebox{90}{\scriptstyle\langle #1|}}
622   \left(\hspace*{-0.4ex}\begin{array}{c|cccc}
623     & \bra{00} & \bra{01} & \bra{10} & \bra{11} \\ \hline

```

```

624 \ket{00} & 1 & 0 & 0 & 0 \\
625 \ket{01} & 0 & 1 & 0 & 0 \\
626 \ket{10} & 0 & 0 & 0 & 1 \\
627 \ket{11} & 0 & 0 & 1 & 0 \\
628 \end{array} \!\! \right)
629 }}
630
631 \newcommand\qgateOCCNOT{%
632 \def\ket##1{\scriptstyle|##1\rangle}
633 \def\bra##1{\rotatebox{90}{\scriptstyle\langle ##1|}}
634 \left(\hspace*{-0.4ex}\begin{array}{c|cccccc}
635 & \bra{000} & \bra{001} & \bra{010} & \bra{011} & \bra{100} & \bra{101} & \bra{110} & \bra{111} \\ \hline
636 \ket{000} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
637 \ket{001} & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
638 \ket{010} & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
639 \ket{011} & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
640 \ket{100} & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
641 \ket{101} & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
642 \ket{110} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
643 \ket{111} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
644 \end{array} \!\! \right)
645 }}
646
647 %% == AUXILIARY COMMANDS =====
648
649 % TikZ node in circuit coordinate system
650 \newcommand\qnode[4] [] {%
651 \pgfmathsetmacro\x{\qgateSx*(#2)}
652 \pgfmathsetmacro\y{(#3)}
653 \node[#1] at (\x,\y) {#4};
654 }
655
656 %% == PACKAGE-INTERNAL COMMANDS =====
657
658 % Draw scale paper for documentations
659 \newcommand{\qScalePaper}{%
660 \draw[help lines,xstep=(\qgateSx/8),ystep=0.25,opacity=0.2] (-1.5,-1.5) grid (1.5,1.5);
661 \draw[help lines,line width=.6pt,xstep=(\qgateSx/2),ystep=1,opacity=0.2] (-1.49,-1.5) grid (1.49,1.5);
662 \node[anchor=west,color=gray] at (-1,-1.7) {\scriptsize $\qgateSx(\texttt{x})\!-\!\frac{1}{2}$};
663 \node[anchor=west,color=gray] at (0,-1.7) {\scriptsize $\qgateSx\texttt{x}$};
664 \node[anchor=west,color=gray] at (1,-1.7) {\scriptsize $\qgateSx(\texttt{x})\!+\!\frac{1}{2}$};
665 \node[anchor=west,color=gray] at (-2.3,-1) {\scriptsize $\texttt{y}\!-\!1$};
666 \node[anchor=west,color=gray] at (-2.3,0) {\scriptsize $\texttt{y}$};
667 \node[anchor=west,color=gray] at (-2.3,1) {\scriptsize $\texttt{y}\!+\!1$};
668 }
669
670 % Draw gate label with sub-label
671 \newcommand\qgateSublabel[2] {%
672 {\renewcommand{\arraystretch}{0.4}%
673 \begin{tabular}{c} #1 \\ \tiny #2 \end{tabular} }%
674 }
675
676 %% == 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.