Circuits for Benchmarking

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Summary

This document describes the classes of quantum circuits and respective data, available at https://github.com/luisps/QCircuits_BenchTest.git.

Each circuit class is identified by a number (usually an exact thousand, hundred or dozen. Particular circuits are then identified by the lower digits.

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Class 19 – variational EfficientSU2

This class of circuits corresponds to the so-called "hardware efficient" ansatz for variational circuits. It is obtained with the Qiskit method:

```
EfficientSU2(num_qubits, entanglement='linear', reps=reps)
```

The number of qubits and the number of layer repetitions is varied for the different circuit instances below.

Circuit 19- variational EfficientSU2: 3 qubits, 1 rep
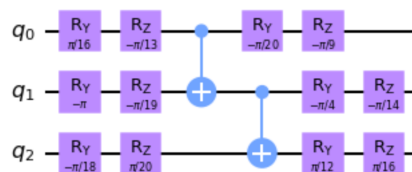
6 layers
32768 paths = $2^{(3*(6-1))} = 2^{15}$
Non zero paths for $\langle 0|U|0\rangle$ = 4
$\langle 0|U|0\rangle = 0.07304992 + 0.01779798$

Available Files	
circuit_19.data	The circuit definition
circuit_19.csv	Exact amplitudes for different transitions
circuit_19-raw-values.csv	Non zero paths for $\langle 0|U|0\rangle$
circuit_19.data_stats_IS_0_0.csv	Amplitudes and variances as a function of the number of samples for Importance Sampling and $\langle 0|U|0\rangle$
circuit_19.data_stats_BD_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling and $\langle 0|U|0\rangle$
circuit_19.data_stats_BD_MIS_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0\rangle$

Circuit 191- variational EfficientSU2: 3 qubits, 2 rep
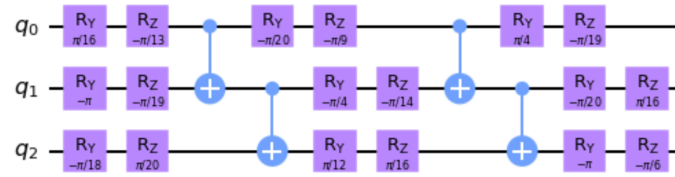
10 layers

1.342 * 10^8 paths = $2^{(3*(9-1))} = 2^{24}$

$\langle 0|U|0 \rangle = -0.29465061 - 0.18699787$

Available Files	
circuit_191.data	The circuit definition
circuit_191.csv	Exact amplitudes for different transitions
circuit_191.data_stats_IS_0_0.csv	Amplitudes and variances as a function of the number of samples for Importance Sampling and $\langle 0|U|0 \rangle$
circuit_191.data_stats_BD_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling and $\langle 0|U|0 \rangle$
circuit_191.data_stats_BD_MIS_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0 \rangle$

Circuit 192- variational EfficientSU2: 4 qubits, 2 layers

11 layers

1.1 * 10^{12} paths = $2^{(4*(10-1))} = 2^{36}$

$\langle 0|U|0 \rangle = 0.06600214 - 0.21540996j$

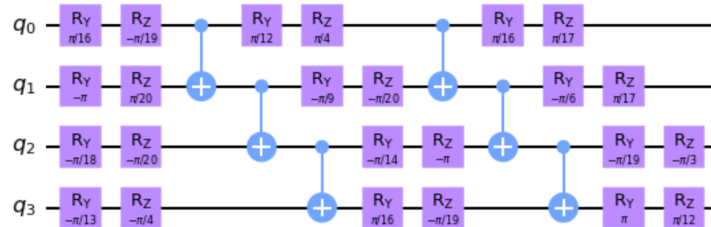| Available Files	
circuit_192.data	The circuit definition
circuit_192.csv	Exact amplitudes for different transitions
circuit_192.data_stats_IS_0_0.csv	Amplitudes and variances as a function of the number of samples for Importance Sampling and $\langle 0|U|0 \rangle$
circuit_192.data_stats_BD_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling and $\langle 0|U|0 \rangle$
circuit_192.data_stats_BD_MIS_0_0.csv	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0 \rangle$

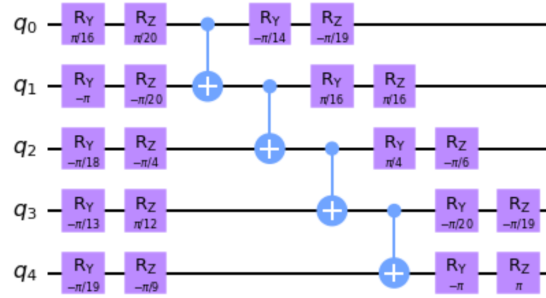## Circuit 193- variational EfficientSU2: 5 qubits, 1 rep

8 layers

3.436e+10 paths = $2^{(5*(8-1))} = 2^{35}$

$\langle 0|U|0 \rangle$ =-0.00172150+0.00127863j

Available Files	
`circuit_193.data`	The circuit definition
`circuit_193.csv`	Exact amplitudes for different transitions
`circuit_193.data_stats_IS_0_0.csv`	Amplitudes and variances as a function of the number of samples for Importance Sampling and $\langle 0|U|0 \rangle$
`circuit_193.data_stats_BD_0_0.csv`	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling and $\langle 0|U|0 \rangle$
`circuit_193.data_stats_BD_MIS_0_0.csv`	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0 \rangle$

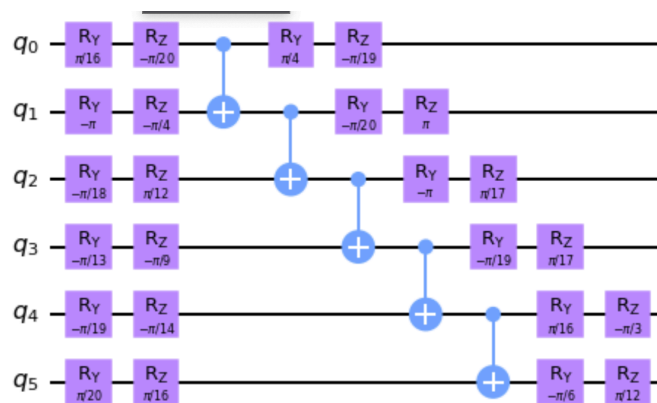## Circuit 194- variational EfficientSU2: 6 qubits, 1 rep

9 layers

2.815e+14 paths = $2^{(6*(9-1))} = 2^{48}$

$\langle 0|U|0 \rangle$ = -0.00273768-0.00909492j

Available Files	
circuit_194.data	The circuit definition
circuit_194.csv	Exact amplitudes for different transitions

Circuit 195- variational EfficientSU2: 6 qubits, 2 rep
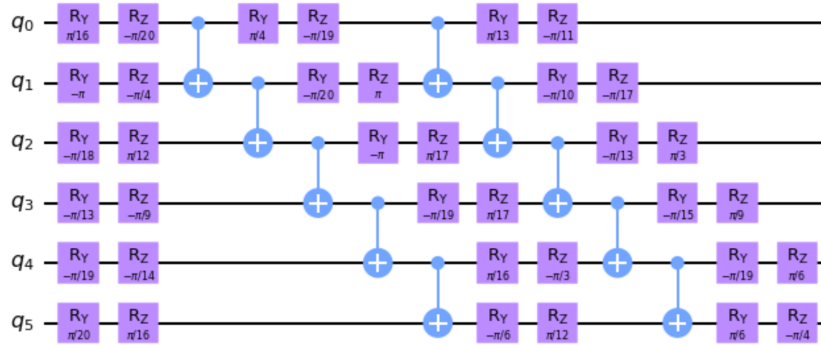
13 layers

4.722e+21 paths = $2^{(6*(13-1))} = 2^{72}$

$\langle 0|U|0 \rangle =$ `-0.00514611-0.02104634j`

Available Files	
circuit_195.data	The circuit definition
circuit_195.csv	Exact amplitudes for different transitions

Circuit 196- variational EfficientSU2: 15 qubits, 2 rep

22 layers

6.675e+94 paths = $2^{(15*(22-1))} = 2^{315}$

$\langle 0|U|0 \rangle =$ `0.00364578+0.00060584j`

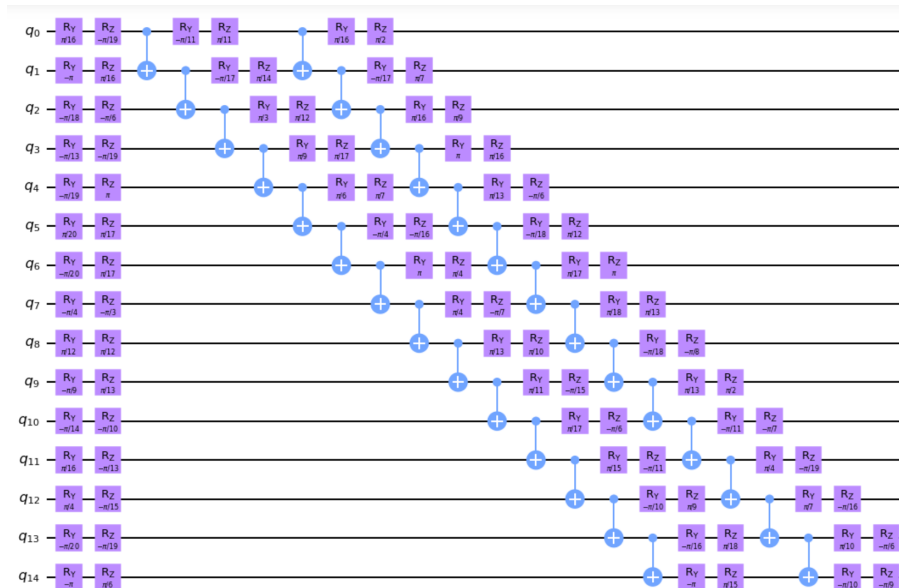| Available Files	
`circuit_196.data`	The circuit definition
`circuit_196.jpg`	Circuit diagram
`circuit_196.csv`	Exact amplitudes for different transitions
`circuit_196.data_stats_IS_0_0.csv`	Amplitudes and variances as a function of the number of samples for Importance Sampling and $\langle 0|U|0\rangle$
`circuit_196.data_stats_BD_0_0.csv`	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling and $\langle 0|U|0\rangle$
`circuit_196.data_stats_BD_MIS_0_0.csv`	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0\rangle$

Class 4100 – Hidden Shift Circuits

Deterministic circuits, in the sense that only one basis state in the output has an amplitude different from 0 (= 1.0).

These are based on the algorithm (and code) presented in Peres, Filipa 2023 (sec 4.1) https://arxiv.org/pdf/2203.01789.pdf

Circuit 4100- Hidden shift: 100 qubits, hidden string = 1023

43 layers

paths = $2^{(100*(43-1))} = 2^{4200}$

$\langle 1023|U|0\rangle$ = `1.0 + 0.0j`

Available Files	
`circuit_4100.data`	The circuit definition
`circuit_4100.jpg`	Circuit diagram

Circuit 4101- Hidden shift: 8 qubits, hidden string = 7

53 layers

1.692e+125 paths $= 2^{(8*(53-1))} = 2^{416}$

$\langle 7|U|0\rangle$ = `1.0 + 0.0j`

Available Files	
`circuit_4101.data`	The circuit definition
`circuit_4101.jpg`	Circuit diagram
`circuit_4101.csv`	Exact amplitudes for different transitions

Circuit 4150- Hidden shift: 50 qubits, hidden string = 1023

43 layers

$$2^{(50*(43-1))} = 2^{2100}$$

$\langle 1023|U|0\rangle = 1.0 + 0.0j$

Available Files	
circuit_4150.data	The circuit definition
circuit_4150.jpg	Circuit diagram

Circuit 4160- Hidden shift: 60 qubits, hidden string = 1023

43 layers

$$paths = 2^{(60*(43-1))} = 2^{2520}$$

$\langle 1023|U|0\rangle = 1.0 + 0.0j$

Available Files	
circuit_4160.data	The circuit definition
circuit_4160.jpg	Circuit diagram

Circuit 4170- Hidden shift: 70 qubits, hidden string = 1023

43 layers

$$paths = 2^{(70*(43-1))} = 2^{2940}$$

$\langle 1023|U|0\rangle = 1.0 + 0.0j$

Available Files	
circuit_4170.data	The circuit definition
circuit_4170.jpg	Circuit diagram

Circuit 4180- Hidden shift: 80 qubits, hidden string = 1023

43 layers

$$paths = 2^{(80*(43-1))} = 2^{3360}$$

$\langle 1023|U|0\rangle = 1.0 + 0.0j$

Available Files	
circuit_4180.data	The circuit definition
circuit_4180.jpg	Circuit diagram

Circuit 4190- Hidden shift: 90 qubits, hidden string = 1023

43 layers

$$paths = 2^{(90*(43-1))} = 2^{3780}$$

$\langle 1023|U|0\rangle = 1.0 + 0.0j$

Available Files	
`circuit_4190.data`	The circuit definition
`circuit_4190.jpg`	Circuit diagram

Class 300 – IQP Inversion test

Inversion test of two random states encoded using IQP.
The probability of $P(|0>^n)$ is the overlap between the states.

Circuit 305- IQP: 5 qubits

17 layers

$1.209e+24$ **paths** $= 2^{(5*(17-1))} = 2^{80}$

$\langle 0|U|0 \rangle = -0.104462+0.106694j$

Available Files	
`circuit_305.data`	The circuit definition
`circuit_305.jpg`	Circuit diagram
`circuit_305.csv`	Exact amplitudes for different transitions

Circuit 315- IQP: 15 qubits

55 layers

$6.828e+243$ **paths** $= 2^{(15*(55-1))} = 2^{810}$

$\langle 0|U|0 \rangle = -0.00128171-0.00008649j$

Available Files	
`circuit_315.data`	The circuit definition
`circuit_315.jpg`	Circuit diagram
`circuit_315.csv`	Exact amplitudes for different transitions

Circuit 325- IQP: 25 qubits

97 layers

paths $= 2^{(25*(97-1))} = 2^{2400}$

$\langle 0|U|0 \rangle = -0.00013443-0.00022139j$

Available Files	
`circuit_325.data`	The circuit definition
`circuit_325.jpg`	Circuit diagram
`circuit_325.csv`	Exact amplitudes for different transitions

Class 500 – Random Circuits

Randomly generated circuits. The output state should follow a quasi-uniform distribution.

These are based on the algorithm (and code) presented in Peres, Filipa 2023 (sec 4.2)
https://arxiv.org/pdf/2203.01789.pdf

Circuit 508- Random: 8 qubits, nCycles = 6

9 layers

`1.845e+19` paths $= 2^{(8*(9-1))} = 2^{64}$

$\langle 0|U|0 \rangle =$ `-0.04419417+0.10669417j`

Available Files	
`circuit_508.data`	The circuit definition
`circuit_508.jpg`	Circuit diagram
`circuit_508.csv`	Exact amplitudes for different transitions
`circuit_508.data_stats_BD_MIS_0_0.csv`	Amplitudes and variances as a function of the number of samples for Bidirectional Sampling with MIS and $\langle 0|U|0 \rangle$

Circuit 516- Random: 16 qubits, nCycles = 12

22 layers

`1.400e+101` paths $= 2^{(16*(22-1))} = 2^{336}$

$\langle 0|U|0 \rangle =$ `-0.00040451-0.00138107j`

Available Files	
`circuit_516.data`	The circuit definition
`circuit_516.jpg`	Circuit diagram
`circuit_516.csv`	Exact amplitudes for different transitions

Circuit 525 - Random: 25 qubits, nCycles = 18

31 layers

`5.922e+225` paths $= 2^{(25*(31-1))} = 2^{750}$

$\langle 0|U|0 \rangle =$ `0.00035204+0.00038255j`

Available Files	
`circuit_525.data`	The circuit definition
`circuit_525.jpg`	Circuit diagram
`circuit_525.csv`	Exact amplitudes for different transitions