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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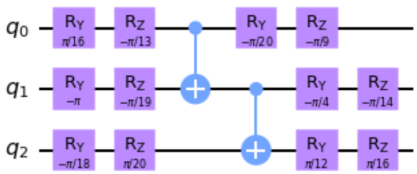
Class 19 – variational EfficientSU2

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.

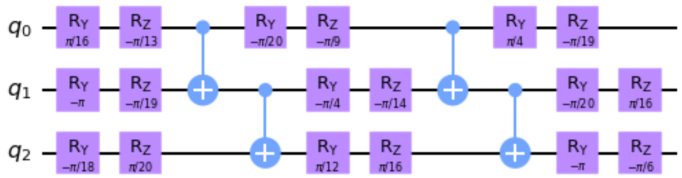
Circuit 19- variational EfficientSU2: 3 qubits, 1 rep



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



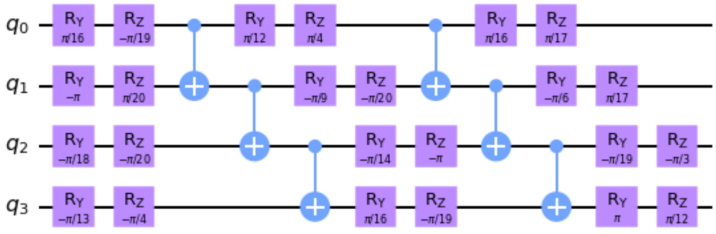
10 layers

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



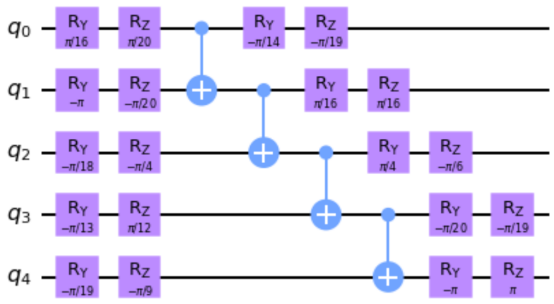
11 layers

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



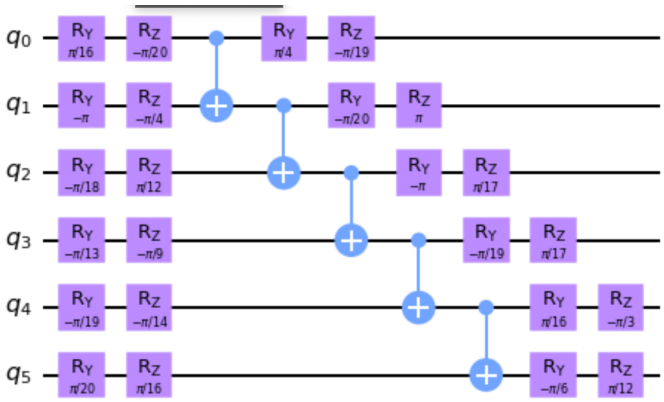
8 layers

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



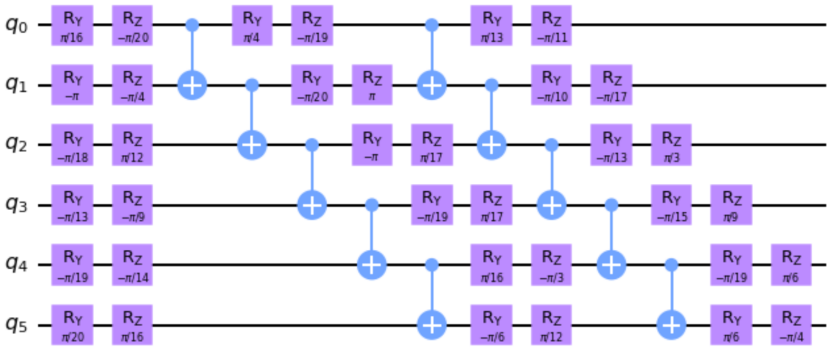
9 layers

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



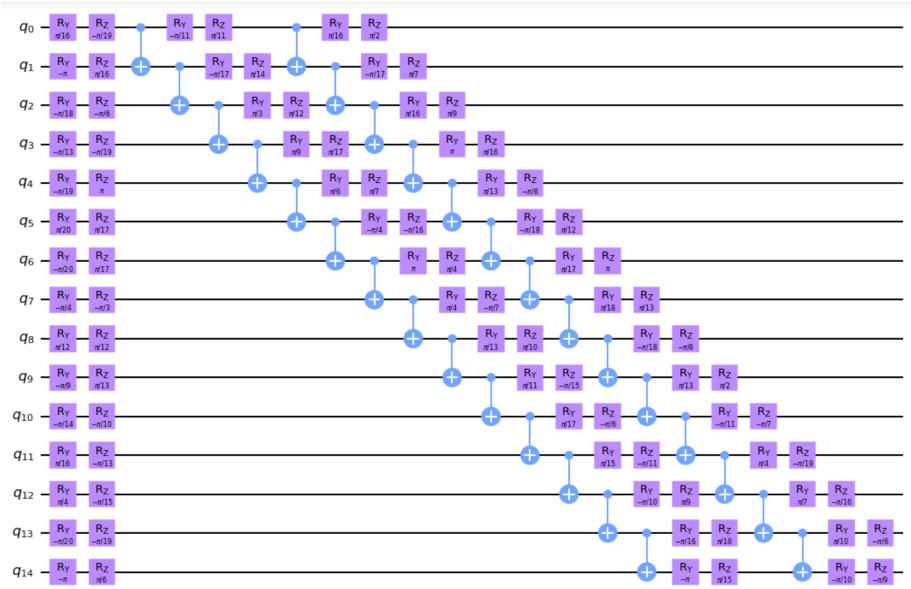
13 layers

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 4110- Hidden shift: 10 qubits, hidden string = 1023

56 layers
$2^{(10*(56-1))} = 2^{560}$
$\langle 1023|U|0\rangle =$ `1.0 + 0.0j`

Available Files	
circuit_4110.data	The circuit definition
circuit_4110.jpg	Circuit diagram

Circuit 4120- Hidden shift: 20 qubits, hidden string = 1023

46 layers
$2^{(20*(46-1))} = 2^{900}$
$\langle 1023|U|0\rangle =$ `1.0 + 0.0j`

Available Files	
circuit_4120.data	The circuit definition
circuit_4120.jpg	Circuit diagram

Circuit 4130- Hidden shift: 30 qubits, hidden string = 1023

43 layers
$2^{(30*(43-1))} = 2^{1260}$
$\langle 1023|U|0\rangle =$ `1.0 + 0.0j`

Available Files	
circuit_4130.data	The circuit definition
circuit_4130.jpg	Circuit diagram

Circuit 4140- Hidden shift: 40 qubits, hidden string = 1023

43 layers
$2^{(40*(43-1))} = 2^{1680}$
$\langle 1023|U|0\rangle =$ `1.0 + 0.0j`

Available Files	
`circuit_4140.data`	The circuit definition
`circuit_4140.jpg`	Circuit diagram

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 510- Random: 10 qubits, nCycles = 7

13 layers
paths = $2^{(10*(13-1))} = 2^{120}$
$\langle 0|U|0\rangle$ = `0.02209709+0.05334709j`

Available Files	
circuit_510.data	The circuit definition
circuit_510.jpg	Circuit diagram
circuit_510.csv	Exact amplitudes for different transitions

Circuit 512- Random: 12 qubits, nCycles = 8

15 layers

paths $= 2^{(12*(15-1))} = 2^{168}$

$\langle 16|U|0\rangle =$ `0.009153-0.022097j`

Available Files	
circuit_512.data	The circuit definition
circuit_512.jpg	Circuit diagram
circuit_512.csv	Exact amplitudes for different transitions

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