Cirq Documentation

Release 0.4.0

The Cirq Developers

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Contents

Cirq is a software library for writing, manipulating, and optimizing quantum circuits and then running them against quantum computers and simulators. Cirq attempts to expose the details of hardware, instead of abstracting them away, because, in the Noisy Intermediate-Scale Quantum (NISQ) regime, these details determine whether or not it is possible to execute a circuit at all.

CHAPTER 1

Alpha Disclaimer

Cirq is currently in alpha. We are still making breaking changes. We *will* break your code when we make new releases. We recommend that you target a specific version of Cirq, and periodically bump to the latest release. That way you have control over when a breaking change affects you.

CHAPTER 2

User Documentation

2.1 Installing Cirq

Choose your operating system:

- *Installing on Linux*
- *Installing on Mac OS X*
- *Installing on Windows*

If you want to create a development environment, see *development.md*.

2.1.1 Alpha Disclaimer

Cirq is currently in alpha. We are still making breaking changes. We *will* break your code when we make new releases. We recommend that you target a specific version of Cirq, and periodically bump to the latest release. That way you have control over when a breaking change affects you.

2.1.2 Installing on Linux

1. Make sure you have python 3.5.2 or greater (or else python 2.7).

   See Installing Python 3 on Linux @ the hitchhiker's guide to python.

2. Consider using a virtual environment.
3. Use `pip` to install `cirq`:

```
pip install --upgrade pip
pip install cirq
```

4. (Optional) install system dependencies that pip can't handle.

```
sudo apt-get install python3-tk texlive-latex-base latexmk
```

- Without `python3-tk`, plotting functionality won't work.
- Without `texlive-latex-base` and `latexmk`, pdf writing functionality will not work.

5. Check that it works!

```
python -c 'import cirq; print(cirq.google.Foxtail)'
# should print:
# (0, 0)———(0, 1)———(0, 2)———(0, 3)———(0, 4)———(0, 5)———(0, 6)———(0, 7)———(0,␣
↪8)———(0, 9)———(0, 10)
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# (1, 0)———(1, 1)———(1, 2)———(1, 3)———(1, 4)———(1, 5)———(1, 6)———(1, 7)———(1,␣
↪8)———(1, 9)———(1, 10)
```

2.1.3 Installing on Mac OS X

1. Make sure you have python 3.5 or greater (or else python 2.7).

   See Installing Python 3 on Mac OS X @ the hitchhiker's guide to python.

2. Consider using a virtual environment.

3. Use `pip` to install `cirq`:

```
pip install --upgrade pip
pip install cirq
```

4. Check that it works!

```
python -c 'import cirq; print(cirq.google.Foxtail)'
# should print:
# (0, 0)———(0, 1)———(0, 2)———(0, 3)———(0, 4)———(0, 5)———(0, 6)———(0, 7)———(0,␣
↪8)———(0, 9)———(0, 10)
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# (1, 0)———(1, 1)———(1, 2)———(1, 3)———(1, 4)———(1, 5)———(1, 6)———(1, 7)———(1,␣
↪8)———(1, 9)———(1, 10)
```

2.1.4 Installing on Windows

1. If you are using the Windows Subsystem for Linux, use the *Linux install instructions* instead of these instructions.

2. Make sure you have python 3.5 or greater (or else python 2.7.9+).

   See Installing Python 3 on Windows @ the hitchhiker's guide to python.

3. Use `pip` to install `cirq`:

```
python -m pip install --upgrade pip
python -m pip install cirq
```

4. Check that it works!

```
python -c "import cirq; print(cirq.google.Foxtail)"
# should print:
# (0, 0)———(0, 1)———(0, 2)———(0, 3)———(0, 4)———(0, 5)———(0, 6)———(0, 7)———(0,␣
↪8)———(0, 9)———(0, 10)
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# │        │        │        │        │        │        │        │        │      ␣
↪ │        │
# (1, 0)———(1, 1)———(1, 2)———(1, 3)———(1, 4)———(1, 5)———(1, 6)———(1, 7)———(1,␣
↪8)———(1, 9)———(1, 10)
```

2.2 Tutorial

In this tutorial we will go from knowing nothing about Cirq to creating a quantum variational algorithm. Note that this tutorial isn't a quantum computing 101 tutorial, we assume familiarity of quantum computing at about the level of the textbook "Quantum Computation and Quantum Information" by Nielsen and Chuang.

To begin, please follow the instructions for *installing Cirq*.

2.2.1 Background: Variational quantum algorithms

The variational method in quantum theory is a classical method for finding low energy states of a quantum system. The rough idea of this method is that one defines a trial wave function (sometimes called an ansatz) as a function of some parameters, and then one finds the values of these parameters that minimize the expectation value of the energy with respect to these parameters. This minimized ansatz is then an approximation to the lowest energy eigenstate, and the expectation value serves as an upper bound on the energy of the ground state.

In the last few years (see arXiv:1304.3061 and arXiv:1507.08969 for example), it has been realized that quantum computers can mimic the classical technique and that a quantum computer does so with certain advantages. In particular, when one applies the classical variational method to a system of `n` qubits, an exponential number (in `n`) of complex numbers are necessary to generically represent the wave function of the system. However with a quantum computer one can directly produce this state using a parameterized quantum circuit, and then by repeated measurements estimate the expectation value of the energy.

This idea has led to a class of algorithms known as variational quantum algorithms. Indeed this approach is not just limited to finding low energy eigenstates, but minimizing any objective function that can be expressed as a quantum observable. It is an open question to identify under what conditions these quantum variational algorithms will succeed, and exploring this class of algorithms is a key part of research for noisy intermediate scale quantum computers.

The classical problem we will focus on is the 2D +/- Ising model with transverse field (ISING). This problem is NP-complete. So it is highly unlikely that quantum computers will be able to efficiently solve it across all instances. Yet this type of problem is illustrative of the general class of problems that Cirq is designed to tackle.

Consider the energy function

Energy: $E(s_1,\dots,s_n) = \sum_{<i,j>} J_{i,j}s_i s_j + \sum_i h_i s_i$

where here each si, Ji,j, and hi are either +1 or -1. Here each index i is associated with a bit on a square lattice, and the <i,j> notation means sums over neighboring bits on this lattice. The problem we would like to solve is, given Ji,j, and hi, find an assignment of si values that minimize E.

How does a variational quantum algorithm work for this? One approach is to consider `n` qubits and associate them with each of the bits in the classical problem. This maps the classical problem onto the quantum problem of minimizing the expectation value of the observable

Hamiltonian: $H=\sum_{<i,j>} J_{i,j} Z_i Z_j + \sum_i h_iZ_i$

Then one defines a set of parameterized quantum circuits, i.e. a quantum circuit where the gates (or more general quantum operations) are parameterized by some values. This produces an ansatz state

State definition: $|\psi(p_1, p_2, \dots, p_k)\rangle$

where pi are the parameters that produce this state (here we assume a pure state, but mixed states are of course possible).

The variational algorithm then works by noting that one can obtain the value of the objective function for a given ansatz state by

1. Prepare the ansatz state.
2. Make a measurement which samples from some terms in H.
3. Goto 1.

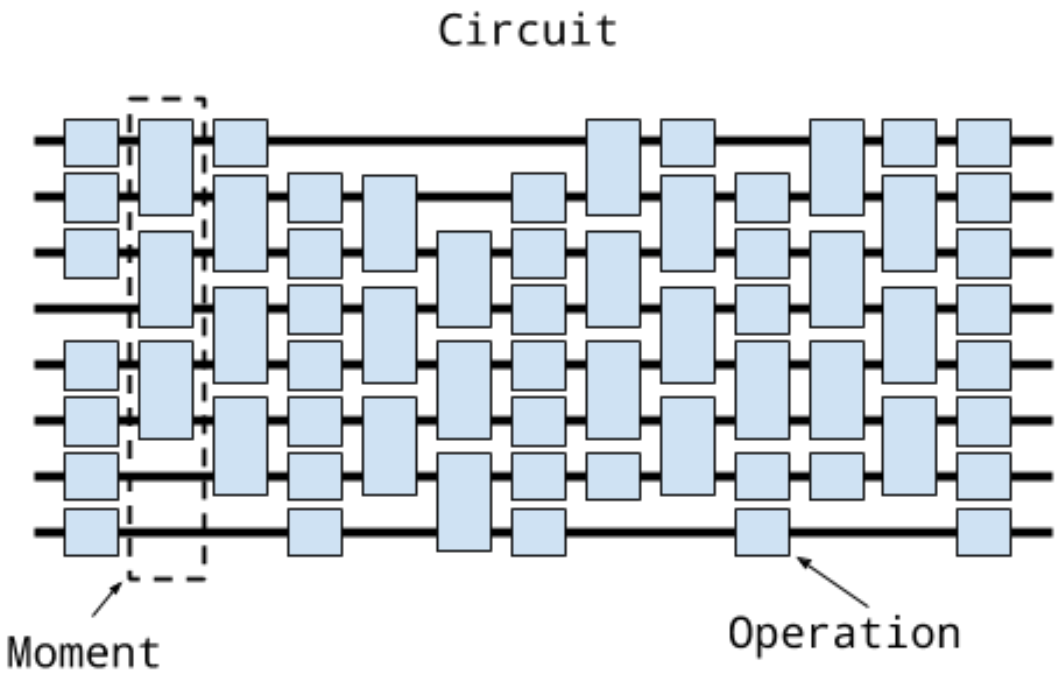
Note that one cannot always measure H directly (without the use of quantum phase estimation). So one often relies on the linearity of expectation values to measure parts of H in step 2. One always needs to repeat the measurements to obtain an estimate of the expectation value. How many measurements needed to achieve a given accuracy is beyond the scope of this tutorial, but Cirq can help investigate this question.

The above shows that one can use a quantum computer to obtain estimates of the objective function for the ansatz. This can then be used in an outer loop to try to obtain parameters for the the lowest value of the objective function. For these values, one can then use that best ansatz to produce samples of solutions to the problem which obtain a hopefully good approximation for the lowest possible value of the objective function.

2.2.2 Create a circuit on a Grid

To build the above variational quantum algorithm using Cirq, one begins by building the appropriate circuit. In Cirq circuits are represented either by a `Circuit` object or a `Schedule` object. `Schedules` offer more control over quantum gates and circuits at the timing level, which we do not need, so here we will work with `Circuits` instead.

Conceptually: a `Circuit` is a collection of `Moments`. A `Moment` is a collection of `Operations` that all act during the same abstract time slice. An `Operation` is a an effect that operates on a specific subset of `Qubits`. The most common type of `Operation` is a `Gate` applied to several qubits (a `GateOperation`). The following diagram should help illustrate these concepts.



Circuits and Moments

Because the problem we have defined has a natural structure on a grid, we will use Cirq's built in `GridQubits` as our qubits. We will demonstrate some of how this works in an interactive Python environment, the following code can be run in series in a Python environment where you have Cirq installed.

Let's begin by talking about our qubits. In an interactive Python environment run

```
import cirq

# define the length of the grid.
length = 3
# define qubits on the grid.
qubits = [cirq.GridQubit(i, j) for i in range(length) for j in range(length)]
print(qubits)
# prints
# [cirq.GridQubit(0, 0), cirq.GridQubit(0, 1), cirq.GridQubit(0, 2), cirq.GridQubit(1,
↪ 0), cirq.GridQubit(1, 1), cirq.GridQubit(1, 2), cirq.GridQubit(2, 0), cirq.
↪GridQubit(2, 1), cirq.GridQubit(2, 2)]
```

Here we see that we've created a bunch of `GridQubits`. `GridQubits` implement the `QubitId` class, which just means that they are equatable and hashable. `QubitId` has an abstract `_comparison_key` method that must be implemented by child types in order to ensure there's a reasonable sorting order for diagrams and that this matches what happens when `sorted(qubits)` is called.`GridQubits` in addition have a row and column, indicating their position on a grid.

Now that we have some qubits, let us construct a `Circuit` on these qubits. For example, suppose we want to apply the Hadamard gate `H` to every qubit whose row index plus column index is even and an `X` gate to every qubit whose row index plus column index is odd. To do this we write

```
circuit = cirq.Circuit()
circuit.append(cirq.H(q) for q in qubits if (q.row + q.col) % 2 == 0)
circuit.append(cirq.X(q) for q in qubits if (q.row + q.col) % 2 == 1)
print(circuit)
# prints
# (0, 0): ———H———————
#
# (0, 1): ———————X———
#
# (0, 2): ———H———————
#
# (1, 0): ———————X———
#
# (1, 1): ———H———————
#
# (1, 2): ———————X———
#
# (2, 0): ———H———————
#
# (2, 1): ———————X———
#
# (2, 2): ———H———————
```

One thing to notice here. First `cirq.X` is a `Gate` object. There are many different gates supported by Cirq. A good place to look at gates that are defined is in common_gates.py. One common confusion to avoid is the difference between a gate class and a gate object (which is an instantiation of a class). The second is that gate objects are transformed into `Operations` (technically `GateOperations`) via either the method `on(qubit)` or, as we see for the `X` gates, via simply applying the gate to the qubits `(qubit)`. Here we only apply single qubit gates, but a similar pattern applies for multiple qubit gates with a sequence of qubits as parameters.

Another thing one notices about the above circuit is that the circuit has staggered gates. This is because the way in which we have applied the gates has created two `Moments`.

```
for i, m in enumerate(circuit):
    print('Moment {}: {}'.format(i, m))
# prints
# Moment 0: H((0, 0)) and H((0, 2)) and H((1, 1)) and H((2, 0)) and H((2, 2))
# Moment 1: X((0, 1)) and X((1, 0)) and X((1, 2)) and X((2, 1))
```

Here we see that we can iterate over a `Circuit`'s `Moments`. The reason that two `Moments` were created was that the `append` method uses an `InsertStrategy` of `NEW_THEN_INLINE`. `InsertStrategys` describe how new insertions into `Circuits` place their gates. Details of these strategies can be found in the *circuit documentation*. If we wanted to insert the gates so that they form one `Moment`, we could instead use the `EARLIEST` insertion strategy:

```
circuit = cirq.Circuit()
circuit.append([cirq.H(q) for q in qubits if (q.row + q.col) % 2 == 0],
               strategy=cirq.InsertStrategy.EARLIEST)
circuit.append([cirq.X(q) for q in qubits if (q.row + q.col) % 2 == 1],
               strategy=cirq.InsertStrategy.EARLIEST)
print(circuit)
# (0, 0): ———H———
#
# (0, 1): ———X———
#
# (0, 2): ———H———
#
# (1, 0): ———X———
```

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```
#
# (1, 1): ———H———
#
# (1, 2): ———X———
#
# (2, 0): ———H———
#
# (2, 1): ———X———
#
# (2, 2): ———H———
```

We now see that we have only one moment, as the `X` gates have been slid over to act at the earliest `Moment` they can.

2.2.3 Creating the Ansatz

If you look closely at the circuit creation code above you will see that we applied the `append` method to both a `generator` and a `list` (recall that in Python one can use generator comprehensions in method calls). Inspecting the code for append one sees that the append method generally takes an `OP_TREE` (or a `Moment`). What is an `OP_TREE`? It is not a class but a contract. Roughly an `OP_TREE` is anything that can be flattened, perhaps recursively, into a list of operations, or into a single operation. Examples of an `OP_TREE` are

- A single `Operation`.
- A list of `Operations`.
- A tuple of `Operations`.
- A list of a list of `Operationss`.
- A generator yielding `Operations`.

This last case yields a nice pattern for defining sub-circuits / layers: define a function that takes in the relevant parameters and then yields the operations for the sub circuit and then this can be appended to the Circuit:

```
def rot_x_layer(length, half_turns):
    """Yields X rotations by half_turns on a square grid of given length."""
    rot = cirq.XPowGate(exponent=half_turns)
    for i in range(length):
        for j in range(length):
            yield rot(cirq.GridQubit(i, j))

circuit = cirq.Circuit()
circuit.append(rot_x_layer(2, 0.1))
print(circuit)
# prints
# (0, 0): ———X^0.1———
#
# (0, 1): ———X^0.1———
#
# (1, 0): ———X^0.1———
#
# (1, 1): ———X^0.1———
```

Another important concept here is that the rotation gate is specified in “half turns”. For a rotation about X this is the gate cos(half_turns * pi) I + i sin(half_turns * pi) X.

There is a lot of freedom defining a variational ansatz. Here we will do a variation on a QOAO strategy and define an ansatz related to the problem we are trying to solve.

First we need to choose how the instances of the problem are represented. These are the values J and h in the Hamiltonian definition. We will represent these as two dimensional arrays (lists of lists). For J we will use two such lists, one for the row links and one for the column links.

Here is code that we can use to generate random problem instances

```
import random
def rand2d(rows, cols):
    return [[random.choice([+1, -1]) for _ in range(rows)] for _ in range(cols)]

def random_instance(length):
    # transverse field terms
    h = rand2d(length, length)
    # links within a row
    jr = rand2d(length, length - 1)
    # links within a column
    jc = rand2d(length - 1, length)
    return (h, jr, jc)

h, jr, jc = random_instance(3)
print('transverse fields: {}'.format(h))
print('row j fields: {}'.format(jr))
print('column j fields: {}'.format(jc))
# prints something like
# transverse fields: [[-1, 1, -1], [1, -1, -1], [-1, 1, -1]]
# row j fields: [[1, 1, -1], [1, -1, 1]]
# column j fields: [[1, -1], [-1, 1], [-1, 1]]
```

where the actual values will be different for an individual run because they are using `random.choice`.

Given this definition of the problem instance we can now introduce our ansatz. Our ansatz will consist of one step of a circuit made up of

1. Apply an XPowGate for the same parameter for all qubits. This is the method we have written above.
2. Apply a ZPowGate for the same parameter for all qubits where the transverse field term h is +1.

```
def rot_z_layer(h, half_turns):
    """Yields Z rotations by half_turns conditioned on the field h."""
    gate = cirq.ZPowGate(exponent=half_turns)
    for i, h_row in enumerate(h):
        for j, h_ij in enumerate(h_row):
            if h_ij == 1:
                yield gate(cirq.GridQubit(i, j))
```

1. Apply a CZPowGate for the same parameter between all qubits where the coupling field term J is +1. If the field is -1 apply CZPowGate conjugated by X gates on all qubits.

```
def rot_11_layer(jr, jc, half_turns):
    """Yields rotations about |11> conditioned on the jr and jc fields."""
    gate = cirq.CZPowGate(exponent=half_turns)
    for i, jr_row in enumerate(jr):
        for j, jr_ij in enumerate(jr_row):
            if jr_ij == -1:
                yield cirq.X(cirq.GridQubit(i, j))
                yield cirq.X(cirq.GridQubit(i + 1, j))
            yield gate(cirq.GridQubit(i, j),
                       cirq.GridQubit(i + 1, j))
            if jr_ij == -1:
```

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```
                yield cirq.X(cirq.GridQubit(i, j))
                yield cirq.X(cirq.GridQubit(i + 1, j))

    for i, jc_row in enumerate(jc):
        for j, jc_ij in enumerate(jc_row):
            if jc_ij == -1:
                yield cirq.X(cirq.GridQubit(i, j))
                yield cirq.X(cirq.GridQubit(i, j + 1))
            yield gate(cirq.GridQubit(i, j),
                       cirq.GridQubit(i, j + 1))
            if jc_ij == -1:
                yield cirq.X(cirq.GridQubit(i, j))
                yield cirq.X(cirq.GridQubit(i, j + 1))
```

Putting this together we can create a step that uses just three parameters. The code to do this uses the generator for each of the layers (note to advanced Python users that this code is not a bug in using yield due to the auto flattening of the OP_TREE concept. Normally one would want to use `yield from` here, but this is not necessary):

```
def one_step(h, jr, jc, x_half_turns, h_half_turns, j_half_turns):
    length = len(h)
    yield rot_x_layer(length, x_half_turns)
    yield rot_z_layer(h, h_half_turns)
    yield rot_11_layer(jr, jc, j_half_turns)

h, jr, jc = random_instance(3)

circuit = cirq.Circuit()
circuit.append(one_step(h, jr, jc, 0.1, 0.2, 0.3),
               strategy=cirq.InsertStrategy.EARLIEST)
print(circuit)
# prints something like
# (0, 0): ───X^0.
↪1──────────────@───────X────────────────────────────────@───────X──────────────────────────────
#                                  │                                       │
# (0, 1): ───X^0.1───Z^(1/5)──────────@───────────────────────X───────@^0.
↪3───X───X───────@───────X──────────
#                                  │       │                                                    ␣
↪       │
# (0, 2): ───X^0.1───Z^(1/
↪5)─────────────────@───────────────X───────────────────────────@^0.3───X─────────
#                                  │       │       │
# (1, 0): ───X^0.1─────────────@^0.
↪3──────────────────@───────X────────────────────────────@───────X────────
#                                          │       │       │                                    ␣
↪       │
# (1, 1): ───X^0.1───Z^(1/5)───────────@^0.
↪3─────────────────X───────@───────X───X───────@^0.3───X───@──────
#                                                  │       │               │                    ␣
↪                   │
# (1, 2): ───X^0.1───Z^(1/5)───────────────────@^0.
↪3───────────@───────────────────────────────────────@^0.3───
#                                                          │       │       │
# (2, 0): ───X^0.1────────────────────────────────────────@^0.
↪3─────────────────────@───────────────────────────
#                                                                  │       │           │
# (2, 1): ───X^0.1───Z^(1/5)───────────X──────────────────────────────@^0.3───X───@^0.
↪3───@──────────────────
```

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```
#                                                                                 │                 ┐
↪       │
# (2, 2): ———X^0.1———Z^(1/5)———————————————————————————————————————————@^0.
↪3———————————————————————————@^0.3———————————————
```

Here we see that we have chosen particular parameter values (0.1, 0.2, 0.3).

2.2.4 Simulation

Now let's see how to simulate the circuit corresponding to creating our ansatz. In Cirq the simulators make a distinction between a "run" and a "simulation". A "run" only allows for a simulation that mimics the actual quantum hardware. For example, it does not allow for access to the amplitudes of the wave function of the system, since that is not experimentally accessible. "Simulate" commands, however, are more broad and allow different forms of simulation. When prototyping small circuits it is useful to execute "simulate" methods, but one should be wary of relying on them when run against actual hardware.

Currently Cirq ships with a simulator tied strongly to the gate set of the Google xmon architecture. However, for convenience, the simulator attempts to automatically convert unknown operations into XmonGates (as long as the operation specifies a matrix or a decomposition into XmonGates). This can in principle allows us to simulate any circuit that has gates that implement one and two qubit `KnownMatrix` gates. Future releases of Cirq will expand these simulators.

Because the simulator is tied to the xmon gate set, the simulator lives, in contrast to core Cirq, in the `cirq.google` module. To run a simulation of the full circuit we simply create a simulator, and pass the circuit to the simulator.

```
simulator = cirq.google.XmonSimulator()
circuit = cirq.Circuit()
circuit.append(one_step(h, jr, jc, 0.1, 0.2, 0.3))
circuit.append(cirq.measure(*qubits, key='x'))
results = simulator.run(circuit, repetitions=100)
print(results.histogram(key='x'))
# prints something like
# Counter({0: 85, 128: 5, 32: 3, 1: 2, 4: 1, 2: 1, 8: 1, 18: 1, 20: 1})
```

Note that we have run the simulation 100 times and produced a histogram of the counts of the measurement results. What are the keys in the histogram counter? Note that we have passed in the order of the qubits. This ordering is then used to translate the order of the measurement results to a register using a big endian representation.

For our optimization problem we will want to calculate the value of the objective function for a given result run. One way to do this is use the raw measurement data from the result of `simulator.run`. Another way to do this is to provide to the histogram a method to calculate the objective: this will then be used as the key for the returned Counter.

```
import numpy as np

def energy_func(length, h, jr, jc):
    def energy(measurements):
        # Reshape measurement into array that matches grid shape.
        meas_list_of_lists = [measurements[i * length:(i + 1) * length]
                              for i in range(length)]
        # Convert true/false to +1/-1.
        pm_meas = 1 - 2 * np.array(meas_list_of_lists).astype(np.int32)

        tot_energy = np.sum(pm_meas * h)
        for i, jr_row in enumerate(jr):
            for j, jr_ij in enumerate(jr_row):
```

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```
                tot_energy += jr_ij * pm_meas[i, j] * pm_meas[i + 1, j]
        for i, jc_row in enumerate(jc):
            for j, jc_ij in enumerate(jc_row):
                tot_energy += jc_ij * pm_meas[i, j] * pm_meas[i, j + 1]
        return tot_energy
    return energy
print(results.histogram(key='x', fold_func=energy_func(3, h, jr, jc)))
# prints something like
# Counter({7: 79, 5: 12, -1: 4, 1: 3, 13: 1, -3: 1})
```

One can then calculate the expectation value over all repetitions

```
def obj_func(result):
    energy_hist = result.histogram(key='x', fold_func=energy_func(3, h, jr, jc))
    return np.sum([k * v for k,v in energy_hist.items()]) / result.repetitions
print('Value of the objective function {}'.format(obj_func(results)))
# prints something like
# Value of the objective function 6.2
```

2.2.5 Parameterizing the Ansatz

Now that we have constructed a variational ansatz and shown how to simulate it using Cirq, we can now think about optimizing the value. On quantum hardware one would most likely want to have the optimization code as close to the hardware as possible. As the classical hardware that is allowed to inter-operate with the quantum hardware becomes better specified, this language will be better defined. Without this specification, however, Cirq also provides a useful concept for optimizing the looping in many optimization algorithms. This is the fact that many of the value in the gate sets can, instead of being specified by a float, be specified by a `Symbol` and this `Symbol` can be substituted for a value specified at execution time.

Luckily for us, we have written our code so that using parameterized values is as simple as passing `Symbol` objects where we previously passed float values.

```
circuit = cirq.Circuit()
alpha = cirq.Symbol('alpha')
beta = cirq.Symbol('beta')
gamma = cirq.Symbol('gamma')
circuit.append(one_step(h, jr, jc, alpha, beta, gamma))
circuit.append(cirq.measure(*qubits, key='x'))
print(circuit)
# prints something like
# (0, 0): ───X^
↪alpha────────────@────────────────────────────────────────────────────X─────────────@──────────X──
↪'x')───
#                                │                                                                    ␣
↪                          │                                                                    │
# (0, 1): ───X^alpha───Z^
↪beta────────────@───────────────────────────────────────────X─────────────@^
↪gamma───X───X───@─────────X──────────────────────────────────────M────────
#                                │         │                                                          ␣
↪                                  │                                                                    │
# (0, 2): ───X^alpha───Z^
↪beta─────────────────────@─────────────────────────────────────────────────────────────X───@^
↪gamma───X──────────────────────────────────M───────
#                                │         │         │                                                ␣
↪                                                                                                    │
```

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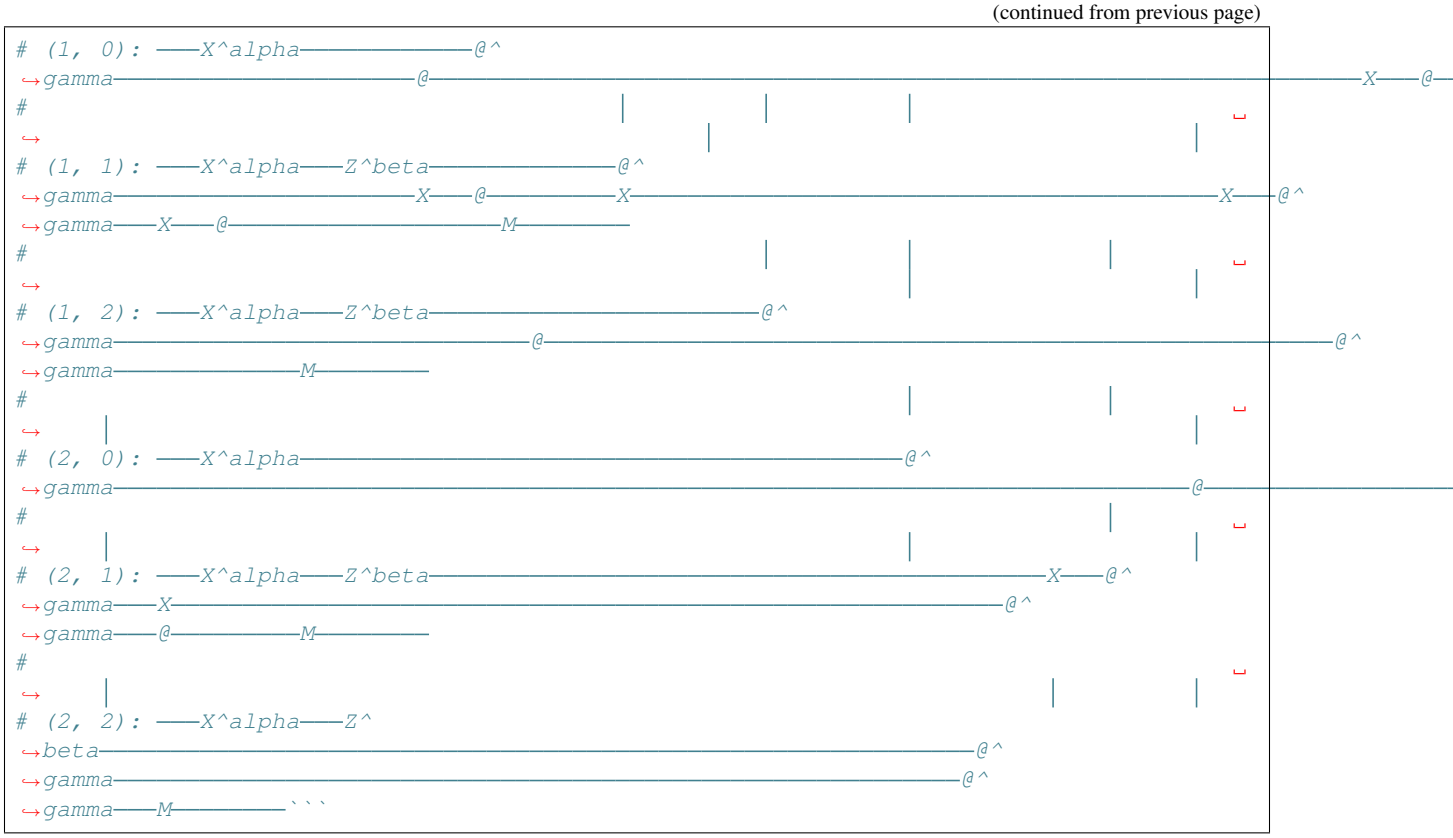

Note now that the circuit's gates are parameterized.

Parameters are specified at runtime using a `ParamResolver` which is which is just a dictionary from `Symbol` keys to runtime values. For example,

```
resolver = cirq.ParamResolver({'alpha': 0.1, 'beta': 0.3, 'gamma': 0.7})
resolved_circuit = cirq.resolve_parameters(circuit, resolver)
```

resolves the parameters to actual values in the above circuit.

More usefully, Cirq also has the concept of a "sweep". A sweep is essentially a collection of parameter resolvers. This runtime information is very useful when one wants to run many circuits for many different parameter values. Sweeps can be created to specify values directly (this is one way to get classical information into a circuit), or a variety of helper methods. For example suppose we want to evaluate our circuit over an equally spaced grid of parameter values. We can easily create this using `LinSpace`.

```
sweep = (cirq.Linspace(key='alpha', start=0.1, stop=0.9, length=5)
         * cirq.Linspace(key='beta', start=0.1, stop=0.9, length=5)
         * cirq.Linspace(key='gamma', start=0.1, stop=0.9, length=5))
results = simulator.run_sweep(circuit, params=sweep, repetitions=100)
for result in results:
    print(result.params.param_dict, obj_func(result))
# prints something like
# OrderedDict([('alpha', 0.1), ('beta', 0.1), ('gamma', 0.1)]) 6.42
# OrderedDict([('alpha', 0.1), ('beta', 0.1), ('gamma', 0.30000000000000004)]) 6.48
# OrderedDict([('alpha', 0.1), ('beta', 0.1), ('gamma', 0.5)]) 6.44
# OrderedDict([('alpha', 0.1), ('beta', 0.1), ('gamma', 0.7000000000000001)]) 6.58
# OrderedDict([('alpha', 0.1), ('beta', 0.1), ('gamma', 0.9)]) 6.58
...
```

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```
# OrderedDict([('alpha', 0.9), ('beta', 0.9), ('gamma', 0.70000000000000001)]) 0.76
# OrderedDict([('alpha', 0.9), ('beta', 0.9), ('gamma', 0.9)]) 0.94```
```

2.2.6 Finding the Minimum

Now we have all the code to we need to do a simple grid search over values to find a minimal value. Grid search is most definitely not the best optimization algorithm, but is here simply illustrative.

```
sweep_size = 10
sweep = (cirq.Linspace(key='alpha', start=0.0, stop=1.0, length=10)
         * cirq.Linspace(key='beta', start=0.0, stop=1.0, length=10)
         * cirq.Linspace(key='gamma', start=0.0, stop=1.0, length=10))
results = simulator.run_sweep(circuit, params=sweep, repetitions=100)

min = None
min_params = None
for result in results:
    value = obj_func(result)
    if min is None or value < min:
        min = value
        min_params = result.params
print('Minimum objective value is {}.'.format(min))
# prints something like
# Minimum objective value is -1.42.
```

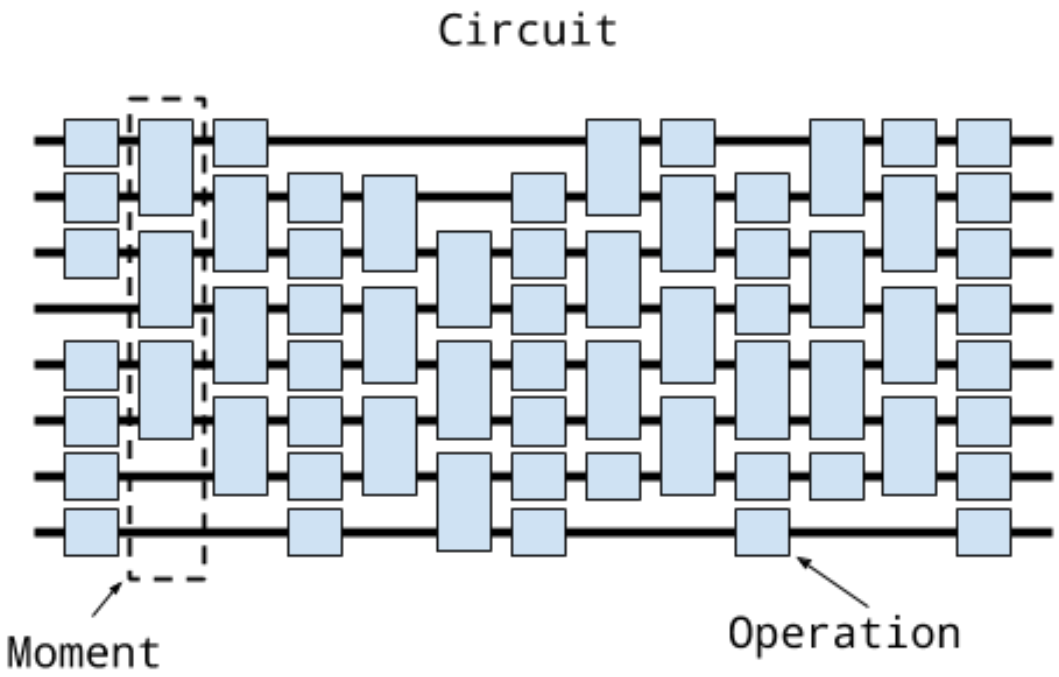
We've created a simple variational quantum algorithm using Cirq. Where to go next? Perhaps you can play around with the above code and work on analyzing the algorithms performance. Add new parameterized circuits and build an end to end program for analyzing these circuits.

2.3 Circuits

2.3.1 Conceptual overview

There are two primary representations of quantum programs in Cirq, each of which are represented by a class: `Circuit` and `Schedule`. Conceptually a Circuit object is very closely related to the abstract quantum circuit model, while a Schedule object is like the abstract quantum circuit model but includes detailed timing information.

Conceptually: a `Circuit` is a collection of `Moments`. A `Moment` is a collection of `Operations` that all act during the same abstract time slice. An `Operation` is a some effect that operates on a specific subset of `Qubits`, the most common type of `Operation` is a `GateOperation`.



Circuits and Moments Let's unpack this.

At the base of this construction is the notion of a qubit. In Cirq, qubits are represented by subclasses of the `QubitId` base class. Different subclasses of `QubitId` can be used for different purposes. For example the qubits that Google's Xmon devices use are often arranged on the vertices of a square grid. For this the class `GridQubit` subclasses `QubitId`. For example, we can create a 3 by 3 grid of qubits using

```
qubits = [cirq.GridQubit(x, y) for x in range(3) for y in range(3)]

print(qubits[0])
# prints "(0, 0)"
```

The next level up conceptually is the notion of a `Gate`. A `Gate` represents a physical process that occurs on a `Qubit`. The important property of a `Gate` is that it can be applied *on* to one or more qubits. This can be done via the `Gate.on` method itself or via `()` and doing this turns the `Gate` into a `GateOperation`.

```
# This is an Pauli X gate. It is an object instance.
x_gate = cirq.X
# Applying it to the qubit at location (0, 0) (defined above)
# turns it into an operation.
x_op = x_gate(qubits[0])

print(x_op)
# prints "X((0, 0))"
```

A `Moment` is quite simply a collection of operations, each of which operates on a different set of qubits, and which conceptually represents these operations as occurring during this abstract time slice. The `Moment` structure itself is not required to be related to the actual scheduling of the operations on a quantum computer, or via a simulator, though it can be. For example, here is a Moment in which Pauli X and a CZ gate operate on three qubits:

```
cz = cirq.CZ(qubits[0], qubits[1])
x = cirq.X(qubits[2])
moment = cirq.Moment([x, cz])

print(moment)
# prints "X((0, 2)) and CZ((0, 0), (0, 1))"
```

Note that is not the only way to construct moments, nor even the typical method, but illustrates that a `Moment` is just a collection of operations on disjoint sets of qubits.

Finally at the top level a `Circuit` is an ordered series of `Moments`. The first `Moment` in this series is, conceptually, contains the first `Operations` that will be applied. Here, for example, is a simple circuit made up of two moments

```
cz01 = cirq.CZ(qubits[0], qubits[1])
x2 = cirq.X(qubits[2])
cz12 = cirq.CZ(qubits[1], qubits[2])
moment0 = cirq.Moment([cz01, x2])
moment1 = cirq.Moment([cz12])
circuit = cirq.Circuit((moment0, moment1))

print(circuit)
# prints the text diagram for the circuit:
# (0, 0): ———@———————
#            │
# (0, 1): ———@———@———
#                  │
# (0, 2): ———X———@———
```

Again, note that this is only one way to construct a `Circuit` but illustrates the concept that a `Circuit` is an iterable of `Moments`.

2.3.2 Constructing circuits

Constructing `Circuits` as a series of `Moments` with each `Moment` being hand-crafted is tedious. Instead we provide a variety of different manners to create a `Circuit`.

One of the most useful ways to construct a `Circuit` is by appending onto the `Circuit` with the `Circuit.append` method.

```
from cirq.ops import CZ, H
q0, q1, q2 = [cirq.GridQubit(i, 0) for i in range(3)]
circuit = cirq.Circuit()
circuit.append([CZ(q0, q1), H(q2)])

print(circuit)
# prints
# (0, 0): ———@———
#            │
# (1, 0): ———@———
#
# (2, 0): ———H———
```

This appended an entire new moment to the qubit, which we can continue to do,

```
circuit.append([H(q0), CZ(q1, q2)])
```

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```
print(circuit)
# prints
# (0, 0): ———@———H———
#            |
# (1, 0): ———@———@———
#                  |
# (2, 0): ———H———@———
```

In these two examples, we have appending full moments, what happens when we append all of these at once?

```
circuit = cirq.Circuit()
circuit.append([CZ(q0, q1), H(q2), H(q0), CZ(q1, q2)])

print(circuit)
# prints
# (0, 0): ———@———H———
#            |
# (1, 0): ———@———@———
#                  |
# (2, 0): ———H———@———
```

We see that here we have again created two `Moments`. How did `Circuit` know how to do this? `Circuit's` `Circuit.append` method (and its cousin `Circuit.insert`) both take an argument called the `InsertStrategy`. By default the `InsertStrategy` is `InsertStrategy.NEW_THEN_INLINE`.

2.3.3 InsertStrategies

`InsertStrategy` defines how `Operations` are placed in a `Circuit` when requested to be inserted at a given location. Here a `location` is identified by the index of the `Moment` (in the `Circuit`) where the insertion is requested to be placed at (in the case of `Circuit.append` this means inserting at the `Moment` at an index one greater than the maximum moment index in the `Circuit`). There are four such strategies: `InsertStrategy.EARLIEST`, `InsertStrategy.NEW`, `InsertStrategy.INLINE` and `InsertStrategy.NEW_THEN_INLINE`.

`InsertStrategy.EARLIEST` is defined as

> `InsertStrategy.EARLIEST`: Scans backward from the insert location until a moment with operations touching qubits affected by the operation to insert is found. The operation is added into the moment just after that location.

For example, if we first create an `Operation` in a single moment, and then use `InsertStrategy.EARLIEST` the `Operation` can slide back to this first `Moment` if there is space:

```
from cirq.circuits import InsertStrategy
circuit = cirq.Circuit()
circuit.append([CZ(q0, q1)])
circuit.append([H(q0), H(q2)], strategy=InsertStrategy.EARLIEST)

print(circuit)
# prints
# (0, 0): ———@———H———
#            |
# (1, 0): ———@———————
#
# (2, 0): ———H———————
```

After creating the first moment with a `CZ` gate, the second append uses the `InsertStrategy.EARLIEST` strategy. The `H` on `q0` cannot slide back, while the `H` on `q2` can and so ends up in the first `Moment`.

Contrast this with the `InsertStrategy.NEW` `InsertStrategy`:

> `InsertStrategy.NEW`: Every operation that is inserted is created in a new moment.

```
circuit = cirq.Circuit()
circuit.append([H(q0), H(q1), H(q2)], strategy=InsertStrategy.NEW)

print(circuit)
# prints
# (0, 0): ———H———————————
#
# (1, 0): ———————H———————
#
# (2, 0): ———————————H———
```

Here every operator processed by the append ends up in a new moment. `InsertStrategy.NEW` is most useful when you are inserting a single operation and don't want it to interfere with other `Moments`.

Another strategy is `InsertStrategy.INLINE`:

> `InsertStrategy.INLINE`: Attempts to add the operation to insert into the moment just before the desired insert location. But, if there's already an existing operation affecting any of the qubits touched by the operation to insert, a new moment is created instead.

```
circuit = cirq.Circuit()
circuit.append([CZ(q1, q2)])
circuit.append([CZ(q1, q2)])
circuit.append([H(q0), H(q1), H(q2)], strategy=InsertStrategy.INLINE)

print(circuit)
# prints
# (0, 0): ———————H———————
#
# (1, 0): ———@———@———H———
#           |   |
# (2, 0): ———@———@———H———
```

After two initial `CZ` between the second and third qubit, we try to insert 3 `H Operations`. We see that the `H` on the first qubit is inserted into the previous `Moment`, but the `H` on the second and third qubits cannot be inserted into the previous `Moment`, so a new `Moment` is created.

Finally we turn to the default strategy:

> `InsertStrategy.NEW_THEN_INLINE`: Creates a new moment at the desired insert location for the first operation, but then switches to inserting operations according to `InsertStrategy.INLINE`.

```
circuit = cirq.Circuit()
circuit.append([H(q0)])
circuit.append([CZ(q1,q2), H(q0)], strategy=InsertStrategy.NEW_THEN_INLINE)

print(circuit)
# prints
# (0, 0): ———H———H———
#
# (1, 0): ———————@———
#               |
# (2, 0): ———————@———
```

The first append creates a single moment with a H on the first qubit. Then the append with the InsertStrategy.NEW_THEN_INLINE strategy begins by inserting the CZ in a new Moment (the InsertStrategy.NEW in InsertStrategy.NEW_THEN_INLINE). Subsequent appending is done InsertStrategy.INLINE so the next H on the first qubit is appending in the just created Moment.

Here is a helpful diagram for the different InsertStrategies.

TODO(dabacon): diagram.

2.3.4 Patterns for Arguments to Append and Insert

Above we have used a series of Circuit.append calls with a list of different Operations we are adding to the circuit. But the argument where we have supplied a list can also take more than just list values.

Example:

```
def my_layer():
    yield CZ(q0, q1)
    yield [H(q) for q in (q0, q1, q2)]
    yield [CZ(q1, q2)]
    yield [H(q0), [CZ(q1, q2)]]

circuit = cirq.Circuit()
circuit.append(my_layer())

for x in my_layer():
    print(x)
# prints
# CZ((0, 0), (1, 0))
# [cirq.H.on(cirq.GridQubit(0, 0)), cirq.H.on(cirq.GridQubit(1, 0)), cirq.H.on(cirq.
↪GridQubit(2, 0))]
# [cirq.CZ.on(cirq.GridQubit(1, 0), cirq.GridQubit(2, 0))]
# [cirq.H.on(cirq.GridQubit(0, 0)), [cirq.CZ.on(cirq.GridQubit(1, 0), cirq.
↪GridQubit(2, 0))]]

print(circuit)
# prints
# (0, 0): ———@———H———H———————
#             │
# (1, 0): ———@———H———@———@———
#                   │   │
# (2, 0): ———————H———@———@———
```

Recall that in Python functions that have a yield are *generators*. Generators are functions that act as *iterators*. Above we see that we can iterate over my_layer(). We see that when we do this each of the yields produces what was yielded, and here these are Operations, lists of Operations or lists of Operations mixed with lists of Operations. But when we pass this iterator to the append method, something magical happens. Circuit is able to flatten all of these an pass them as one giant list to Circuit.append (this also works for Circuit.insert).

> The above idea uses a concept we call an OP_TREE. An OP_TREE is not a class, but a contract. The basic idea is that, if the input can be iteratively flattened into a list of operations, then the input is an OP_TREE.

A very nice pattern emerges from this structure: define *generators* for sub-circuits, which can vary by size or Operation parameters.

Another useful method is to construct a Circuit fully formed from an OP_TREE via the static method Circuit.from_ops (which takes an insertion strategy as a parameter):

```
circuit = cirq.Circuit.from_ops(H(q0), H(q1))
print(circuit)
# prints
# (0, 0): ———H———
#
# (1, 0): ———H———
```

2.3.5 Slicing and Iterating over Circuits

`Circuits` can be iterated over and sliced. When they are iterated over each item in the iteration is a moment:

```
circuit = cirq.Circuit.from_ops(H(q0), CZ(q0, q1))
for moment in circuit:
    print(moment)
# prints
# H((0, 0))
# CZ((0, 0), (1, 0))
```

Slicing a `Circuit` on the other hand, produces a new `Circuit` with only the moments corresponding to the slice:

```
circuit = cirq.Circuit.from_ops(H(q0), CZ(q0, q1), H(q1), CZ(q0, q1))
print(circuit[1:3])
# prints
# (0, 0): ———@———————
#            |
# (1, 0): ———@———H———
```

Especially useful is dropping the last moment (which are often just measurements): `circuit[:-1]`, or reversing a circuit: `circuit[::-1]`.

2.4 Gates

A `Gate` is an operation that can be applied to a collection of qubits (objects with a `QubitId`). `Gates` can be applied to qubits by calling their `on` method, or, alternatively calling the gate on the qubits. The object created by such calls is an `Operation`.

```
from cirq.ops import CNOT
from cirq.devices import GridQubit
q0, q1 = (GridQubit(0, 0), GridQubit(0, 1))
print(CNOT.on(q0, q1))
print(CNOT(q0, q1))
# prints
# CNOT((0, 0), (0, 1))
# CNOT((0, 0), (0, 1))
```

2.4.1 Magic Methods

A class that implements `Gate` can be applied to qubits to produce an `Operation`. In order to support functionality beyond that basic task, it is necessary to implement several *magic methods*.

Standard magic methods in python are `__add__`, `__eq__`, and `__len__`. Cirq defines several additional magic methods, for functionality such as parameterization, diagramming, and simulation. For example, if a gate specifies a

unitary method that returns a matrix for the gate, then simulators will be able to simulate applying the gate. Or, if a gate specifies a __pow__ method that works for an exponent of -1, then `cirq.inverse` will start to work on lists including the gate.

We describe some magic methods below.

`cirq.inverse` and `__pow__`

Gates and operations are considered to be *invertable* when they implement a __pow__ method that returns a result besides `NotImplemented` for an exponent of -1. This inverse can be accessed either directly as `value**-1`, or via the utility method `cirq.inverse(value)`. If you are sure that `value` has an inverse, saying `value**-1` is more convenient than saying `cirq.inverse(value)`. `cirq.inverse` is for cases where you aren't sure if `value` is invertable, or where `value` might be a *sequence* of invertible operations.

`cirq.inverse` has a `default` parameter used as a fallback when `value` isn't invertable. For example, `cirq.inverse(value, default=None)` returns the inverse of `value`, or else returns `None` if `value` isn't invertable. (If no `default` is specified and `value` isn't invertible, a `TypeError` is raised.)

When you give `cirq.inverse` a list, or any other kind of iterable thing, it will return a sequence of operations that (if run in order) undoes the operations of the original sequence (if run in order). Basically, the items of the list are individually inverted and returned in reverse order. For example, the expression `cirq.inverse([cirq.S(b), cirq.CNOT(a, b)])` will return the tuple `(cirq.CNOT(a, b), cirq.S(b)**-1)`.

Gates and operations can also return values beside `NotImplemented` from their __pow__ method for exponents besides `-1`. This pattern is used often by Cirq. For example, the square root of X gate can be created by raising `cirq.X` to 0.5:

```
import cirq
print(cirq.unitary(cirq.X))
# prints
# [[0.+0.j 1.+0.j]
#  [1.+0.j 0.+0.j]]

sqrt_x = cirq.X**0.5
print(cirq.unitary(sqrt_x))
# prints
# [[0.5+0.5j 0.5-0.5j]
#  [0.5-0.5j 0.5+0.5j]]
```

The Pauli gates included in Cirq use the convention `Z**0.5  S  np.diag(1, i)`, `Z**-0.5  S**-1`, `X**0.5  H·S·H`, and the square root of `Y` is inferred via the right hand rule.

`cirq.unitary` and `def _unitary_`

When objects can be described by a unitary matrix, they let `Cirq` know by implementing the `_unitary_` method. This method should return a numpy `ndarray` matrix and this array should be the unitary matrix corresponding to the object. The method may also return `NotImplemented`, in which case `cirq.unitary` behaves as if the method is not implemented.

`cirq.decompose` and `def _decompose_`

A `cirq.Operation` indicates that it can be broken down into smaller simpler operations by implementing a `def _decompose_(self):` method. Code that doesn't understand a particular operation can call `cirq.decompose_once` or `cirq.decompose` on that operation in order to get a set of simpler operations that it does understand.

One useful thing about `cirq.decompose` is that it will decompose *recursively*, until only operations meeting a `keep` predicate remain. You can also give an `intercepting_decomposer` to `cirq.decompose`, which will take priority over operations' own decompositions.

For `cirq.Gates`, the decompose method is slightly different; it takes qubits: `def _decompose_(self, qubits)`. Callers who know the qubits that the gate is being applied to will use `cirq.decompose_once_with_qubits` to trigger this method.

`_circuit_diagram_info_(self, args)` and `cirq.circuit_diagram_info(val, [args], [default])`

Circuit diagrams are useful for visualizing the structure of a `Circuit`. Gates can specify compact representations to use in diagrams by implementing a `_circuit_diagram_info_` method. For example, this is why SWAP gates are shown as linked '×' characters in diagrams.

The `_circuit_diagram_info_` method takes an `args` parameter of type `cirq.CircuitDiagramInfoArgs` and returns either a string (typically the gate's name), a sequence of strings (a label to use on each qubit targeted by the gate), or an instance of `cirq.CircuitDiagramInfo` (which can specify more advanced properties such as exponents and will expand in the future).

You can query the circuit diagram info of a value by passing it into `cirq.circuit_diagram_info`.

2.4.2 Xmon gates

Google's Xmon devices support a specific gate set. Gates in this gate set operate on `GridQubits`, which are qubits arranged on a square grid and which have an `x` and `y` coordinate.

The native Xmon gates are

cirq.PhasedXPowGate This gate is a rotation about an axis in the XY plane of the Bloch sphere. The `PhasedXPowGate` takes two parameters, `exponent` and `phase_exponent`. The gate is equivalent to the circuit `——Z^-p——X^t——Z^p——` where `p` is the `phase_exponent` and `t` is the `exponent`.

cirq.Z / cirq.Rz Rotations about the Pauli `Z` axis. The matrix of `cirq.Z**t` is `exp(i pi |1><1| t)` whereas the matrix of `cirq.Rz(`θ`)` is `exp(-i Z `θ`/2)`. Note that in quantum computing hardware, this gate is often implemented in the classical control hardware as a phase change on later operations, instead of as a physical modification applied to the qubits. (TODO: explain this in more detail)

cirq.CZ The controlled-Z gate. A two qubit gate that phases the `|11>` state. The matrix of `cirq.CZ**t` is `exp(i pi |11><11| t)`.

cirq.MeasurementGate This is a single qubit measurement in the computational basis.

2.4.3 Other Common Gates

Cirq comes with a number of common named gates:

CNOT the controlled-X gate

SWAP the swap gate

H the Hadamard gate

S the square root of Z gate

and our error correcting friend the **T** gate

TODO: describe these in more detail.

2.5 Simulation

Cirq comes with built in Python simulators for testing out small circuits. One of these simulators works for generic gates that implement their unitary matrix, `cirq.Simulator`. The other simulator is customized for the native gate set of Google's Xmon hardware `cirq.google.XmonSimulator`. This later simulator can shard its simulation across different processes/threads and so take advantage of multiple cores/CPUs. Depending on your local computer architecture one or the other of these may be faster, but we recommend starting with `cirq.Simulator`.

Here is a simple circuit

```
import cirq

q0 = cirq.GridQubit(0, 0)
q1 = cirq.GridQubit(1, 0)

def basic_circuit(meas=True):
    sqrt_x = cirq.X**0.5
    yield sqrt_x(q0), sqrt_x(q1)
    yield cirq.CZ(q0, q1)
    yield sqrt_x(q0), sqrt_x(q1)
    if meas:
        yield cirq.measure(q0, key='q0'), cirq.measure(q1, key='q1')

circuit = cirq.Circuit()
circuit.append(basic_circuit())

print(circuit)
# prints
# (0, 0): ———X^0.5———@———X^0.5———M('q0')———
#                     |
# (1, 0): ———X^0.5———@———X^0.5———M('q1')———
```

We can simulate this by creating a `cirq.Simulator` and passing the circuit into its `run` method:

```
from cirq import Simulator
simulator = Simulator()
result = simulator.run(circuit)

print(result)
# prints something like
# q0=1 q1=1
```

Run returns an `TrialResult`. As you can see the result contains the result of any measurements for the simulation run.

The actual measurement results here depend on the seeding `numpy`s random seed generator. (You can set this using `numpy.random_seed`) Another run, can result in a different set of measurement results:

```
result = simulator.run(circuit)

print(result)
# prints something like
# q0=1 q1=0
```

The simulator is designed to mimic what running a program on a quantum computer is actually like. In particular the `run` methods (`run` and `run_sweep`) on the simulator do not give access to the wave function of the quantum computer (since one doesn't have access to this on the actual quantum hardware). Instead the `simulate` methods

(simulate, simulate_sweep, simulate_moment_steps) should be used if one wants to debug the circuit and get access to the full wave function:

```
import numpy as np
circuit = cirq.Circuit()
circuit.append(basic_circuit(False))
result = simulator.simulate(circuit, qubit_order=[q0, q1])

print(np.around(result.final_state, 3))
# prints
# [0.5+0.j 0. +0.5j 0. +0.5j 0.5+0.j]
```

Note that the simulator uses numpy's float32 precision (which is complex64 for complex numbers) by default, but that the simulator can take in a a dtype of np.complex128 if higher precision is needed.

2.5.1 Qubit and Amplitude Ordering

The qubit_order argument to the simulator's run method determines the ordering of some results, such as the amplitudes in the final wave function. The qubit_order argument is optional. When it is omitted, qubits are ordered ascending by their name (i.e. what their __str__ method returns).

The simplest qubit_order value you can provide is a list of the qubits in the desired ordered. Any qubits from the circuit that are not in the list will be ordered using the default __str__ ordering, but come after qubits that are in the list. Be aware that all qubits in the list are included in the simulation, even if they are not operated on by the circuit.

The mapping from the order of the qubits to the order of the amplitudes in the wave function can be tricky to understand. Basically, it is the same as the ordering used by numpy.kron:

```
outside = [1, 10]
inside = [1, 2]
print(np.kron(outside, inside))
# prints
# [ 1  2 10 20]
```

More concretely, the k'th amplitude in the wave function will correspond to the k'th case that would be encountered when nesting loops over the possible values of each qubit. The first qubit's computational basis values are looped over in the outermost loop, the last qubit's computational basis values are looped over in the inner-most loop, etc:

```
i = 0
for first in [0, 1]:
    for second in [0, 1]:
        print('amps[{}] is for first={}, second={}'.format(i, first, second))
        i += 1
# prints
# amps[0] is for first=0, second=0
# amps[1] is for first=0, second=1
# amps[2] is for first=1, second=0
# amps[3] is for first=1, second=1
```

We can check that this is in fact the ordering with a circuit that flips one qubit out of two:

```
q_stay = cirq.NamedQubit('q_stay')
q_flip = cirq.NamedQubit('q_flip')
c = cirq.Circuit.from_ops(cirq.X(q_flip))

# first qubit in order flipped
```

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```
result = simulator.simulate(c, qubit_order=[q_flip, q_stay])
print(abs(result.final_state).round(3))
# prints
# [0. 0. 1. 0.]

# second qubit in order flipped
result = simulator.simulate(c, qubit_order=[q_stay, q_flip])
print(abs(result.final_state).round(3))
# prints
# [0. 1. 0. 0.]
```

2.5.2 Stepping through a Circuit

Often when debugging it is useful to not just see the end result of a circuit, but to inspect, or even modify, the state of the system at different steps in the circuit. To support this Cirq provides a method to return an iterator over a `Moment` by `Moment` simulation. This is the method `simulate_moment_steps`:

```
circuit = cirq.Circuit()
circuit.append(basic_circuit())
for i, step in enumerate(simulator.simulate_moment_steps(circuit)):
    print('state at step %d: %s' % (i, np.around(step.state(), 3)))
# prints something like
# state at step 0: [ 0.5+0.j   0.0+0.5j  0.0+0.5j -0.5+0.j ]
# state at step 1: [ 0.5+0.j   0.0+0.5j  0.0+0.5j  0.5+0.j ]
# state at step 2: [-0.5-0.j  -0.0+0.5j -0.0+0.5j -0.5+0.j ]
# state at step 3: [ 0.+0.j  0.+0.j -0.+1.j  0.+0.j]
```

The object returned by the `moment_steps` iterator is a `StepResult`. This object has the state along with any measurements that occurred **during** that step (so does not include measurement results from previous `Moments`). In addition, the `StepResult` contains `set_state()` which can be used to set the `state`. One can pass a valid full state to this method by passing a numpy array. Or alternatively one can pass an integer and then the state will be set lie entirely in the computation basis state for the binary expansion of the passed integer.

2.5.3 XmonSimulator

In addition to `cirq.Simulator` there is also a simulator which is specialized to the Google native gate set. In particular this simulator is specialized to use the `CZPowGate`, `MeasurementGate`, `PhasedXPowGate`, `XPowGate`, `YPowGate`, and the `ZPowGate`. This simulator can be configured to use processes or threads, and depending on your local computing architecture may sometimes be faster or slower that `cirq.Simulator`.

2.5.4 Gate sets

The `XmonSimulator` is designed to work with operations that are either a `GateOperation` applying a supported gate (such as `cirq.CZ`), a composite operation that implements `_decompose_`, or a 1-qubit or 2-qubit operation that returns a unitary matrix from its `_unitary_` method.

So if you are implementing a custom gate, there are two options for getting it to work with the simulator:

- Implement a `_decompose_` method that returns supported gates (or gates that decompose into supported gates).
- If the operation applies to two or fewer qubits, implement a `_unitary_` method that returns the operation's matrix.

2.5.5 Parameterized Values and Studies

In addition to circuit gates with fixed values, Cirq also supports gates which can have `Symbol` value (see *Gates*). These are values that can be resolved at *run-time*. For simulators these values are resolved by providing a `ParamResolver`. A `ParamResolver` provides a map from the `Symbol`'s name to its assigned value.

```
rot_w_gate = cirq.X**cirq.Symbol('x')
circuit = cirq.Circuit()
circuit.append([rot_w_gate(q0), rot_w_gate(q1)])
for y in range(5):
    resolver = cirq.ParamResolver({'x': y / 4.0})
    result = simulator.simulate(circuit, resolver)
    print(np.round(result.final_state, 2))
# prints something like
# [1.  +0.j  0.+0.j   0.+0.j    0.  +0.j]
# [0.85+0.j  0.-0.35j 0.-0.35j -0.15+0.j]
# [0.5 +0.j  0.-0.5j  0.-0.5j  -0.5 +0.j]
# [0.15+0.j  0.-0.35j 0.-0.35j -0.85+0.j]
# [0.  +0.j  0.-0.j   0.-0.j   -1.  +0.j]
```

Here we see that the `Symbol` is used in two gates, and then the resolver provide this value at run time.

Parameterized values are most useful in defining what we call a `Study`. A `Study` is a collection of trials, where each trial is a run with a particular set of configurations and which may be run repeatedly. Running a study returns one `TrialContext` and `TrialResult` per set of fixed parameter values and repetitions (which are reported as the `repetition_id` in the `TrialContext` object). Example:

```
resolvers = [cirq.ParamResolver({'x': y / 2.0}) for y in range(3)]
circuit = cirq.Circuit()
circuit.append([rot_w_gate(q0), rot_w_gate(q1)])
circuit.append([cirq.measure(q0, key='q0'), cirq.measure(q1, key='q1')])
results = simulator.run_sweep(program=circuit,
                              params=resolvers,
                              repetitions=2)
for result in results:
    print(result)
# prints something like
# repetition_id=0 x=0.0 q0=0 q1=0
# repetition_id=1 x=0.0 q0=0 q1=0
# repetition_id=0 x=0.5 q0=0 q1=1
# repetition_id=1 x=0.5 q0=1 q1=1
# repetition_id=0 x=1.0 q0=1 q1=1
# repetition_id=1 x=1.0 q0=1 q1=1
```

where we see that different repetitions for the case that the qubit has been rotated into a superposition over computational basis states yield different measurement results per run. Also note that we now see the use of the `TrialContext` returned as the first tuple from `run`: it contains the `param_dict` describing what values were actually used in resolving the `Symbols`.

TODO(dabacon): Describe the iterable of parameterized resolvers supported by Google's API.

2.5.6 XmonSimulator Configurations and Options

The xmon simulator also contain some extra configuration on the simulate commands. One of these is `initial_state`.This can be passed the full wave function as a numpy array, or the initial state as the binary expansion of a supplied integer (following the order supplied by the qubits list).

A simulator itself can also be passed `Options` in it's constructor. These options define some configuration for how the simulator runs. For the xmon simulator, these include

num_shards: The simulator works by sharding the wave function over this many shards. If this is not a power of two, the smallest power of two less than or equal to this number will be used. The sharding shards on the first log base 2 of this number qubit's state. When this is not set the simulator will use the number of cpus, which tends to max out the benefit of multi-processing.

min_qubits_before_shard: Sharding and multiprocessing does not really help for very few number of qubits, and in fact can hurt because processes have a fixed (large) cost in Python. This is the minimum number of qubits that are needed before the simulator starts to do sharding. By default this is 10.

2.6 Schedules and Devices

`Schedule` and `Circuit` are the two major container classes for quantum circuits. In contrast to `Circuit`, a `Schedule` includes detailed information about the timing and duration of the gates.

Conceptually a `Schedule` is made up of a set of `ScheduledOperations` as well as a description of the `Device` on which the schedule is intended to be run. Each `ScheduledOperation` is made up of a `time` when the operation starts and a `duration` describing how long the operation takes, in addition to the `Operation` itself (like in a `Circuit` an `Operation` is made up of a `Gate` and the `QubitIds` upon which the gate acts.)

2.6.1 Devices

The `Device` class is an abstract class which encapsulates constraints (or lack thereof) that come when running a circuit on actual hardware. For instance, most hardware only allows certain gates to be enacted on qubits. Or, as another example, some gates may be constrained to not be able to run at the same time as neighboring gates. Further the `Device` class knows more about the scheduling of `Operations`.

Here for example is a `Device` made up of 10 qubits on a line:

```
import cirq
from cirq.devices import GridQubit
class Xmon10Device(cirq.Device):

  def __init__(self):
      self.qubits = [GridQubit(i, 0) for i in range(10)]

  def duration_of(self, operation):
      # Wouldn't it be nice if everything took 10ns?
      return cirq.Duration(nanos=10)

  def validate_operation(self, operation):
      if not isinstance(operation, cirq.GateOperation):
          raise ValueError('{!r} is not a supported operation'.format(operation))
      if not isinstance(operation.gate, (cirq.CZPowGate,
                                         cirq.XPowGate,
                                         cirq.PhasedXPowGate,
                                         cirq.YPowGate)):
          raise ValueError('{!r} is not a supported gate'.format(operation.gate))
      if len(operation.qubits) == 2:
          p, q = operation.qubits
          if not p.is_adjacent(q):
            raise ValueError('Non-local interaction: {}'.format(repr(operation)))
```

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```
  def validate_scheduled_operation(self, schedule, scheduled_operation):
      self.validate_operation(scheduled_operation.operation)

  def validate_circuit(self, circuit):
      for moment in circuit:
          for operation in moment.operations:
              self.validate_operation(operation)

  def validate_schedule(self, schedule):
      for scheduled_operation in schedule.scheduled_operations:
          self.validate_scheduled_operation(schedule, scheduled_operation)
```

This device, for example, knows that two qubit gates between next-nearest-neighbors is not valid:

```
device = Xmon10Device()
circuit = cirq.Circuit()
circuit.append([cirq.CZ(device.qubits[0], device.qubits[2])])
try:
  device.validate_circuit(circuit)
except ValueError as e:
  print(e)
# prints something like
# ValueError: Non-local interaction: Operation(cirq.CZ, (GridQubit(0, 0), GridQubit(2,
↪ 0)))
```

2.6.2 Schedules

A `Schedule` contains more timing information above and beyond that which is provided by the `Moment` structure of a `Circuit`. This can be used both for fine grained timing control, but also to optimize a circuit for a particular device. One can work directly with `Schedules` or, more common, use a custom scheduler that converts a `Circuit` to a `Schedule`. A simple example of such a scheduler is the `moment_by_moment_schedule` method of `schedulers.py`. This scheduler attempts to keep the `Moment` structure of the underlying `Circuit` as much as possible: each `Operation` in a `Moment` is scheduled to start at the same time (such a schedule may not be possible, in which case this method raises an exception.)

Here, for example, is a simple `Circuit` on the `Xmon10Device` defined above

```
circuit = cirq.Circuit()
circuit.append([cirq.CZ(device.qubits[0], device.qubits[1]), cirq.X(device.
↪qubits[0])])
print(circuit)
# prints:
# (0, 0): ———@———X———
#             │
# (1, 0): ———@———————
```

This can be converted over into a schedule using the moment by moment schedule

```
schedule = cirq.moment_by_moment_schedule(device, circuit)
```

Schedules have an attributed `scheduled_operations` which contains all the scheduled operations in a `SortedListWithKey`, where the key is the start time of the `SortedOperation`. `Schedules` support nice helpers for querying about the time-space layout of the schedule. For instance, the `Schedule` behaves as if it has an index corresponding to time. So, we can look up which operations occur at a specific time

```
print(schedule[cirq.Timestamp(nanos=15)])
# prints something like
# [ScheduledOperation(Timestamp(picos=10000), Duration(picos=10000),...)]
```

or even a start and end time using slicing notation

```
slice = schedule[cirq.Timestamp(nanos=5):cirq.Timestamp(nanos=15)]
slice_schedule = cirq.Schedule(device, slice)
print(slice_schedule == schedule)
# prints True
```

More complicated queries across `Schedules` can be done using the `query`.

`Schedules` are usually built by converting from `Circuits`, but one can also directly manipulate the schedule using the `include` and `exclude` methods. `include` will check if there are any collisions with other schedule operations.

2.7 Development

This document is a summary of how to do various tasks one runs into as a developer of Cirq. Note that all commands assume a Debian environment, and all commands (except the initial repository cloning command) assume your current working directory is the cirq repo root.

2.7.1 Cloning the repository

The simplest way to get a local copy of cirq that you can edit is by cloning Cirq's github repository:

```
git clone git@github.com:quantumlib/cirq.git
cd cirq
```

If you want to contribute changes to Cirq, you will instead want to fork the repository and submit pull requests from your fork.

2.7.2 Forking the repository

1. Fork the Cirq repo (Fork button in upper right corner of repo page). Forking creates a new github repo at the location `https://github.com/USERNAME/cirq` where `USERNAME` is your github id.
2. Clone the fork you created to your local machine at the directory where you would like to store your local copy of the code, and `cd` into the newly created directory.

   ```
   git clone git@github.com:USERNAME/cirq.git
   cd cirq
   ```

   (Alternatively, you can clone the repository using the URL provided on your repo page under the green "Clone or Download" button)
3. Add a remote called `upstream` to git. This remote will represent the main git repo for cirq (as opposed to the clone, which you just created, which will be the `origin` remote). This remote can be used to merge changes from Cirq's main repository into your local development copy.

   ```
   git remote add upstream https://github.com/quantumlib/cirq.git
   ```

To verify the remote, run `git remote -v`. You should see both the `origin` and `upstream` remotes.

4. Sync up your local git with the `upstream` remote:

```
git fetch upstream
```

You can check the branches that are on the `upstream` remote by running `git remote -va` or `git branch -r`. Most importantly you should see `upstream/master` listed.

5. Merge the upstream master into your local master so that it is up to date.

```
git checkout master
git merge upstream/master
```

At this point your local git master should be synced with the master from the main cirq repo.

2.7.3 Setting up an environment

1. First clone the repository, if you have not already done so. See the previous section for instructions.
2. Install system dependencies.

   Make sure you have python 3.5 or greater. You can install most other dependencies via `apt-get`:

```
cat apt-system-requirements.txt dev_tools/conf/apt-list-dev-tools.txt | xargs␣
↪sudo apt-get install --yes
```

   If you change protocol buffers you will need to regenerate the proto files, so you should install the protocol buffer compiler. Instructions for this can be found here.

3. Prepare a virtual environment including the dev tools (such as mypy).

   One of the system dependencies we installed was `virtualenvwrapper`, which makes it easy to create virtual environments. If you did not have `virtualenvwrapper` previously, you may need to re-open your terminal or run `source ~/.bashrc` before these commands will work:

```
mkvirtualenv cirq-py3 --python=/usr/bin/python3
pip install --upgrade pip
pip install -r requirements.txt
pip install -r dev_tools/conf/pip-list-dev-tools.txt
```

   (When you later open another terminal, you can activate the virtualenv with `workon cirq-py3`.)

4. Check that the tests pass.

```
pytest .
```

5. (**OPTIONAL**) include your development copy of cirq in your python path.

```
PYTHONPATH="$(pwd)":"${PYTHONPATH}"
```

   or add it to the python path, but only in the virtualenv.

```
add2virtualenv ./
```

2.7.4 Running continuous integration checks locally

There are a few options for running continuous integration checks, varying from easy and fast to slow and reliable.

The simplest way to run checks is to invoke `pytest`, `pylint`, or `mypy` for yourself as follows:

```
pytest
pylint --rcfile=dev_tools/conf/.pylintrc cirq
mypy --config-file=dev_tools/conf/mypy.ini .
```

This can be a bit tedious, because you have to specify the configuration files each time. A more convenient way to run checks is to via the scripts in the check/ directory, which specify configuration arguments for you and cover more use cases:

```
# Run all tests in the repository.
./check/pytest [files-and-flags-for-pytest]

# Check all relevant files in the repository for lint.
./check/pylint [files-and-flags-for-pylint]

# Typecheck all python files in the repository.
./check/mypy [files-and-flags-for-mypy]

# Transpile to python 2 and run tests.
./check/pytest2  # Note: you must be in a python 2 virtual env to run this.

# Compute incremental coverage vs master (or a custom revision of your choice).
./check/pytest-and-incremental-coverage [BASE_REVISION]

# Only run tests associated with files that have changed when diffed vs master (or a␣
↪custom revision of your choice).
./check/pytest-changed-files [BASE_REVISION]
```

The above scripts are convenient and reasonably fast, but they often won't exactly match the results computed by the continuous integration builds run on travis. For example, you may be running an older version of `pylint` or `numpy`. In order to run a check that is significantly more likely to agree with the travis builds, you can use the continuous-integration/check.sh script:

```
./continuous-integration/check.sh
```

This script will create (temporary) virtual environments, do a fresh install of all relevant dependencies, transpile the python 2 code, and run all relevant checks within those clean environments. Note that creating the virtual environments takes time, and prevents some caching mechanisms from working, so `continuous-integration/check.sh` is significantly slower than the simpler check scripts. When using this script, you can run a subset of the checks using the `--only` flag. This flag value can be `pylint`, `typecheck`, `pytest`, `pytest2`, or `incremental-coverage`.

2.7.5 Producing the Python 2.7 code

Run dev_tools/python2.7-generate.sh to transpile cirq's python 3 code into python 2.7 code:

```
./dev_tools/python2.7-generate.sh [output_dir] [input_dir] [virtual_env_with_3to2]
```

If you don't specify any arguments then the input directory will be the current working directory, the output directory will be `python2.7-output` within the current directory, and `3to2` will be invoked in the current environment.

The script fails with no effects if the output directory already exists.

2.7.6 Writing docstrings and generating documentation

Cirq uses Google style doc strings with a markdown flavor and support for latex. Here is an example docstring:

```
def some_method(a: int, b: str) -> float:
    r"""One line summary of method.

    Additional information about the method, perhaps with some sort of latex
    equation to make it clearer:

        $$
        M = \begin{bmatrix}
                0 & 1 \\
                1 & 0
            \end{bmatrix}
        $$

    Notice that this docstring is an r-string, since the latex has backslashes.
    We can also include example code:

        print(cirq.google.Foxtail)

    You can also do inline latex like $y = x^2$ and inline code like
    `cirq.unitary(cirq.X)`.

    And of course there's the standard sections.

    Args:
        a: The first argument.
        b: Another argument.

    Returns:
        An important value.

    Raises:
        ValueError: The value of `a` wasn't quite right.
    """
```

Documentation is generated automatically by readthedocs when pushing to `master`, but you can also generated a local copy by running:

```
dev_tools/build-docs.sh
```

The HTML output will go into the `docs/_build` directory.

2.7.7 Producing a pypi package

1. Do a dry run with test pypi.

   If you're making a release, you should have access to a test pypi account capable of uploading packages to cirq. Put its credentials into the environment variables `TEST_TWINE_USERNAME` and `TEST_TWINE_PASSWORD` then run

   ```
   ./dev_tools/packaging/publish-dev-package.sh EXPECTED_VERSION --test
   ```

   You must specify the EXPECTED_VERSION argument to match the version in `cirq/_version.py`, and it must contain the string `dev`. This is to prevent accidentally uploading the wrong version.

The script will append the current date and time to the expected version number before uploading to test pypi. It will print out the full version that it uploaded. Take not of this value.

Once the package has uploaded, verify that it works

```
./dev_tools/packaging/verify-published-package.sh FULL_VERSION_REPORTED_BY_
↪PUBLISH_SCRIPT --test
```

The script will create fresh virtual environments, install cirq and its dependencies, check that code importing cirq executes, and run the tests over the installed code. It will do this for both python 2 and python 3. If everything goes smoothly, the script will finish by printing `VERIFIED`.

2. Do a dry run with prod pypi

   This step is essentially identical to the test dry run, but with production pypi. You should have access to a production pypi account capable of uploading packages to cirq. Put its credentials into the environment variables `PROD_TWINE_USERNAME` and `PROD_TWINE_PASSWORD` then run

   ```
   ./dev_tools/packaging/publish-dev-package.sh EXPECTED_VERSION --prod
   ```

   Once the package has uploaded, verify that it works

   ```
   ./dev_tools/packaging/verify-published-package.sh FULL_VERSION_REPORTED_BY_
   ↪PUBLISH_SCRIPT --prod
   ```

   If everything goes smoothly, the script will finish by printing `VERIFIED`.

3. Set the version number in cirq/_version.py.

   Development versions end with `.dev` or `.dev#`. For example, `0.0.4.dev500` is a development version of the release version `0.0.4`. For a release, create a pull request turning `#.#.#.dev*` into `#.#.#` and a follow up pull request turning `#.#.#` into `(#+1).#.#.dev`.

4. Run dev_tools/packaging/produce-package.sh to produce pypi artifacts.

   ```
   dev_tools/packaging/produce-package.sh dist
   ```

   The output files will be placed in the directory `dist/`.

5. Create a github release.

   Describe major changes (especially breaking changes) in the summary. Make sure you point the tag being created at the one and only revision with the non-dev version number. Attach the package files you produced to the release.

6. Upload to pypi.

   You can use a tool such as `twine` for this. For example:

   ```
   twine upload -u "${PROD_TWINE_USERNAME}" -p "${PROD_TWINE_PASSWORD}" dist/*
   ```

   You should then run the verification script to check that the uploaded package works:

   ```
   ./dev_tools/packaging/verify-published-package.sh VERSION_YOU_UPLOADED --prod
   ```

   And try it out for yourself:

   ```
   pip install cirq
   python -c "import cirq; print(cirq.google.Foxtail)"
   python -c "import cirq; print(cirq.__version__)"
   ```

CHAPTER 3

API Reference

3.1 API Reference

3.1.1 Devices and Qubits

Classes for identifying the qubits and hardware you want to operate on.

Device	Hardware constraints for validating circuits and schedules.
GridQubit(row, col)	A qubit on a 2d square lattice.
LineQubit(x)	A qubit on a 1d lattice with nearest-neighbor connectivity.
NamedQubit(name)	A qubit identified by name.
QubitId	Identifies a qubit.
UnconstrainedDevice	A device that allows everything.

cirq.Device

class cirq.**Device**

Hardware constraints for validating circuits and schedules.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

can_add_operation_into_moment(operation, moment)	Determines if it's possible to add an operation into a moment.

Continued on next page

Table 2 – continued from previous page

decompose_operation(operation)	Returns a device-valid decomposition for the given operation.
duration_of(operation)	
validate_circuit(circuit)	Raises an exception if a circuit is not valid.
validate_moment(moment)	Raises an exception if a moment is not valid.
validate_operation(operation)	Raises an exception if an operation is not valid.
validate_schedule(schedule)	Raises an exception if a schedule is not valid.
validate_scheduled_operation(schedule, ...)	Raises an exception if the scheduled operation is not valid.

cirq.Device.can_add_operation_into_moment

Device.**can_add_operation_into_moment**(*operation: cirq.Operation*, *moment: cirq.Moment*) → bool

Determines if it's possible to add an operation into a moment.

For example, on the XmonDevice two CZs shouldn't be placed in the same moment if they are on adjacent qubits.

Parameters

- **operation** – The operation being added.
- **moment** – The moment being transformed.

Returns Whether or not the moment will validate after adding the operation.

cirq.Device.decompose_operation

Device.**decompose_operation**(*operation: cirq.Operation*) → cirq.OP_TREE

Returns a device-valid decomposition for the given operation.

This method is used when adding operations into circuits with a device specified, to avoid spurious failures due to e.g. using a Hadamard gate that must be decomposed into native gates.

cirq.Device.duration_of

Device.**duration_of**(*operation: cirq.Operation*) → cirq.value.duration.Duration

cirq.Device.validate_circuit

Device.**validate_circuit**(*circuit: cirq.Circuit*) → None

Raises an exception if a circuit is not valid.

Parameters **circuit** – The circuit to validate.

Raises ValueError – The circuit isn't valid for this device.

cirq.Device.validate_moment

Device.**validate_moment**(*moment: cirq.Moment*) → None
Raises an exception if a moment is not valid.

Parameters **moment** – The moment to validate.

Raises ValueError – The moment isn't valid for this device.

cirq.Device.validate_operation

Device.**validate_operation**(*operation: cirq.Operation*) → None
Raises an exception if an operation is not valid.

Parameters **operation** – The operation to validate.

Raises ValueError – The operation isn't valid for this device.

cirq.Device.validate_schedule

Device.**validate_schedule**(*schedule: cirq.Schedule*) → None
Raises an exception if a schedule is not valid.

Parameters **schedule** – The schedule to validate.

Raises ValueError – The schedule isn't valid for this device.

cirq.Device.validate_scheduled_operation

Device.**validate_scheduled_operation**(*schedule: cirq.Schedule*, *scheduled_operation: cirq.ScheduledOperation*) → None
Raises an exception if the scheduled operation is not valid.

Parameters

- **schedule** – The schedule to validate against.
- **scheduled_operation** – The scheduled operation to validate.

Raises ValueError – If the scheduled operation is not valid for the schedule.

cirq.GridQubit

class cirq.**GridQubit**(*row: int*, *col: int*)
A qubit on a 2d square lattice.

GridQubits use row-major ordering:

```
GridQubit(0, 0) < GridQubit(0, 1) < GridQubit(1, 0) < GridQubit(1, 1)
```

__init__(*row: int*, *col: int*)
Initialize self. See help(type(self)) for accurate signature.

Methods

from_proto_dict(proto_dict)	Proto dict must have 'row' and 'col' keys.
is_adjacent(other)	Determines if two qubits are adjacent qubits.
to_proto_dict()	Return the proto in dictionary form.

cirq.GridQubit.from_proto_dict

static GridQubit.**from_proto_dict**(*proto_dict: Dict*) → cirq.devices.grid_qubit.GridQubit
Proto dict must have 'row' and 'col' keys.

cirq.GridQubit.is_adjacent

GridQubit.**is_adjacent**(*other: cirq.ops.raw_types.QubitId*) → bool
Determines if two qubits are adjacent qubits.

cirq.GridQubit.to_proto_dict

GridQubit.**to_proto_dict**() → Dict
Return the proto in dictionary form.

cirq.LineQubit

class cirq.**LineQubit**(*x: int*)
A qubit on a 1d lattice with nearest-neighbor connectivity.

__init__(*x: int*) → None
Initializes a line qubit at the given x coordinate.

Methods

is_adjacent(other)	Determines if two qubits are adjacent line qubits.
range(*range_args)	Returns a range of line qubits.

cirq.LineQubit.is_adjacent

LineQubit.**is_adjacent**(*other: cirq.ops.raw_types.QubitId*) → bool
Determines if two qubits are adjacent line qubits.

cirq.LineQubit.range

static LineQubit.**range**(**range_args*) → List[cirq.line.line_qubit.LineQubit]
Returns a range of line qubits.

Parameters ***range_args** – Same arguments as python's built-in range method.

Returns A list of line qubits.

cirq.NamedQubit

class cirq.**NamedQubit**(*name: str*)
A qubit identified by name.

By default, NamedQubit has a lexicographic order. However, numbers within the name are handled correctly. So, for example, if you print a circuit containing `cirq.NamedQubit('qubit22')` and `cirq.NamedQubit('qubit3')`, the wire for 'qubit3' will correctly come before 'qubit22'.

__init__(*name: str*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

—

cirq.QubitId

class cirq.**QubitId**
Identifies a qubit. Child classes implement specific types of qubits.

The main criteria that a "qubit id" must satisfy is *comparability*. Child classes meet this criteria by implementing the `_comparison_key` method. For example, `cirq.LineQubit`'s `_comparison_key` method returns `self.x`. This ensures that line qubits with the same `x` are equal, and that line qubits will be sorted ascending by `x`. `QubitId` implements all equality, comparison, and hashing methods via `_comparison_key`.

__init__()
Initialize self. See help(type(self)) for accurate signature.

cirq.UnconstrainedDevice

cirq.**UnconstrainedDevice = cirq.UnconstrainedDevice**
A device that allows everything.

3.1.2 Single Qubit Gates

Unitary operations you can apply to a single qubit. Also measurement.

H	A Gate that performs a rotation around the X+Z axis of the Bloch sphere.
HPowGate(*, exponent, float] = 1.0, global_shift)	A Gate that performs a rotation around the X+Z axis of the Bloch sphere.

Continued on next page

Table 6 – continued from previous page

measure(*qubits, key, invert_mask, . . .] = ())	Returns a single MeasurementGate applied to all the given qubits.
measure_each(*qubits, key_func, str] = <class >)	Returns a list of operations individually measuring the given qubits.
MeasurementGate(key, invert_mask, . . .] = ())	A gate that measures qubits in the computational basis.
PhasedXPowGate(*, phase_exponent, . . .)	A gate equivalent to the circuit ——Z^-p——X^t——Z^p——.
Rx(rads)	Returns a gate with the matrix e^{-i X rads / 2}.
Ry(rads)	Returns a gate with the matrix e^{-i Y rads / 2}.
Rz(rads)	Returns a gate with the matrix e^{-i Z rads / 2}.
S	A gate that rotates around the Z axis of the Bloch sphere.
SingleQubitMatrixGate(matrix)	A 1-qubit gate defined by its matrix.
T	A gate that rotates around the Z axis of the Bloch sphere.
TwoQubitMatrixGate(matrix)	A 2-qubit gate defined only by its matrix.
X	A gate that rotates around the X axis of the Bloch sphere.
XPowGate(*, exponent, float] = 1.0, global_shift)	A gate that rotates around the X axis of the Bloch sphere.
Y	A gate that rotates around the Y axis of the Bloch sphere.
YPowGate(*, exponent, float] = 1.0, global_shift)	A gate that rotates around the Y axis of the Bloch sphere.
Z	A gate that rotates around the Z axis of the Bloch sphere.
ZPowGate(*, exponent, float] = 1.0, global_shift)	A gate that rotates around the Z axis of the Bloch sphere.

cirq.H

cirq.**H = cirq.H**

A Gate that performs a rotation around the X+Z axis of the Bloch sphere.

The unitary matrix of `HPowGate(exponent=t)` is:

```
[[g·(c-i·s/sqrt(2)), -i·g·s/sqrt(2)],
[-i·g·s/sqrt(2)], g·(c+i·s/sqrt(2))]]
```

where

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that for `t=1`, this gives the Hadamard matrix.

`cirq.H`, the Hadamard gate, is an instance of this gate at `exponent=1`.

cirq.HPowGate

class cirq.**HPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A Gate that performs a rotation around the X+Z axis of the Bloch sphere.

The unitary matrix of `HPowGate(exponent=t)` is:

```
[[g·(c-i·s/sqrt(2)), -i·g·s/sqrt(2)],
[-i·g·s/sqrt(2)], g·(c+i·s/sqrt(2))]]
```

where

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that for `t=1`, this gives the Hadamard matrix.

`cirq.H`, the Hadamard gate, is an instance of this gate at `exponent=1`.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.

Continued on next page

Table 7 – continued from previous page

on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.HPowGate.on

HPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.HPowGate.on_each

HPowGate.**on_each**(*targets: Iterable[cirq.ops.raw_types.QubitId]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Returns a list of operations apply this gate to each of the targets.

Parameters **targets** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.HPowGate.validate_args

HPowGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.HPowGate.exponent

HPowGate.**exponent**

cirq.measure

cirq.**measure**(**qubits*, *key: Optional[str] = None*, *invert_mask: Tuple[bool, ...] = ()*) → cirq.ops.gate_operation.GateOperation

Returns a single MeasurementGate applied to all the given qubits.

The qubits are measured in the computational basis.

Parameters

- ***qubits** – The qubits that the measurement gate should measure.

- **key** – The string key of the measurement. If this is None, it defaults to a comma-separated list of the target qubits' str values.
- **invert_mask** – A list of Truthy or Falsey values indicating whether the corresponding qubits should be flipped. None indicates no inverting should be done.

Returns An operation targeting the given qubits with a measurement.

Raises ValueError if the qubits are not instances of QubitId.

cirq.measure_each

cirq.**measure_each**(**qubits*, *key_func: Callable[cirq.ops.raw_types.QubitId, str] = <class 'str'>*) → List[cirq.ops.gate_operation.GateOperation]

Returns a list of operations individually measuring the given qubits.

The qubits are measured in the computational basis.

Parameters

- ***qubits** – The qubits to measure.
- **key_func** – Determines the key of the measurements of each qubit. Takes the qubit and returns the key for that qubit. Defaults to str.

Returns A list of operations individually measuring the given qubits.

cirq.MeasurementGate

class cirq.**MeasurementGate**(*key: str = ''*, *invert_mask: Tuple[bool, ...] = ()*)

A gate that measures qubits in the computational basis.

The measurement gate contains a key that is used to identify results of measurements.

__init__(*key: str = ''*, *invert_mask: Tuple[bool, ...] = ()*) → None

Parameters

- **key** – The string key of the measurement.
- **invert_mask** – A list of values indicating whether the corresponding qubits should be flipped. The list's length must not be longer than the number of qubits, but it is permitted to be shorter. Qubits with indices past the end of the mask are not flipped.

Methods

is_measurement(op, cirq.ops.raw_types.Operation])	
on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.
with_bits_flipped(*bit_positions)	Toggles whether or not the measurement inverts various outputs.

cirq.MeasurementGate.is_measurement

static MeasurementGate.**is_measurement**(*op: Union[cirq.ops.raw_types.Gate, cirq.ops.raw_types.Operation]*) → bool

cirq.MeasurementGate.on

MeasurementGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.MeasurementGate.validate_args

MeasurementGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.MeasurementGate.with_bits_flipped

MeasurementGate.**with_bits_flipped**(**bit_positions*) → cirq.ops.common_gates.MeasurementGate

Toggles whether or not the measurement inverts various outputs.

cirq.PhasedXPowGate

class cirq.**PhasedXPowGate**(**, phase_exponent: Union[float, cirq.value.symbol.Symbol], exponent: Union[float, cirq.value.symbol.Symbol] = 1.0, global_shift: float = 0.0*)

A gate equivalent to the circuit ——Z^-p——X^t——Z^p——.

__init__(**, phase_exponent: Union[float, cirq.value.symbol.Symbol], exponent: Union[float, cirq.value.symbol.Symbol] = 1.0, global_shift: float = 0.0*) → None

Parameters

- **phase_exponent** – The exponent on the Z gates conjugating the X gate.
- **exponent** – The exponent on the X gate conjugated by Zs.
- **global_shift** – How much to shift the operation's eigenvalues at exponent=1.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.PhasedXPowGate.on

PhasedXPowGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.PhasedXPowGate.on_each

PhasedXPowGate.**on_each**(*targets: Iterable[cirq.ops.raw_types.QubitId]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]
Returns a list of operations apply this gate to each of the targets.

Parameters **targets** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.PhasedXPowGate.validate_args

PhasedXPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent	The exponent on the central X gate conjugated by the Z gates.
phase_exponent	The exponent on the Z gates conjugating the X gate.

cirq.PhasedXPowGate.exponent

PhasedXPowGate.**exponent**
The exponent on the central X gate conjugated by the Z gates.

cirq.PhasedXPowGate.phase_exponent

PhasedXPowGate.**phase_exponent**
The exponent on the Z gates conjugating the X gate.

cirq.Rx

cirq.**Rx**(*rads: float*) → cirq.ops.common_gates.XPowGate
Returns a gate with the matrix e^{-i X rads / 2}.

cirq.Ry

cirq.**Ry**(*rads: float*) → cirq.ops.common_gates.YPowGate
Returns a gate with the matrix e^{-i Y rads / 2}.

cirq.Rz

cirq.**Rz**(*rads: float*) → cirq.ops.common_gates.ZPowGate
Returns a gate with the matrix e^{-i Z rads / 2}.

cirq.S

cirq.**S = cirq.S**
A gate that rotates around the Z axis of the Bloch sphere.

The unitary matrix of `ZPowGate(exponent=t)` is:

```
[[1, 0],
 [0, g]]
```

where:

```
g = exp(i·π·t).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Z axis. See `cirq.Rz` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Z`, the Pauli Z gate, is an instance of this gate at exponent=1.

cirq.SingleQubitMatrixGate

class cirq.**SingleQubitMatrixGate**(*matrix: numpy.ndarray*)
A 1-qubit gate defined by its matrix.

More general than specialized classes like `ZPowGate`, but more expensive
and more float-error sensitive to work with (due to using
eigendecompositions).

__init__(*matrix: numpy.ndarray*) → None
Initializes the 2-qubit matrix gate.

Parameters **matrix** – The matrix that defines the gate.

Methods

approx_eq(other[, ignore_global_phase])	
on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.SingleQubitMatrixGate.approx_eq

SingleQubitMatrixGate.**approx_eq**(*other*, *ignore_global_phase=True*)

cirq.SingleQubitMatrixGate.on

SingleQubitMatrixGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.SingleQubitMatrixGate.validate_args

SingleQubitMatrixGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.T

cirq.**T = cirq.T**

A gate that rotates around the Z axis of the Bloch sphere.

The unitary matrix of `ZPowGate(exponent=t)` is:

```
[[1, 0],
 [0, g]]
```

where:

```
g = exp(i·π·t).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Z axis. See `cirq.Rz` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Z`, the Pauli Z gate, is an instance of this gate at exponent=1.

cirq.TwoQubitMatrixGate

class cirq.**TwoQubitMatrixGate**(*matrix: numpy.ndarray*)
A 2-qubit gate defined only by its matrix.

More general than specialized classes like `CZPowGate`, but more expensive and more float-error sensitive to work with (due to using eigendecompositions).

__init__(*matrix: numpy.ndarray*) → None
Initializes the 2-qubit matrix gate.

Parameters **matrix** – The matrix that defines the gate.

Methods

approx_eq(other[, ignore_global_phase])	
on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.TwoQubitMatrixGate.approx_eq

TwoQubitMatrixGate.**approx_eq**(*other*, *ignore_global_phase=True*)

cirq.TwoQubitMatrixGate.on

TwoQubitMatrixGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.TwoQubitMatrixGate.validate_args

TwoQubitMatrixGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.X

cirq.**X = cirq.X**
A gate that rotates around the X axis of the Bloch sphere.

The unitary matrix of `XPowGate(exponent=t)` is:

```
[[g·c, −i·g·s],
 [−i·g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli X axis. See `cirq.Rx` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.X`, the Pauli X gate, is an instance of this gate at exponent=1.

cirq.XPowGate

class cirq.**XPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A gate that rotates around the X axis of the Bloch sphere.

The unitary matrix of `XPowGate(exponent=t)` is:

```
[[g·c, −i·g·s],
 [−i·g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli X axis. See `cirq.Rx` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.X`, the Pauli X gate, is an instance of this gate at exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.XPowGate.on

`XPowGate.on`(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.XPowGate.on_each

`XPowGate.on_each`(*targets: Iterable[cirq.ops.raw_types.QubitId]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Returns a list of operations apply this gate to each of the targets.

Parameters **targets** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.XPowGate.validate_args

XPowGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.XPowGate.exponent

XPowGate.**exponent**

cirq.Y

cirq.**Y = cirq.Y**

A gate that rotates around the Y axis of the Bloch sphere.

The unitary matrix of `YPowGate(exponent=t)` is:

```
[[g·c, g·s],
 [-g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Y axis. See `cirq.Ry` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Y`, the Pauli Y gate, is an instance of this gate at exponent=1.

cirq.YPowGate

class cirq.**YPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A gate that rotates around the Y axis of the Bloch sphere.

The unitary matrix of `YPowGate(exponent=t)` is:

```
[[g·c, g·s],
 [-g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Y axis. See `cirq.Ry` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Y`, the Pauli Y gate, is an instance of this gate at exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

   ```
   θ
   ```

2. Shifting the angle by `global_shift`:

   ```
   θ + s
   ```

3. Scaling the angle by `exponent`:

   ```
   (θ + s) * e
   ```

4. Converting from half turns to a complex number on the unit circle:

   ```
   exp(i * pi * (θ + s) * e)
   ```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.YPowGate.on

YPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.YPowGate.on_each

YPowGate.**on_each**(*targets: Iterable[cirq.ops.raw_types.QubitId]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Returns a list of operations apply this gate to each of the targets.

Parameters **targets** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.YPowGate.validate_args

YPowGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.YPowGate.exponent

YPowGate.**exponent**

cirq.Z

cirq.**Z = cirq.Z**

A gate that rotates around the Z axis of the Bloch sphere.

The unitary matrix of `ZPowGate(exponent=t)` is:

```
[[1, 0],
 [0, g]]
```

where:

```
g = exp(i·π·t).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Z axis. See `cirq.Rz` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Z`, the Pauli Z gate, is an instance of this gate at exponent=1.

cirq.ZPowGate

class cirq.**ZPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A gate that rotates around the Z axis of the Bloch sphere.

The unitary matrix of `ZPowGate(exponent=t)` is:

```
[[1, 0],
 [0, g]]
```

where:

```
g = exp(i·π·t).
```

Note in particular that this gate has a global phase factor of
e^{i·π·t/2} vs the traditionally defined rotation matrices
about the Pauli Z axis. See `cirq.Rz` for rotations without the global
phase. The global phase factor can be adjusted by using the `global_shift`
parameter when initializing.

`cirq.Z`, the Pauli Z gate, is an instance of this gate at exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

   θ

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.ZPowGate.on

`ZPowGate.`**`on`**`(`*`*qubits`*`)` → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters **`*qubits`** – The collection of qubits to potentially apply the gate to.

cirq.ZPowGate.on_each

`ZPowGate.`**`on_each`**`(`*`targets:` `Iterable[cirq.ops.raw_types.QubitId]`*`)` → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Returns a list of operations apply this gate to each of the targets.

Parameters **`targets`** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.ZPowGate.validate_args

ZPowGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.ZPowGate.exponent

ZPowGate.**exponent**

3.1.3 Two Qubit Gates

Unitary operations you can apply to pairs of qubits.

CNOT	A gate that applies a controlled power of an X gate.
CNotPowGate(*, exponent, float] = 1.0, ...)	A gate that applies a controlled power of an X gate.
CZ	A gate that applies a phase to the |11⟩ state of two qubits.
CZPowGate(*, exponent, float] = 1.0, ...)	A gate that applies a phase to the |11⟩ state of two qubits.
ISWAP	Rotates the |01⟩-vs-|10⟩ subspace of two qubits around its Bloch X-axis.
ISwapPowGate(*, exponent, float] = 1.0, ...)	Rotates the |01⟩-vs-|10⟩ subspace of two qubits around its Bloch X-axis.
MS(rads)	The Mølmer–Sørensen gate, a native two-qubit operation in ion traps.
SWAP	The SWAP gate, possibly raised to a power.
SwapPowGate(*, exponent, float] = 1.0, ...)	The SWAP gate, possibly raised to a power.
XX	The X-parity gate, possibly raised to a power.
XXPowGate(*, exponent, float] = 1.0, ...)	The X-parity gate, possibly raised to a power.
YY	The Y-parity gate, possibly raised to a power.
YYPowGate(*, exponent, float] = 1.0, ...)	The Y-parity gate, possibly raised to a power.
ZZ	The Z-parity gate, possibly raised to a power.
ZZPowGate(*, exponent, float] = 1.0, ...)	The Z-parity gate, possibly raised to a power.

cirq.CNOT

cirq.**CNOT = cirq.CNOT**

A gate that applies a controlled power of an X gate.

When applying CNOT (controlled-not) to qubits, you can either use positional arguments CNOT(q1, q2), where q2 is toggled when q1 is on,

or named arguments CNOT(control=q1, target=q2).
(Mixing the two is not permitted.)

The unitary matrix of `CNotPowGate(exponent=t)` is:

```
[[1, 0, 0, 0],
 [0, 1, 0, 0],
 [0, 0, g·c, -i·g·s],
 [0, 0, -i·g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

`cirq.CNOT`, the controlled NOT gate, is an instance of this gate at `exponent=1`.

cirq.CNotPowGate

class cirq.**CNotPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A gate that applies a controlled power of an X gate.

When applying CNOT (controlled-not) to qubits, you can either use
positional arguments CNOT(q1, q2), where q2 is toggled when q1 is on,
or named arguments CNOT(control=q1, target=q2).
(Mixing the two is not permitted.)

The unitary matrix of `CNotPowGate(exponent=t)` is:

```
[[1, 0, 0, 0],
 [0, 1, 0, 0],
 [0, 0, g·c, -i·g·s],
 [0, 0, -i·g·s, g·c]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

`cirq.CNOT`, the controlled NOT gate, is an instance of this gate at `exponent=1`.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*args, **kwargs)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.CNotPowGate.on

CNotPowGate.**on**(**args*, ***kwargs*) → cirq.ops.gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.CNotPowGate.validate_args

CNotPowGate.**validate_args**(*qubits*)

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.CNotPowGate.exponent

CNotPowGate.**exponent**

cirq.CZ

cirq.**CZ = cirq.CZ**

A gate that applies a phase to the |11⟩ state of two qubits.

The unitary matrix of `CZPowGate(exponent=t)` is:

```
[[1, 0, 0, 0],
 [0, 1, 0, 0],
 [0, 0, 1, 0],
 [0, 0, 0, g]]
```

where:

```
g = exp(i·π·t/2).
```

`cirq.CZ`, the controlled Z gate, is an instance of this gate at `exponent=1`.

cirq.CZPowGate

class cirq.**CZPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A gate that applies a phase to the |11⟩ state of two qubits.

The unitary matrix of `CZPowGate(exponent=t)` is:

```
[[1, 0, 0, 0],
 [0, 1, 0, 0],
 [0, 0, 1, 0],
 [0, 0, 0, g]]
```

where:

```
g = exp(i·π·t/2).
```

`cirq.CZ`, the controlled Z gate, is an instance of this gate at

exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.CZPowGate.on

CZPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.CZPowGate.qubit_index_to_equivalence_group_key

CZPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.CZPowGate.validate_args

CZPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.CZPowGate.exponent

CZPowGate.**exponent**

cirq.ISWAP

cirq.**ISWAP = cirq.ISWAP**
Rotates the |01-vs-|10 subspace of two qubits around its Bloch X-axis.

When exponent=1, swaps the two qubits and phases |01 and |10 by i. More generally, this gate's matrix is defined as follows:

```
ISWAP**t  exp(+i π t (XX + YY) / 4)
```

which is given by the matrix:

```
[[1, 0, 0, 0],
 [0, c, i·s, 0],
 [0, i·s, c, 0],
 [0, 0, 0, 1]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
```

cirq.ISWAP, the swap gate that applies -i to the |01> and |10> states, is an instance of this gate at exponent=1.

cirq.ISwapPowGate

class cirq.**ISwapPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

Rotates the |01-vs-|10 subspace of two qubits around its Bloch X-axis.

When exponent=1, swaps the two qubits and phases |01 and |10 by i. More generally, this gate's matrix is defined as follows:

```
ISWAP**t  exp(+i π t (XX + YY) / 4)
```

which is given by the matrix:

```
[[1, 0, 0, 0],
 [0, c, i·s, 0],
 [0, i·s, c, 0],
 [0, 0, 0, 1]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
```

cirq.ISWAP, the swap gate that applies -i to the |01> and |10> states, is an instance of this gate at exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's _eigen_components method:

   ```
   θ
   ```

2. Shifting the angle by global_shift:

   ```
   θ + s
   ```

3. Scaling the angle by exponent:

   ```
   (θ + s) * e
   ```

4. Converting from half turns to a complex number on the unit circle:

   ```
   exp(i * pi * (θ + s) * e)
   ```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.ISwapPowGate.on

ISwapPowGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.ISwapPowGate.qubit_index_to_equivalence_group_key

ISwapPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.ISwapPowGate.validate_args

ISwapPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.ISwapPowGate.exponent

ISwapPowGate.**exponent**

cirq.MS

cirq.**MS**(*rads: float*) → cirq.ops.parity_gates.XXPowGate
The Mølmer–Sørensen gate, a native two-qubit operation in ion traps.

A rotation around the XX axis in the two-qubit bloch sphere.

The gate implements the following unitary:

```
exp(-i t XX) = [ cos(t)    0         0        -isin(t)]
               [ 0         cos(t)   -isin(t)   0      ]
               [ 0        -isin(t)   cos(t)    0      ]
               [-isin(t)   0         0         cos(t) ]
```

Parameters **rads** – The rotation angle in radians.

Returns Mølmer–Sørensen gate rotating by the desired amount.

cirq.SWAP

cirq.**SWAP = cirq.SWAP**
The SWAP gate, possibly raised to a power. Exchanges qubits.

SwapPowGate()**t = SwapPowGate(exponent=t) and acts on two qubits in the computational basis as the matrix:

```
[[1, 0, 0, 0],
 [0, g·c, -i·g·s, 0],
 [0, -i·g·s, g·c, 0],
 [0, 0, 0, 1]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

cirq.SWAP, the swap gate, is an instance of this gate at exponent=1.

cirq.SwapPowGate

class cirq.**SwapPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)
The SWAP gate, possibly raised to a power. Exchanges qubits.

SwapPowGate()**t = SwapPowGate(exponent=t) and acts on two qubits in the computational basis as the matrix:

```
[[1, 0, 0, 0],
 [0, g·c, -i·g·s, 0],
 [0, -i·g·s, g·c, 0],
 [0, 0, 0, 1]]
```

where:

```
c = cos(π·t/2)
s = sin(π·t/2)
g = exp(i·π·t/2).
```

`cirq.SWAP`, the swap gate, is an instance of this gate at exponent=1.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

   ```
   θ
   ```

2. Shifting the angle by `global_shift`:

   ```
   θ + s
   ```

3. Scaling the angle by `exponent`:

   ```
   (θ + s) * e
   ```

4. Converting from half turns to a complex number on the unit circle:

   ```
   exp(i * pi * (θ + s) * e)
   ```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.

Continued on next page

Table 27 – continued from previous page

qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.SwapPowGate.on

SwapPowGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.SwapPowGate.qubit_index_to_equivalence_group_key

SwapPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.SwapPowGate.validate_args

SwapPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.SwapPowGate.exponent

SwapPowGate.**exponent**

cirq.XX

cirq.**XX = cirq.XX**
The X-parity gate, possibly raised to a power.

At exponent=1, this gate implements the following unitary:

```
XX = [0 0 0 1]
     [0 0 1 0]
     [0 1 0 0]
     [1 0 0 0]
```

See also: cirq.MS (the Mølmer–Sørensen gate), which is implemented via this class.

cirq.XXPowGate

class cirq.**XXPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

The X-parity gate, possibly raised to a power.

At exponent=1, this gate implements the following unitary:

```
XX = [0 0 0 1]
     [0 0 1 0]
     [0 1 0 0]
     [1 0 0 0]
```

See also: `cirq.MS` (the Mølmer–Sørensen gate), which is implemented via this class.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

   ```
   θ
   ```

2. Shifting the angle by `global_shift`:

   ```
   θ + s
   ```

3. Scaling the angle by `exponent`:

   ```
   (θ + s) * e
   ```

4. Converting from half turns to a complex number on the unit circle:

   ```
   exp(i * pi * (θ + s) * e)
   ```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.XXPowGate.on

XXPowGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.XXPowGate.qubit_index_to_equivalence_group_key

XXPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.XXPowGate.validate_args

XXPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.XXPowGate.exponent

XXPowGate.**exponent**

cirq.YY

cirq.**YY = cirq.YY**
The Y-parity gate, possibly raised to a power.

cirq.YYPowGate

class cirq.**YYPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)
The Y-parity gate, possibly raised to a power.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.YYPowGate.on

YYPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.YYPowGate.qubit_index_to_equivalence_group_key

YYPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.YYPowGate.validate_args

YYPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.YYPowGate.exponent

YYPowGate.**exponent**

cirq.ZZ

cirq.**ZZ = cirq.ZZ**
The Z-parity gate, possibly raised to a power.

The ZZ**t gate implements the following unitary:

```
(ZZ)^t = [1 . . .]
         [. w . .]
         [. . w .]
         [. . . 1]

where w = e^{i \pi t} and '.' means '0'.
```

cirq.ZZPowGate

class cirq.**ZZPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)
The Z-parity gate, possibly raised to a power.

The ZZ**t gate implements the following unitary:

```
(ZZ)^t = [1 . . .]
         [. w . .]
         [. . w .]
         [. . . 1]

where w = e^{i \pi t} and '.' means '0'.
```

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.ZZPowGate.on

ZZPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.ZZPowGate.qubit_index_to_equivalence_group_key

ZZPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.ZZPowGate.validate_args

ZZPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.ZZPowGate.exponent

ZZPowGate.**exponent**

3.1.4 Three Qubit Gates

Unitary operations you can apply to triplets of qubits, with helpful adjacency-respecting decompositions.

CCX	A Toffoli (doubly-controlled-NOT) that can be raised to a power.
CCXPowGate(*, exponent, float] = 1.0, ...)	A Toffoli (doubly-controlled-NOT) that can be raised to a power.
CCZ	A doubly-controlled-Z that can be raised to a power.
CCZPowGate(*, exponent, float] = 1.0, ...)	A doubly-controlled-Z that can be raised to a power.
CSWAP	A controlled swap gate.
CSwapGate	A controlled swap gate.
FREDKIN	A controlled swap gate.
TOFFOLI	A Toffoli (doubly-controlled-NOT) that can be raised to a power.

cirq.CCX

cirq.**CCX = cirq.TOFFOLI**
A Toffoli (doubly-controlled-NOT) that can be raised to a power.

The matrix of CCX**t is an 8x8 identity except the bottom right 2x2 area
is the matrix of X**t.

cirq.CCXPowGate

class cirq.**CCXPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)

A Toffoli (doubly-controlled-NOT) that can be raised to a power.

The matrix of `CCX**t` is an 8x8 identity except the bottom right 2x2 area
is the matrix of `X**t`.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.CCXPowGate.on

CCXPowGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.CCXPowGate.qubit_index_to_equivalence_group_key

CCXPowGate.**qubit_index_to_equivalence_group_key**(*index*)
Returns a key that differs between non-interchangeable qubits.

cirq.CCXPowGate.validate_args

CCXPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.CCXPowGate.exponent

CCXPowGate.**exponent**

cirq.CCZ

cirq.**CCZ = cirq.CCZ**
A doubly-controlled-Z that can be raised to a power.

The matrix of `CCZ**t` is `diag(1, 1, 1, 1, 1, 1, 1, exp(i pi t))`.

cirq.CCZPowGate

class cirq.**CCZPowGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)
A doubly-controlled-Z that can be raised to a power.

The matrix of `CCZ**t` is `diag(1, 1, 1, 1, 1, 1, 1, exp(i pi t))`.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None
Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's

`_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.CCZPowGate.on

CCZPowGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.CCZPowGate.qubit_index_to_equivalence_group_key

CCZPowGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int

Returns a key that differs between non-interchangeable qubits.

cirq.CCZPowGate.validate_args

CCZPowGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.CCZPowGate.exponent

CCZPowGate.**exponent**

cirq.CSWAP

cirq.**CSWAP = cirq.FREDKIN**
A controlled swap gate. The Fredkin gate.

cirq.CSwapGate

class cirq.**CSwapGate**
A controlled swap gate. The Fredkin gate.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.CSwapGate.on

CSwapGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.CSwapGate.qubit_index_to_equivalence_group_key

CSwapGate.**qubit_index_to_equivalence_group_key**(*index*)
Returns a key that differs between non-interchangeable qubits.

cirq.CSwapGate.validate_args

CSwapGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.FREDKIN

cirq.**FREDKIN = cirq.FREDKIN**
A controlled swap gate. The Fredkin gate.

cirq.TOFFOLI

cirq.**TOFFOLI = cirq.TOFFOLI**
A Toffoli (doubly-controlled-NOT) that can be raised to a power.

The matrix of `CCX**t` is an 8x8 identity except the bottom right 2x2 area
is the matrix of `X**t`.

3.1.5 Other Gate and Operation Classes

Generic classes for creating new kinds of gates and operations.

ControlledGate(sub_gate)	Augments existing gates with a control qubit.
EigenGate(*, exponent, float] = 1.0, ...)	A gate with a known eigendecomposition.
Gate	An operation type that can be applied to a collection of qubits.
GateOperation(gate, qubits)	An application of a gate to a sequence of qubits.
InterchangeableQubitsGate	Indicates operations should be equal under some qubit permutations.
Operation	An effect applied to a collection of qubits.
ReversibleCompositeGate	A composite gate that gets decomposed into reversible gates.
SingleQubitGate	A gate that must be applied to exactly one qubit.
ThreeQubitGate	A gate that must be applied to exactly three qubits.
TwoQubitGate	A gate that must be applied to exactly two qubits.

cirq.ControlledGate

class cirq.**ControlledGate**(*sub_gate: cirq.ops.raw_types.Gate*)
Augments existing gates with a control qubit.

__init__(*sub_gate: cirq.ops.raw_types.Gate*) → None
Initializes the controlled gate.

Parameters **sub_gate** – The gate to add a control qubit to.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.ControlledGate.on

ControlledGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.ControlledGate.validate_args

ControlledGate.**validate_args**(*qubits*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.EigenGate

class cirq.**EigenGate**(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*)
A gate with a known eigendecomposition.

EigenGate is particularly useful when one wishes for different parts of the same eigenspace to be extrapolated differently. For example, if a gate has a 2-dimensional eigenspace with eigenvalue -1, but one wishes for the square root of the gate to split this eigenspace into a part with eigenvalue i and a part with eigenvalue -i, then EigenGate allows this functionality to be unambiguously specified via the _eigen_components method.

__init__(*, *exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*, *global_shift: float = 0.0*) → None

Initializes the parameters used to compute the gate's matrix.

The eigenvalue of each eigenspace of a gate is computed by

1. Starting with an angle in half turns as returned by the gate's `_eigen_components` method:

```
θ
```

2. Shifting the angle by `global_shift`:

```
θ + s
```

3. Scaling the angle by `exponent`:

```
(θ + s) * e
```

4. Converting from half turns to a complex number on the unit circle:

```
exp(i * pi * (θ + s) * e)
```

Parameters

- **exponent** – The t in gate**t. Determines how much the eigenvalues of the gate are scaled by. For example, eigenvectors phased by -1 when *gate**1* is applied will gain a relative phase of e^{i pi exponent} when *gate**exponent* is applied (relative to eigenvectors unaffected by *gate**1*).
- **global_shift** – Offsets the eigenvalues of the gate at exponent=1. In effect, this controls a global phase factor on the gate's unitary matrix. The factor is:

  exp(i * pi * global_shift * exponent)

  For example, *cirq.X**t* uses a *global_shift* of 0 but *cirq.Rx(t)* uses a *global_shift* of -0.5, which is why *cirq.unitary(cirq.Rx(pi))* equals -iX instead of X.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.EigenGate.on

EigenGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.EigenGate.validate_args

EigenGate.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

exponent

cirq.EigenGate.exponent

EigenGate.**exponent**

cirq.Gate

class cirq.**Gate**

An operation type that can be applied to a collection of qubits.

Gates can be applied to qubits by calling their on() method with
the qubits to be applied to supplied, or, alternatively, by simply
calling the gate on the qubits. In other words calling MyGate.on(q1, q2)
to create an Operation on q1 and q2 is equivalent to MyGate(q1,q2).

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.Gate.on

Gate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.Gate.validate_args

Gate.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.GateOperation

class cirq.**GateOperation**(*gate: cirq.ops.raw_types.Gate, qubits: Sequence[cirq.ops.raw_types.QubitId]*)

An application of a gate to a sequence of qubits.

__init__(*gate: cirq.ops.raw_types.Gate, qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Parameters

- **gate** – The gate to apply.
- **qubits** – The qubits to operate on.

Methods

transform_qubits(func, ...)	Returns the same operation, but with different qubits.
with_gate(new_gate)	
with_qubits(*new_qubits)	

cirq.GateOperation.transform_qubits

GateOperation.**transform_qubits**(*func: Callable[cirq.ops.raw_types.QubitId, cirq.ops.raw_types.QubitId]*) → TSelf_Operation

Returns the same operation, but with different qubits.

Parameters **func** – The function to use to turn each current qubit into a desired new qubit.

Returns

The receiving operation but with qubits transformed by the given function.

cirq.GateOperation.with_gate

GateOperation.**with_gate**(*new_gate: cirq.ops.raw_types.Gate*) → cirq.ops.gate_operation.GateOperation

cirq.GateOperation.with_qubits

GateOperation.**with_qubits**(**new_qubits*) → cirq.ops.gate_operation.GateOperation

Attributes

gate	The gate applied by the operation.
qubits	The qubits targeted by the operation.

cirq.GateOperation.gate

GateOperation.**gate**
The gate applied by the operation.

cirq.GateOperation.qubits

GateOperation.**qubits**
The qubits targeted by the operation.

cirq.InterchangeableQubitsGate

class cirq.**InterchangeableQubitsGate**
Indicates operations should be equal under some qubit permutations.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.

cirq.InterchangeableQubitsGate.qubit_index_to_equivalence_group_key

InterchangeableQubitsGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.Operation

class cirq.**Operation**
An effect applied to a collection of qubits.

The most common kind of Operation is a GateOperation, which separates its effect into a qubit-independent Gate and the qubits it should be applied to.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

transform_qubits(func, ...)	Returns the same operation, but with different qubits.
with_qubits(*new_qubits)	

cirq.Operation.transform_qubits

Operation.**transform_qubits**(*func: Callable[cirq.ops.raw_types.QubitId, cirq.ops.raw_types.QubitId]*) → TSelf_Operation

Returns the same operation, but with different qubits.

Parameters **func** – The function to use to turn each current qubit into a desired new qubit.

Returns

The receiving operation but with qubits transformed by the given function.

cirq.Operation.with_qubits

Operation.**with_qubits**(**new_qubits*) → TSelf_Operation

Attributes

qubits

cirq.Operation.qubits

Operation.**qubits**

cirq.ReversibleCompositeGate

class cirq.**ReversibleCompositeGate**

A composite gate that gets decomposed into reversible gates.

__init__()

Initialize self. See help(type(self)) for accurate signature.

cirq.SingleQubitGate

class cirq.**SingleQubitGate**

A gate that must be applied to exactly one qubit.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
on_each(targets)	Returns a list of operations apply this gate to each of the targets.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.SingleQubitGate.on

SingleQubitGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.SingleQubitGate.on_each

SingleQubitGate.**on_each**(*targets: Iterable[cirq.ops.raw_types.QubitId]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]
Returns a list of operations apply this gate to each of the targets.

Parameters **targets** – The qubits to apply this gate to.

Returns Operations applying this gate to the target qubits.

cirq.SingleQubitGate.validate_args

SingleQubitGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.ThreeQubitGate

class cirq.**ThreeQubitGate**
A gate that must be applied to exactly three qubits.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.ThreeQubitGate.on

ThreeQubitGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.ThreeQubitGate.validate_args

ThreeQubitGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.TwoQubitGate

class cirq.**TwoQubitGate**
A gate that must be applied to exactly two qubits.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.TwoQubitGate.on

TwoQubitGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.TwoQubitGate.validate_args

TwoQubitGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

3.1.6 Circuits and Schedules

Utilities for representing and manipulating quantum computations.

Circuit(moments, device)	A mutable list of groups of operations to apply to some qubits.
flatten_op_tree(root, Iterable[Any]])	Performs an in-order iteration of the operations (leaves) in an OP_TREE.

Continued on next page

Table 54 – continued from previous page

freeze_op_tree(root, Iterable[Any]])	Replaces all iterables in the OP_TREE with tuples.
InsertStrategy(name, doc)	Indicates preferences on how to add multiple operations to a circuit.
Moment(operations)	A simplified time-slice of operations within a sequenced circuit.
moment_by_moment_schedule(device, circuit)	Returns a schedule aligned with the moment structure of the Circuit.
OP_TREE	Union type; Union[X, Y] means either X or Y.
QubitOrder(explicit_func, ...)	Defines the kronecker product order of qubits.
QubitOrderOrList	Union type; Union[X, Y] means either X or Y.
Schedule(device, scheduled_operations)	A quantum program with operations happening at specific times.
ScheduledOperation(time, duration, operation)	An operation that happens over a specified time interval.
transform_op_tree(root, Iterable[Any]], ...)	Maps transformation functions onto the nodes of an OP_TREE.

cirq.Circuit

class cirq.**Circuit**(*moments: Iterable[cirq.circuits.moment.Moment] = ()*, *device: cirq.devices.device.Device = cirq.UnconstrainedDevice*)

A mutable list of groups of operations to apply to some qubits.

Methods returning information about the circuit:
next_moment_operating_on
prev_moment_operating_on
operation_at
qubits
findall_operations
to_unitary_matrix
apply_unitary_effect_to_state
to_text_diagram
to_text_diagram_drawer

Methods for mutation:
insert
append
insert_into_range
clear_operations_touching

Circuits can also be iterated over,
for moment in circuit:
...
and sliced,
circuit[1:3] is a new Circuit made up of two moments, the first being
circuit[1] and the second being circuit[2];
and concatenated,

circuit1 + circuit2 is a new Circuit made up of the moments in circuit1
followed by the moments in circuit2;
and multiplied by an integer,
circuit * k is a new Circuit made up of the moments in circuit repeated
k times.
and mutated,
circuit[1:7] = [Moment(...)]

__init__(*moments: Iterable[cirq.circuits.moment.Moment] = ()*, *device: cirq.devices.device.Device = cirq.UnconstrainedDevice*) → None
Initializes a circuit.

Parameters

- **moments** – The initial list of moments defining the circuit.
- **device** – Hardware that the circuit should be able to run on.

Methods

all_operations()	Iterates over the operations applied by this circuit.
all_qubits()	Returns the qubits acted upon by Operations in this circuit.
append(moment_or_operation_tree, ...)	Appends operations onto the end of the circuit.
apply_unitary_effect_to_state(initial_state, ...)	Left-multiplies a state vector by the circuit's unitary effect.
are_all_measurements_terminal()	
batch_insert(insertions, ...)	Applies a batched insert operation to the circuit.
batch_insert_into(insert_intos, ...)	Inserts operations into empty spaces in existing moments.
batch_remove(removals, ...)	Removes several operations from a circuit.
clear_operations_touching(qubits, moment_indices)	Clears operations that are touching given qubits at given moments.
copy()	
findall_operations(predicate, bool])	Find the locations of all operations that satisfy a given condition.
findall_operations_between(start_frontier, ...)	Finds operations between the two given frontiers.
findall_operations_with_gate_type(gate_type)	Find the locations of all gate operations of a given type.
from_ops(*operations, strategy, device)	Creates an empty circuit and appends the given operations.
insert(index, moment_or_operation_tree, ...)	Inserts a moment or operations into the circuit.
insert_at_frontier(operations, ...)	Inserts operations inline at frontier.
insert_into_range(operations, ...)	Writes operations inline into an area of the circuit.
next_moment_operating_on(qubits, ...)	Finds the index of the next moment that touches the given qubits.
next_moments_operating_on(qubits, ...)	Finds the index of the next moment that touches each qubit.

Continued on next page

Table 55 – continued from previous page

operation_at(qubit, moment_index)	Finds the operation on a qubit within a moment, if any.
prev_moment_operating_on(qubits, ...)	Finds the index of the next moment that touches the given qubits.
reachable_frontier_from(start_frontier, ...)	Determines how far can be reached into a circuit under certain rules.
save_qasm(file_path, bytes, int], header, ...)	Save a QASM file equivalent to the circuit.
to_qasm(header, precision, qubit_order, ...)	Returns QASM equivalent to the circuit.
to_text_diagram(*, use_unicode_characters, ...)	Returns text containing a diagram describing the circuit.
to_text_diagram_drawer(*, ...)	Returns a TextDiagramDrawer with the circuit drawn into it.
to_unitary_matrix(qubit_order, ...)	Converts the circuit into a unitary matrix, if possible.
with_device(new_device, qubit_mapping, ...)	Maps the current circuit onto a new device, and validates.

cirq.Circuit.all_operations

Circuit.**all_operations**() → Iterator[cirq.ops.raw_types.Operation]
Iterates over the operations applied by this circuit.

Operations from earlier moments will be iterated over first. Operations within a moment are iterated in the order they were given to the moment's constructor.

cirq.Circuit.all_qubits

Circuit.**all_qubits**() → FrozenSet[cirq.ops.raw_types.QubitId]
Returns the qubits acted upon by Operations in this circuit.

cirq.Circuit.append

Circuit.**append**(*moment_or_operation_tree: Union[cirq.circuits.moment.Moment, cirq.ops.raw_types.Operation, Iterable[Any]], strategy: cirq.circuits.insert_strategy.InsertStrategy = cirq.InsertStrategy.NEW_THEN_INLINE*)
Appends operations onto the end of the circuit.

Parameters

- **moment_or_operation_tree** – An operation or tree of operations.
- **strategy** – How to pick/create the moment to put operations into.

cirq.Circuit.apply_unitary_effect_to_state

Circuit.**apply_unitary_effect_to_state**(*initial_state: Union[int, numpy.ndarray] = 0*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *qubits_that_should_be_present: Iterable[cirq.ops.raw_types.QubitId] = ()*, *ignore_terminal_measurements: bool = True*, *dtype: Type[numpy.number] = <class 'numpy.complex128'>*) → numpy.ndarray

Left-multiplies a state vector by the circuit's unitary effect.

A circuit's "unitary effect" is the unitary matrix produced by multiplying together all of its gates' unitary matrices. A circuit with non-unitary gates (such as measurement or parameterized gates) does not have a well-defined unitary effect, and the method will fail if such operations are present.

For convenience, terminal measurements are automatically ignored instead of causing a failure. Set the `ignore_terminal_measurements` argument to False to disable this behavior.

This method is equivalent to left-multiplying the input state by `cirq.unitary(circuit)` but it's computed in a more efficient way.

Parameters

- **initial_state** – The input state for the circuit. This can be an int or a vector. When this is an int, it refers to a computational basis state (e.g. 5 means initialize to `|5 = |...000101`). If this is a state vector, it directly specifies the initial state's amplitudes. The vector must be a flat numpy array with a type that can be converted to np.complex128.
- **qubit_order** – Determines how qubits are ordered when passing matrices into np.kron.
- **qubits_that_should_be_present** – Qubits that may or may not appear in operations within the circuit, but that should be included regardless when generating the matrix.
- **ignore_terminal_measurements** – When set, measurements at the end of the circuit are ignored instead of causing the method to fail.
- **dtype** – The numpy dtype for the returned unitary. Defaults to np.complex128. Specifying np.complex64 will run faster at the cost of precision. *dtype* must be a complex np.dtype, unless all operations in the circuit have unitary matrices with exclusively real coefficients (e.g. an H + TOFFOLI circuit).

Returns A (possibly gigantic) numpy array storing the superposition that came out of the circuit for the given input state.

Raises

- `ValueError` – The circuit contains measurement gates that are not ignored.
- `TypeError` – The circuit contains gates that don't have a known unitary matrix, e.g. gates parameterized by a Symbol.

cirq.Circuit.are_all_measurements_terminal

`Circuit.`**`are_all_measurements_terminal`**`()`

cirq.Circuit.batch_insert

`Circuit.`**`batch_insert`**(*insertions: Iterable[Tuple[int, Union[cirq.ops.raw_types.Operation, Iterable[Any]]]]*) → None

Applies a batched insert operation to the circuit.

Transparently handles the fact that earlier insertions may shift the index that later insertions should occur at. For example, if you insert an operation at index 2 and at index 4, but the insert at index 2 causes a new moment to be created, then the insert at "4" will actually occur at index 5 to account for the shift from the new moment.

All insertions are done with the strategy 'EARLIEST'.

When multiple inserts occur at the same index, the gates from the later inserts end up before the gates from the earlier inserts (exactly as if you'd called list.insert several times with the same index: the later inserts shift the earliest inserts forward).

Parameters **`insertions`** – A sequence of (insert_index, operations) pairs indicating operations to add into the circuit at specific places.

cirq.Circuit.batch_insert_into

`Circuit.`**`batch_insert_into`**(*insert_intos: Iterable[Tuple[int, cirq.ops.raw_types.Operation]]*) → None

Inserts operations into empty spaces in existing moments.

If any of the insertions fails (due to colliding with an existing operation), this method fails without making any changes to the circuit.

Parameters **`insert_intos`** – A sequence of (moment_index, new_operation) pairs indicating a moment to add a new operation into.

ValueError: One of the insertions collided with an existing operation.

IndexError: Inserted into a moment index that doesn't exist.

cirq.Circuit.batch_remove

Circuit.**batch_remove**(*removals: Iterable[Tuple[int, cirq.ops.raw_types.Operation]]*) → None
Removes several operations from a circuit.

Parameters **removals** – A sequence of (moment_index, operation) tuples indicating operations to delete from the moments that are present. All listed operations must actually be present or the edit will fail (without making any changes to the circuit).

ValueError: One of the operations to delete wasn't present to start with.

IndexError: Deleted from a moment that doesn't exist.

cirq.Circuit.clear_operations_touching

Circuit.**clear_operations_touching**(*qubits: Iterable[cirq.ops.raw_types.QubitId], moment_indices: Iterable[int]*)
Clears operations that are touching given qubits at given moments.

Parameters

- **qubits** – The qubits to check for operations on.
- **moment_indices** – The indices of moments to check for operations within.

cirq.Circuit.copy

Circuit.**copy**() → cirq.circuits.circuit.Circuit

cirq.Circuit.findall_operations

Circuit.**findall_operations**(*predicate: Callable[cirq.ops.raw_types.Operation, bool]*) → Iterable[Tuple[int, cirq.ops.raw_types.Operation]]
Find the locations of all operations that satisfy a given condition.

This returns an iterator of (index, operation) tuples where each
operation satisfies op_cond(operation) is truthy. The indices are
in order of the moments and then order of the ops within that moment.

Parameters **predicate** – A method that takes an Operation and returns a Truthy value indicating the operation meets the find condition.

Returns An iterator (index, operation)'s that satisfy the op_condition.

cirq.Circuit.findall_operations_between

Circuit.**findall_operations_between**(*start_frontier: Dict[cirq.ops.raw_types.QubitId, int], end_frontier: Dict[cirq.ops.raw_types.QubitId, int], omit_crossing_operations: bool = False*) → List[Tuple[int, cirq.ops.raw_types.Operation]]
Finds operations between the two given frontiers.

If a qubit is in `start_frontier` but not `end_frontier`, its end index defaults to the end of the circuit. If a qubit is in `end_frontier` but not `start_frontier`, its start index defaults to the start of the circuit. Operations on qubits not mentioned in either frontier are not included in the results.

Parameters

- **start_frontier** – Just before where to start searching for operations, for each qubit of interest. Start frontier indices are inclusive.
- **end_frontier** – Just before where to stop searching for operations, for each qubit of interest. End frontier indices are exclusive.
- **omit_crossing_operations** – Determines whether or not operations that cross from a location between the two frontiers to a location outside the two frontiers are included or excluded. (Operations completely inside are always included, and operations completely outside are always excluded.)

Returns A list of tuples. Each tuple describes an operation found between the two frontiers. The first item of each tuple is the index of the moment containing the operation, and the second item is the operation itself. The list is sorted so that the moment index increases monotonically.

cirq.Circuit.findall_operations_with_gate_type

Circuit.**findall_operations_with_gate_type**(*gate_type: Type[T_DESIRED_GATE_TYPE]*) → Iterable[Tuple[int, cirq.ops.gate_operation.GateOperation, T_DESIRED_GATE_TYPE]]

Find the locations of all gate operations of a given type.

Parameters **gate_type** – The type of gate to find, e.g. XPowGate or MeasurementGate.

Returns An iterator (index, operation, gate)'s for operations with the given gate type.

cirq.Circuit.from_ops

static Circuit.**from_ops**(**operations*, *strategy: cirq.circuits.insert_strategy.InsertStrategy = cirq.InsertStrategy.NEW_THEN_INLINE*, *device: cirq.devices.device.Device = cirq.UnconstrainedDevice*) → cirq.circuits.circuit.Circuit

Creates an empty circuit and appends the given operations.

Parameters

- **operations** – The operations to append to the new circuit.
- **strategy** – How to append the operations.
- **device** – Hardware that the circuit should be able to run on.

Returns The constructed circuit containing the operations.

cirq.Circuit.insert

Circuit.**insert**(*index: int, moment_or_operation_tree: Union[cirq.circuits.moment.Moment, cirq.ops.raw_types.Operation, Iterable[Any]], strategy: cirq.circuits.insert_strategy.InsertStrategy = cirq.InsertStrategy.NEW_THEN_INLINE*) → int

Inserts a moment or operations into the circuit.
Moments are inserted at the specified index.
Operations are inserted into the moment specified by the index and
'InsertStrategy'.

Parameters

- **index** – The index to insert all of the operations at.
- **moment_or_operation_tree** – An operation or tree of operations.
- **strategy** – How to pick/create the moment to put operations into.

Returns The insertion index that will place operations just after the operations that were inserted by this method.

Raises ValueError – Bad insertion strategy.

cirq.Circuit.insert_at_frontier

Circuit.**insert_at_frontier**(*operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]], start: int, frontier: Dict[cirq.ops.raw_types.QubitId, int] = None*) → Dict[cirq.ops.raw_types.QubitId, int]

Inserts operations inline at frontier.

Parameters

- **operations** – the operations to insert
- **start** – the moment at which to start inserting the operations
- **frontier** – frontier[q] is the earliest moment in which an operation acting on qubit q can be placed.

cirq.Circuit.insert_into_range

Circuit.**insert_into_range**(*operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]], start: int, end: int*) → int

Writes operations inline into an area of the circuit.

Parameters

- **start** – The start of the range (inclusive) to write the given operations into.
- **end** – The end of the range (exclusive) to write the given operations into. If there are still operations remaining, new moments are created to fit them.
- **operations** – An operation or tree of operations to insert.

Returns An insertion index that will place operations after the operations that were inserted by this method.

Raises `IndexError` – Bad inline_start and/or inline_end.

cirq.Circuit.next_moment_operating_on

`Circuit.`**`next_moment_operating_on`**(*qubits: Iterable[cirq.ops.raw_types.QubitId], start_moment_index: int = 0, max_distance: int = None*) → Optional[int]

Finds the index of the next moment that touches the given qubits.

Parameters

- **`qubits`** – We're looking for operations affecting any of these qubits.
- **`start_moment_index`** – The starting point of the search.
- **`max_distance`** – The number of moments (starting from the start index and moving forward) to check. Defaults to no limit.

Returns None if there is no matching moment, otherwise the index of the earliest matching moment.

Raises `ValueError` – negative max_distance.

cirq.Circuit.next_moments_operating_on

`Circuit.`**`next_moments_operating_on`**(*qubits: Iterable[cirq.ops.raw_types.QubitId], start_moment_index: int = 0*) → Dict[cirq.ops.raw_types.QubitId, int]

Finds the index of the next moment that touches each qubit.

Parameters

- **`qubits`** – The qubits to find the next moments acting on.
- **`start_moment_index`** – The starting point of the search.

Returns The index of the next moment that touches each qubit. If there is no such moment, the next moment is specified as the number of moments in the circuit. Equivalently, can be characterized as one plus the index of the last moment after start_moment_index (inclusive) that does *not* act on a given qubit.

cirq.Circuit.operation_at

`Circuit.`**`operation_at`**(*qubit: cirq.ops.raw_types.QubitId, moment_index: int*) → Optional[cirq.ops.raw_types.Operation]

Finds the operation on a qubit within a moment, if any.

Parameters

- **`qubit`** – The qubit to check for an operation on.
- **`moment_index`** – The index of the moment to check for an operation within. Allowed to be beyond the end of the circuit.

Returns None if there is no operation on the qubit at the given moment, or else the operation.

cirq.Circuit.prev_moment_operating_on

Circuit.**prev_moment_operating_on**(*qubits: Sequence[cirq.ops.raw_types.QubitId], end_moment_index: Optional[int] = None, max_distance: Optional[int] = None*) → Optional[int]

Finds the index of the next moment that touches the given qubits.

Parameters

- **qubits** – We're looking for operations affecting any of these qubits.
- **end_moment_index** – The moment index just after the starting point of the reverse search. Defaults to the length of the list of moments.
- **max_distance** – The number of moments (starting just before from the end index and moving backward) to check. Defaults to no limit.

Returns None if there is no matching moment, otherwise the index of the latest matching moment.

Raises ValueError – negative max_distance.

cirq.Circuit.reachable_frontier_from

Circuit.**reachable_frontier_from**(*start_frontier: Dict[cirq.ops.raw_types.QubitId, int], *, is_blocker: Callable[cirq.ops.raw_types.Operation, bool] = <function Circuit.<lambda>>*) → Dict[cirq.ops.raw_types.QubitId, int]

Determines how far can be reached into a circuit under certain rules.

The location L = (qubit, moment_index) is *reachable* if and only if:

```
a) L is one of the items in `start_frontier`.

OR

b) There is no operation at L and prev(L) = (qubit, moment_index-1)
    is reachable and L is within the bounds of the circuit.

OR

c) There is an operation P covering L and, for every location
    M = (q', moment_index) that P covers, the location
    prev(M) = (q', moment_index-1) is reachable. Also, P must not be
    classified as a blocker by the given `is_blocker` argument.
```

In other words, the reachable region extends forward through time along each qubit until it hits a blocked operation or an operation that crosses into the set of not-involved-at-the-moment qubits.

For each qubit q in start_frontier, the reachable locations will correspond to a contiguous range starting at start_frontier[q] and ending just before some index end_q. The result of this method is a dictionary, and that dictionary maps each qubit q to its end_q.

Examples

If start_frontier is {
cirq.LineQubit(0): 6,
cirq.LineQubit(1): 2,
cirq.LineQubit(2): 2,
} then the reachable wire locations in the following circuit are
highlighted with ‘’ characters:

```
0   1   2   3   4   5   6   7   8   9   10  11  12  13
```

```
0: ──H──@──────────────────@──H──
        │                  │
1: ──────@─H@─@──H──@──────
              │    │
2: ────────@H─@────@──H──@─────────
           │         │
3: ────────────────────@──H──@─────────────────
```

And the computed end_frontier is {
cirq.LineQubit(0): 11,
cirq.LineQubit(1): 9,
cirq.LineQubit(2): 6,
}

Note that the frontier indices (shown above the circuit) are
best thought of (and shown) as happening *between* moment indices.

If we specify a blocker as follows:

```
is_blocker=lambda: op == cirq.CZ(cirq.LineQubit(1),
                                 cirq.LineQubit(2))
```

and use this start_frontier:

```
{
    cirq.LineQubit(0): 0,
    cirq.LineQubit(1): 0,
    cirq.LineQubit(2): 0,
    cirq.LineQubit(3): 0,
}
```

Then this is the reachable area:

```
0   1   2   3   4   5   6   7   8   9   10  11  12  13
```

```
0: –H@–@——H——
   | |
1: –@H–@———————————————@——H——@———————
   | |
2: —@——H——@———————@——H——@———————————
   | |
3: —@——H——@———————————————————
```

and the computed end_frontier is:

```
{
    cirq.LineQubit(0): 11,
    cirq.LineQubit(1): 3,
    cirq.LineQubit(2): 3,
    cirq.LineQubit(3): 5,
}
```

Parameters

- **start_frontier** – A starting set of reachable locations.
- **is_blocker** – A predicate that determines if operations block reachability. Any location covered by an operation that causes *is_blocker* to return True is considered to be an unreachable location.

Returns

An end_frontier dictionary, containing an end index for each qubit q mapped to a start index by the given *start_frontier* dictionary.

To determine if a location (q, i) was reachable, you can use this expression:

q in start_frontier and start_frontier[q] <= i < end_frontier[q]

where i is the moment index, q is the qubit, and end_frontier is the result of this method.

cirq.Circuit.save_qasm

Circuit.**save_qasm**(*file_path: Union[str, bytes, int], header: Optional[str] = None, precision: int = 10, qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*) → None

Save a QASM file equivalent to the circuit.

Parameters

- **file_path** – The location of the file where the qasm will be written.
- **header** – A multi-line string that is placed in a comment at the top of the QASM. Defaults to a cirq version specifier.
- **precision** – Number of digits to use when representing numbers.
- **qubit_order** – Determines how qubits are ordered in the QASM register.

cirq.Circuit.to_qasm

Circuit.**to_qasm**(*header: Optional[str] = None*, *precision: int = 10*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*) → str

Returns QASM equivalent to the circuit.

Parameters

- **header** – A multi-line string that is placed in a comment at the top of the QASM. Defaults to a cirq version specifier.
- **precision** – Number of digits to use when representing numbers.
- **qubit_order** – Determines how qubits are ordered in the QASM register.

cirq.Circuit.to_text_diagram

Circuit.**to_text_diagram**(***, *use_unicode_characters: bool = True*, *transpose: bool = False*, *precision: Optional[int] = 3*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*) → str

Returns text containing a diagram describing the circuit.

Parameters

- **use_unicode_characters** – Determines if unicode characters are allowed (as opposed to ascii-only diagrams).
- **transpose** – Arranges qubit wires vertically instead of horizontally.
- **precision** – Number of digits to display in text diagram
- **qubit_order** – Determines how qubits are ordered in the diagram.

Returns The text diagram.

cirq.Circuit.to_text_diagram_drawer

Circuit.**to_text_diagram_drawer**(***, *use_unicode_characters: bool = True*, *qubit_name_suffix: str = ''*, *transpose: bool = False*, *precision: Optional[int] = 3*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*) → cirq.circuits.text_diagram_drawer.TextDiagramDrawer

Returns a TextDiagramDrawer with the circuit drawn into it.

Parameters

- **use_unicode_characters** – Determines if unicode characters are allowed (as opposed to ascii-only diagrams).
- **qubit_name_suffix** – Appended to qubit names in the diagram.
- **transpose** – Arranges qubit wires vertically instead of horizontally.
- **precision** – Number of digits to use when representing numbers.

- **qubit_order** – Determines how qubits are ordered in the diagram.

Returns The TextDiagramDrawer instance.

cirq.Circuit.to_unitary_matrix

Circuit.**to_unitary_matrix**(*qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *qubits_that_should_be_present: Iterable[cirq.ops.raw_types.QubitId] = ()*, *ignore_terminal_measurements: bool = True*, *dtype: Type[numpy.number] = <class 'numpy.complex128'>*) → numpy.ndarray

Converts the circuit into a unitary matrix, if possible.

Parameters

- **qubit_order** – Determines how qubits are ordered when passing matrices into np.kron.
- **qubits_that_should_be_present** – Qubits that may or may not appear in operations within the circuit, but that should be included regardless when generating the matrix.
- **ignore_terminal_measurements** – When set, measurements at the end of the circuit are ignored instead of causing the method to fail.
- **dtype** – The numpy dtype for the returned unitary. Defaults to np.complex128. Specifying np.complex64 will run faster at the cost of precision. *dtype* must be a complex np.dtype, unless all operations in the circuit have unitary matrices with exclusively real coefficients (e.g. an H + TOFFOLI circuit).

Returns A (possibly gigantic) 2d numpy array corresponding to a matrix equivalent to the circuit's effect on a quantum state.

Raises

- ValueError – The circuit contains measurement gates that are not ignored.
- TypeError – The circuit contains gates that don't have a known unitary matrix, e.g. gates parameterized by a Symbol.

cirq.Circuit.with_device

Circuit.**with_device**(*new_device: cirq.devices.device.Device*, *qubit_mapping: Callable[cirq.ops.raw_types.QubitId, cirq.ops.raw_types.QubitId] = <function Circuit.<lambda>>*) → cirq.circuits.circuit.Circuit

Maps the current circuit onto a new device, and validates.

Parameters

- **new_device** – The new device that the circuit should be on.
- **qubit_mapping** – How to translate qubits from the old device into qubits on the new device.

Returns The translated circuit.

Attributes

device

cirq.Circuit.device

Circuit.**device**

cirq.flatten_op_tree

cirq.**flatten_op_tree**(*root: Union[cirq.ops.raw_types.Operation, Iterable[Any]]*) → Iterable[cirq.ops.raw_types.Operation]

Performs an in-order iteration of the operations (leaves) in an OP_TREE.

Parameters **root** – The operation or tree of operations to iterate.

Yields Operations from the tree.

Raises TypeError – root isn't a valid OP_TREE.

cirq.freeze_op_tree

cirq.**freeze_op_tree**(*root: Union[cirq.ops.raw_types.Operation, Iterable[Any]]*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Replaces all iterables in the OP_TREE with tuples.

Parameters **root** – The operation or tree of operations to freeze.

Returns An OP_TREE with the same operations and branching structure, but where all internal nodes are tuples instead of arbitrary iterables.

cirq.InsertStrategy

class cirq.**InsertStrategy**(*name*, *doc*)

Indicates preferences on how to add multiple operations to a circuit.

__init__(*name*, *doc*)

Initialize self. See help(type(self)) for accurate signature.

Methods

—

Attributes

EARLIEST
INLINE
NEW
NEW_THEN_INLINE

cirq.InsertStrategy.EARLIEST

InsertStrategy.**EARLIEST = cirq.InsertStrategy.EARLIEST**

cirq.InsertStrategy.INLINE

InsertStrategy.**INLINE = cirq.InsertStrategy.INLINE**

cirq.InsertStrategy.NEW

InsertStrategy.**NEW = cirq.InsertStrategy.NEW**

cirq.InsertStrategy.NEW_THEN_INLINE

InsertStrategy.**NEW_THEN_INLINE = cirq.InsertStrategy.NEW_THEN_INLINE**

cirq.Moment

class cirq.**Moment**(*operations: Iterable[cirq.ops.raw_types.Operation] = ()*)

A simplified time-slice of operations within a sequenced circuit.

Note that grouping sequenced circuits into moments is an abstraction that may not carry over directly to the scheduling on the hardware or simulator. Operations in the same moment may or may not actually end up scheduled to occur at the same time. However the topological quantum circuit ordering will be preserved, and many schedulers or consumers will attempt to maximize the moment representation.

operations

A tuple of the Operations for this Moment.

qubits

A set of the qubits acted upon by this Moment.

__init__(*operations: Iterable[cirq.ops.raw_types.Operation] = ()*) → None

Constructs a moment with the given operations.

Parameters **operations** – The operations applied within the moment. Will be frozen into a tuple before storing.

Raises ValueError – A qubit appears more than once.

Methods

operates_on(qubits)	Determines if the moment has operations touching the given qubits.
transform_qubits(func, ...)	
with_operation(operation)	Returns an equal moment, but with the given op added.
without_operations_touching(qubits)	Returns an equal moment, but without ops on the given qubits.

cirq.Moment.operates_on

Moment.**operates_on**(*qubits: Iterable[cirq.ops.raw_types.QubitId]*) → bool

Determines if the moment has operations touching the given qubits.

Parameters **qubits** – The qubits that may or may not be touched by operations.

Returns Whether this moment has operations involving the qubits.

cirq.Moment.transform_qubits

Moment.**transform_qubits**(*func: Callable[cirq.ops.raw_types.QubitId, cirq.ops.raw_types.QubitId]*) → TSelf_Moment

cirq.Moment.with_operation

Moment.**with_operation**(*operation: cirq.ops.raw_types.Operation*)

Returns an equal moment, but with the given op added.

Parameters **operation** – The operation to append.

Returns The new moment.

cirq.Moment.without_operations_touching

Moment.**without_operations_touching**(*qubits: Iterable[cirq.ops.raw_types.QubitId]*)

Returns an equal moment, but without ops on the given qubits.

Parameters **qubits** – Operations that touch these will be removed.

Returns The new moment.

cirq.moment_by_moment_schedule

cirq.**moment_by_moment_schedule**(*device: cirq.devices.device.Device*, *circuit: cirq.circuits.circuit.Circuit*)

Returns a schedule aligned with the moment structure of the Circuit.

This method attempts to create a schedule in which each moment of a circuit is scheduled starting at the same time. Given the constraints of the given device, such a schedule may not be possible, in this case the the method will raise a ValueError with a description of the conflict.

The schedule that is produced will take each moments and schedule the operations in this moment in a time slice of length equal to the maximum time of an operation in the moment.

Returns A Schedule for the circuit.

Raises `ValueError` – if the scheduling cannot be done.

cirq.OP_TREE

`cirq.`**`OP_TREE = typing.Union[cirq.ops.raw_types.Operation, typing.Iterable[typing.Any]]`**

Union type; Union[X, Y] means either X or Y.

To define a union, use e.g. Union[int, str]. Details:

- The arguments must be types and there must be at least one.
- None as an argument is a special case and is replaced by type(None).
- Unions of unions are flattened, e.g.:

```
Union[Union[int, str], float] == Union[int, str, float]
```

- Unions of a single argument vanish, e.g.:

```
Union[int] == int  # The constructor actually returns int
```

- Redundant arguments are skipped, e.g.:

```
Union[int, str, int] == Union[int, str]
```

- When comparing unions, the argument order is ignored, e.g.:

```
Union[int, str] == Union[str, int]
```

- When two arguments have a subclass relationship, the least derived argument is kept, e.g.:

```
class Employee: pass
class Manager(Employee): pass
Union[int, Employee, Manager] == Union[int, Employee]
Union[Manager, int, Employee] == Union[int, Employee]
Union[Employee, Manager] == Employee
```

- Similar for object:

```
Union[int, object] == object
```

- You cannot subclass or instantiate a union.
- You can use Optional[X] as a shorthand for Union[X, None].

cirq.QubitOrder

`class` `cirq.`**`QubitOrder`**(*explicit_func: Callable[Iterable[cirq.ops.raw_types.QubitId], Tuple[cirq.ops.raw_types.QubitId, ...]]*)

Defines the kronecker product order of qubits.

__init__(*explicit_func: Callable[Iterable[cirq.ops.raw_types.QubitId], Tuple[cirq.ops.raw_types.QubitId, ...]]*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

as_qubit_order(val)	Converts a value into a basis.
explicit(fixed_qubits, fallback)	A basis that contains exactly the given qubits in the given order.
map(internalize, TInternalQubit], ...)	Transforms the Basis so that it applies to wrapped qubits.
order_for(qubits)	Returns a qubit tuple ordered corresponding to the basis.
sorted_by(key, Any])	A basis that orders qubits ascending based on a key function.

cirq.QubitOrder.as_qubit_order

static QubitOrder.**as_qubit_order**(*val: qubit_order_or_list.QubitOrderOrList*) → QubitOrder
Converts a value into a basis.

Parameters **val** – An iterable or a basis.

Returns The basis implied by the value.

cirq.QubitOrder.explicit

static QubitOrder.**explicit**(*fixed_qubits: Iterable[cirq.ops.raw_types.QubitId], fallback: Optional[QubitOrder] = None*) → cirq.ops.qubit_order.QubitOrder
A basis that contains exactly the given qubits in the given order.

Parameters

- **fixed_qubits** – The qubits in basis order.
- **fallback** – A fallback order to use for extra qubits not in the fixed_qubits list. Extra qubits will always come after the fixed_qubits, but will be ordered based on the fallback. If no fallback is specified, a ValueError is raised when extra qubits are specified.

Returns A Basis instance that forces the given qubits in the given order.

cirq.QubitOrder.map

QubitOrder.**map**(*internalize: Callable[TExternalQubit, TInternalQubit], externalize: Callable[TInternalQubit, TExternalQubit]*) → cirq.ops.qubit_order.QubitOrder
Transforms the Basis so that it applies to wrapped qubits.

Parameters

- **externalize** – Converts an internal qubit understood by the underlying basis into an external qubit understood by the caller.

- **internalize** – Converts an external qubit understood by the caller into an internal qubit understood by the underlying basis.

Returns A basis that transforms qubits understood by the caller into qubits understood by an underlying basis, uses that to order the qubits, then wraps the ordered qubits back up for the caller.

cirq.QubitOrder.order_for

QubitOrder.**order_for**(*qubits: Iterable[cirq.ops.raw_types.QubitId]*) → Tuple[cirq.ops.raw_types.QubitId, ...]

Returns a qubit tuple ordered corresponding to the basis.

Parameters **qubits** – Qubits that should be included in the basis. (Additional qubits may be added into the output by the basis.)

Returns A tuple of qubits in the same order that their single-qubit matrices would be passed into *np.kron* when producing a matrix for the entire system.

cirq.QubitOrder.sorted_by

static QubitOrder.**sorted_by**(*key: Callable[cirq.ops.raw_types.QubitId, Any]*) → cirq.ops.qubit_order.QubitOrder

A basis that orders qubits ascending based on a key function.

Parameters **key** – A function that takes a qubit and returns a key value. The basis will be ordered ascending according to these key values.

Returns A basis that orders qubits ascending based on a key function.

Attributes

DEFAULT	A basis that orders qubits in the same way that calling `sorted` does.

cirq.QubitOrder.DEFAULT

QubitOrder.**DEFAULT = <cirq.ops.qubit_order.QubitOrder object>**

A basis that orders qubits in the same way that calling `sorted` does.

| Specifically, qubits are ordered first by their type name and then by
| whatever comparison value qubits of a given type provide (e.g. for LineQubit
| it is the x coordinate of the qubit).

cirq.QubitOrderOrList

cirq.**QubitOrderOrList = typing.Union[cirq.ops.qubit_order.QubitOrder, typing.Iterable[cirq**

Union type; Union[X, Y] means either X or Y.

To define a union, use e.g. Union[int, str]. Details:

- The arguments must be types and there must be at least one.
- None as an argument is a special case and is replaced by type(None).
- Unions of unions are flattened, e.g.:

```
Union[Union[int, str], float] == Union[int, str, float]
```

- Unions of a single argument vanish, e.g.:

```
Union[int] == int  # The constructor actually returns int
```

- Redundant arguments are skipped, e.g.:

```
Union[int, str, int] == Union[int, str]
```

- When comparing unions, the argument order is ignored, e.g.:

```
Union[int, str] == Union[str, int]
```

- When two arguments have a subclass relationship, the least derived argument is kept, e.g.:

```
class Employee: pass
class Manager(Employee): pass
Union[int, Employee, Manager] == Union[int, Employee]
Union[Manager, int, Employee] == Union[int, Employee]
Union[Employee, Manager] == Employee
```

- Similar for object:

```
Union[int, object] == object
```

- You cannot subclass or instantiate a union.
- You can use Optional[X] as a shorthand for Union[X, None].

cirq.Schedule

class cirq.**Schedule**(*device: cirq.devices.device.Device*, *scheduled_operations: Iterable[cirq.schedules.scheduled_operation.ScheduledOperation] = ()*)

A quantum program with operations happening at specific times.

Supports schedule[time] point lookups and schedule[inclusive_start_time:exclusive_end_time] slice lookups.

device

The hardware this will schedule on.

scheduled_operations

A SortedListWithKey containing the ScheduledOperations for this schedule. The key is the start time of the ScheduledOperation.

__init__(*device: cirq.devices.device.Device*, *scheduled_operations: Iterable[cirq.schedules.scheduled_operation.ScheduledOperation] = ()*) → None
Initializes a new schedule.

Parameters

- **device** – The hardware this schedule will run on.
- **scheduled_operations** – Initial list of operations to apply. These will be moved into a sorted list, with a key equal to each operation's start time.

Methods

exclude(scheduled_operation)	Omits a scheduled operation from the schedule, if present.
include(scheduled_operation)	Adds a scheduled operation to the schedule.
operations_happening_at_same_time_as(...)	Finds operations happening at the same time as the given operation.
query(*, time, duration, qubits[, ...])	Finds operations by time and qubit.
to_circuit()	Convert the schedule to a circuit.

cirq.Schedule.exclude

Schedule.**exclude**(*scheduled_operation: cirq.schedules.scheduled_operation.ScheduledOperation*) → bool
Omits a scheduled operation from the schedule, if present.

Parameters **scheduled_operation** – The operation to try to remove.

Returns True if the operation was present and is now removed, False if it was already not present.

cirq.Schedule.include

Schedule.**include**(*scheduled_operation: cirq.schedules.scheduled_operation.ScheduledOperation*)
Adds a scheduled operation to the schedule.

Parameters **scheduled_operation** – The operation to add.

Raises ValueError – The operation collided with something already in the schedule.

cirq.Schedule.operations_happening_at_same_time_as

Schedule.**operations_happening_at_same_time_as**(*scheduled_operation: cirq.schedules.scheduled_operation.ScheduledOperation*) → List[cirq.schedules.scheduled_operation.ScheduledOpera
Finds operations happening at the same time as the given operation.

Parameters **scheduled_operation** – The operation specifying the time to query.

Returns Scheduled operations that overlap with the given operation.

cirq.Schedule.query

Schedule.**query**(*, *time: cirq.value.timestamp.Timestamp*, *duration: cirq.value.duration.Duration = cirq.Duration(picos=0)*, *qubits: Iterable[cirq.ops.raw_types.QubitId] = None*, *include_query_end_time=False*, *include_op_end_times=False*) → List[cirq.schedules.scheduled_operation.ScheduledOperation]

Finds operations by time and qubit.

Parameters

- **time** – Operations must end after this time to be returned.
- **duration** – Operations must start by time+duration to be returned.
- **qubits** – If specified, only operations touching one of the included qubits will be returned.
- **include_query_end_time** – Determines if the query interval includes its end time. Defaults to no.
- **include_op_end_times** – Determines if the scheduled operation intervals include their end times or not. Defaults to no.

Returns A list of scheduled operations meeting the specified conditions.

cirq.Schedule.to_circuit

Schedule.**to_circuit**() → cirq.circuits.circuit.Circuit

Convert the schedule to a circuit.

This discards most timing information from the schedule, but does place operations that are scheduled at the same time in the same Moment.

cirq.ScheduledOperation

class cirq.**ScheduledOperation**(*time: cirq.value.timestamp.Timestamp*, *duration: cirq.value.duration.Duration*, *operation: cirq.ops.raw_types.Operation*)

An operation that happens over a specified time interval.

__init__(*time: cirq.value.timestamp.Timestamp*, *duration: cirq.value.duration.Duration*, *operation: cirq.ops.raw_types.Operation*) → None

Initializes the scheduled operation.

Parameters

- **time** – When the operation starts.
- **duration** – How long the operation lasts.
- **operation** – The operation.

Methods

op_at_on(operation, time, device)	Creates a scheduled operation with a device-determined duration.

cirq.ScheduledOperation.op_at_on

static ScheduledOperation.**op_at_on**(*operation: cirq.ops.raw_types.Operation*, *time: cirq.value.timestamp.Timestamp*, *device: cirq.devices.device.Device*)

Creates a scheduled operation with a device-determined duration.

cirq.transform_op_tree

cirq.**transform_op_tree**(*root: Union[cirq.ops.raw_types.Operation, Iterable[Any]]*, *op_transformation: Callable[cirq.ops.raw_types.Operation, Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function <lambda>>*, *iter_transformation: Callable[Iterable[Union[cirq.ops.raw_types.Operation, Iterable[Any]]], Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function <lambda>>*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Maps transformation functions onto the nodes of an OP_TREE.

Parameters

- **root** – The operation or tree of operations to transform.
- **op_transformation** – How to transform the operations (i.e. leaves).
- **iter_transformation** – How to transform the iterables (i.e. internal nodes).

Returns A transformed operation tree.

Raises TypeError – root isn't a valid OP_TREE.

3.1.7 Trials and Simulations

Classes for parameterized circuits.

bloch_vector_from_state_vector(state, index)	Returns the bloch vector of a qubit.
density_matrix_from_state_vector(state, indices)	Returns the density matrix of the wavefunction.
dirac_notation(state, decimals)	Returns the wavefunction as a string in Dirac notation.
Linspace(key, start, stop, length)	A simple sweep over linearly-spaced values.
measure_state_vector(state, indices, out)	Performs a measurement of the state in the computational basis.
ParamResolver(param_dict, float])	Resolves Symbols to actual values.
plot_state_histogram(result)	Plot the state histogram from a single result with repetitions.
Points(key, points)	A simple sweep with explicitly supplied values.
sample_state_vector(state, indices, repetitions)	Samples repeatedly from measurements in the computational basis.
SimulatesSamples	Simulator that mimics running on quantum hardware.

Continued on next page

Table 64 – continued from previous page

SimulationTrialResult(params, measurements, ...)	Results of a simulation by a SimulatesFinalWaveFunction.
Simulator([dtype])	A sparse matrix wave function simulator that uses numpy.
SimulatorStep(state, measurements, ...)	
StepResult(qubit_map, measurements, List[bool]]])	Results of a step of a SimulatesFinalWaveFunction.
SimulatesFinalWaveFunction	Simulator that allows access to a quantum computer's wavefunction.
SimulatesIntermediateWaveFunction	A SimulatesFinalWaveFunction that simulates a circuit by moments.
Sweep	A sweep is an iterator over ParamResolvers.
Sweepable	Union type; Union[X, Y] means either X or Y.
to_valid_state_vector(state_rep, ...)	Verifies the initial_state is valid and converts it to ndarray form.
validate_normalized_state(state, num_qubits, ...)	Validates that the given state is a valid wave function.
to_resolvers(sweepable, ...)	Convert a Sweepable to a list of ParamResolvers.
TrialResult(*, params, measurements, ...)	The results of multiple executions of a circuit with fixed parameters.
UnitSweep	A sweep with a single element that assigns no parameter values.

cirq.bloch_vector_from_state_vector

cirq.**bloch_vector_from_state_vector**(*state: Sequence*, *index: int*) → numpy.ndarray

Returns the bloch vector of a qubit.

Calculates the bloch vector of the qubit at index
in the wavefunction given by state, assuming state follows
the standard Kronecker convention of numpy.kron.

Parameters

- **state** – A sequence representing a wave function in which the ordering mapping to qubits follows the standard Kronecker convention of numpy.kron.
- **index** – index of qubit who's bloch vector we want to find. follows the standard Kronecker convention of numpy.kron.

Returns A length 3 numpy array representing the qubit's bloch vector.

Raises

- ValueError – if the size of state is not a power of 2.
- ValueError – if the size of the state represents more than 25 qubits.
- IndexError – if index is out of range for the number of qubits corresponding to the state.

cirq.density_matrix_from_state_vector

cirq.**density_matrix_from_state_vector**(*state: Sequence*, *indices: Iterable[int] = None*) → numpy.ndarray

Returns the density matrix of the wavefunction.

Calculate the density matrix for the system on the given qubit indices, with the qubits not in indices that are present in state traced out. If indices is None the full density matrix for state is returned. We assume state follows the standard Kronecker convention of numpy.kron.

For example:

::

state = np.array([1/np.sqrt(2), 1/np.sqrt(2)], dtype=np.complex64) indices = None

gives us

$$ \rho = \begin{bmatrix} 0.5 & 0.5 0.5 & 0.5 \end{bmatrix} $$

Parameters

- **state** – A sequence representing a wave function in which the ordering mapping to qubits follows the standard Kronecker convention of numpy.kron.
- **indices** – list containing indices for qubits that you would like to include in the density matrix (i.e.) qubits that WON'T be traced out. follows the standard Kronecker convention of numpy.kron.

Returns A numpy array representing the density matrix.

Raises

- `ValueError` – if the size of state is not a power of 2.
- `ValueError` – if the size of the state represents more than 25 qubits.
- `IndexError` – if the indices are out of range for the number of qubits corresponding to the state.

cirq.dirac_notation

cirq.**dirac_notation**(*state: Sequence*, *decimals: int = 2*) → str

Returns the wavefunction as a string in Dirac notation.

For example:

```
state = np.array([1/np.sqrt(2), 1/np.sqrt(2)], dtype=np.complex64)
print(dirac_notation(state)) -> 0.71|0 + 0.71|1
```

Parameters

- **state** – A sequence representing a wave function in which the ordering mapping to qubits follows the standard Kronecker convention of numpy.kron.
- **decimals** – How many decimals to include in the pretty print.

Returns A pretty string consisting of a sum of computational basis kets and non-zero floats of the specified accuracy.

cirq.Linspace

class cirq.**Linspace**(*key: str*, *start: float*, *stop: float*, *length: int*)

A simple sweep over linearly-spaced values.

__init__(*key: str*, *start: float*, *stop: float*, *length: int*) → None

Creates a linear-spaced sweep for a given key.

For the given args, assigns to the list of values
start, start + (stop - start) / (length - 1), . . . , stop

Methods

param_tuples()	An iterator over (key, value) pairs assigning Symbol key to value.

cirq.Linspace.param_tuples

Linspace.**param_tuples**() → Iterator[Tuple[Tuple[str, float], ...]]

An iterator over (key, value) pairs assigning Symbol key to value.

Attributes

keys	The keys for the all of the Symbols that are resolved.

cirq.Linspace.keys

Linspace.**keys**

The keys for the all of the Symbols that are resolved.

cirq.measure_state_vector

cirq.**measure_state_vector**(*state: numpy.ndarray*, *indices: List[int]*, *out: numpy.ndarray = None*) → Tuple[List[bool], numpy.ndarray]

Performs a measurement of the state in the computational basis.

This does not modify `state` unless the optional `out` is `state`.

Parameters

- **state** – The state to be measured. This state is assumed to be normalized. The state must be of size 2 ** integer. The state can be of shape (2 ** integer) or (2, 2, . . . , 2).
- **indices** – Which qubits are measured. The state is assumed to be supplied in big endian order. That is the xth index of v, when expressed as a bitstring, has the largest values in the 0th index.

- **out** – An optional place to store the result. If *out* is the same as the *state* parameter, then state will be modified inline. If *out* is not None, then the result is put into *out*. If *out* is None a new value will be allocated. In all of these case out will be the same as the returned ndarray of the method. The shape and dtype of *out* will match that of state if *out* is None, otherwise it will match the shape and dtype of *out*.

Returns A tuple of a list and an numpy array. The list is an array of booleans corresponding to the measurement values (ordered by the indices). The numpy array is the post measurement state. This state has the same shape and dtype as the input state.

Raises

- ValueError if the size of state is not a power of 2.
- *IndexError if the indices are out of range for the number of qubits* – corresponding to the state.

cirq.ParamResolver

class cirq.**ParamResolver**(*param_dict: Dict[str, float]*)

Resolves Symbols to actual values.

A Symbol is a wrapped parameter name (str). A ParamResolver is an object that can be used to assign values for these keys.

ParamResolvers are hashable.

param_dict

A dictionary from the ParameterValue key (str) to its assigned value.

__init__(*param_dict: Dict[str, float]*) → None

Initialize self. See help(type(self)) for accurate signature.

Methods

value_of(value, float, str])	Attempt to resolve a Symbol or name or float to its assigned value.

cirq.ParamResolver.value_of

ParamResolver.**value_of**(*value: Union[cirq.value.symbol.Symbol, float, str]*) → Union[cirq.value.symbol.Symbol, float]

Attempt to resolve a Symbol or name or float to its assigned value.

If unable to resolve a Symbol, returns it unchanged.

If unable to resolve a name, returns a Symbol with that name.

Parameters **value** – The Symbol or name or float to try to resolve into just a float.

Returns The value of the parameter as resolved by this resolver.

cirq.plot_state_histogram

cirq.**plot_state_histogram**(*result: cirq.study.trial_result.TrialResult*) → numpy.ndarray
Plot the state histogram from a single result with repetitions.

States is a bitstring representation of all the qubit states in a single result.
Currently this function assumes each measurement gate applies to only a single qubit.

Parameters **result** – The trial results to plot.

Returns The histogram. A list of values plotted on the y-axis.

cirq.Points

class cirq.**Points**(*key: str, points: Sequence[float]*)
A simple sweep with explicitly supplied values.

__init__(*key: str, points: Sequence[float]*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

param_tuples()	An iterator over (key, value) pairs assigning Symbol key to value.

cirq.Points.param_tuples

Points.**param_tuples**() → Iterator[Tuple[Tuple[str, float], ...]]
An iterator over (key, value) pairs assigning Symbol key to value.

Attributes

keys	The keys for the all of the Symbols that are resolved.

cirq.Points.keys

Points.**keys**
The keys for the all of the Symbols that are resolved.

cirq.sample_state_vector

cirq.**sample_state_vector**(*state: numpy.ndarray, indices: List[int], repetitions: int = 1*) → List[List[bool]]

Samples repeatedly from measurements in the computational basis.

Note that this does not modify the passed in state.

Parameters

- **state** – The multi-qubit wavefunction to be sampled. This is an array of 2 to the power of the number of qubit complex numbers, and so state must be of size `2**integer`. The state can be a vector of size `2**integer` or a tensor of shape `(2, 2, ..., 2)`.
- **indices** – Which qubits are measured. The state is assumed to be supplied in big endian order. That is the xth index of v, when expressed as a bitstring, has the largest values that the 0th index.
- **repetitions** – The number of times to sample the state.

Returns Measurement results with True corresponding to the `|1` state. The outer list is for repetitions, and the inner corresponds to measurements ordered by the input indices.

Raises

- `ValueError` – `repetitions` is less than one or size of `state` is not a power of 2.
- `IndexError` – An index from `indices` is out of range, given the number of qubits corresponding to the state.

cirq.SimulatesSamples

class cirq.**SimulatesSamples**

Simulator that mimics running on quantum hardware.

Implementors of this interface should implement the _run method.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

run(circuit, param_resolver, repetitions)	Runs the entire supplied Circuit, mimicking the quantum hardware.
run_sweep(program, ...)	Runs the entire supplied Circuit, mimicking the quantum hardware.

cirq.SimulatesSamples.run

SimulatesSamples.**run**(*circuit: cirq.circuits.circuit.Circuit, param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({}), repetitions: int = 1*) → cirq.study.trial_result.TrialResult

Runs the entire supplied Circuit, mimicking the quantum hardware.

Parameters

- **circuit** – The circuit to simulate.

- **param_resolver** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult for a run.

cirq.SimulatesSamples.run_sweep

SimulatesSamples.**run_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({}), repetitions: int = 1*) → List[cirq.study.trial_result.TrialResult]

Runs the entire supplied Circuit, mimicking the quantum hardware.

In contrast to run, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult list for this run; one for each possible parameter resolver.

cirq.SimulationTrialResult

class cirq.**SimulationTrialResult**(*params: cirq.study.resolver.ParamResolver, measurements: Dict[str, numpy.ndarray], final_state: numpy.ndarray*)

Results of a simulation by a SimulatesFinalWaveFunction.

Unlike TrialResult these results contain the final state (wave function) of the system.

params

A ParamResolver of settings used for this result.

measurements

A dictionary from measurement gate key to measurement results. Measurement results are a numpy ndarray of actual boolean measurement results (ordered by the qubits acted on by the measurement gate.)

final_state

The final state (wave function) of the system after the
trial finishes. The state is returned in the computational basis
with these basis states defined by the qubit ordering of the
simulation. In particular the qubit ordering can be used to produce
a list of qubits, and these qubits can the be associated with their
index in the list. This mapping of qubit to index is then
translated into binary vectors where the last qubit is the
1s bit of the index, the second-to-last is the 2s bit of the index,
and so forth (i.e. big endian ordering). Example:
qubit ordering: [QubitA, QubitB, QubitC]
Then the returned vector will have indices mapped to qubit basis
states like the following table
| | QubitA | QubitB | QubitC |
+—+———+———+———+
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1
+—+———+———+———+

__init__(*params: cirq.study.resolver.ParamResolver, measurements: Dict[str, numpy.ndarray], final_state: numpy.ndarray*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

bloch_vector(index)	Returns the bloch vector of a qubit.
density_matrix(indices)	Returns the density matrix of the wavefunction.
dirac_notation(decimals)	Returns the wavefunction as a string in Dirac notation.

cirq.SimulationTrialResult.bloch_vector

SimulationTrialResult.**bloch_vector**(*index: int*) → numpy.ndarray
Returns the bloch vector of a qubit.

Calculates the bloch vector of the qubit at index
in the wavefunction given by self.state. Given that self.state
follows the standard Kronecker convention of numpy.kron.

Parameters **index** – index of qubit who's bloch vector we want to find.

Returns A length 3 numpy array representing the qubit's bloch vector.

Raises

- ValueError – if the size of the state represents more than 25 qubits.
- IndexError – if index is out of range for the number of qubits corresponding to the state.

cirq.SimulationTrialResult.density_matrix

SimulationTrialResult.**density_matrix**(*indices: Iterable[int] = None*) → numpy.ndarray

Returns the density matrix of the wavefunction.

```
Calculate the density matrix for the system on the given qubit
indices, with the qubits not in indices that are present in
self.final_state traced out. If indices is None the full density
matrix for self.final_state is returned, given self.final_state
follows the standard Kronecker convention of numpy.kron.

For example:
    self.final_state = np.array([1/np.sqrt(2), 1/np.sqrt(2)],
        dtype=np.complex64)
    indices = None
    gives us
```

ho = egin{bmatrix}
0.5 & 0.5
0.5 & 0.5
\end{bmatrix}

```
Args:
    indices: list containing indices for qubits that you would like
        to include in the density matrix (i.e.) qubits that WON'T
        be traced out.

Returns:
    A numpy array representing the density matrix.

Raises:
    ValueError: if the size of the state represents more than 25 qubits.
    IndexError: if the indices are out of range for the number of qubits
        corresponding to the state.
```

cirq.SimulationTrialResult.dirac_notation

SimulationTrialResult.**dirac_notation**(*decimals: int = 2*) → str

Returns the wavefunction as a string in Dirac notation.

Parameters **decimals** – How many decimals to include in the pretty print.

Returns A pretty string consisting of a sum of computational basis kets and non-zero floats of the specified accuracy.

cirq.Simulator

class cirq.**Simulator**(*dtype=<class 'numpy.complex64'>*)

A sparse matrix wave function simulator that uses numpy.

This simulator can be applied on circuits that are made up of operations that have a _unitary_ method, or _has_unitary_ and _apply_unitary_ methods, or else a _decompose_ method that returns operations satisfying these same conditions. That is to say, the operations should follow the cirq.SupportsApplyUnitary protocol, the cirq.SupportsUnitary protocol, or the cirq.CompositeOperation protocol. (It is also permitted for the circuit to contain measurements.)

This simulator supports three types of simulation.

Run simulations which mimic running on actual quantum hardware. These simulations do not give access to the wave function (like actual hardware). There are two variations of run methods, one which takes in a single (optional) way to resolve parameterized circuits, and a second which takes in a list or sweep of parameter resolver:

```
run(circuit, param_resolver, repetitions)

run_sweep(circuit, params, repetitions)
```

The simulation performs optimizations if the number of repetitions is greater than one and all measurements in the circuit are terminal (at the end of the circuit). These methods return TrialResults which contain both the measurement results, but also the parameters used for the parameterized circuit operations. The initial state of a run is always the all 0s state in the computational basis.

By contrast the simulate methods of the simulator give access to the wave function of the simulation at the end of the simulation of the circuit. These methods take in two parameters that the run methods do not: a qubit order and an initial state. The qubit order is necessary because an ordering must be chosen for the kronecker product (see SimulationTrialResult for details of this ordering). The initial state can be either the full wave function, or an integer which represents

the initial state of being in a computational basis state for the binary representation of that integer. Similar to run methods, there are two simulate methods that run for single runs or for sweeps across different

Parameters

- **simulate** (*circuit, param_resolver, qubit_order, initial_state*) –
- **simulate_sweep** (*circuit, params, qubit_order, initial_state*) –

The simulate methods in contrast to the run methods do not perform repetitions. The result of these simulations is a *SimulationTrialResult* which contains in addition to measurement results and information about the parameters that were used in the simulation access to the state viat the *final_state* method.

Finally if one wishes to perform simulations that have access to the wave function as one steps through running the circuit there is a generator which can be iterated over and each step is an object that gives access to the wave function. This stepping through a *Circuit* is done on a *Moment* by *Moment* manner.

simulate_moment_steps(circuit, param_resolver, qubit_order, initial_state)

One can iterate over the moments via

for step_result in simulate_moments(circuit): # do something with the wave function via step_result.state

See *Simulator* for the definitions of the supported methods.

__init__ (*dtype=<class 'numpy.complex64'>*)
A sparse matrix simulator.

Parameters

- **dtype** – The *numpy.dtype* used by the simulation. One of
- **or numpy.complex128** (*numpy.complex64*) –

Methods

run(circuit, param_resolver, repetitions)	Runs the entire supplied Circuit, mimicking the quantum hardware.
run_sweep(program, ...)	Runs the entire supplied Circuit, mimicking the quantum hardware.
simulate(circuit, param_resolver, ...)	Simulates the entire supplied Circuit.
simulate_moment_steps(circuit, ...)	Returns an iterator of StepResults for each moment simulated.
simulate_sweep(program, ...)	Simulates the entire supplied Circuit.

cirq.Simulator.run

Simulator.**run** (*circuit: cirq.circuits.circuit.Circuit, param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({}), repetitions: int = 1*) → cirq.study.trial_result.TrialResult
Runs the entire supplied Circuit, mimicking the quantum hardware.

Parameters

- **circuit** – The circuit to simulate.

- **param_resolver** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult for a run.

cirq.Simulator.run_sweep

Simulator.**run_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({}), repetitions: int = 1*) → List[cirq.study.trial_result.TrialResult]

Runs the entire supplied Circuit, mimicking the quantum hardware.

In contrast to run, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult list for this run; one for each possible parameter resolver.

cirq.Simulator.simulate

Simulator.**simulate**(*circuit: cirq.circuits.circuit.Circuit, param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({}), qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>, initial_state: Union[int, numpy.ndarray] = 0*) → cirq.sim.simulator.SimulationTrialResult

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function.

Parameters

- **circuit** – The circuit to simulate.
- **param_resolver** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it

must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns SimulateTrialResults for the simulation. Includes the final wave function.

cirq.Simulator.simulate_moment_steps

Simulator.**simulate_moment_steps**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = None*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → Iterator[cirq.sim.simulator.StepResult]

Returns an iterator of StepResults for each moment simulated.

Parameters

- **circuit** – The Circuit to simulate.
- **param_resolver** – A ParamResolver for determining values of Symbols.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns Iterator that steps through the simulation, simulating each moment and returning a StepResult for each moment.

cirq.Simulator.simulate_sweep

Simulator.**simulate_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule]*, *params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({})*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → List[cirq.sim.simulator.SimulationTrialResult]

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function. In contrast to simulate, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.

- **params** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns List of SimulatorTrialResults for this run, one for each possible parameter resolver.

cirq.SimulatorStep

class cirq.**SimulatorStep**(*state*, *measurements*, *qubit_map*, *dtype*)

__init__(*state*, *measurements*, *qubit_map*, *dtype*)

Results of a step of the simulator.

qubit_map

A map from the Qubits in the Circuit to the the index of this qubit for a canonical ordering. This canonical ordering is used to define the state (see the state() method).

measurements

A dictionary from measurement gate key to measurement results, ordered by the qubits that the measurement operates on.

Methods

bloch_vector(index)	Returns the bloch vector of a qubit.
density_matrix(indices)	Returns the density matrix of the wavefunction.
dirac_notation(decimals)	Returns the wavefunction as a string in Dirac notation.
sample(qubits, repetitions)	Samples from the wave function at this point in the computation.
sample_measurement_ops(measurement_ops, ...)	Samples from the wave function at this point in the computation.
set_state(state, numpy.ndarray])	Updates the state of the simulator to the given new state.
state()	Return the state (wave function) at this point in the computation.

cirq.SimulatorStep.bloch_vector

SimulatorStep.**bloch_vector**(*index: int*) → numpy.ndarray

Returns the bloch vector of a qubit.

Calculates the bloch vector of the qubit at index
in the wavefunction given by self.state. Given that self.state
follows the standard Kronecker convention of numpy.kron.

Parameters **index** – index of qubit who's bloch vector we want to find.

Returns A length 3 numpy array representing the qubit's bloch vector.

Raises

- `ValueError` – if the size of the state represents more than 25 qubits.
- `IndexError` – if index is out of range for the number of qubits corresponding to the state.

cirq.SimulatorStep.density_matrix

`SimulatorStep.`**`density_matrix`**(*indices: Iterable[int] = None*) → numpy.ndarray

Returns the density matrix of the wavefunction.

```
Calculate the density matrix for the system on the given qubit
indices, with the qubits not in indices that are present in self.state
traced out. If indices is None the full density matrix for self.state
is returned, given self.state follows standard Kronecker convention
of numpy.kron.

For example:
    self.state = np.array([1/np.sqrt(2), 1/np.sqrt(2)],
        dtype=np.complex64)
    indices = None
    gives us
```

ho = egin{bmatrix}
0.5 & 0.5
0.5 & 0.5
\end{bmatrix}

```
Args:
    indices: list containing indices for qubits that you would like
        to include in the density matrix (i.e.) qubits that WON'T
        be traced out.

Returns:
    A numpy array representing the density matrix.

Raises:
    ValueError: if the size of the state represents more than 25 qubits.
    IndexError: if the indices are out of range for the number of qubits
        corresponding to the state.
```

cirq.SimulatorStep.dirac_notation

SimulatorStep.**dirac_notation**(*decimals: int = 2*) → str

Returns the wavefunction as a string in Dirac notation.

Parameters **decimals** – How many decimals to include in the pretty print.

Returns A pretty string consisting of a sum of computational basis kets and non-zero floats of the specified accuracy.

cirq.SimulatorStep.sample

SimulatorStep.**sample**(*qubits: List[cirq.ops.raw_types.QubitId], repetitions: int = 1*) → List[List[bool]]

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

Parameters

- **qubits** – The qubits to be sampled in an order that influence the returned measurement results.
- **repetitions** – The number of samples to take.

Returns Measurement results with True corresponding to the |1⟩ state. The outer list is for repetitions, and the inner corresponds to measurements ordered by the supplied qubits. These lists are wrapped as an numpy ndarray.

cirq.SimulatorStep.sample_measurement_ops

SimulatorStep.**sample_measurement_ops**(*measurement_ops: List[cirq.ops.gate_operation.GateOperation], repetitions: int = 1*) → Dict[str, List[List[bool]]]

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

In contrast to `sample` which samples qubits, this takes a list of `cirq.GateOperation` instances whose gates are `cirq.MeasurementGate` instances and then returns a mapping from the key in the measurement gate to the resulting bit strings. Different measurement operations must not act on the same qubits.

Parameters

- **measurement_ops** – *GateOperation* instances whose gates are *MeasurementGate* instances to be sampled form.
- **repetitions** – The number of samples to take.

Returns: A dictionary from the measurement gate keys to the measurement results. These results are lists of lists, with the outer list corresponding to repetitions and the inner list corresponding to the qubits acted upon by the measurement operation with the given key.

Raises `ValueError` – If the operation's gates are not *MeasurementGate* instances or a qubit is acted upon multiple times by different operations from *measurement_ops*.

cirq.SimulatorStep.set_state

`SimulatorStep.`**`set_state`**(*state: Union[int, numpy.ndarray]*)

Updates the state of the simulator to the given new state.

Parameters

- **`state`** – If this is an int, then this is the state to reset
- **`stepper to, expressed as an integer of the computational basis.`** (*the*) –
- **`to bitwise indices is little endian. Otherwise if this is`** (*Integer*) –
- **`np.ndarray this must be the correct size and have dtype of`** (*a*) –
- **`np.complex64.`** –

Raises

- ValueError if the state is incorrectly sized or not of the correct
- `dtype.`

cirq.SimulatorStep.state

`SimulatorStep.`**`state`**`()` → numpy.ndarray

Return the state (wave function) at this point in the computation.

The state is returned in the computational basis with these basis states defined by the `qubit_map`. In particular the value in the `qubit_map` is the index of the qubit, and these are translated into binary vectors where the last qubit is the 1s bit of the index, the second-to-last is the 2s bit of the index, and so forth (i.e. big endian ordering).

Example

qubit_map: {QubitA: 0, QubitB: 1, QubitC: 2}
Then the returned vector will have indices mapped to qubit basis states like the following table
| | QubitA | QubitB | QubitC |
+---+--------+--------+--------+
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1

```
| 4 | 1 | 0 | 0 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 1 | 0 |
| 7 | 1 | 1 | 1 |
+---+---+---+---+
```

cirq.StepResult

class cirq.**StepResult**(*qubit_map: Optional[Dict], measurements: Optional[Dict[str, List[bool]]]*)

Results of a step of a SimulatesFinalWaveFunction.

qubit_map

A map from the Qubits in the Circuit to the the index of this qubit for a canonical ordering. This canonical ordering is used to define the state (see the state() method).

measurements

A dictionary from measurement gate key to measurement results, ordered by the qubits that the measurement operates on.

__init__(*qubit_map: Optional[Dict], measurements: Optional[Dict[str, List[bool]]]*) → None

Initialize self. See help(type(self)) for accurate signature.

Methods

bloch_vector(index)	Returns the bloch vector of a qubit.
density_matrix(indices)	Returns the density matrix of the wavefunction.
dirac_notation(decimals)	Returns the wavefunction as a string in Dirac notation.
sample(qubits, repetitions)	Samples from the wave function at this point in the computation.
sample_measurement_ops(measurement_ops, ...)	Samples from the wave function at this point in the computation.
set_state(state, numpy.ndarray])	Updates the state of the simulator to the given new state.
state()	Return the state (wave function) at this point in the computation.

cirq.StepResult.bloch_vector

StepResult.**bloch_vector**(*index: int*) → numpy.ndarray

Returns the bloch vector of a qubit.

Calculates the bloch vector of the qubit at index
in the wavefunction given by self.state. Given that self.state
follows the standard Kronecker convention of numpy.kron.

Parameters **index** – index of qubit who's bloch vector we want to find.

Returns A length 3 numpy array representing the qubit's bloch vector.

Raises

- `ValueError` – if the size of the state represents more than 25 qubits.
- `IndexError` – if index is out of range for the number of qubits corresponding to the state.

cirq.StepResult.density_matrix

`StepResult.`**`density_matrix`**(*indices: Iterable[int] = None*) → numpy.ndarray

Returns the density matrix of the wavefunction.

```
Calculate the density matrix for the system on the given qubit
indices, with the qubits not in indices that are present in self.state
traced out. If indices is None the full density matrix for self.state
is returned, given self.state follows standard Kronecker convention
of numpy.kron.

For example:
    self.state = np.array([1/np.sqrt(2), 1/np.sqrt(2)],
        dtype=np.complex64)
    indices = None
    gives us
```

ho = egin{bmatrix}
0.5 & 0.5
0.5 & 0.5
\end{bmatrix}

```
Args:
    indices: list containing indices for qubits that you would like
        to include in the density matrix (i.e.) qubits that WON'T
        be traced out.

Returns:
    A numpy array representing the density matrix.

Raises:
    ValueError: if the size of the state represents more than 25 qubits.
    IndexError: if the indices are out of range for the number of qubits
        corresponding to the state.
```

cirq.StepResult.dirac_notation

StepResult.**dirac_notation**(*decimals: int = 2*) → str

Returns the wavefunction as a string in Dirac notation.

Parameters **decimals** – How many decimals to include in the pretty print.

Returns A pretty string consisting of a sum of computational basis kets and non-zero floats of the specified accuracy.

cirq.StepResult.sample

StepResult.**sample**(*qubits: List[cirq.ops.raw_types.QubitId], repetitions: int = 1*) → List[List[bool]]

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

Parameters

- **qubits** – The qubits to be sampled in an order that influence the returned measurement results.
- **repetitions** – The number of samples to take.

Returns Measurement results with True corresponding to the |1⟩ state. The outer list is for repetitions, and the inner corresponds to measurements ordered by the supplied qubits. These lists are wrapped as an numpy ndarray.

cirq.StepResult.sample_measurement_ops

StepResult.**sample_measurement_ops**(*measurement_ops: List[cirq.ops.gate_operation.GateOperation], repetitions: int = 1*) → Dict[str, List[List[bool]]]

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

In contrast to `sample` which samples qubits, this takes a list of `cirq.GateOperation` instances whose gates are `cirq.MeasurementGate` instances and then returns a mapping from the key in the measurement gate to the resulting bit strings. Different measurement operations must not act on the same qubits.

Parameters

- **measurement_ops** – *GateOperation* instances whose gates are *MeasurementGate* instances to be sampled form.
- **repetitions** – The number of samples to take.

Returns: A dictionary from the measurement gate keys to the measurement results. These results are lists of lists, with the outer list corresponding to repetitions and the inner list corresponding to the qubits acted upon by the measurement operation with the given key.

Raises `ValueError` – If the operation's gates are not *MeasurementGate* instances or a qubit is acted upon multiple times by different operations from *measurement_ops*.

cirq.StepResult.set_state

`StepResult.`**`set_state`**(*state: Union[int, numpy.ndarray]*) → None

Updates the state of the simulator to the given new state.

Parameters

- **`state`** – If this is an int, then this is the state to reset
- **`stepper to, expressed as an integer of the computational basis.`** (*the*) –
- **`to bitwise indices is little endian. Otherwise if this is`** (*Integer*) –
- **`np.ndarray this must be the correct size and have dtype of`** (*a*) –
- **`np.complex64.`** –

Raises

- ValueError if the state is incorrectly sized or not of the correct
- `dtype.`

cirq.StepResult.state

`StepResult.`**`state`**() → numpy.ndarray

Return the state (wave function) at this point in the computation.

The state is returned in the computational basis with these basis states defined by the `qubit_map`. In particular the value in the `qubit_map` is the index of the qubit, and these are translated into binary vectors where the last qubit is the 1s bit of the index, the second-to-last is the 2s bit of the index, and so forth (i.e. big endian ordering).

Example

qubit_map: {QubitA: 0, QubitB: 1, QubitC: 2}
Then the returned vector will have indices mapped to qubit basis states like the following table
| | QubitA | QubitB | QubitC |
+---+--------+--------+--------+
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1

```
| 4 | 1 | 0 | 0 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 1 | 0 |
| 7 | 1 | 1 | 1 |
+---+---+---+---+
```

cirq.SimulatesFinalWaveFunction

class cirq.**SimulatesFinalWaveFunction**

Simulator that allows access to a quantum computer's wavefunction.

Implementors of this interface should implement the simulate_sweep method. This simulator only returns the wave function for the final step of a simulation. For simulators that also allow stepping through a circuit see `SimulatesIntermediateWaveFunction`.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

simulate(circuit, param_resolver, ...)	Simulates the entire supplied Circuit.
simulate_sweep(program, ...)	Simulates the entire supplied Circuit.

cirq.SimulatesFinalWaveFunction.simulate

SimulatesFinalWaveFunction.**simulate**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({})*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → cirq.sim.simulator.SimulationTrialResult

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function.

Parameters

- **circuit** – The circuit to simulate.
- **param_resolver** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.

- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns SimulateTrialResults for the simulation. Includes the final wave function.

cirq.SimulatesFinalWaveFunction.simulate_sweep

SimulatesFinalWaveFunction.**simulate_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({}), qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>, initial_state: Union[int, numpy.ndarray] = 0*) → List[cirq.sim.simulator.SimulationTrialResult]

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function. In contrast to simulate, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns List of SimulatorTrialResults for this run, one for each possible parameter resolver.

cirq.SimulatesIntermediateWaveFunction

class cirq.**SimulatesIntermediateWaveFunction**

A SimulatesFinalWaveFunction that simulates a circuit by moments.

Whereas a general SimulatesFinalWaveFunction may return the entire wave function at the end of a circuit, a SimulatesIntermediateWaveFunction can simulate stepping through the moments of a circuit.

Implementors of this interface should implement the _simulator_iterator method.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

simulate(circuit, param_resolver, ...)	Simulates the entire supplied Circuit.
simulate_moment_steps(circuit, ...)	Returns an iterator of StepResults for each moment simulated.
simulate_sweep(program, ...)	Simulates the entire supplied Circuit.

cirq.SimulatesIntermediateWaveFunction.simulate

SimulatesIntermediateWaveFunction.**simulate**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({})*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → cirq.sim.simulator.SimulationTrialResult

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function.

Parameters

- **circuit** – The circuit to simulate.
- **param_resolver** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns SimulateTrialResults for the simulation. Includes the final wave function.

cirq.SimulatesIntermediateWaveFunction.simulate_moment_steps

SimulatesIntermediateWaveFunction.**simulate_moment_steps**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = None*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → Iterator[cirq.sim.simulator.StepResult]

Returns an iterator of StepResults for each moment simulated.

Parameters

- **circuit** – The Circuit to simulate.
- **param_resolver** – A ParamResolver for determining values of Symbols.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns Iterator that steps through the simulation, simulating each moment and returning a StepResult for each moment.

cirq.SimulatesIntermediateWaveFunction.simulate_sweep

SimulatesIntermediateWaveFunction.**simulate_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({}), qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>, initial_state: Union[int, numpy.ndarray] = 0*) → List[cirq.sim.simulator.SimulationTrialResult]

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function. In contrast to simulate, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns List of SimulatorTrialResults for this run, one for each possible parameter resolver.

cirq.Sweep

class cirq.**Sweep**

A sweep is an iterator over ParamResolvers.

A ParamResolver assigns values to Symbols. For sweeps, each ParamResolver must specify the same Symbols that are assigned. So a sweep is a way to iterate over a set of different values for a fixed set of Symbols. This is

useful for a circuit, where there are a fixed set of Symbols, and you want
to iterate over an assignment of all values to all symbols.

For example, a sweep can explicitly assign a set of equally spaced points
between two endpoints using a Linspace,
sweep = Linspace("angle", start=0.0, end=2.0, length=10)
This can then be used with a circuit that has an 'angle' Symbol to
run simulations multiple simulations, one for each of the values in the
sweep
result = simulator.run_sweep(program=circuit, params=sweep)

Sweeps support Cartesian and Zip products using the '*' and '+' operators,
see the Product and Zip documentation.

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

param_tuples()	An iterator over (key, value) pairs assigning Symbol key to value.

cirq.Sweep.param_tuples

Sweep.**param_tuples**() → Iterator[Tuple[Tuple[str, float], ...]]
An iterator over (key, value) pairs assigning Symbol key to value.

Attributes

keys	The keys for the all of the Symbols that are resolved.

cirq.Sweep.keys

Sweep.**keys**
The keys for the all of the Symbols that are resolved.

cirq.Sweepable

cirq.**Sweepable = typing.Union[cirq.study.resolver.ParamResolver, typing.Iterable[cirq.study**
Union type; Union[X, Y] means either X or Y.

To define a union, use e.g. Union[int, str]. Details:

- The arguments must be types and there must be at least one.
- None as an argument is a special case and is replaced by type(None).

- Unions of unions are flattened, e.g.:

```
Union[Union[int, str], float] == Union[int, str, float]
```

- Unions of a single argument vanish, e.g.:

```
Union[int] == int  # The constructor actually returns int
```

- Redundant arguments are skipped, e.g.:

```
Union[int, str, int] == Union[int, str]
```

- When comparing unions, the argument order is ignored, e.g.:

```
Union[int, str] == Union[str, int]
```

- When two arguments have a subclass relationship, the least derived argument is kept, e.g.:

```
class Employee: pass
class Manager(Employee): pass
Union[int, Employee, Manager] == Union[int, Employee]
Union[Manager, int, Employee] == Union[int, Employee]
Union[Employee, Manager] == Employee
```

- Similar for object:

```
Union[int, object] == object
```

- You cannot subclass or instantiate a union.
- You can use Optional[X] as a shorthand for Union[X, None].

cirq.to_valid_state_vector

cirq.**to_valid_state_vector**(*state_rep: Union[int, numpy.ndarray], num_qubits: int, dtype: Type[numpy.number] = <class 'numpy.complex64'>*) → numpy.ndarray

Verifies the initial_state is valid and converts it to ndarray form.

This method is used to support passing in an integer representing a computational basis state or a full wave function as a representation of a state.

Parameters

- **state_rep** – If an int, the state returned is the state corresponding to a computational basis state. If an numpy array this is the full wave function. Both of these are validated for the given number of qubits, and the state must be properly normalized and of the appropriate dtype.
- **num_qubits** – The number of qubits for the state. The state_rep must be valid for this number of qubits.
- **dtype** – The numpy dtype of the state, will be used when creating the state for a computational basis state, or validated against if state_rep is a numpy array.

Returns A numpy ndarray corresponding to the state on the given number of qubits.

cirq.validate_normalized_state

cirq.**validate_normalized_state**(*state: numpy.ndarray*, *num_qubits: int*, *dtype: Type[numpy.number] = <class 'numpy.complex64'>*) → None

Validates that the given state is a valid wave function.

cirq.to_resolvers

cirq.**to_resolvers**(*sweepable: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]]*) → List[cirq.study.resolver.ParamResolver]

Convert a Sweepable to a list of ParamResolvers.

cirq.TrialResult

class cirq.**TrialResult**(**, params: cirq.study.resolver.ParamResolver, measurements: Dict[str, numpy.ndarray], repetitions: int*)

The results of multiple executions of a circuit with fixed parameters.

params

A ParamResolver of settings used when sampling result.

measurements

A dictionary from measurement gate key to measurement results. Measurement results are a list of lists (a numpy ndarray), the first list corresponding to the repetition, and the second is the actual boolean measurement results (ordered by the qubits acted the measurement gate.)

repetitions

The number of times a circuit was sampled to get these results.

__init__(**, params: cirq.study.resolver.ParamResolver, measurements: Dict[str, numpy.ndarray], repetitions: int*) → None

Parameters

- **params** – A ParamResolver of settings used for this result.
- **measurements** – A dictionary from measurement gate key to measurement results. The value for each key is a 2-D array of booleans, with the first index running over the repetitions, and the second index running over the qubits for the corresponding measurements.
- **repetitions** – The number of times the circuit was sampled.

Methods

histogram(*, key, fold_func, ...)	Counts the number of times a measurement result occurred.
multi_measurement_histogram(*, keys, ...)	Counts the number of times combined measurement results occurred.

cirq.TrialResult.histogram

TrialResult.**histogram**(*, *key: str*, *fold_func: Callable[numpy.ndarray, T] = <function _big_endian_int>*) → collections.Counter

Counts the number of times a measurement result occurred.

For example, suppose that:

```
- fold_func is not specified
- key='abc'
- the measurement with key 'abc' measures qubits a, b, and c.
- the circuit was sampled 3 times.
- the sampled measurement values were:
    1. a=1 b=0 c=0
    2. a=0 b=1 c=0
    3. a=1 b=0 c=0
```

Then the counter returned by this method will be:

```
collections.Counter({
    0b100: 2,
    0b010: 1
})
```

Where '0b100' is binary for '4' and '0b010' is binary for '2'. Notice that the bits are combined in a big-endian way by default, with the first measured qubit determining the highest-value bit.

Parameters

- **positional_args** – Never specified. Forces keyword arguments.
- **key** – Keys of measurements to include in the histogram.
- **fold_func** – A function used to convert a sampled measurement result into a countable value. The input is a list of bits sampled together by a measurement. If this argument is not specified, it defaults to interpreting the bits as a big endian integer.

Returns A counter indicating how often a measurement sampled various results.

cirq.TrialResult.multi_measurement_histogram

TrialResult.**multi_measurement_histogram**(*, *keys: Iterable[str]*, *fold_func: Callable[Tuple[numpy.ndarray, ...], T] = <function _tuple_of_big_endian_int>*) → collections.Counter

Counts the number of times combined measurement results occurred.

This is a more general version of the 'histogram' method. Instead of only counting how often results occurred for one specific measurement, this method tensors multiple measurement results together and counts how often the combined results occurred.

For example, suppose that:

```
- fold_func is not specified
- keys=['abc', 'd']
- the measurement with key 'abc' measures qubits a, b, and c.
- the measurement with key 'd' measures qubit d.
- the circuit was sampled 3 times.
- the sampled measurement values were:
    1. a=1 b=0 c=0 d=0
    2. a=0 b=1 c=0 d=1
    3. a=1 b=0 c=0 d=0
```

Then the counter returned by this method will be:

```
collections.Counter({
    (0b100, 0): 2,
    (0b010, 1): 1
})
```

Where '0b100' is binary for '4' and '0b010' is binary for '2'. Notice that the bits are combined in a big-endian way by default, with the first measured qubit determining the highest-value bit.

Parameters

- **fold_func** – A function used to convert sampled measurement results into countable values. The input is a tuple containing the list of bits measured by each measurement specified by the keys argument. If this argument is not specified, it defaults to returning tuples of integers, where each integer is the big endian interpretation of the bits a measurement sampled.
- **keys** – Keys of measurements to include in the histogram.

Returns A counter indicating how often measurements sampled various results.

cirq.UnitSweep

cirq.**UnitSweep = cirq.UnitSweep**

A sweep with a single element that assigns no parameter values.

This is useful as a base sweep, instead of special casing None.

3.1.8 Magic Method Protocols

Utility methods for accessing generic functionality exposed by some gates, operations, and other types.

apply_unitary(unitary_value, args, default)	High performance left-multiplication of a unitary effect onto a tensor.
circuit_diagram_info(val, args[, default, ...])	Requests information on drawing an operation in a circuit diagram.
decompose(val, *, intercepting_decomposer, ...)	Recursively decomposes a value into `cirq.Operations` meeting a criteria.
decompose_once(val[, default])	Decomposes a value into operations, if possible.
decompose_once_with_qubits(val, qubits[, ...])	Decomposes a value into operations on the given qubits.
inverse(val, default)	Returns the inverse `val**-1` of the given value, if defined.
mul(lhs, rhs, default)	Returns lhs * rhs, or else a default if the operator is not implemented.
pow(val, exponent, default)	Returns `val**factor` of the given value, if defined.
qasm(val, *, args, qubits, default)	Returns QASM code for the given value, if possible.
is_parameterized(val)	Returns whether the object is parameterized with any Symbols.
resolve_parameters(val, param_resolver)	Resolves symbol parameters in the effect using the param resolver.
has_unitary(val)	Returns whether the value has a unitary matrix representation.
unitary(val, default[, dtype])	Returns a unitary matrix describing the given value.
trace_distance_bound(val)	Returns a maximum on the trace distance between this effect's input
phase_by(val, phase_turns, qubit_index, default)	Returns a phased version of the effect.

cirq.apply_unitary

cirq.**apply_unitary**(*unitary_value: Any*, *args: cirq.protocols.apply_unitary.ApplyUnitaryArgs*, *default: TDefault = array([], dtype=float64)*) → Union[numpy.ndarray, TDefault]

High performance left-multiplication of a unitary effect onto a tensor.

If `unitary_value` defines an `_apply_unitary_` method, that method will be used to apply `unitary_value`'s unitary effect to the target tensor. Otherwise, if `unitary_value` defines a `_unitary_` method, its unitary matrix will be retrieved and applied using a generic method. Otherwise the application fails, and either an exception is raised or the specified default value is returned.

Parameters

- **unitary_value** – The value with a unitary effect to apply to the target.
- **args** – A mutable *cirq.ApplyUnitaryArgs* object describing the target tensor, available workspace, and axes to operate on. The attributes of this object will be mutated as part of computing the result.
- **default** – What should be returned if *unitary_value* doesn't have a unitary effect. If not specified, a TypeError is raised instead of returning a default value.

Returns

If the receiving object is not able to apply its unitary effect, the specified default value is returned (or a TypeError is raised). If this occurs, then *target_tensor* should not have been mutated.

If the receiving object was able to work inline, directly mutating target_tensor it will return target_tensor. The caller is responsible for checking if the result is target_tensor.

If the receiving object wrote its output over available_buffer, the result will be available_buffer. The caller is responsible for checking if the result is available_buffer (and e.g. swapping the buffer for the target tensor before the next call).

The receiving object may also write its output over a new buffer that it created, in which case that new array is returned.

Raises `TypeError` – *unitary_value* doesn't have a unitary effect and *default* wasn't specified.

cirq.circuit_diagram_info

`cirq.`**`circuit_diagram_info`**(*val: Any*, *args: Optional[cirq.protocols.circuit_diagram_info.CircuitDiagramInfoArgs] = None*, *default=cirq.CircuitDiagramInfo(wire_symbols=(), exponent=1, connected=True)*)

Requests information on drawing an operation in a circuit diagram.

Calls *circuit_diagram_info* on `val`. If `val` doesn't have *circuit_diagram_info*, or it returns NotImplemented, that indicates that diagram information is not available.

Parameters

- **`val`** – The operation or gate that will need to be drawn.
- **`args`** – A CircuitDiagramInfoArgs describing the desired drawing style.
- **`default`** – A default result to return if the value doesn't have circuit diagram information. If not specified, a TypeError is raised instead.

Returns

If *val* has no _circuit_diagram_info_ method or it returns NotImplemented, then *default* is returned (or a TypeError is raised if no *default* is specified).

Otherwise, the value returned by _circuit_diagram_info_ is returned.

Raises `TypeError` – *val* doesn't have circuit diagram information and *default* was not specified.

cirq.decompose

`cirq.`**`decompose`**(*val: TValue*, ***, *intercepting_decomposer: Callable[cirq.Operation, Union[None, Any, cirq.OP_TREE]] = None*, *fallback_decomposer: Callable[cirq.Operation, Union[None, Any, cirq.OP_TREE]] = None*, *keep: Callable[cirq.Operation, bool] = None*, *on_stuck_raise=<function _value_error_describing_bad_operation>*) → List[cirq.Operation]

Recursively decomposes a value into `cirq.Operations` meeting a criteria.

Parameters

- **`val`** – The value to decompose into operations.

- **intercepting_decomposer** – An optional method that is called before the default decomposer (the value's *_decompose_* method). If *intercepting_decomposer* is specified and returns a result that isn't *NotImplemented* or *None*, that result is used. Otherwise the decomposition falls back to the default decomposer.

  Note that *val* will be passed into *intercepting_decomposer*, even if *val* isn't a *cirq.Operation*.

- **fallback_decomposer** – An optional decomposition that used after the *intercepting_decomposer* and the default decomposer (the value's *_decompose_* method) both fail.

- **keep** – A predicate that determines if the initial operation or intermediate decomposed operations should be kept or else need to be decomposed further. If *keep* isn't specified, it defaults to "value can't be decomposed anymore".

- **on_stuck_raise** – If there is an operation that can't be decomposed and also can't be kept, *on_stuck_raise* is used to determine what error to raise. *on_stuck_raise* can either directly be an *Exception*, or a method that takes the problematic operation and returns an *Exception*. If *on_stuck_raise* is set to *None*, undecomposable operations are simply silently kept. *on_stuck_raise* defaults to a *ValueError* describing the unwanted undecomposable operation.

Returns A list of operations that the given value was decomposed into. If *on_stuck_raise* isn't set to None, all operations in the list will satisfy the predicate specified by *keep*.

Raises

- `TypeError` – *val* isn't a *cirq.Operation* and can't be decomposed even once. (So it's not possible to return a list of operations.)
- `ValueError` – Default type of error raised if there's an undecomposable operation that doesn't satisfy the given *keep* predicate.
- `TError` – Custom type of error raised if there's an undecomposable operation that doesn't satisfy the given *keep* predicate.

cirq.decompose_once

`cirq.`**`decompose_once`**(*val: Any*, *default=([]*, *)*, ***kwargs*)

Decomposes a value into operations, if possible.

This method decomposes the value exactly once, instead of decomposing it and then continuing to decomposing the decomposed operations recursively until some criteria is met (which is what `cirq.decompose` does).

Parameters

- **val** – The value to call *_decompose_* on, if possible.
- **default** – A default result to use if the value doesn't have a *_decompose_* method or that method returns *NotImplemented* or *None*. If not specified, undecomposable values cause a *TypeError*.
- **kwargs** – Arguments to forward into the *_decompose_* method of *val*. For example, this is used to tell gates what qubits they are being applied to.

Returns The result of *val._decompose_(**kwargs)*, if *val* has a *_decompose_* method and it didn't return *NotImplemented* or *None*. Otherwise *default* is returned, if it was specified. Otherwise an error is raised.

TypeError: *val* didn't have a *_decompose_* method (or that method returned *NotImplemented* or *None*) and *default* wasn't set.

cirq.decompose_once_with_qubits

cirq.**decompose_once_with_qubits**(*val: Any, qubits: Iterable[cirq.QubitId], default=([],)*)
Decomposes a value into operations on the given qubits.

This method is used when decomposing gates, which don't know which qubits they are being applied to unless told. It decomposes the gate exactly once, instead of decomposing it and then continuing to decomposing the decomposed operations recursively until some criteria is met.

Parameters

- **val** – The value to call *._decompose_(qubits=qubits)* on, if possible.
- **qubits** – The value to pass into the named *qubits* parameter of *val._decompose_*.
- **default** – A default result to use if the value doesn't have a *_decompose_* method or that method returns *NotImplemented* or *None*. If not specified, undecomposable values cause a *TypeError*.

Returns The result of *val._decompose_(qubits=qubits)*, if *val* has a *_decompose_* method and it didn't return *NotImplemented* or *None*. Otherwise *default* is returned, if it was specified. Otherwise an error is raised.

TypeError: *val* didn't have a *_decompose_* method (or that method returned *NotImplemented* or *None*) and *default* wasn't set.

cirq.inverse

cirq.**inverse**(*val: Any*, *default: Any = ([]*, *)*) → Any
Returns the inverse `val**-1` of the given value, if defined.

An object can define an inverse by defining a **pow**(self, exponent) method that returns something besides NotImplemented when given the exponent -1. The inverse of iterables is by default defined to be the iterable's items, each inverted, in reverse order.

Parameters

- **val** – The value (or iterable of invertible values) to invert.
- **default** – Determines the fallback behavior when *val* doesn't have an inverse defined. If *default* is not set, a TypeError is raised. If *default* is set to a value, that value is returned.

Returns If *val* has a __pow__ method that returns something besides NotImplemented when given an exponent of -1, that result is returned. Otherwise, if *val* is iterable, the result is a tuple with the same items as *val* but in reverse order and with each item inverted. Otherwise, if a *default* argument was specified, it is returned.

Raises `TypeError` – *val* doesn't have a __pow__ method, or that method returned NotImplemented when given -1. Furthermore *val* isn't an iterable containing invertible items. Also, no *default* argument was specified.

cirq.mul

`cirq.`**`mul`**(*lhs: Any*, *rhs: Any*, *default: Any = ([],)*) → Any

Returns lhs * rhs, or else a default if the operator is not implemented.

This method is mostly used by **pow** methods trying to return NotImplemented instead of causing a TypeError.

Parameters

- **`lhs`** – Left hand side of the multiplication.
- **`rhs`** – Right hand side of the multiplication.
- **`default`** – Default value to return if the multiplication is not defined. If not default is specified, a type error is raised when the multiplication fails.

Returns The product of the two inputs, or else the default value if the product is not defined, or else raises a TypeError if no default is defined.

Raises `TypeError` – lhs doesn't have __mul__ or it returned NotImplemented AND lhs doesn't have __rmul__ or it returned NotImplemented AND a default value isn't specified.

cirq.pow

`cirq.`**`pow`**(*val: Any*, *exponent: Any*, *default: Any = ([],)*) → Any

Returns `val**factor` of the given value, if defined.

Values define an extrapolation by defining a **pow**(self, exponent) method. Note that the method may return NotImplemented to indicate a particular extrapolation can't be done.

Parameters

- **`val`** – The value or iterable of values to invert.
- **`exponent`** – The extrapolation factor. For example, if this is 0.5 and val is a gate then the caller is asking for a square root of the gate.
- **`default`** – Determines the fallback behavior when *val* doesn't have an extrapolation defined. If *default* is not set and that occurs, a TypeError is raised instead.

Returns If *val* has a __pow__ method that returns something besides NotImplemented, that result is returned. Otherwise, if a default value was specified, the default value is returned.

Raises `TypeError` – *val* doesn't have a __pow__ method (or that method returned NotImplemented) and no *default* value was specified.

cirq.qasm

cirq.**qasm**(*val: Any*, ***, *args: Optional[cirq.protocols.qasm.QasmArgs] = None*, *qubits: Optional[Iterable[cirq.QubitId]] = None*, *default: TDefault = ([],)*) → Union[str, TDefault]

Returns QASM code for the given value, if possible.

Different values require different sets of arguments. The general rule of thumb is that circuits don't need any, operations need a `QasmArgs`, and gates need both a `QasmArgs` and `qubits`.

Parameters

- **val** – The value to turn into QASM code.
- **args** – A *QasmArgs* object to pass into the value's *_qasm_* method. This is for needed for objects that only have a local idea of what's going on, e.g. a *cirq.Operation* in a bigger *cirq.Circuit* involving qubits that the operation wouldn't otherwise know about.
- **qubits** – A list of qubits that the value is being applied to. This is needed for *cirq.Gate* values, which otherwise wouldn't know what qubits to talk about.
- **default** – A default result to use if the value doesn't have a *_qasm_* method or that method returns *NotImplemented* or *None*. If not specified, undecomposable values cause a *TypeError*.

Returns The result of *val._qasm_(...)*, if *val* has a *_qasm_* method and it didn't return *NotImplemented* or *None*. Otherwise *default* is returned, if it was specified. Otherwise an error is raised.

TypeError: *val* didn't have a *_qasm_* method (or that method returned *NotImplemented* or *None*) and *default* wasn't set.

cirq.is_parameterized

cirq.**is_parameterized**(*val: Any*) → bool

Returns whether the object is parameterized with any Symbols.

A value is parameterized when it has an `_is_parameterized_` method and that method returns a truthy value.

Returns True if the gate has any unresolved Symbols and False otherwise. If no implementation of the magic method above exists or if that method returns NotImplemented, this will default to False.

cirq.resolve_parameters

cirq.**resolve_parameters**(*val: Any*, *param_resolver: cirq.study.resolver.ParamResolver*) → Any

Resolves symbol parameters in the effect using the param resolver.

This function will use the `_resolve_parameters_` magic method of `val` to resolve any Symbols with concrete values from the given

parameter resolver.

Parameters

- **val** – The object to resolve (e.g. the gate, operation, etc)
- **param_resolver** – the object to use for resolving all symbols

Returns a gate or operation of the same type, but with all Symbols replaced with floats according to the given ParamResolver. If *val* has no *_resolve_parameters_* method or if it returns NotImplemented, *val* itself is returned.

cirq.has_unitary

cirq.**has_unitary**(*val: Any*) → bool

Returns whether the value has a unitary matrix representation.

Returns If *val* has a _has_unitary_ method and its result is not NotImplemented, that result is returned. Otherwise, if the value has a _unitary_ method return if that has a non-default value. Returns False if neither function exists.

cirq.unitary

cirq.**unitary**(*val: Any*, *default: TDefault = array([], dtype=float64)*) → Union[numpy.ndarray, TDefault]

Returns a unitary matrix describing the given value.

Parameters

- **val** – The value to describe with a unitary matrix.
- **default** – Determines the fallback behavior when *val* doesn't have a unitary matrix. If *default* is not set, a TypeError is raised. If default is set to a value, that value is returned.

Returns If *val* has a _unitary_ method and its result is not NotImplemented, that result is returned. Otherwise, if a default value was specified, the default value is returned.

Raises `TypeError` – *val* doesn't have a _unitary_ method (or that method returned NotImplemented) and also no default value was specified.

cirq.trace_distance_bound

cirq.**trace_distance_bound**(*val: Any*) → float

Returns a maximum on the trace distance between this effect's input
and output. This method makes use of the effect's `_trace_distance_bound_`
method to determine the maximum bound on the trace difference between
before and after the effect.

Parameters **val** – The effect of which the bound should be calculated

Returns If *val* has a _trace_distance_bound_ method and its result is not NotImplemented, that result is returned. Otherwise, 1 is returned. Result is capped at a maximum of 1, even if the underlying function produces a result greater than 1.

cirq.phase_by

cirq.**phase_by**(*val: Any*, *phase_turns: float*, *qubit_index: int*, *default: TDefault = ([],)*)
Returns a phased version of the effect.

For example, an X gate phased by 90 degrees would be a Y gate.
This works by calling `val`'s *phase_by* method and returning
the result.

Parameters

- **val** – The value to describe with a unitary matrix.
- **phase_turns** – The amount to phase the gate, in fractions of a whole turn. Divide by 2pi to get radians.
- **qubit_index** – The index of the target qubit the phasing applies to. For operations this is the index of the qubit within the operation's qubit list. For gates it's the index of the qubit within the tuple of qubits taken by the gate's *on* method.
- **default** – The default value to return if *val* can't be phased. If not specified, an error is raised when *val* can't be phased.

Returns If *val* has a _phase_by_ method and its result is not NotImplemented, that result is returned. Otherwise, the function will return the default value provided or raise a TypeError if none was provided.

Raises `TypeError` – *val* doesn't have a _phase_by_ method (or that method returned NotImplemented) and no *default* was specified.

3.1.9 Magic Method Protocol Types

Classes defining and used by the magic method protocols.

CircuitDiagramInfo(wire_symbols, ...], ...)	Describes how to draw an operation in a circuit diagram.
CircuitDiagramInfoArgs(known_qubits, ...)	A request for information on drawing an operation in a circuit diagram.
QasmArgs(precision, version, qubit_id_map, ...)	
QasmOutput(operations, Iterable[Any]], ...)	
SupportsApplyUnitary(*args, **kwargs)	An object that can be efficiently left-multiplied into tensors.
SupportsCircuitDiagramInfo(*args, **kwargs)	A diagrammable operation on qubits.
SupportsDecompose(*args, **kwargs)	An object that can be decomposed into simpler operations.
SupportsDecomposeWithQubits(*args, **kwargs)	An object that can be decomposed into operations on given qubits.
SupportsParameterization(*args, **kwargs)	An object that can be parameterized by Symbols and resolved
SupportsPhase(*args, **kwargs)	An effect that can be phased around the Z axis of target qubits.

Continued on next page

Table 81 – continued from previous page

SupportsQasm(*args, **kwargs)	An object that can be turned into QASM code.
SupportsQasmWithArgs(*args, **kwargs)	An object that can be turned into QASM code.
SupportsQasmWithArgsAndQubits(*args, **kwargs)	An object that can be turned into QASM code if it knows its qubits.
SupportsTraceDistanceBound(*args, **kwargs)	An effect with known bounds on how easy it is to detect.
SupportsUnitary(*args, **kwargs)	An object that may be describable by a unitary matrix.

cirq.CircuitDiagramInfo

class cirq.**CircuitDiagramInfo**(*wire_symbols: Tuple[str, ...], exponent: Any = 1, connected: bool = True*)

Describes how to draw an operation in a circuit diagram.

__init__(*wire_symbols: Tuple[str, ...], exponent: Any = 1, connected: bool = True*) → None

Parameters

- **wire_symbols** – The symbols that should be shown on the qubits affected by this operation. Must match the number of qubits that the operation is applied to.
- **exponent** – An optional convenience value that will be appended onto an operation's final gate symbol with a caret in front (unless it's equal to 1). For example, the square root of X gate has a text diagram exponent of 0.5 and symbol of 'X' so it is drawn as 'X^0.5'.
- **connected** – Whether or not to draw a line connecting the qubits.

Methods

—

cirq.CircuitDiagramInfoArgs

class cirq.**CircuitDiagramInfoArgs**(*known_qubits: Optional[Iterable[cirq.QubitId]], known_qubit_count: Optional[int], use_unicode_characters: bool, precision: Optional[int], qubit_map: Optional[Dict[cirq.QubitId, int]]*)

A request for information on drawing an operation in a circuit diagram.

known_qubits

The qubits the gate is being applied to. None means this information is not known by the caller.

known_qubit_count

The number of qubits the gate is being applied to
None means this information is not known by the caller.

use_unicode_characters

If true, the wire symbols are permitted to include unicode characters (as long as they work well in fixed width fonts). If false, use only ascii characters. ASCII is preferred in cases where UTF8 support is done poorly, or where the fixed-width font being used to show the diagrams does not properly handle unicode characters.

precision

The number of digits after the decimal to show for numbers in the text diagram. None means use full precision.

qubit_map

The map from qubits to diagram positions.

__init__(*known_qubits: Optional[Iterable[cirq.QubitId]], known_qubit_count: Optional[int], use_unicode_characters: bool, precision: Optional[int], qubit_map: Optional[Dict[cirq.QubitId, int]]*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

—

Attributes

UNINFORMED_DEFAULT

cirq.CircuitDiagramInfoArgs.UNINFORMED_DEFAULT

CircuitDiagramInfoArgs.**UNINFORMED_DEFAULT = cirq.CircuitDiagramInfoArgs(known_qubits=N**

cirq.QasmArgs

class cirq.**QasmArgs**(*precision: int = 10, version: str = '2.0', qubit_id_map: Dict[cirq.QubitId, str] = None, meas_key_id_map: Dict[str, str] = None*)

__init__(*precision: int = 10, version: str = '2.0', qubit_id_map: Dict[cirq.QubitId, str] = None, meas_key_id_map: Dict[str, str] = None*) → None

Parameters

- **precision** – The number of digits after the decimal to show for numbers in the qasm code.
- **version** – The QASM version to target. Objects may return different qasm depending on version.
- **qubit_id_map** – A dictionary mapping qubits to qreg QASM identifiers.

- **meas_key_id_map** – A dictionary mapping measurement keys to creg QASM identifiers.

Methods

check_unused_args(used_args, args, kwargs)	
convert_field(value, conversion)	
format(**kwargs)	
format_field(value, spec)	Method of string.Formatter that specifies the output of format().
get_field(field_name, args, kwargs)	
get_value(key, args, kwargs)	
parse(format_string)	
validate_version(*supported_versions)	
vformat(format_string, args, kwargs)	

cirq.QasmArgs.check_unused_args

QasmArgs.**check_unused_args**(*used_args*, *args*, *kwargs*)

cirq.QasmArgs.convert_field

QasmArgs.**convert_field**(*value*, *conversion*)

cirq.QasmArgs.format

QasmArgs.**format**(***kwargs*)

cirq.QasmArgs.format_field

QasmArgs.**format_field**(*value: Any*, *spec: str*) → str
Method of string.Formatter that specifies the output of format().

cirq.QasmArgs.get_field

QasmArgs.**get_field**(*field_name*, *args*, *kwargs*)

cirq.QasmArgs.get_value

QasmArgs.**get_value**(*key*, *args*, *kwargs*)

cirq.QasmArgs.parse

QasmArgs.**parse**(*format_string*)

cirq.QasmArgs.validate_version

QasmArgs.**validate_version**(**supported_versions*) → None

cirq.QasmArgs.vformat

QasmArgs.**vformat**(*format_string*, *args*, *kwargs*)

cirq.QasmOutput

class cirq.**QasmOutput**(*operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]], qubits: Tuple[cirq.ops.raw_types.QubitId, ...], header: str = '', precision: int = 10, version: str = '2.0'*)

__init__(*operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]], qubits: Tuple[cirq.ops.raw_types.QubitId, ...], header: str = '', precision: int = 10, version: str = '2.0'*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

is_valid_qasm_id(id_str)	Test if id_str is a valid id in QASM grammar.
save(path, bytes, int])	Write QASM output to a file specified by path.

cirq.QasmOutput.is_valid_qasm_id

QasmOutput.**is_valid_qasm_id**(*id_str: str*) → bool
Test if id_str is a valid id in QASM grammar.

cirq.QasmOutput.save

QasmOutput.**save**(*path: Union[str, bytes, int]*) → None
Write QASM output to a file specified by path.

Attributes

valid_id_re

cirq.QasmOutput.valid_id_re

QasmOutput.**valid_id_re = re.compile('[a-z][a-zA-Z0-9_]*\\Z')**

cirq.SupportsApplyUnitary

class cirq.**SupportsApplyUnitary**(**args*, ***kwargs*)
An object that can be efficiently left-multiplied into tensors.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsCircuitDiagramInfo

class cirq.**SupportsCircuitDiagramInfo**(**args*, ***kwargs*)
A diagrammable operation on qubits.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsDecompose

class cirq.**SupportsDecompose**(**args*, ***kwargs*)
An object that can be decomposed into simpler operations.

Returning `NotImplemented` means "not decomposable". Otherwise an operation, list of operations, or generally anything meeting the `OP_TREE` contract can be returned.

For example, a Toffoli could be decomposed into Hadamards, CNOTs, and Ts. These operations are simpler because they act on fewer qubits. In general, a decomposition should move closer towards the basic 1-qubit and 2-qubit gates included by default in cirq. It is not necessary to get all the way there, just closer (callers will iteratively decompose if needed).

DECOMPOSITIONS MUST NEVER BE CYCLIC. If B has A in its decomposition, A should not have B in its decomposition. Decomposition is often performed iteratively, until a fixed point or some desired criteria is met. Cyclic decompositions cause that kind of code to loop forever.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsDecomposeWithQubits

class cirq.**SupportsDecomposeWithQubits**(**args*, ***kwargs*)
An object that can be decomposed into operations on given qubits.

Returning `NotImplemented` or `None` means "not decomposable". Otherwise an operation, list of operations, or generally anything meeting the `OP_TREE` contract can be returned.

For example, a SWAP gate can be turned into three CNOTs. But in order to describe those CNOTs one must be able to talk about "the target qubit" and "the control qubit". This can only be done once the qubits-to-be-swapped are known.

The main user of this protocol is `GateOperation`, which decomposes itself by delegating to its gate. The qubits argument is needed because gates are specified independently of target qubits and so must be told the relevant qubits. A `GateOperation` implements `SupportsDecompose` as long as its gate implements `SupportsDecomposeWithQubits`.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsParameterization

class cirq.**SupportsParameterization**(**args*, ***kwargs*)

An object that can be parameterized by Symbols and resolved via a ParamResolver

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsPhase

class cirq.**SupportsPhase**(**args*, ***kwargs*)

An effect that can be phased around the Z axis of target qubits.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsQasm

class cirq.**SupportsQasm**(**args*, ***kwargs*)
An object that can be turned into QASM code.

Returning `NotImplemented` or `None` means "don't know how to turn into QASM". In that case fallbacks based on decomposition and known unitaries will be used instead.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsQasmWithArgs

class cirq.**SupportsQasmWithArgs**(**args*, ***kwargs*)
An object that can be turned into QASM code.

Returning `NotImplemented` or `None` means "don't know how to turn into QASM". In that case fallbacks based on decomposition and known unitaries will be used instead.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsQasmWithArgsAndQubits

class cirq.**SupportsQasmWithArgsAndQubits**(**args*, ***kwargs*)
An object that can be turned into QASM code if it knows its qubits.

Returning `NotImplemented` or `None` means "don't know how to turn into QASM". In that case fallbacks based on decomposition and known unitaries will be used instead.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsTraceDistanceBound

class cirq.**SupportsTraceDistanceBound**(**args*, ***kwargs*)

An effect with known bounds on how easy it is to detect.

Used when deciding whether or not an operation is negligible. For example, the trace distance between the states before and after a Z**0.00000001 operation is very close to 0, so it would typically be considered negligible.

__init__(**args*, ***kwargs*)

Methods

---

cirq.SupportsUnitary

class cirq.**SupportsUnitary**(**args*, ***kwargs*)

An object that may be describable by a unitary matrix.

__init__(**args*, ***kwargs*)

Methods

3.1.10 Optimization

Classes and methods for rewriting circuits.

ConvertToCzAndSingleGates(ignore_failures, ...)	Attempts to convert strange multi-qubit gates into CZ and single qubit
DropEmptyMoments	Removes empty moments from a circuit.
DropNegligible(tolerance)	An optimization pass that removes operations with tiny effects.
EjectPhasedPaulis(tolerance)	Pushes X, Y, and PhasedX gates towards the end of the circuit.
EjectZ(tolerance)	Pushes Z gates towards the end of the circuit.
ExpandComposite(no_decomp, ...)	An optimizer that expands composite operations via cirq.decompose.
google.optimized_for_xmon(circuit, ...)	Optimizes a circuit with XmonDevice in mind.
merge_single_qubit_gates_into_phased_x_z(ano)	Canonicalizes runs of single-qubit rotations in a circuit.

Continued on next page

Table 99 – continued from previous page

MergeInteractions(tolerance, ...)	Combines series of adjacent one and two-qubit gates operating on a
MergeSingleQubitGates(*, rewriter, ...)	Optimizes runs of adjacent unitary 1-qubit operations.
OptimizationPass	Rewrites a circuit's operations in place to make them better.
PointOptimizationSummary(clear_span, ...)	A description of a local optimization to perform.
PointOptimizer(post_clean_up, ...)	Makes circuit improvements focused on a specific location.
single_qubit_matrix_to_gates(mat, tolerance)	Implements a single-qubit operation with few gates.
single_qubit_matrix_to_pauli_rotations(mat, ...)	Implements a single-qubit operation with few rotations.
single_qubit_matrix_to_phased_x_z(mat, atol)	Implements a single-qubit operation with a PhasedX and Z gate.
single_qubit_op_to_framed_phase_form(mat)	Decomposes a 2x2 unitary M into U^-1 * diag(1, r) * U * diag(g, g).
two_qubit_matrix_to_operations(q0, q1, mat, ...)	Decomposes a two-qubit operation into Z/XY/CZ gates.

cirq.ConvertToCzAndSingleGates

class cirq.**ConvertToCzAndSingleGates**(*ignore_failures: bool = False*, *allow_partial_czs: bool = False*)

Attempts to convert strange multi-qubit gates into CZ and single qubit gates.

First, checks if the operation has a unitary effect. If so, and the gate is a 1-qubit or 2-qubit gate, then performs circuit synthesis of the operation.

Second, attempts to `cirq.decompose` to the operation.

Third, if ignore_failures is set, gives up and returns the gate unchanged. Otherwise raises a TypeError.

__init__(*ignore_failures: bool = False*, *allow_partial_czs: bool = False*) → None

Parameters

- **ignore_failures** – If set, gates that fail to convert are forwarded unchanged. If not set, conversion failures raise a TypeError.
- **allow_partial_czs** – If set, the decomposition is permitted to use gates of the form *cirq.CZ**t*, instead of only *cirq.CZ*.

Methods

optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.ConvertToCzAndSingleGates.optimization_at

ConvertToCzAndSingleGates.**optimization_at**(*circuit: cirq.circuits.circuit.Circuit*, *index: int*, *op: cirq.ops.raw_types.Operation*) → Optional[cirq.circuits.optimization_pass.PointOptimizationSummary]

Describes how to change operations near the given location.

For example, this method could realize that the given operation is an X gate and that in the very next moment there is a Z gate. It would indicate that they should be combined into a Y gate by returning PointOptimizationSummary(clear_span=2, clear_qubits=op.qubits, new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.
- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.ConvertToCzAndSingleGates.optimize_circuit

ConvertToCzAndSingleGates.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.DropEmptyMoments

class cirq.**DropEmptyMoments**

Removes empty moments from a circuit.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.DropEmptyMoments.optimize_circuit

DropEmptyMoments.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)
Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.DropNegligible

class cirq.**DropNegligible**(*tolerance: float = 1e-08*)
An optimization pass that removes operations with tiny effects.

__init__(*tolerance: float = 1e-08*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.DropNegligible.optimize_circuit

DropNegligible.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*) → None
Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.EjectPhasedPaulis

class cirq.**EjectPhasedPaulis**(*tolerance: float = 1e-08*)
Pushes X, Y, and PhasedX gates towards the end of the circuit.

As the gates get pushed, they may absorb Z gates, cancel against other X, Y, or PhasedX gates with exponent=1, get merged into measurements (as output bit flips), and cause phase kickback operations across CZs (which can then be removed by the EjectZ optimization).

__init__(*tolerance: float = 1e-08*) → None

Parameters **tolerance** – Maximum absolute error tolerance. The optimization is permitted to simply drop negligible combinations of Z gates, with a threshold determined by this tolerance.

Methods

optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.EjectPhasedPaulis.optimize_circuit

EjectPhasedPaulis.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)
Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.EjectZ

class cirq.**EjectZ**(*tolerance: float = 0.0*)
Pushes Z gates towards the end of the circuit.

As the Z gates get pushed they may absorb other Z gates, get absorbed into measurements, cross CZ gates, cross W gates (by phasing them), etc.

__init__(*tolerance: float = 0.0*) → None

Parameters **tolerance** – Maximum absolute error tolerance. The optimization is permitted to simply drop negligible combinations of Z gates, with a threshold determined by this tolerance.

Methods

optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.EjectZ.optimize_circuit

EjectZ.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)
Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.ExpandComposite

class cirq.**ExpandComposite**(*no_decomp: Callable[cirq.ops.raw_types.Operation, bool] = <function ExpandComposite.<lambda>>*)
An optimizer that expands composite operations via cirq.decompose.

For each operation in the circuit, this pass examines if the operation can be decomposed. If it can be, the operation is cleared out and and replaced

with its decomposition using a fixed insertion strategy.

__init__(*no_decomp: Callable[cirq.ops.raw_types.Operation, bool] = <function ExpandComposite.<lambda>>*) → None
Construct the optimization pass.

Parameters **no_decomp** – A predicate that determines whether an operation should be decomposed or not. Defaults to decomposing everything.

Methods

optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.ExpandComposite.optimization_at

ExpandComposite.**optimization_at**(*circuit*, *index*, *op*)
Describes how to change operations near the given location.

For example, this method could realize that the given operation is an
X gate and that in the very next moment there is a Z gate. It would
indicate that they should be combined into a Y gate by returning
PointOptimizationSummary(clear_span=2,
clear_qubits=op.qubits,
new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.
- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.ExpandComposite.optimize_circuit

ExpandComposite.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)
Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.google.optimized_for_xmon

cirq.google.**optimized_for_xmon**(*circuit: cirq.circuits.circuit.Circuit*, *new_device: Optional[cirq.google.xmon_device.XmonDevice] = None*, *qubit_map: Callable[cirq.ops.raw_types.QubitId, cirq.devices.grid_qubit.GridQubit] = <function <lambda>>*, *allow_partial_czs: bool = False*) → cirq.circuits.circuit.Circuit

Optimizes a circuit with XmonDevice in mind.

Starts by converting the circuit's operations to the xmon gate set, then begins merging interactions and rotations, ejecting pi-rotations and phasing operations, dropping unnecessary operations, and pushing operations earlier.

Parameters

- **circuit** – The circuit to optimize.
- **new_device** – The device the optimized circuit should be targeted at. If set to None, the circuit's current device is used.
- **qubit_map** – Transforms the qubits (e.g. so that they are GridQubits).
- **allow_partial_czs** – If true, the optimized circuit may contain partial CZ gates. Otherwise all partial CZ gates will be converted to full CZ gates. At worst, two CZ gates will be put in place of each partial CZ from the input.

Returns The optimized circuit.

cirq.merge_single_qubit_gates_into_phased_x_z

cirq.**merge_single_qubit_gates_into_phased_x_z**(*circuit: cirq.circuits.circuit.Circuit*, *atol: float = 1e-08*) → None

Canonicalizes runs of single-qubit rotations in a circuit.

Specifically, any run of non-parameterized circuits will be replaced by an optional PhasedX operation followed by an optional Z operation.

Parameters

- **circuit** – The circuit to rewrite. This value is mutated in-place.
- **atol** – Absolute tolerance to angle error. Larger values allow more negligible gates to be dropped, smaller values increase accuracy.

cirq.MergeInteractions

class cirq.**MergeInteractions**(*tolerance: float = 1e-08, allow_partial_czs: bool = True, post_clean_up: Callable[Sequence[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function MergeInteractions.<lambda>>*)

Combines series of adjacent one and two-qubit gates operating on a pair of qubits.

__init__(*tolerance: float = 1e-08, allow_partial_czs: bool = True, post_clean_up: Callable[Sequence[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function MergeInteractions.<lambda>>*) → None

Args:
post_clean_up: This function is called on each set of optimized
operations before they are put into the circuit to replace the
old operations.

Methods

optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.MergeInteractions.optimization_at

MergeInteractions.**optimization_at**(*circuit: cirq.circuits.circuit.Circuit, index: int, op: cirq.ops.raw_types.Operation*) → Optional[cirq.circuits.optimization_pass.PointOptimizationSummary]

Describes how to change operations near the given location.

For example, this method could realize that the given operation is an
X gate and that in the very next moment there is a Z gate. It would
indicate that they should be combined into a Y gate by returning
PointOptimizationSummary(clear_span=2,
clear_qubits=op.qubits,
new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.
- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.MergeInteractions.optimize_circuit

MergeInteractions.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.MergeSingleQubitGates

class cirq.**MergeSingleQubitGates**(**, rewriter: Optional[Callable[List[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any], None]]] = None, synthesizer: Optional[Callable[[cirq.ops.raw_types.QubitId, numpy.ndarray], Union[cirq.ops.raw_types.Operation, Iterable[Any], None]]] = None*)

Optimizes runs of adjacent unitary 1-qubit operations.

__init__(**, rewriter: Optional[Callable[List[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any], None]]] = None, synthesizer: Optional[Callable[[cirq.ops.raw_types.QubitId, numpy.ndarray], Union[cirq.ops.raw_types.Operation, Iterable[Any], None]]] = None*)

Parameters

- **rewriter** – Specifies how to merge runs of single-qubit operations into a more desirable form. Takes a list of operations and produces a list of operations. The default rewriter computes the matrix of the run and returns a *cirq.SingleQubitMatrixGate*. If *rewriter* returns *None*, that means "do not rewrite the operations".
- **synthesizer** – A special kind of rewriter that operates purely on the unitary matrix of the intended operation. Takes a qubit and a unitary matrix and returns a list of operations. Can't be specified at the same time as *rewriter*. If *synthesizer* returns *None*, that means "do not rewrite the operations used to make this matrix".

Methods

optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.MergeSingleQubitGates.optimization_at

MergeSingleQubitGates.**optimization_at**(*circuit: cirq.circuits.circuit.Circuit, index: int, op: cirq.ops.raw_types.Operation*) → Optional[cirq.circuits.optimization_pass.PointOptimizationSummary]

Describes how to change operations near the given location.

For example, this method could realize that the given operation is an X gate and that in the very next moment there is a Z gate. It would indicate that they should be combined into a Y gate by returning PointOptimizationSummary(clear_span=2, clear_qubits=op.qubits, new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.

- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.MergeSingleQubitGates.optimize_circuit

MergeSingleQubitGates.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.OptimizationPass

class cirq.**OptimizationPass**

Rewrites a circuit's operations in place to make them better.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.OptimizationPass.optimize_circuit

OptimizationPass.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.PointOptimizationSummary

class cirq.**PointOptimizationSummary**(*clear_span: int, clear_qubits: Iterable[cirq.ops.raw_types.QubitId], new_operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]]*)

A description of a local optimization to perform.

__init__(*clear_span: int, clear_qubits: Iterable[cirq.ops.raw_types.QubitId], new_operations: Union[cirq.ops.raw_types.Operation, Iterable[Any]]*) → None

Parameters

- **clear_span** – Defines the range of moments to affect. Specifically, refers to the indices in range(start, start+clear_span) where start is an index known from surrounding context.
- **clear_qubits** – Defines the set of qubits that should be cleared with each affected moment.
- **new_operations** – The operations to replace the cleared out operations with.

Methods

—

cirq.PointOptimizer

class cirq.**PointOptimizer**(*post_clean_up: Callable[Sequence[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function PointOptimizer.<lambda>>*)

Makes circuit improvements focused on a specific location.

__init__(*post_clean_up: Callable[Sequence[cirq.ops.raw_types.Operation], Union[cirq.ops.raw_types.Operation, Iterable[Any]]] = <function PointOptimizer.<lambda>>*) → None

Parameters **post_clean_up** – This function is called on each set of optimized operations before they are put into the circuit to replace the old operations.

Methods

optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.PointOptimizer.optimization_at

PointOptimizer.**optimization_at**(*circuit: cirq.circuits.circuit.Circuit*, *index: int*, *op: cirq.ops.raw_types.Operation*) → Optional[cirq.circuits.optimization_pass.PointOptimizationSummary]

Describes how to change operations near the given location.

For example, this method could realize that the given operation is an X gate and that in the very next moment there is a Z gate. It would indicate that they should be combined into a Y gate by returning PointOptimizationSummary(clear_span=2, clear_qubits=op.qubits, new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.
- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.PointOptimizer.optimize_circuit

PointOptimizer.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.single_qubit_matrix_to_gates

cirq.**single_qubit_matrix_to_gates**(*mat: numpy.ndarray*, *tolerance: float = 0*) → List[cirq.ops.gate_features.SingleQubitGate]

Implements a single-qubit operation with few gates.

Parameters

- **mat** – The 2x2 unitary matrix of the operation to implement.
- **tolerance** – A limit on the amount of error introduced by the construction.

Returns

A list of gates that, when applied in order, perform the desired operation.

cirq.single_qubit_matrix_to_pauli_rotations

cirq.**single_qubit_matrix_to_pauli_rotations**(*mat: numpy.ndarray*, *tolerance: float = 0*) → List[Tuple[cirq.ops.pauli.Pauli, float]]

Implements a single-qubit operation with few rotations.

Parameters

- **mat** – The 2x2 unitary matrix of the operation to implement.
- **tolerance** – A limit on the amount of error introduced by the construction.

Returns A list of (Pauli, half_turns) tuples that, when applied in order, perform the desired operation.

cirq.single_qubit_matrix_to_phased_x_z

cirq.**single_qubit_matrix_to_phased_x_z**(*mat: numpy.ndarray*, *atol: float = 0*) → List[cirq.ops.gate_features.SingleQubitGate]

Implements a single-qubit operation with a PhasedX and Z gate.

If one of the gates isn't needed, it will be omitted.

Parameters

- **mat** – The 2x2 unitary matrix of the operation to implement.
- **atol** – A limit on the amount of error introduced by the construction.

Returns

A list of gates that, when applied in order, perform the desired operation.

cirq.single_qubit_op_to_framed_phase_form

cirq.**single_qubit_op_to_framed_phase_form**(*mat: numpy.ndarray*) → Tuple[numpy.ndarray, complex, complex]

Decomposes a 2x2 unitary M into U^-1 * diag(1, r) * U * diag(g, g).

U translates the rotation axis of M to the Z axis.
g fixes a global phase factor difference caused by the translation.
r's phase is the amount of rotation around M's rotation axis.

This decomposition can be used to decompose controlled single-qubit rotations into controlled-Z operations bordered by single-qubit operations.

Parameters **mat** – The qubit operation as a 2x2 unitary matrix.

Returns A 2x2 unitary U, the complex relative phase factor r, and the complex global phase factor g. Applying M is equivalent (up to global phase) to applying U, rotating around the Z axis to apply r, then un-applying U. When M is controlled, the control must be rotated around the Z axis to apply g.

cirq.two_qubit_matrix_to_operations

cirq.**two_qubit_matrix_to_operations**(*q0: cirq.ops.raw_types.QubitId*, *q1: cirq.ops.raw_types.QubitId*, *mat: numpy.ndarray*, *allow_partial_czs: bool*, *tolerance: float = 1e-08*) → List[cirq.ops.raw_types.Operation]

Decomposes a two-qubit operation into Z/XY/CZ gates.

Parameters

- **q0** – The first qubit being operated on.
- **q1** – The other qubit being operated on.
- **mat** – Defines the operation to apply to the pair of qubits.
- **allow_partial_czs** – Enables the use of Partial-CZ gates.
- **tolerance** – A limit on the amount of error introduced by the construction.

Returns A list of operations implementing the matrix.

3.1.11 Utilities

General utility methods, mostly related to performing relevant linear algebra operations and decompositions.

allclose_up_to_global_phase(a, b, rtol, ...)	Determines if a ~= b * exp(i t) for some t.
apply_matrix_to_slices(target, matrix, ...)	Left-multiplies an NxN matrix onto N slices of a numpy array.
bidiagonalize_real_matrix_pair_with_symmetric_products(...)	Finds orthogonal matrices that diagonalize both mat1 and mat2.
bidiagonalize_unitary_with_special_orthogonals(...)	Finds orthogonal matrices L, R such that L @ matrix @ R is diagonal.
canonicalize_half_turns(half_turns, float])	Wraps the input into the range (-1, +1].
chosen_angle_to_canonical_half_turns(...)	Returns a canonicalized half_turns based on the given arguments.
chosen_angle_to_half_turns(half_turns, ...)	Returns a half_turns value based on the given arguments.

Continued on next page

Table 111 – continued from previous page

slice_for_qubits_equal_to(target_qubit_axes, ...)	Returns an index corresponding to a desired subset of an np.ndarray.
block_diag(*blocks)	Concatenates blocks into a block diagonal matrix.
match_global_phase(a, b)	Phases the given matrices so that they agree on the phase of one entry.
commutes(m1, m2, tolerance[, atol, equal_nan])	Determines if two matrices approximately commute.
CONTROL_TAG	
diagonalize_real_symmetric_and_sorted_diagonal_matrices(...)	Returns an orthogonal matrix that diagonalizes both given matrices.
diagonalize_real_symmetric_matrix(matrix, ...)	Returns an orthogonal matrix that diagonalizes the given matrix.
dot(*values)	Computes the dot/matrix product of a sequence of values.
Duration(*, picos, float] = 0, nanos, float] = 0)	A time delta that supports picosecond accuracy.
is_diagonal(matrix, tolerance[, atol, equal_nan])	Determines if a matrix is a approximately diagonal.
is_hermitian(matrix, tolerance[, atol, ...])	Determines if a matrix is approximately Hermitian.
is_negligible_turn(turns, tolerance)	
is_orthogonal(matrix, tolerance[, atol, ...])	Determines if a matrix is approximately orthogonal.
is_special_orthogonal(matrix, tolerance[, ...])	Determines if a matrix is approximately special orthogonal.
is_special_unitary(matrix, tolerance[, ...])	Determines if a matrix is approximately unitary with unit determinant.
is_unitary(matrix, tolerance[, atol, equal_nan])	Determines if a matrix is approximately unitary.
kak_canonicalize_vector(x, y, z)	Canonicalizes an XX/YY/ZZ interaction by swap/negate/shift-ing axes.
kak_decomposition(mat, tolerance[, atol, ...])	Decomposes a 2-qubit unitary into 1-qubit ops and XX/YY/ZZ interactions.
KakDecomposition(*, global_phase, ...)	A convenient description of an arbitrary two-qubit operation.
kron(*matrices)	Computes the kronecker product of a sequence of matrices.
kron_factor_4x4_to_2x2s(matrix, tolerance[, ...])	Splits a 4x4 matrix U = kron(A, B) into A, B, and a global factor.
kron_with_controls(*matrices)	Computes the kronecker product of a sequence of matrices and controls.
map_eigenvalues(matrix, func, complex], ...)	Applies a function to the eigenvalues of a matrix.
reflection_matrix_pow(reflection_matrix, ...)	Raises a matrix with two opposing eigenvalues to a power.
so4_to_magic_su2s(mat, tolerance[, atol, ...])	Finds 2x2 special-unitaries A, B where mat = Mag.H @ kron(A, B) @ Mag.
Symbol(name)	A constant plus the runtime value of a parameter with a given key.
targeted_left_multiply(left_matrix, ...)	Left-multiplies the given axes of the target tensor by the given matrix.
TextDiagramDrawer()	A utility class for creating simple text diagrams.
Timestamp(*, picos, float] = 0, nanos, ...)	A location in time with picosecond accuracy.
Tolerance(rtol, atol, equal_nan)	Specifies thresholds for doing approximate equality.
value_equality(cls, *, unhashable, ...)	Implements **eq/ne/hash** via a *value_equality_values* method.

cirq.allclose_up_to_global_phase

cirq.**allclose_up_to_global_phase**(*a: numpy.ndarray*, *b: numpy.ndarray*, *rtol: float = 1e-05*, *atol: float = 1e-08*, *equal_nan: bool = False*) → bool

Determines if a ~= b * exp(i t) for some t.

Parameters

- **a** – A numpy array.
- **b** – Another numpy array.
- **rtol** – Relative error tolerance.
- **atol** – Absolute error tolerance.
- **equal_nan** – Whether or not NaN entries should be considered equal to other NaN entries.

cirq.apply_matrix_to_slices

cirq.**apply_matrix_to_slices**(*target: numpy.ndarray*, *matrix: numpy.ndarray*, *slices: List[Union[int, slice, ellipsis, Sequence[Union[int, slice, ellipsis]]]]*, **, out: Optional[numpy.ndarray] = None*) → numpy.ndarray

Left-multiplies an NxN matrix onto N slices of a numpy array.

Example

The 4x4 matrix of a fractional SWAP gate can be expressed as

[1][X**t]
[1]

Where X is the 2x2 Pauli X gate and t is the power of the swap with t=1 being a full swap. X**t is a power of the Pauli X gate's matrix. Applying the fractional swap is equivalent to applying a fractional X within the inner 2x2 subspace; the rest of the matrix is identity. This can be expressed using `apply_matrix_to_slices` as follows:

```
def fractional_swap(target):
    assert target.shape == (4,)
    return apply_matrix_to_slices(
        target=target,
        matrix=cirq.unitary(cirq.X**t),
        slices=[1, 2]
    )
```

Parameters

- **target** – The input array with slices that need to be left-multiplied.
- **matrix** – The linear operation to apply to the subspace defined by the slices.

- **slices** – The parts of the tensor that correspond to the "vector entries" that the matrix should operate on. May be integers or complicated multi-dimensional slices into a tensor. The slices must refer to non-overlapping sections of the input all with the same shape.
- **out** – Where to write the output. If not specified, a new numpy array is created, with the same shape and dtype as the target, to store the output.

Returns The transformed array.

cirq.bidiagonalize_real_matrix_pair_with_symmetric_products

cirq.**bidiagonalize_real_matrix_pair_with_symmetric_products**(*mat1: numpy.ndarray*, *mat2: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → Tuple[numpy.ndarray, numpy.ndarray]

Finds orthogonal matrices that diagonalize both mat1 and mat2.

Requires mat1 and mat2 to be real.
Requires mat1.T @ mat2 to be symmetric.
Requires mat1 @ mat2.T to be symmetric.

Parameters

- **mat1** – One of the real matrices.
- **mat2** – The other real matrix.
- **tolerance** – Numeric error thresholds.

Returns A tuple (L, R) of two orthogonal matrices, such that both L @ mat1 @ R and L @ mat2 @ R are diagonal matrices.

Raises

- `ValueError` – Matrices don't meet preconditions (e.g. not real).
- `ArithmeticError` – Failed to meet specified tolerance.

cirq.bidiagonalize_unitary_with_special_orthogonals

cirq.**bidiagonalize_unitary_with_special_orthogonals**(*mat: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → Tuple[numpy.ndarray, numpy.array, numpy.ndarray]

Finds orthogonal matrices L, R such that L @ matrix @ R is diagonal.

Parameters

- **mat** – A unitary matrix.
- **tolerance** – Numeric error thresholds.

Returns A triplet (L, d, R) such that L @ mat @ R = diag(d). Both L and R will be orthogonal matrices with determinant equal to 1.

Raises

- `ValueError` – Matrices don't meet preconditions (e.g. not real).
- `ArithmeticError` – Failed to meet specified tolerance.

cirq.canonicalize_half_turns

`cirq.`**`canonicalize_half_turns`**(*half_turns: Union[cirq.value.symbol.Symbol, float]*) → Union[cirq.value.symbol.Symbol, float]

Wraps the input into the range (-1, +1].

cirq.chosen_angle_to_canonical_half_turns

`cirq.`**`chosen_angle_to_canonical_half_turns`**(*half_turns: Union[cirq.value.symbol.Symbol, float, None] = None*, *rads: Optional[float] = None*, *degs: Optional[float] = None*, *default: float = 1.0*) → Union[cirq.value.symbol.Symbol, float]

Returns a canonicalized half_turns based on the given arguments.

At most one of half_turns, rads, degs must be specified. If none are specified, the output defaults to half_turns=1.

Parameters

- **half_turns** – The number of half turns to rotate by.
- **rads** – The number of radians to rotate by.
- **degs** – The number of degrees to rotate by
- **default** – The half turns angle to use if nothing else is specified.

Returns A number of half turns.

cirq.chosen_angle_to_half_turns

`cirq.`**`chosen_angle_to_half_turns`**(*half_turns: Union[cirq.value.symbol.Symbol, float, None] = None*, *rads: Optional[float] = None*, *degs: Optional[float] = None*, *default: float = 1.0*) → Union[cirq.value.symbol.Symbol, float]

Returns a half_turns value based on the given arguments.

At most one of half_turns, rads, degs must be specified. If none are specified, the output defaults to half_turns=1.

Parameters

- **half_turns** – The number of half turns to rotate by.
- **rads** – The number of radians to rotate by.
- **degs** – The number of degrees to rotate by
- **default** – The half turns angle to use if nothing else is specified.

Returns A number of half turns.

cirq.slice_for_qubits_equal_to

cirq.**slice_for_qubits_equal_to**(*target_qubit_axes: Sequence[int], little_endian_qureg_value: int*) → Tuple[Union[slice, int, ellipsis], ...]

Returns an index corresponding to a desired subset of an np.ndarray.

It is assumed that the np.ndarray's shape is of the form (2, 2, 2, ..., 2).

Example

```
# A '4 qubit' tensor with values from 0 to 15.
r = np.array(range(16)).reshape((2,) * 4)

# We want to index into the subset where qubit #1 and qubit #3 are ON.
s = cirq.slice_for_qubits_equal_to([1, 3], 0b11)
print(s)
# (slice(None, None, None), 1, slice(None, None, None), 1, Ellipsis)

# Get that subset. It corresponds to numbers of the form 0b*1*1.
# where here '*' indicates any possible value.
print(r[s])
# [[ 5  7]
#  [13 15]]
```

Parameters

- **target_qubit_axes** – The qubits that are specified by the index bits. All other axes of the slice are unconstrained.
- **little_endian_qureg_value** – An integer whose bits specify what value is desired for of the target qubits. The integer is little endian w.r.t. the target quit axes, meaning the low bit of the integer determines the desired value of the first targeted qubit, and so forth with the k'th targeted qubit's value set to bool(qureg_value & (1 << k)).

Returns An index object that will slice out a mutable view of the desired subset of a tensor.

cirq.block_diag

cirq.**block_diag**(**blocks*) → numpy.ndarray

Concatenates blocks into a block diagonal matrix.

Parameters ***blocks** – Square matrices to place along the diagonal of the result.

Returns A block diagonal matrix with the given blocks along its diagonal.

Raises ValueError – A block isn't square.

cirq.match_global_phase

cirq.**match_global_phase**(*a: numpy.ndarray*, *b: numpy.ndarray*) → Tuple[numpy.ndarray, numpy.ndarray]

Phases the given matrices so that they agree on the phase of one entry.

To maximize precision, the position with the largest entry from one of the matrices is used when attempting to compute the phase difference between the two matrices.

Parameters

- **a** – A numpy array.
- **b** – Another numpy array.

Returns A tuple (a', b') where a' == b' implies a == b*exp(i t) for some t.

cirq.commutes

cirq.**commutes**(*m1: numpy.ndarray*, *m2: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if two matrices approximately commute.

Two matrices A and B commute if they are square and have the same size and AB = BA.

Parameters

- **m1** – One of the matrices.
- **m2** – The other matrix.
- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the two matrices have compatible sizes and a commutator equal to zero within tolerance.

cirq.CONTROL_TAG

cirq.**CONTROL_TAG = array([[nan, 0.], [0., 1.]])**

cirq.diagonalize_real_symmetric_and_sorted_diagonal_matrices

cirq.**diagonalize_real_symmetric_and_sorted_diagonal_matrices**(*symmetric_matrix: numpy.ndarray*, *diagonal_matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → numpy.ndarray

Returns an orthogonal matrix that diagonalizes both given matrices.

The given matrices must commute.
Guarantees that the sorted diagonal matrix is not permuted by the diagonalization (except for nearly-equal values).

Parameters

- **symmetric_matrix** – A real symmetric matrix.
- **diagonal_matrix** – A real diagonal matrix with entries along the diagonal sorted into descending order.
- **tolerance** – Numeric error thresholds.

Returns An orthogonal matrix P such that P.T @ symmetric_matrix @ P is diagonal and P.T @ diagonal_matrix @ P = diagonal_matrix (up to tolerance).

Raises

- `ValueError` – Matrices don't meet preconditions (e.g. not symmetric).
- `ArithmeticError` – Failed to meet specified tolerance.

cirq.diagonalize_real_symmetric_matrix

cirq.**diagonalize_real_symmetric_matrix**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → numpy.ndarray

Returns an orthogonal matrix that diagonalizes the given matrix.

Parameters

- **matrix** – A real symmetric matrix to diagonalize.
- **tolerance** – Numeric error thresholds.

Returns An orthogonal matrix P such that P.T @ matrix @ P is diagonal.

Raises

- `ValueError` – Matrix isn't real symmetric.
- `ArithmeticError` – Failed to meet specified tolerance.

cirq.dot

cirq.**dot**(**values*) → Union[float, complex, numpy.ndarray]
Computes the dot/matrix product of a sequence of values.

A *args version of np.linalg.multi_dot.

Parameters ***values** – The values to combine with the dot/matrix product.

Returns The resulting value or matrix.

cirq.Duration

class cirq.**Duration**(*, *picos: Union[int, float] = 0*, *nanos: Union[int, float] = 0*)
A time delta that supports picosecond accuracy.

__init__(*, *picos: Union[int, float] = 0*, *nanos: Union[int, float] = 0*) → None
Initializes a Duration with a time specified in ns and/or ps.

If both picos and nanos are specified, their contributions are added.

Parameters

- **picos** – A number of picoseconds to add to the time delta.
- **nanos** – A number of nanoseconds to add to the time delta.

Methods

total_nanos()	Returns the number of nanoseconds that the duration spans.
total_picos()	Returns the number of picoseconds that the duration spans.

cirq.Duration.total_nanos

Duration.**total_nanos**() → float
Returns the number of nanoseconds that the duration spans.

cirq.Duration.total_picos

Duration.**total_picos**() → float
Returns the number of picoseconds that the duration spans.

cirq.is_diagonal

cirq.**is_diagonal**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool
Determines if a matrix is a approximately diagonal.

A matrix is diagonal if i!=j implies m[i,j]==0.

Parameters

- **matrix** – The matrix to check.

- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is diagonal within the given tolerance.

cirq.is_hermitian

cirq.**is_hermitian**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if a matrix is approximately Hermitian.

A matrix is Hermitian if it's square and equal to its adjoint.

Parameters

- **matrix** – The matrix to check.
- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is Hermitian within the given tolerance.

cirq.is_negligible_turn

cirq.**is_negligible_turn**(*turns: float*, *tolerance: float*) → bool

cirq.is_orthogonal

cirq.**is_orthogonal**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if a matrix is approximately orthogonal.

A matrix is orthogonal if it's square and real and its transpose is its inverse.

Parameters

- **matrix** – The matrix to check.
- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is orthogonal within the given tolerance.

cirq.is_special_orthogonal

cirq.**is_special_orthogonal**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if a matrix is approximately special orthogonal.

A matrix is special orthogonal if it is square and real and its transpose is its inverse and its determinant is one.

Parameters

- **matrix** – The matrix to check.

- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is special orthogonal within the given tolerance.

cirq.is_special_unitary

cirq.**is_special_unitary**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if a matrix is approximately unitary with unit determinant.

A matrix is special-unitary if it is square and its adjoint is its inverse
and its determinant is one.

Parameters

- **matrix** – The matrix to check.
- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is unitary with unit determinant within the given tolerance.

cirq.is_unitary

cirq.**is_unitary**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → bool

Determines if a matrix is approximately unitary.

A matrix is unitary if it's square and its adjoint is its inverse.

Parameters

- **matrix** – The matrix to check.
- **tolerance** – The per-matrix-entry tolerance on equality.

Returns Whether the matrix is unitary within the given tolerance.

cirq.kak_canonicalize_vector

cirq.**kak_canonicalize_vector**(*x: float*, *y: float*, *z: float*) → cirq.linalg.decompositions.KakDecomposition

Canonicalizes an XX/YY/ZZ interaction by swap/negate/shift-ing axes.

Parameters

- **x** – The strength of the XX interaction.
- **y** – The strength of the YY interaction.
- **z** – The strength of the ZZ interaction.

Returns

The canonicalized decomposition, with vector coefficients (x2, y2, z2) satisfying:

0 abs(z2) y2 x2 π/4 z2 -π/4

Guarantees that the implied output matrix:

g · (a1 a0) · exp(i·(x2·XX + y2·YY + z2·ZZ)) · (b1 b0)

is approximately equal to the implied input matrix:

exp(i·(x·XX + y·YY + z·ZZ))

cirq.kak_decomposition

cirq.**kak_decomposition**(*mat: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → cirq.linalg.decompositions.KakDecomposition

Decomposes a 2-qubit unitary into 1-qubit ops and XX/YY/ZZ interactions.

Parameters

- **mat** – The 4x4 unitary matrix to decompose.
- **tolerance** – Per-matrix-entry tolerance on equality.

Returns

A *cirq.KakDecomposition* canonicalized such that the interaction coefficients x, y, z satisfy:

0 ≤ abs(z) ≤ y ≤ x ≤ π/4 z ≥ -π/4

Raises

- ValueError – Bad matrix.
- ArithmeticError – Failed to perform the decomposition.

References

'An Introduction to Cartan's KAK Decomposition for QC Programmers' https://arxiv.org/abs/quant-ph/0507171

cirq.KakDecomposition

class cirq.**KakDecomposition**(**, global_phase: complex, single_qubit_operations_before: Tuple[numpy.ndarray, numpy.ndarray], interaction_coefficients: Tuple[float, float, float], single_qubit_operations_after: Tuple[numpy.ndarray, numpy.ndarray]*)

A convenient description of an arbitrary two-qubit operation.

Any two qubit operation U can be decomposed into the form

```
U = g · (a1 ⊗ a0) · exp(i·(x·XX + y·YY + z·ZZ)) · (b1 ⊗ b0)
```

This class stores g, (b0, b1), (x, y, z), and (a0, a1).

global_phase

g from the above equation.

single_qubit_operations_before

b0, b1 from the above equation.

interaction_coefficients

x, y, z from the above equation.

single_qubit_operations_after

a0, a1 from the above equation.

References

'An Introduction to Cartan's KAK Decomposition for QC Programmers'
https://arxiv.org/abs/quant-ph/0507171

__init__(*, *global_phase: complex, single_qubit_operations_before: Tuple[numpy.ndarray, numpy.ndarray], interaction_coefficients: Tuple[float, float, float], single_qubit_operations_after: Tuple[numpy.ndarray, numpy.ndarray]*)
Initializes a decomposition for a two-qubit operation U.

U = g · (a1 ⊗ a0) · exp(i·(x·XX + y·YY + z·ZZ)) · (b1 ⊗ b0)

Parameters

- **global_phase** – g from the above equation.
- **single_qubit_operations_before** – b0, b1 from the above equation.
- **interaction_coefficients** – x, y, z from the above equation.
- **single_qubit_operations_after** – a0, a1 from the above equation.

Methods

—

cirq.kron

cirq.**kron**(**matrices*) → numpy.ndarray
Computes the kronecker product of a sequence of matrices.

A *args version of lambda args: functools.reduce(np.kron, args).

Parameters ***matrices** – The matrices and controls to combine with the kronecker product.

Returns The resulting matrix.

cirq.kron_factor_4x4_to_2x2s

cirq.**kron_factor_4x4_to_2x2s**(*matrix: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → Tuple[complex, numpy.ndarray, numpy.ndarray]
Splits a 4x4 matrix U = kron(A, B) into A, B, and a global factor.

Requires the matrix to be the kronecker product of two 2x2 unitaries.
Requires the matrix to have a non-zero determinant.

Parameters

- **matrix** – The 4x4 unitary matrix to factor.
- **tolerance** – Acceptable numeric error thresholds.

Returns A scalar factor and a pair of 2x2 unit-determinant matrices. The kronecker product of all three is equal to the given matrix.

Raises `ValueError` – The given matrix can't be tensor-factored into 2x2 pieces.

cirq.kron_with_controls

`cirq.`**`kron_with_controls`**(**matrices*) → numpy.ndarray
Computes the kronecker product of a sequence of matrices and controls.

Use linalg.CONTROL_TAG to represent controls. Any entry of the output matrix corresponding to a situation where the control is not satisfied will be overwritten by identity matrix elements.

The control logic works by imbuing NaN with the meaning "failed to meet one or more controls". The normal kronecker product then spreads the per-item NaNs to all the entries in the product that need to be replaced by identity matrix elements. This method rewrites those NaNs. Thus CONTROL_TAG can be the matrix [[NaN, 0], [0, 1]] or equivalently [[NaN, NaN], [NaN, 1]].

Because this method re-interprets NaNs as control-failed elements, it won't propagate error-indicating NaNs from its input to its output in the way you'd otherwise expect.

Parameters **`*matrices`** – The matrices and controls to combine with the kronecker product.

Returns The resulting matrix.

cirq.map_eigenvalues

`cirq.`**`map_eigenvalues`**(*matrix: numpy.ndarray, func: Callable[complex, complex], tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → numpy.ndarray
Applies a function to the eigenvalues of a matrix.

Given M = sum_k a_k |v_k><v_k|.

Parameters

- **`matrix`** – The matrix to modify with the function.
- **`func`** – The function to apply to the eigenvalues of the matrix.
- **`tolerance`** – Thresholds used when separating eigenspaces.

Returns The transformed matrix.

cirq.reflection_matrix_pow

`cirq.`**`reflection_matrix_pow`**(*reflection_matrix: numpy.ndarray*, *exponent: float*)
Raises a matrix with two opposing eigenvalues to a power.

Parameters

- **`reflection_matrix`** – The matrix to raise to a power.

- **exponent** – The power to raise the matrix to.

Returns The given matrix raised to the given power.

cirq.so4_to_magic_su2s

cirq.**so4_to_magic_su2s**(*mat: numpy.ndarray*, *tolerance: cirq.linalg.tolerance.Tolerance = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)*) → Tuple[numpy.ndarray, numpy.ndarray]

Finds 2x2 special-unitaries A, B where mat = Mag.H @ kron(A, B) @ Mag.

Mag is the magic basis matrix:

```
1  0  0  i
0  i  1  0
0  i -1  0      (times sqrt(0.5) to normalize)
1  0  0 -i
```

Parameters

- **mat** – A real 4x4 orthogonal matrix.
- **tolerance** – Per-matrix-entry tolerance on equality.

Returns A pair (A, B) of matrices in SU(2) such that Mag.H @ kron(A, B) @ Mag is approximately equal to the given matrix.

Raises

- ValueError – Bad matrix.
- ArithmeticError – Failed to perform the decomposition to desired tolerance.

cirq.Symbol

class cirq.**Symbol**(*name: str*)

A constant plus the runtime value of a parameter with a given key.

name

The non-empty name of a parameter to lookup at runtime and add to the constant offset.

__init__(*name: str*) → None

Initializes a Symbol with the given name.

Parameters **name** – The name of a parameter.

Methods

—

cirq.targeted_left_multiply

cirq.**targeted_left_multiply**(*left_matrix: numpy.ndarray, right_target: numpy.ndarray, target_axes: Sequence[int], out: Optional[numpy.ndarray] = None*) → numpy.ndarray

Left-multiplies the given axes of the target tensor by the given matrix.

Note that the matrix must have a compatible tensor structure.

For example, if you have an 6-qubit state vector `input_state` with shape (2, 2, 2, 2, 2, 2), and a 2-qubit unitary operation `op` with shape (2, 2, 2, 2), and you want to apply `op` to the 5'th and 3'rd qubits within `input_state`, then the output state vector is computed as follows:

```
output_state = cirq.targeted_left_multiply(op, input_state, [5, 3])
```

This method also works when the right hand side is a matrix instead of a vector. If a unitary circuit's matrix is `old_effect`, and you append a CNOT(q1, q4) operation onto the circuit, where the control q1 is the qubit at offset 1 and the target q4 is the qubit at offset 4, then the appended circuit's unitary matrix is computed as follows:

```
new_effect = cirq.targeted_left_multiply(
    left_matrix=cirq.unitary(cirq.CNOT).reshape((2, 2, 2, 2)),
    right_target=old_effect,
    target_axes=[1, 4])
```

Parameters

- **left_matrix** – What to left-multiply the target tensor by.
- **right_target** – A tensor to carefully broadcast a left-multiply over.
- **target_axes** – Which axes of the target are being operated on.
- **out** – The buffer to store the results in. If not specified or None, a new buffer is used. Must have the same shape as right_target.

Returns The output tensor.

cirq.TextDiagramDrawer

class cirq.**TextDiagramDrawer**

A utility class for creating simple text diagrams.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

content_present(x, y)	Determines if a line or printed text is at the given location.
force_horizontal_padding_after(index, padding)	Change the padding after the given column.
force_vertical_padding_after(index, padding)	Change the padding after the given row.
grid_line(x1, y1, x2, y2, emphasize)	Adds a vertical or horizontal line from (x1, y1) to (x2, y2).
height()	Determines how many entry rows are in the diagram.
horizontal_line(y, x1, x2, emphasize)	Adds a line from (x1, y) to (x2, y).
insert_empty_columns(x, amount)	Insert a number of columns after the given column.
insert_empty_rows(y, amount)	Insert a number of rows after the given row.
render(horizontal_spacing, vertical_spacing, ...)	Outputs text containing the diagram.
transpose()	Returns the same diagram, but mirrored across its diagonal.
vertical_line(x, y1, y2, emphasize)	Adds a line from (x, y1) to (x, y2).
width()	Determines how many entry columns are in the diagram.
write(x, y, text, transposed_text)	Adds text to the given location.

cirq.TextDiagramDrawer.content_present

`TextDiagramDrawer.`**`content_present`**(*x: int*, *y: int*) → bool
Determines if a line or printed text is at the given location.

cirq.TextDiagramDrawer.force_horizontal_padding_after

`TextDiagramDrawer.`**`force_horizontal_padding_after`**(*index: int*, *padding: int*) → None
Change the padding after the given column.

cirq.TextDiagramDrawer.force_vertical_padding_after

`TextDiagramDrawer.`**`force_vertical_padding_after`**(*index: int*, *padding: int*) → None
Change the padding after the given row.

cirq.TextDiagramDrawer.grid_line

`TextDiagramDrawer.`**`grid_line`**(*x1: int*, *y1: int*, *x2: int*, *y2: int*, *emphasize: bool = False*)
Adds a vertical or horizontal line from (x1, y1) to (x2, y2).

Horizontal line is selected on equality in the second coordinate and vertical line is selected on equality in the first coordinate.

Raises `ValueError` – If line is neither horizontal nor vertical.

cirq.TextDiagramDrawer.height

TextDiagramDrawer.**height**() → int
Determines how many entry rows are in the diagram.

cirq.TextDiagramDrawer.horizontal_line

TextDiagramDrawer.**horizontal_line**(*y: int*, *x1: int*, *x2: int*, *emphasize: bool = False*) → None
Adds a line from (x1, y) to (x2, y).

cirq.TextDiagramDrawer.insert_empty_columns

TextDiagramDrawer.**insert_empty_columns**(*x: int*, *amount: int = 1*) → None
Insert a number of columns after the given column.

cirq.TextDiagramDrawer.insert_empty_rows

TextDiagramDrawer.**insert_empty_rows**(*y: int*, *amount: int = 1*) → None
Insert a number of rows after the given row.

cirq.TextDiagramDrawer.render

TextDiagramDrawer.**render**(*horizontal_spacing: int = 1*, *vertical_spacing: int = 1*, *crossing_char: str = None*, *use_unicode_characters: bool = True*) → str
Outputs text containing the diagram.

cirq.TextDiagramDrawer.transpose

TextDiagramDrawer.**transpose**() → cirq.circuits.text_diagram_drawer.TextDiagramDrawer
Returns the same diagram, but mirrored across its diagonal.

cirq.TextDiagramDrawer.vertical_line

TextDiagramDrawer.**vertical_line**(*x: int*, *y1: int*, *y2: int*, *emphasize: bool = False*) → None
Adds a line from (x, y1) to (x, y2).

cirq.TextDiagramDrawer.width

TextDiagramDrawer.**width**() → int
Determines how many entry columns are in the diagram.

cirq.TextDiagramDrawer.write

TextDiagramDrawer.**write**(*x: int*, *y: int*, *text: str*, *transposed_text: str = None*)
Adds text to the given location.

Parameters

- **x** – The column in which to write the text.
- **y** – The row in which to write the text.
- **text** – The text to write at location (x, y).
- **transposted_text** – Optional text to write instead, if the text diagram is transposed.

cirq.Timestamp

class cirq.**Timestamp**(*, *picos: Union[int, float] = 0*, *nanos: Union[int, float] = 0*)
A location in time with picosecond accuracy.

Supports affine operations against Duration.

__init__(*, *picos: Union[int, float] = 0*, *nanos: Union[int, float] = 0*) → None
Initializes a Timestamp with a time specified in ns and/or ps.

The time is relative to some unspecified "time zero". If both picos and nanos are specified, their contributions away from zero are added.

Parameters

- **picos** – How many picoseconds away from time zero?
- **nanos** – How many nanoseconds away from time zero?

Methods

raw_picos()	The timestamp's location in picoseconds from arbitrary time zero.

cirq.Timestamp.raw_picos

Timestamp.**raw_picos**() → float
The timestamp's location in picoseconds from arbitrary time zero.

cirq.Tolerance

class cirq.**Tolerance**(*rtol: float = 1e-05*, *atol: float = 1e-08*, *equal_nan: bool = False*)
Specifies thresholds for doing approximate equality.

__init__(*rtol: float = 1e-05*, *atol: float = 1e-08*, *equal_nan: bool = False*) → None
Initializes a Tolerance instance with the specified parameters.

Notes

Matrix Comparisons (methods beginning with "all_") are done by numpy.allclose, which considers x and y to be close when abs(x - y) <= atol + rtol * abs(y). See numpy.allclose's documentation for more details. The scalar methods perform the same calculations without the numpy matrix construction.

Parameters

- **rtol** – Relative tolerance.
- **atol** – Absolute tolerance.
- **equal_nan** – Whether NaNs are equal to each other.

Methods

all_close(a, b)	
all_near_zero(a)	
all_near_zero_mod(a, period)	
close(a, b)	
near_zero(a)	
near_zero_mod(a, period)	

cirq.Tolerance.all_close

Tolerance.**all_close**(*a*, *b*)

cirq.Tolerance.all_near_zero

Tolerance.**all_near_zero**(*a*)

cirq.Tolerance.all_near_zero_mod

Tolerance.**all_near_zero_mod**(*a*, *period*)

cirq.Tolerance.close

Tolerance.**close**(*a*, *b*)

cirq.Tolerance.near_zero

Tolerance.**near_zero**(*a*)

cirq.Tolerance.near_zero_mod

Tolerance.**near_zero_mod**(*a*, *period*)

Attributes

DEFAULT
ZERO

cirq.Tolerance.DEFAULT

Tolerance.**DEFAULT = Tolerance(rtol=1e-05, atol=1e-08, equal_nan=False)**

cirq.Tolerance.ZERO

Tolerance.**ZERO = Tolerance(rtol=0, atol=0, equal_nan=False)**

cirq.value_equality

cirq.**value_equality**(*cls: type = None*, ***, *unhashable: bool = False*, *distinct_child_types: bool = False*) → Union[Callable[type, type], type]

Implements **eq/ne/hash** via a *value_equality_values* method.

value_equality_values is a method that the decorated class must implement.

Note that the type of the decorated value is included as part of the value equality values. This is so that completely separate classes with identical equality values (e.g. a Point2D and a Vector2D) don't compare as equal. Further note that this means that child types of the decorated type will be considered equal to each other, though this behavior can be changed via the 'distinct_child_types''argument. The type logic is implemented behind the scenes by a''*value_equality_values_cls*' method added to the class.

Parameters

- **cls** – The type to decorate. Automatically passed in by python when using the @cirq.value_equality decorator notation on a class.
- **unhashable** – When set, the __hash__ method will be set to None instead of to a hash of the equality class and equality values. Useful for mutable types such as dictionaries.
- **distinct_child_types** – When set, classes that inherit from the decorated class will not be considered equal to it. Also, different child classes will not be considered equal to each other. Useful for when the decorated class is an abstract class or trait that is helping to define equality for many conceptually distinct concrete classes.

3.1.12 Experiments

Utilities for running experiments on hardware, or producing things required to run experiments.

generate_supremacy_circuit_google_v2(qubits, ...)	Generates Google Random Circuits v2 as in github.com/sboixo/GRCS
generate_supremacy_circuit_google_v2_bristlecone(...)	Generates Google Random Circuits v2 in Bristlecone.
generate_supremacy_circuit_google_v2_grid(...)	Generates Google Random Circuits v2 as in github.com/sboixo/GRCS

cirq.generate_supremacy_circuit_google_v2

cirq.**generate_supremacy_circuit_google_v2**(*qubits: Iterable[cirq.devices.grid_qubit.GridQubit], cz_depth: int, seed: int*) → cirq.circuits.circuit.Circuit

Generates Google Random Circuits v2 as in github.com/sboixo/GRCS cz_v2.
See also https://arxiv.org/abs/1807.10749

Parameters

- **qubits** – qubit grid in which to generate the circuit.
- **cz_depth** – number of layers with CZ gates.
- **seed** – seed for the random instance.

Returns A circuit corresponding to instance inst_{n_rows}x{n_cols}_{cz_depth+1}_{seed}

The mapping of qubits is cirq.GridQubit(j,k) -> q[j*n_cols+k] (as in the QASM mapping)

cirq.generate_supremacy_circuit_google_v2_bristlecone

cirq.**generate_supremacy_circuit_google_v2_bristlecone**(*n_rows: int, cz_depth: int, seed: int*) → cirq.circuits.circuit.Circuit

Generates Google Random Circuits v2 in Bristlecone.
See also https://arxiv.org/abs/1807.10749

Parameters

- **n_rows** – number of rows in a Bristlecone lattice. Note that we do not include single qubit corners.
- **cz_depth** – number of layers with CZ gates.
- **seed** – seed for the random instance.

Returns A circuit with given size and seed.

cirq.generate_supremacy_circuit_google_v2_grid

cirq.**generate_supremacy_circuit_google_v2_grid**(*n_rows: int*, *n_cols: int*, *cz_depth: int*, *seed: int*) → cirq.circuits.circuit.Circuit

Generates Google Random Circuits v2 as in github.com/sboixo/GRCS cz_v2.
See also https://arxiv.org/abs/1807.10749

Parameters

- **n_rows** – number of rows of a 2D lattice.
- **n_cols** – number of columns.
- **cz_depth** – number of layers with CZ gates.
- **seed** – seed for the random instance.

Returns A circuit corresponding to instance inst_{n_rows}x{n_cols}_{cz_depth+1}_{seed}

The mapping of qubits is cirq.GridQubit(j,k) -> q[j*n_cols+k] (as in the QASM mapping)

3.1.13 Google

Functionality specific to quantum hardware and services from Google.

google.AnnealSequenceSearchStrategy(...)	Linearized sequence search using simulated annealing method.
google.GreedySequenceSearchStrategy(algorithm)	Greedy search method for linear sequence of qubits on a chip.
google.Bristlecone	
google.ConvertToXmonGates([ignore_failures])	Attempts to convert strange gates into XmonGates.
google.Engine(api_key, api, version, ...)	Runs programs via the Quantum Engine API.
google.engine_from_environment()	Returns an Engine instance configured using environment variables.
google.Foxtail	
google.gate_to_proto_dict(gate, qubits, ...])	
google.is_native_xmon_op(op)	Check if the gate corresponding to an operation is a native xmon gate.
google.JobConfig(project_id, program_id, ...)	Configuration for a program and job to run on the Quantum Engine API.
google.line_on_device(device, length, method)	Searches for linear sequence of qubits on device.
google.LinePlacementStrategy	Choice and options for the line placement calculation method.
google.optimized_for_xmon(circuit, ...)	Optimizes a circuit with XmonDevice in mind.
google.pack_results(measurements, ...)	Pack measurement results into a byte string.
google.schedule_from_proto_dicts(device, ops)	Convert proto dictionaries into a Schedule for the given device.
google.schedule_to_proto_dicts(schedule)	Convert a schedule into an iterable of proto dictionaries.
google.unpack_results(data, repetitions, ...)	Unpack data from a bitstring into individual measurement results.
google.xmon_op_from_proto_dict(proto_dict)	Convert the proto dictionary to the corresponding operation.

Continued on next page

Table 120 – continued from previous page

google.XmonDevice(measurement_duration, ...)	A device with qubits placed in a grid.
google.XmonOptions(num_shards, ...)	XmonOptions for the XmonSimulator.
google.XmonSimulator(options)	XmonSimulator for Xmon class quantum circuits.
google.XmonStepResult(stepper, qubit_map, ...)	Results of a step of the simulator.

cirq.google.AnnealSequenceSearchStrategy

class cirq.google.**AnnealSequenceSearchStrategy**(*trace_func: Callable[[List[List[cirq.devices.grid_qubit.GridQubit]], float, float, float, bool], None] = None, seed: int = None*)

Linearized sequence search using simulated annealing method.

TODO: This line search strategy is still work in progress and requires efficiency improvements.

__init__(*trace_func: Callable[[List[List[cirq.devices.grid_qubit.GridQubit]], float, float, float, bool], None] = None, seed: int = None*) → None

Linearized sequence search using simulated annealing method.

Parameters

- **trace_func** – Optional callable which will be called for each simulated annealing step with arguments: solution candidate (list of linear sequences on the chip), current temperature (float), candidate cost (float), probability of accepting candidate (float), and acceptance decision (boolean).
- **seed** – Optional seed value for random number generator.

Returns List of linear sequences on the chip found by simulated annealing method.

Methods

place_line(device, length)	Runs line sequence search.

cirq.google.AnnealSequenceSearchStrategy.place_line

AnnealSequenceSearchStrategy.**place_line**(*device: cirq.google.XmonDevice, length: int*) → cirq.google.line.placement.sequence.GridQubitLineTuple

Runs line sequence search.

Parameters

- **device** – Chip description.
- **length** – Required line length.

Returns List of linear sequences on the chip found by simulated annealing method.

cirq.google.GreedySequenceSearchStrategy

class cirq.google.**GreedySequenceSearchStrategy**(*algorithm: str = 'best'*)
Greedy search method for linear sequence of qubits on a chip.

__init__(*algorithm: str = 'best'*) → None
Initializes greedy sequence search strategy.

Parameters

- **algorithm** – Greedy algorithm to be used. Available options are:
- **- runs all heuristics and chooses the best result,** (*best*) –
- **- on every step takes the qubit which has connection** (*largest_area*) –
- **the largest number of unassigned qubits, and** (*with*) –
- **- on every step takes the qubit with minimal** (*minimal_connectivity*) –
- **of unassigned neighbouring qubits.** (*number*) –

Methods

place_line(device, length)	Runs line sequence search.

cirq.google.GreedySequenceSearchStrategy.place_line

GreedySequenceSearchStrategy.**place_line**(*device: cirq.google.XmonDevice*, *length: int*) → cirq.google.line.placement.sequence.GridQubitLineTuple
Runs line sequence search.

Parameters

- **device** – Chip description.
- **length** – Required line length.

Returns Linear sequences found on the chip.

Raises ValueError – If search algorithm passed on initialization is not recognized.

cirq.google.Bristlecone

cirq.google.**Bristlecone = cirq.google.Bristlecone**

cirq.google.ConvertToXmonGates

class cirq.google.**ConvertToXmonGates**(*ignore_failures=False*)
Attempts to convert strange gates into XmonGates.

First, checks if the given operation is already a native xmon operation.

Second, checks if the operation has a known unitary. If so, and the gate

is a 1-qubit or 2-qubit gate, then performs circuit synthesis of the operation.

Third, attempts to `cirq.decompose` to the operation.

Fourth, if ignore_failures is set, gives up and returns the gate unchanged. Otherwise raises a TypeError.

__init__(*ignore_failures=False*) → None

Parameters **ignore_failures** – If set, gates that fail to convert are forwarded unchanged. If not set, conversion failures raise a TypeError.

Methods

convert(op)	
optimization_at(circuit, index, op)	Describes how to change operations near the given location.
optimize_circuit(circuit)	Rewrites the given circuit to make it better.

cirq.google.ConvertToXmonGates.convert

ConvertToXmonGates.**convert**(*op: cirq.ops.raw_types.Operation*) → List[cirq.ops.raw_types.Operation]

cirq.google.ConvertToXmonGates.optimization_at

ConvertToXmonGates.**optimization_at**(*circuit*, *index*, *op*)

Describes how to change operations near the given location.

For example, this method could realize that the given operation is an X gate and that in the very next moment there is a Z gate. It would indicate that they should be combined into a Y gate by returning PointOptimizationSummary(clear_span=2, clear_qubits=op.qubits, new_operations=cirq.Y(op.qubits[0]))

Parameters

- **circuit** – The circuit to improve.
- **index** – The index of the moment with the operation to focus on.
- **op** – The operation to focus improvements upon.

Returns A description of the optimization to perform, or else None if no change should be made.

cirq.google.ConvertToXmonGates.optimize_circuit

ConvertToXmonGates.**optimize_circuit**(*circuit: cirq.circuits.circuit.Circuit*)

Rewrites the given circuit to make it better.

Note that this performs an in place optimization.

Parameters **circuit** – The circuit to improve.

cirq.google.Engine

class cirq.google.**Engine**(*api_key: str*, *api: str = 'quantum'*, *version: str = 'v1alpha1'*, *default_project_id: Optional[str] = None*, *discovery_url: Optional[str] = None*, *default_gcs_prefix: Optional[str] = None*, ***kwargs*)

Runs programs via the Quantum Engine API.

This class has methods for creating programs and jobs that execute on
Quantum Engine:
run
run_sweep

Another set of methods return information about programs and jobs that
have been previously created on the Quantum Engine:
get_program
get_job
get_job_results

Finally, the engine has methods to update existing programs and jobs:
cancel_job
set_program_labels
add_program_labels
remove_program_labels
set_job_labels
add_job_labels
remove_job_labels

__init__(*api_key: str*, *api: str = 'quantum'*, *version: str = 'v1alpha1'*, *default_project_id: Optional[str] = None*, *discovery_url: Optional[str] = None*, *default_gcs_prefix: Optional[str] = None*, ***kwargs*) → None

Engine service client.

Parameters

- **api_key** – API key to use to retrieve discovery doc.
- **api** – API name.
- **version** – API version.
- **default_project_id** – A fallback project_id to use when one isn't specified in the JobConfig given to 'run' methods. See JobConfig for more information on project_id.

- **discovery_url** – Discovery url for the API. If not supplied, uses Google's default api.googleapis.com endpoint.
- **default_gcs_prefix** – A fallback gcs_prefix to use when one isn't specified in the JobConfig given to 'run' methods. See JobConfig for more information on gcs_prefix.

Methods

add_job_labels(job_resource_name, labels, str])	
add_program_labels(program_resource_name, ...)	
cancel_job(job_resource_name)	Cancels the given job.
get_job(job_resource_name)	Returns metadata about a previously created job.
get_job_results(job_resource_name)	Returns the actual results (not metadata) of a completed job.
get_program(program_resource_name)	Returns the previously created quantum program.
implied_job_config(job_config)	
program_as_schedule(program, ...)	
remove_job_labels(job_resource_name, label_keys)	
remove_program_labels(program_resource_name, ...)	
run(*, program, ...)	Runs the supplied Circuit or Schedule via Quantum Engine.
run_sweep(*, program, ...)	Runs the supplied Circuit or Schedule via Quantum Engine.
set_job_labels(job_resource_name, labels, str])	
set_program_labels(program_resource_name, ...)	

cirq.google.Engine.add_job_labels

Engine.**add_job_labels**(*job_resource_name: str, labels: Dict[str, str]*)

cirq.google.Engine.add_program_labels

Engine.**add_program_labels**(*program_resource_name: str, labels: Dict[str, str]*)

cirq.google.Engine.cancel_job

Engine.**cancel_job**(*job_resource_name: str*)

Cancels the given job.

See also the cancel method on EngineJob.

Params:
job_resource_name: A string of the form

projects/project_id/programs/program_id/jobs/job_id.

cirq.google.Engine.get_job

Engine.**get_job**(*job_resource_name: str*) → Dict
Returns metadata about a previously created job.

See get_job_result if you want the results of the job and not just metadata about the job.

Params:
job_resource_name: A string of the form
projects/project_id/programs/program_id/jobs/job_id.

Returns A dictionary containing the metadata.

cirq.google.Engine.get_job_results

Engine.**get_job_results**(*job_resource_name: str*) → List[cirq.study.trial_result.TrialResult]
Returns the actual results (not metadata) of a completed job.

Params:
job_resource_name: A string of the form
projects/project_id/programs/program_id/jobs/job_id.

Returns An iterable over the TrialResult, one per parameter in the parameter sweep.

cirq.google.Engine.get_program

Engine.**get_program**(*program_resource_name: str*) → Dict
Returns the previously created quantum program.

Params:
program_resource_name: A string of the form
projects/project_id/programs/program_id.

Returns A dictionary containing the metadata and the program.

cirq.google.Engine.implied_job_config

Engine.**implied_job_config**(*job_config: Optional[cirq.google.engine.engine.JobConfig]*) → cirq.google.engine.engine.JobConfig

cirq.google.Engine.program_as_schedule

Engine.**program_as_schedule**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule]*) → cirq.schedules.schedule.Schedule

cirq.google.Engine.remove_job_labels

Engine.**remove_job_labels**(*job_resource_name: str, label_keys: List[str]*)

cirq.google.Engine.remove_program_labels

Engine.**remove_program_labels**(*program_resource_name: str, label_keys: List[str]*)

cirq.google.Engine.run

Engine.**run**(**, program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], job_config: Optional[cirq.google.engine.engine.JobConfig] = None, param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({}), repetitions: int = 1, priority: int = 50, target_route: str = '/xmonsim'*) → cirq.study.trial_result.TrialResult

Runs the supplied Circuit or Schedule via Quantum Engine.

Parameters

- **program** – The Circuit or Schedule to execute. If a circuit is provided, a moment by moment schedule will be used.
- **job_config** – Configures the names of programs and jobs.
- **param_resolver** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.
- **priority** – The priority to run at, 0-100.
- **target_route** – The engine route to run against.

Returns A single TrialResult for this run.

cirq.google.Engine.run_sweep

Engine.**run_sweep**(**, program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], job_config: Optional[cirq.google.engine.engine.JobConfig] = None, params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = None, repetitions: int = 1, priority: int = 500, target_route: str = '/xmonsim'*) → cirq.google.engine.engine.EngineJob

Runs the supplied Circuit or Schedule via Quantum Engine.

In contrast to run, this runs across multiple parameter sweeps, and does not block until a result is returned.

Parameters

- **program** – The Circuit or Schedule to execute. If a circuit is provided, a moment by moment schedule will be used.
- **job_config** – Configures the names of programs and jobs.
- **params** – Parameters to run with the program.
- **repetitions** – The number of circuit repetitions to run.
- **priority** – The priority to run at, 0-100.
- **target_route** – The engine route to run against.

Returns An EngineJob. If this is iterated over it returns a list of TrialResults, one for each parameter sweep.

cirq.google.Engine.set_job_labels

Engine.**set_job_labels**(*job_resource_name: str, labels: Dict[str, str]*)

cirq.google.Engine.set_program_labels

Engine.**set_program_labels**(*program_resource_name: str, labels: Dict[str, str]*)

cirq.google.engine_from_environment

cirq.google.**engine_from_environment**() → cirq.google.engine.engine.Engine

Returns an Engine instance configured using environment variables.

If the environment variables are set, but incorrect, an authentication failure will occur when attempting to run jobs on the engine.

Required Environment Variables:
QUANTUM_ENGINE_PROJECT: The name of a google cloud project, with the quantum engine enabled, that you have access to.
QUANTUM_ENGINE_API_KEY: An API key for the google cloud project named by QUANTUM_ENGINE_PROJECT.

Raises EnvironmentError – The environment variables are not set.

cirq.google.Foxtail

cirq.google.**Foxtail = cirq.google.Foxtail**

cirq.google.gate_to_proto_dict

cirq.google.**gate_to_proto_dict**(*gate: cirq.ops.raw_types.Gate, qubits: Tuple[cirq.ops.raw_types.QubitId, ...]*) → Dict

cirq.google.is_native_xmon_op

cirq.google.**is_native_xmon_op**(*op: cirq.ops.raw_types.Operation*) → bool
Check if the gate corresponding to an operation is a native xmon gate.

Parameters **op** – Input operation.

Returns True if the operation is native to the xmon, false otherwise.

cirq.google.JobConfig

class cirq.google.**JobConfig**(*project_id: Optional[str] = None*, *program_id: Optional[str] = None*, *job_id: Optional[str] = None*, *gcs_prefix: Optional[str] = None*, *gcs_program: Optional[str] = None*, *gcs_results: Optional[str] = None*)
Configuration for a program and job to run on the Quantum Engine API.

Quantum engine has two resources: programs and jobs. Programs live
under cloud projects. Every program may have many jobs, which represent
scheduled or terminated programs executions. Program and job resources have
string names. This object contains the information necessary to create a
program and then create a job on Quantum Engine, hence running the program.
Program ids are of the form
`projects/project_id/programs/program_id`
while job ids are of the form
`projects/project_id/programs/program_id/jobs/job_id`

__init__(*project_id: Optional[str] = None*, *program_id: Optional[str] = None*, *job_id: Optional[str] = None*, *gcs_prefix: Optional[str] = None*, *gcs_program: Optional[str] = None*, *gcs_results: Optional[str] = None*) → None
Configuration for a job that is run on Quantum Engine.

Requires project_id.

Parameters

- **project_id** – The project id string of the Google Cloud Project to use. Programs and Jobs will be created under this project id. If this is set to None, the engine's default project id will be used instead. If that also isn't set, calls will fail.
- **program_id** – Id of the program to create, defaults to a random version of 'prog-ABCD'.
- **job_id** – Id of the job to create, defaults to 'job-0'.
- **gcs_prefix** – Google Cloud Storage bucket and object prefix to use for storing programs and results. The bucket will be created if needed. Must be in the form "gs://bucket-name/object-prefix/".
- **gcs_program** – Explicit override for the program storage location.
- **gcs_results** – Explicit override for the results storage location.

Methods

copy()	

cirq.google.JobConfig.copy

JobConfig.**copy**()

cirq.google.line_on_device

cirq.google.**line_on_device**(*device: cirq.google.XmonDevice*, *length: int*, *method: cirq.google.line.placement.place_strategy.LinePlacementStrategy = <cirq.google.line.placement.greedy.GreedySequenceSearchStrategy object>*) → cirq.google.line.placement.sequence.GridQubitLineTuple

Searches for linear sequence of qubits on device.

Parameters

- **device** – Google Xmon device instance.
- **length** – Desired number of qubits making up the line.
- **method** – Line placement method. Defaults to cirq.greedy.GreedySequenceSearchMethod.

Returns Line sequences search results.

cirq.google.LinePlacementStrategy

class cirq.google.**LinePlacementStrategy**

Choice and options for the line placement calculation method.

Currently two methods are available: cirq.line.GreedySequenceSearchMethod and cirq.line.AnnealSequenceSearchMethod.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

place_line(device, length)	Runs line sequence search.

cirq.google.LinePlacementStrategy.place_line

LinePlacementStrategy.**place_line**(*device: cirq.google.XmonDevice*, *length: int*) → cirq.google.line.placement.sequence.GridQubitLineTuple

Runs line sequence search.

Parameters

- **device** – Chip description.

- **length** – Required line length.

Returns Linear sequences found on the chip.

cirq.google.pack_results

cirq.google.**pack_results**(*measurements: Sequence[Tuple[str, numpy.ndarray]]*) → bytes

Pack measurement results into a byte string.

Parameters **measurements** – A sequence of tuples, one for each measurement, consisting of a string key and an array of boolean data. The data should be a 2-D array indexed by (repetition, qubit_index). All data for all measurements must have the same number of repetitions.

Returns Packed bytes, as described in the unpack_results docstring below.

Raises ValueError if the measurement data do not have the compatible shapes.

cirq.google.schedule_from_proto_dicts

cirq.google.**schedule_from_proto_dicts**(*device: xmon_device.XmonDevice, ops: Iterable[Dict]*) → cirq.schedules.schedule.Schedule

Convert proto dictionaries into a Schedule for the given device.

cirq.google.schedule_to_proto_dicts

cirq.google.**schedule_to_proto_dicts**(*schedule: cirq.schedules.schedule.Schedule*) → Iterable[Dict]

Convert a schedule into an iterable of proto dictionaries.

Parameters **schedule** – The schedule to convert to a proto dict. Must contain only gates that can be cast to xmon gates.

Yields A proto dictionary corresponding to an Operation proto.

cirq.google.unpack_results

cirq.google.**unpack_results**(*data: bytes, repetitions: int, key_sizes: Sequence[Tuple[str, int]]*) → Dict[str, numpy.ndarray]

Unpack data from a bitstring into individual measurement results.

Parameters

- **data** – Packed measurement results, in the form <rep0><rep1>... where each repetition is <key0_0>..<key0_{size0-1}><key1_0>... with bits packed in little-endian order in each byte.
- **repetitions** – number of repetitions.
- **key_sizes** – Keys and sizes of the measurements in the data.

Returns Dict mapping measurement key to a 2D array of boolean results. Each array has shape (repetitions, size) with size for that measurement.

cirq.google.xmon_op_from_proto_dict

cirq.google.**xmon_op_from_proto_dict**(*proto_dict: Dict*) → cirq.ops.raw_types.Operation
Convert the proto dictionary to the corresponding operation.

See protos in api/google/v1 for specification of the protos.

Parameters **proto_dict** – Dictionary representing the proto. Keys are always strings, but values may be types correspond to a raw proto type or another dictionary (for messages).

Returns The operation.

Raises

- ValueError if the dictionary does not contain required values
- corresponding to the proto.

cirq.google.XmonDevice

class cirq.google.**XmonDevice**(*measurement_duration: cirq.value.duration.Duration, exp_w_duration: cirq.value.duration.Duration, exp_11_duration: cirq.value.duration.Duration, qubits: Iterable[cirq.devices.grid_qubit.GridQubit]*)
A device with qubits placed in a grid. Neighboring qubits can interact.

__init__(*measurement_duration: cirq.value.duration.Duration, exp_w_duration: cirq.value.duration.Duration, exp_11_duration: cirq.value.duration.Duration, qubits: Iterable[cirq.devices.grid_qubit.GridQubit]*) → None
Initializes the description of an xmon device.

Parameters

- **measurement_duration** – The maximum duration of a measurement.
- **exp_w_duration** – The maximum duration of an ExpW operation.
- **exp_11_duration** – The maximum duration of an ExpZ operation.
- **qubits** – Qubits on the device, identified by their x, y location.

Methods

at(row, col)	Returns the qubit at the given position, if there is one, else None.
can_add_operation_into_moment(operation, moment)	Determines if it's possible to add an operation into a moment.
col(col)	Returns the qubits in the given column, in ascending order.
decompose_operation(operation)	Returns a device-valid decomposition for the given operation.
duration_of(operation)	
neighbors_of(qubit)	Returns the qubits that the given qubit can interact with.
row(row)	Returns the qubits in the given row, in ascending order.
validate_circuit(circuit)	Raises an exception if a circuit is not valid.

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validate_gate(gate)	Raises an error if the given gate isn't allowed.
validate_moment(moment)	Raises an exception if a moment is not valid.
validate_operation(operation)	Raises an exception if an operation is not valid.
validate_schedule(schedule)	Raises an exception if a schedule is not valid.
validate_scheduled_operation(schedule, ...)	Raises an exception if the scheduled operation is not valid.

cirq.google.XmonDevice.at

XmonDevice.**at**(*row: int*, *col: int*) → Optional[cirq.devices.grid_qubit.GridQubit]
Returns the qubit at the given position, if there is one, else None.

cirq.google.XmonDevice.can_add_operation_into_moment

XmonDevice.**can_add_operation_into_moment**(*operation: cirq.ops.raw_types.Operation*, *moment: cirq.circuits.moment.Moment*) → bool
Determines if it's possible to add an operation into a moment.

For example, on the XmonDevice two CZs shouldn't be placed in the same moment if they are on adjacent qubits.

Parameters

- **operation** – The operation being added.
- **moment** – The moment being transformed.

Returns Whether or not the moment will validate after adding the operation.

cirq.google.XmonDevice.col

XmonDevice.**col**(*col: int*) → List[cirq.devices.grid_qubit.GridQubit]
Returns the qubits in the given column, in ascending order.

cirq.google.XmonDevice.decompose_operation

XmonDevice.**decompose_operation**(*operation: cirq.ops.raw_types.Operation*) → Union[cirq.ops.raw_types.Operation, Iterable[Any]]
Returns a device-valid decomposition for the given operation.

This method is used when adding operations into circuits with a device specified, to avoid spurious failures due to e.g. using a Hadamard gate that must be decomposed into native gates.

cirq.google.XmonDevice.duration_of

XmonDevice.**duration_of**(*operation*)

cirq.google.XmonDevice.neighbors_of

XmonDevice.**neighbors_of**(*qubit: cirq.devices.grid_qubit.GridQubit*)
Returns the qubits that the given qubit can interact with.

cirq.google.XmonDevice.row

XmonDevice.**row**(*row: int*) → List[cirq.devices.grid_qubit.GridQubit]
Returns the qubits in the given row, in ascending order.

cirq.google.XmonDevice.validate_circuit

XmonDevice.**validate_circuit**(*circuit: cirq.circuits.circuit.Circuit*)
Raises an exception if a circuit is not valid.

Parameters **circuit** – The circuit to validate.

Raises ValueError – The circuit isn't valid for this device.

cirq.google.XmonDevice.validate_gate

XmonDevice.**validate_gate**(*gate: cirq.ops.raw_types.Gate*)
Raises an error if the given gate isn't allowed.

Raises ValueError – Unsupported gate.

cirq.google.XmonDevice.validate_moment

XmonDevice.**validate_moment**(*moment: cirq.circuits.moment.Moment*)
Raises an exception if a moment is not valid.

Parameters **moment** – The moment to validate.

Raises ValueError – The moment isn't valid for this device.

cirq.google.XmonDevice.validate_operation

XmonDevice.**validate_operation**(*operation: cirq.ops.raw_types.Operation*)
Raises an exception if an operation is not valid.

Parameters **operation** – The operation to validate.

Raises ValueError – The operation isn't valid for this device.

cirq.google.XmonDevice.validate_schedule

XmonDevice.**validate_schedule**(*schedule*)
Raises an exception if a schedule is not valid.

Parameters **schedule** – The schedule to validate.

Raises ValueError – The schedule isn't valid for this device.

cirq.google.XmonDevice.validate_scheduled_operation

XmonDevice.**validate_scheduled_operation**(*schedule*, *scheduled_operation*)
Raises an exception if the scheduled operation is not valid.

Parameters

- **schedule** – The schedule to validate against.
- **scheduled_operation** – The scheduled operation to validate.

Raises ValueError – If the scheduled operation is not valid for the schedule.

cirq.google.XmonOptions

class cirq.google.**XmonOptions**(*num_shards: int = None*, *min_qubits_before_shard: int = 18*, *use_processes: bool = False*)
XmonOptions for the XmonSimulator.

num_prefix_qubits

Sharding of the wave function is performed over 2
raised to this value number of qubits.

min_qubits_before_shard

Sharding will be done only for this number
of qubits or more. The default is 18.

use_processes

Whether or not to use processes instead of threads.
Processes can improve the performance slightly (varies by machine
but on the order of 10 percent faster). However this varies
significantly by architecture, and processes should not be used
for interactive use on Windows.

__init__(*num_shards: int = None*, *min_qubits_before_shard: int = 18*, *use_processes: bool = False*)
→ None
XmonSimulator options constructor.

Parameters

- **num_shards** – sharding will be done for the greatest value of a power of two less than this value. If None, the default will be used which is the smallest power of two less than or equal to the number of CPUs.
- **min_qubits_before_shard** – Sharding will be done only for this number of qubits or more. The default is 18.
- **use_processes** – Whether or not to use processes instead of threads. Processes can improve the performance slightly (varies by machine but on the order of 10 percent faster). However this varies significantly by architecture, and processes should not be used for interactive python use on Windows.

Methods

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cirq.google.XmonSimulator

class cirq.google.**XmonSimulator**(*options: cirq.google.sim.xmon_simulator.XmonOptions = None*)

XmonSimulator for Xmon class quantum circuits.

This simulator has different methods for different types of simulations.

For simulations that mimic the quantum hardware, the run methods are
defined in the SimulatesSamples interface:
run
run_sweep
These methods do not return or give access to the full wave function.

To get access to the wave function during a simulation, including being
able to set the wave function, the simulate methods are defined in the
SimulatesFinalWaveFunction interface:
simulate
simulate_sweep
simulate_moment_steps (for stepping through a circuit moment by moment)

__init__(*options: cirq.google.sim.xmon_simulator.XmonOptions = None*) → None

Construct a XmonSimulator.

Parameters **options** – XmonOptions configuring the simulation.

Methods

run(circuit, param_resolver, repetitions)	Runs the entire supplied Circuit, mimicking the quantum hardware.

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run_sweep(program, ...)	Runs the entire supplied Circuit, mimicking the quantum hardware.
simulate(circuit, param_resolver, ...)	Simulates the entire supplied Circuit.
simulate_moment_steps(circuit, ...)	Returns an iterator of StepResults for each moment simulated.
simulate_sweep(program, ...)	Simulates the entire supplied Circuit.

cirq.google.XmonSimulator.run

XmonSimulator.**run**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({})*, *repetitions: int = 1*) → cirq.study.trial_result.TrialResult

Runs the entire supplied Circuit, mimicking the quantum hardware.

Parameters

- **circuit** – The circuit to simulate.
- **param_resolver** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult for a run.

cirq.google.XmonSimulator.run_sweep

XmonSimulator.**run_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule]*, *params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({})*, *repetitions: int = 1*) → List[cirq.study.trial_result.TrialResult]

Runs the entire supplied Circuit, mimicking the quantum hardware.

In contrast to run, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **repetitions** – The number of repetitions to simulate.

Returns TrialResult list for this run; one for each possible parameter resolver.

cirq.google.XmonSimulator.simulate

XmonSimulator.**simulate**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = cirq.ParamResolver({})*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → cirq.sim.simulator.SimulationTrialResult

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function.

Parameters

- **circuit** – The circuit to simulate.
- **param_resolver** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns SimulateTrialResults for the simulation. Includes the final wave function.

cirq.google.XmonSimulator.simulate_moment_steps

XmonSimulator.**simulate_moment_steps**(*circuit: cirq.circuits.circuit.Circuit*, *param_resolver: cirq.study.resolver.ParamResolver = None*, *qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>*, *initial_state: Union[int, numpy.ndarray] = 0*) → Iterator[cirq.sim.simulator.StepResult]

Returns an iterator of StepResults for each moment simulated.

Parameters

- **circuit** – The Circuit to simulate.
- **param_resolver** – A ParamResolver for determining values of Symbols.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns Iterator that steps through the simulation, simulating each moment and returning a StepResult for each moment.

cirq.google.XmonSimulator.simulate_sweep

XmonSimulator.**simulate_sweep**(*program: Union[cirq.circuits.circuit.Circuit, cirq.schedules.schedule.Schedule], params: Union[cirq.study.resolver.ParamResolver, Iterable[cirq.study.resolver.ParamResolver], cirq.study.sweeps.Sweep, Iterable[cirq.study.sweeps.Sweep]] = cirq.ParamResolver({}), qubit_order: Union[cirq.ops.qubit_order.QubitOrder, Iterable[cirq.ops.raw_types.QubitId]] = <cirq.ops.qubit_order.QubitOrder object>, initial_state: Union[int, numpy.ndarray] = 0*) → List[cirq.sim.simulator.SimulationTrialResult]

Simulates the entire supplied Circuit.

This method returns a result which allows access to the entire wave function. In contrast to simulate, this allows for sweeping over different parameter values.

Parameters

- **program** – The circuit or schedule to simulate.
- **params** – Parameters to run with the program.
- **qubit_order** – Determines the canonical ordering of the qubits used to define the order of amplitudes in the wave function.
- **initial_state** – If an int, the state is set to the computational basis state corresponding to this state. Otherwise if this is a np.ndarray it is the full initial state. In this case it must be the correct size, be normalized (an L2 norm of 1), and be safely castable to an appropriate dtype for the simulator.

Returns List of SimulatorTrialResults for this run, one for each possible parameter resolver.

cirq.google.XmonStepResult

class cirq.google.**XmonStepResult**(*stepper: cirq.google.sim.xmon_stepper.Stepper, qubit_map: Dict, measurements: Dict[str, numpy.ndarray]*)

Results of a step of the simulator.

qubit_map

A map from the Qubits in the Circuit to the the index of this qubit for a canonical ordering. This canonical ordering is used to define the state (see the state() method).

measurements

A dictionary from measurement gate key to measurement results, ordered by the qubits that the measurement operates on.

__init__(*stepper: cirq.google.sim.xmon_stepper.Stepper, qubit_map: Dict, measurements: Dict[str, numpy.ndarray]*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

bloch_vector(index)	Returns the bloch vector of a qubit.
density_matrix(indices)	Returns the density matrix of the wavefunction.
dirac_notation(decimals)	Returns the wavefunction as a string in Dirac notation.
sample(qubits, repetitions)	Samples from the wave function at this point in the computation.
sample_measurement_ops(measurement_ops, ...)	Samples from the wave function at this point in the computation.
set_state(state, numpy.ndarray])	Updates the state of the simulator to the given new state.
state()	Return the state (wave function) at this point in the computation.

cirq.google.XmonStepResult.bloch_vector

XmonStepResult.**bloch_vector**(*index: int*) → numpy.ndarray
Returns the bloch vector of a qubit.

Calculates the bloch vector of the qubit at index
in the wavefunction given by self.state. Given that self.state
follows the standard Kronecker convention of numpy.kron.

Parameters **index** – index of qubit who's bloch vector we want to find.

Returns A length 3 numpy array representing the qubit's bloch vector.

Raises

- ValueError – if the size of the state represents more than 25 qubits.
- IndexError – if index is out of range for the number of qubits corresponding to the state.

cirq.google.XmonStepResult.density_matrix

XmonStepResult.**density_matrix**(*indices: Iterable[int] = None*) → numpy.ndarray
Returns the density matrix of the wavefunction.

```
Calculate the density matrix for the system on the given qubit
indices, with the qubits not in indices that are present in self.state
traced out. If indices is None the full density matrix for self.state
is returned, given self.state follows standard Kronecker convention
of numpy.kron.

For example:
```

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```
    self.state = np.array([1/np.sqrt(2), 1/np.sqrt(2)],
        dtype=np.complex64)
    indices = None
    gives us
```

ho = egin{bmatrix}
0.5 & 0.5
0.5 & 0.5
\end{bmatrix}

```
Args:
    indices: list containing indices for qubits that you would like
        to include in the density matrix (i.e.) qubits that WON'T
        be traced out.

Returns:
    A numpy array representing the density matrix.

Raises:
    ValueError: if the size of the state represents more than 25 qubits.
    IndexError: if the indices are out of range for the number of qubits
        corresponding to the state.
```

cirq.google.XmonStepResult.dirac_notation

XmonStepResult.**dirac_notation**(*decimals: int = 2*) → str

Returns the wavefunction as a string in Dirac notation.

Parameters **decimals** – How many decimals to include in the pretty print.

Returns A pretty string consisting of a sum of computational basis kets and non-zero floats of the specified accuracy.

cirq.google.XmonStepResult.sample

XmonStepResult.**sample**(*qubits: List[cirq.ops.raw_types.QubitId], repetitions: int = 1*)

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

Returns Measurement results with True corresponding to the |1> state. The outer list is for repetitions, and the inner corresponds to measurements ordered by the supplied qubits.

cirq.google.XmonStepResult.sample_measurement_ops

XmonStepResult.**sample_measurement_ops**(*measurement_ops: List[cirq.ops.gate_operation.GateOperation], repetitions: int = 1*) → Dict[str, List[List[bool]]]

Samples from the wave function at this point in the computation.

Note that this does not collapse the wave function.

In contrast to `sample` which samples qubits, this takes a list of `cirq.GateOperation` instances whose gates are `cirq.MeasurementGate` instances and then returns a mapping from the key in the measurement gate to the resulting bit strings. Different measurement operations must not act on the same qubits.

Parameters

- **measurement_ops** – *GateOperation* instances whose gates are *MeasurementGate* instances to be sampled form.
- **repetitions** – The number of samples to take.

Returns: A dictionary from the measurement gate keys to the measurement results. These results are lists of lists, with the outer list corresponding to repetitions and the inner list corresponding to the qubits acted upon by the measurement operation with the given key.

Raises `ValueError` – If the operation's gates are not *MeasurementGate* instances or a qubit is acted upon multiple times by different operations from *measurement_ops*.

cirq.google.XmonStepResult.set_state

`XmonStepResult.`**`set_state`**(*state: Union[int, numpy.ndarray]*)

Updates the state of the simulator to the given new state.

Parameters

- **state** – If this is an int, then this is the state to reset
- **stepper to, expressed as an integer of the computational basis.** (*the*) –
- **to bitwise indices is little endian. Otherwise if this is** (*Integer*) –
- **np.ndarray this must be the correct size and have dtype of** (*a*) –
- **np.complex64.** –

Raises

- ValueError if the state is incorrectly sized or not of the correct
- `dtype.`

cirq.google.XmonStepResult.state

`XmonStepResult.`**`state`**() → numpy.ndarray

Return the state (wave function) at this point in the computation.

The state is returned in the computational basis with these basis

states defined by the qubit_map. In particular the value in the qubit_map is the index of the qubit, and these are translated into binary vectors where the last qubit is the 1s bit of the index, the second-to-last is the 2s bit of the index, and so forth (i.e. big endian ordering).

Example

qubit_map: {QubitA: 0, QubitB: 1, QubitC: 2}
Then the returned vector will have indices mapped to qubit basis states like the following table
| | QubitA | QubitB | QubitC |
+---+--------+--------+--------+
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1
+---+--------+--------+--------+

3.1.14 Testing

Functionality for writing unit tests involving objects from Cirq, and also some general testing utilities.

testing.assert_allclose_up_to_global_phase(a, b, ...)	Checks if a ~= b * exp(i t) for some t.
testing.assert_circuits_with_terminal_measurements_are_equivalent(...)	Determines if two circuits have equivalent effects.
testing.assert_decompose_is_consistent_with_unitary(val)	Uses `val._unitary_` to check `val._phase_by_`'s behavior.
testing.assert_eigen_gate_has_consistent_apply_unitary(...)	Tests whether an EigenGate type's *apply_unitary* is correct.
testing.assert_equivalent_repr(value, *, ...)	Checks that eval(repr(v)) == v.
testing.assert_has_consistent_apply_unitary(val)	Tests whether a value's *apply_unitary* is correct.
testing.assert_has_consistent_apply_unitary_for_various_exponents(val, *)	Tests whether a value's *apply_unitary* is correct.
testing.assert_has_diagram(actual, desired, ...)	Determines if a given circuit has the desired text diagram.
testing.assert_phase_by_is_consistent_with_unitary(val)	Uses `val._unitary_` to check `val._phase_by_`'s behavior.
testing.assert_qasm_is_consistent_with_unitary(val)	Uses `val._unitary_` to check `val._qasm_`'s behavior.
testing.assert_same_circuits(actual, expected)	Asserts that two circuits are identical, with a descriptive error.

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Table 131 – continued from previous page

testing.EqualsTester()	Tests equality against user-provided disjoint equivalence groups.
testing.highlight_text_differences(actual, ...)	
testing.nonoptimal_toffoli_circuit(q0, q1, ...)	
testing.only_test_in_python3(func)	A decorator that indicates a test should not execute in python 2.
testing.OrderTester()	Tests ordering against user-provided disjoint ordered groups or items.
testing.random_circuit(qubits, int], ...)	Generates a random circuit.
testing.random_orthogonal(dim)	
testing.random_special_orthogonal(dim)	
testing.random_special_unitary(dim)	
testing.random_unitary(dim)	Returns a random unitary matrix distributed with Haar measure.
testing.TempDirectoryPath	A context manager that provides a temporary directory for use within a
testing.TempFilePath	A context manager that provides a temporary file path for use within a

cirq.testing.assert_allclose_up_to_global_phase

cirq.testing.**assert_allclose_up_to_global_phase**(*actual: numpy.ndarray*, *desired: numpy.ndarray*, ***, *rtol: float = 1e-07*, *atol: float*, *equal_nan: bool = True*, *err_msg: Optional[str] = ''*, *verbose: bool = True*) → None

Checks if a ~= b * exp(i t) for some t.

Parameters

- **actual** – A numpy array.
- **desired** – Another numpy array.
- **rtol** – Relative error tolerance.
- **atol** – Absolute error tolerance.
- **equal_nan** – Whether or not NaN entries should be considered equal to other NaN entries.
- **err_msg** – The error message to be printed in case of failure.
- **verbose** – If True, the conflicting values are appended to the error message.

Raises `AssertionError` – The matrices aren't nearly equal up to global phase.

cirq.testing.assert_circuits_with_terminal_measurements_are_equivalent

cirq.testing.**assert_circuits_with_terminal_measurements_are_equivalent**(*actual: cirq.circuits.circuit.Circuit*, *reference: cirq.circuits.circuit.Circuit*, *atol: float*) → None

Determines if two circuits have equivalent effects.

The circuits can contain measurements, but the measurements must be at the end of the circuit. Circuits are equivalent if, for all possible inputs, their outputs (classical bits for lines terminated with measurement and qubits for lines without measurement) are observationally indistinguishable up to a tolerance. Note that under this definition of equivalence circuits that differ solely in the overall phase of the post-measurement state of measured qubits are considered equivalent.

For example, applying an extra Z gate to an unmeasured qubit changes the effect of a circuit. But inserting a Z gate operation just before a measurement does not.

Parameters

- **actual** – The circuit that was actually computed by some process.
- **reference** – A circuit with the correct function.
- **atol** – Absolute error tolerance.

cirq.testing.assert_decompose_is_consistent_with_unitary

cirq.testing.**assert_decompose_is_consistent_with_unitary**(*val: Any*, *including_global_phase: bool = False*)

Uses `val._unitary_` to check `val._phase_by_`'s behavior.

cirq.testing.assert_eigen_gate_has_consistent_apply_unitary

cirq.testing.**assert_eigen_gate_has_consistent_apply_unitary**(*eigen_gate_type: Type[cirq.ops.eigen_gate.EigenGate], *, exponents=(0, 1, -1, 0.5, 0.25, -0.5, 0.1, cirq.Symbol('s')), global_shifts=(0, 0.5, -0.5, 0.1), qubit_count: Optional[int] = None*) → None

Tests whether an EigenGate type's *apply_unitary* is correct.

Contrasts the effects of the gate's _apply_unitary_ with the matrix returned by the gate's _unitary_ method, trying various values for the gate exponent and global shift.

Parameters

- **eigen_gate_type** – The type of gate to test. The type must have an __init__ method that takes an exponent and a global_shift.
- **exponents** – The exponents to try. Defaults to a variety of special and arbitrary angles, as well as a parameterized angle (a symbol).
- **global_shifts** – The global shifts to try. Defaults to a variety of special angles.
- **qubit_count** – The qubit count to use for the gate. This argument isn't needed if the gate has a unitary matrix or implements *cirq.SingleQubitGate*/*cirq.TwoQubitGate*/*cirq.ThreeQubitGate*; it will be inferred.

cirq.testing.assert_equivalent_repr

cirq.testing.**assert_equivalent_repr**(*value: Any, *, setup_code: str = 'import cirq\nimport numpy as np'*) → None

Checks that eval(repr(v)) == v.

Parameters

- **value** – A value whose repr should be evaluatable python code that produces an equivalent value.
- **setup_code** – Code that must be executed before the repr can be evaluated. Ideally this should just be a series of 'import' lines.

cirq.testing.assert_has_consistent_apply_unitary

cirq.testing.**assert_has_consistent_apply_unitary**(*val: Any, *, qubit_count: Optional[int] = None, atol: float = 1e-08*) → None

Tests whether a value's *apply_unitary* is correct.

Contrasts the effects of the value's _apply_unitary_ with the

matrix returned by the value's _unitary_ method.

Parameters

- **val** – The value under test. Should have a *__pow__* method.
- **qubit_count** – Usually inferred. The number of qubits the value acts on. This argument isn't needed if the gate has a unitary matrix or implements *cirq.SingleQubitGate*/*cirq.TwoQubitGate*/ *cirq.ThreeQubitGate*.

cirq.testing.assert_has_consistent_apply_unitary_for_various_exponents

cirq.testing.**assert_has_consistent_apply_unitary_for_various_exponents**(*val: Any*, ***, *exponents=(0, 1, -1, 0.5, 0.25, -0.5, 0.1, cirq.Symbol('s'))*, *qubit_count: Optional[int] = None*) → None

Tests whether a value's *apply_unitary* is correct.

Contrasts the effects of the value's _apply_unitary_ with the matrix returned by the value's _unitary_ method. Attempts this after attempting to raise the value to several exponents.

Parameters

- **val** – The value under test. Should have a *__pow__* method.
- **exponents** – The exponents to try. Defaults to a variety of special and arbitrary angles, as well as a parameterized angle (a symbol). If the value's *__pow__* returns *NotImplemented* for any of these, they are skipped.
- **qubit_count** – A minimum qubit count for the test system. This argument isn't needed if the gate has a unitary matrix or implements *cirq.SingleQubitGate*/*cirq.TwoQubitGate*/*cirq.ThreeQubitGate*; it will be inferred.

cirq.testing.assert_has_diagram

cirq.testing.**assert_has_diagram**(*actual: cirq.circuits.circuit.Circuit*, *desired: str*, ***kwargs*) → None

Determines if a given circuit has the desired text diagram.

Parameters

- **actual** – The circuit that was actually computed by some process.
- **desired** – The desired text diagram as a string. Newlines at the beginning and whitespace at the end are ignored.
- ****kwargs** – Keyword arguments to be passed to actual.to_text_diagram().

cirq.testing.assert_phase_by_is_consistent_with_unitary

cirq.testing.**assert_phase_by_is_consistent_with_unitary**(*val: Any*)

Uses `val._unitary_` to check `val._phase_by_`'s behavior.

cirq.testing.assert_qasm_is_consistent_with_unitary

cirq.testing.**assert_qasm_is_consistent_with_unitary**(*val: Any*)

Uses `val._unitary_` to check `val._qasm_`'s behavior.

cirq.testing.assert_same_circuits

cirq.testing.**assert_same_circuits**(*actual: cirq.circuits.circuit.Circuit*, *expected: cirq.circuits.circuit.Circuit*) → None

Asserts that two circuits are identical, with a descriptive error.

Parameters

- **actual** – A circuit computed by some code under test.
- **expected** – The circuit that should have been computed.

cirq.testing.EqualsTester

class cirq.testing.**EqualsTester**

Tests equality against user-provided disjoint equivalence groups.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

add_equality_group(*group_items)	Tries to add a disjoint equivalence group to the equality tester.
make_equality_group(*factories)	Tries to add a disjoint equivalence group to the equality tester.

cirq.testing.EqualsTester.add_equality_group

EqualsTester.**add_equality_group**(**group_items*)

Tries to add a disjoint equivalence group to the equality tester.

This methods asserts that items within the group must all be equal to each other, but not equal to any items in other groups that have been or will be added.

Parameters ***group_items** – The items making up the equivalence group.

Raises AssertionError – Items within the group are not equal to each other, or items in another group are equal to items within the new group, or the items violate the equals-implies-same-hash rule.

cirq.testing.EqualsTester.make_equality_group

EqualsTester.**make_equality_group**(**factories*)

Tries to add a disjoint equivalence group to the equality tester.

Uses the factory methods to produce two different objects with the same initialization for each factory. Asserts that the objects are equal, but not equal to any items in other groups that have been or will be added. Adds the objects as a group.

Parameters **factories** – Methods for producing independent copies of an item.

Raises AssertionError – The factories produce items not equal to the others, or items in another group are equal to items from the factory, or the items violate the equal-implies-same-hash rule.

cirq.testing.highlight_text_differences

cirq.testing.**highlight_text_differences**(*actual: str*, *expected: str*) → str

cirq.testing.nonoptimal_toffoli_circuit

cirq.testing.**nonoptimal_toffoli_circuit**(*q0: cirq.ops.raw_types.QubitId*, *q1: cirq.ops.raw_types.QubitId*, *q2: cirq.ops.raw_types.QubitId*, *device: cirq.devices.device.Device = cirq.UnconstrainedDevice*) → cirq.circuits.circuit.Circuit

cirq.testing.only_test_in_python3

cirq.testing.**only_test_in_python3**(*func*)

A decorator that indicates a test should not execute in python 2.

For example, in python 2 repr('a') is "u'a'" instead of "'a'" when from **future** import unicode is present (which it will be, since 3to2 inserts it for us). This is annoying to work around when testing repr methods, so instead you can just tag the test with this decorator.

cirq.testing.OrderTester

class cirq.testing.**OrderTester**

Tests ordering against user-provided disjoint ordered groups or items.

__init__()

Initialize self. See help(type(self)) for accurate signature.

Methods

add_ascending(*items)	Tries to add a sequence of ascending items to the order tester.
add_ascending_equivalence_group(*group_items)	Tries to add an ascending equivalence group to the order tester.

cirq.testing.OrderTester.add_ascending

OrderTester.**add_ascending**(**items*)

Tries to add a sequence of ascending items to the order tester.

This methods asserts that items must all be ascending
with regard to both each other and the elements which have been already
added during previous calls.
Some of the previously added elements might be equivalence groups,
which are supposed to be equal to each other within that group.

Parameters ***items** – The sequence of strictly ascending items.

Raises AssertionError – Items are not ascending either with regard to each other, or with regard to the elements which have been added before.

cirq.testing.OrderTester.add_ascending_equivalence_group

OrderTester.**add_ascending_equivalence_group**(**group_items*)

Tries to add an ascending equivalence group to the order tester.

Asserts that the group items are equal to each other, but strictly
ascending with regard to the already added groups.

Adds the objects as a group.

Parameters **group_items** – items making the equivalence group

Raises AssertionError – The group elements aren't equal to each other, or items in another group overlap with the new group.

cirq.testing.random_circuit

cirq.testing.**random_circuit**(*qubits: Union[Sequence[cirq.ops.raw_types.QubitId], int], n_moments: int, op_density: float, gate_domain: Optional[Dict[cirq.ops.raw_types.Gate, int]] = None*) → cirq.circuits.circuit.Circuit

Generates a random circuit.

Parameters

- **qubits** – the qubits that the circuit acts on. Because the qubits on which an operation acts are chosen randomly, not all given qubits may be acted upon.
- **n_moments** – the number of moments in the generated circuit.
- **op_density** – the expected proportion of qubits that are acted on in any moment.
- **gate_domain** – The set of gates to choose from, with a specified arity.

Raises ValueError – * op_density is not in (0, 1). * gate_domain is empty. * qubits is an int less than 1 or an empty sequence.

Returns The randomly generated Circuit.

cirq.testing.random_orthogonal

cirq.testing.**random_orthogonal**(*dim: int*) → numpy.ndarray

cirq.testing.random_special_orthogonal

cirq.testing.**random_special_orthogonal**(*dim: int*) → numpy.ndarray

cirq.testing.random_special_unitary

cirq.testing.**random_special_unitary**(*dim: int*) → numpy.ndarray

cirq.testing.random_unitary

cirq.testing.**random_unitary**(*dim: int*) → numpy.ndarray

Returns a random unitary matrix distributed with Haar measure.

Parameters **dim** – The width and height of the matrix.

Returns The sampled unitary matrix.

References

'How to generate random matrices from the classical compact groups' http://arxiv.org/abs/math-ph/0609050

cirq.testing.TempDirectoryPath

class cirq.testing.**TempDirectoryPath**

A context manager that provides a temporary directory for use within a 'with' statement.

__init__()
Initialize self. See help(type(self)) for accurate signature.

cirq.testing.TempFilePath

class cirq.testing.**TempFilePath**

A context manager that provides a temporary file path for use within a 'with' statement.

__init__()
Initialize self. See help(type(self)) for accurate signature.

3.1.15 Work in Progress - Noisy Channels

Imperfect operations.

amplitude_damp(gamma)	Returns an AmplitudeDampingChannel with the given probability gamma.
AmplitudeDampingChannel(gamma)	Dampen qubit amplitudes through dissipation.
asymmetric_depolarize(p_x, p_y, p_z)	Returns a AsymmetricDepolarizingChannel with given parameter.
AsymmetricDepolarizingChannel(p_x, p_y, p_z)	A channel that depolarizes asymmetrically along different directions.
bit_flip(p)	Construct a BitFlipChannel that flips a qubit state
BitFlipChannel(p)	Probabilistically flip a qubit from 1 to 0 state or vice versa.
channel(val, default[, dtype])	Returns a list of matrices describing the channel for the given value.
depolarize(p)	Returns a DepolarizingChannel with given probability of error.
DepolarizingChannel(p)	A channel that depolarizes a qubit.
generalized_amplitude_damp(p, gamma)	Returns a GeneralizedAmplitudeDampingChannel with the given
GeneralizedAmplitudeDampingChannel(p, gamma)	Dampen qubit amplitudes through non ideal dissipation.
phase_damp(gamma)	Creates a PhaseDampingChannel with damping constant gamma.
PhaseDampingChannel(gamma)	Dampen qubit phase.

Continued on next page

Table 134 – continued from previous page

phase_flip(p)	Returns a PhaseFlipChannel that flips a qubit's phase with probability
PhaseFlipChannel(p)	Probabilistically flip the sign of the phase of a qubit.
rotation_error(eps_x, eps_y, eps_z)	Constructs a RotationErrorChannel that can over/under rotate
RotationErrorChannel(eps_x, eps_y, eps_z)	Channel to introduce rotation error in X, Y, Z.
SupportsChannel(*args, **kwargs)	An object that may be describable as a quantum channel.

cirq.amplitude_damp

cirq.**amplitude_damp**(*gamma: float*) → cirq.ops.common_channels.AmplitudeDampingChannel
Returns an AmplitudeDampingChannel with the given probability gamma.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \begin{bmatrix}
        1 & 0  \\
        0 & \sqrt{1 - \gamma}
      \end{bmatrix}

M_1 = \begin{bmatrix}
        0 & \sqrt{\gamma} \\
        0 & 0
      \end{bmatrix}
```

Parameters **gamma** – the probability of the interaction being dissipative.

Raises ValueError – if gamma is not a valid probability.

cirq.AmplitudeDampingChannel

class cirq.**AmplitudeDampingChannel**(*gamma*)
Dampen qubit amplitudes through dissipation.

This channel models the effect of energy dissipation to the surrounding environment.

__init__(*gamma*) → None
The amplitude damping channel.

Construct a channel that dissipates energy. The probability of

energy exchange occurring is given by gamma.

This channel evolves a density matrix as follows:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \begin{bmatrix}
        1 & 0  \\
        0 & \sqrt{1 - \gamma}
      \end{bmatrix}

M_1 = \begin{bmatrix}
        0 & \sqrt{\gamma} \\
        0 & 0
      \end{bmatrix}
```

Parameters **gamma** – the probability of the interaction being dissipative.

Raises ValueError – is gamma is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.AmplitudeDampingChannel.on

AmplitudeDampingChannel.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.AmplitudeDampingChannel.validate_args

AmplitudeDampingChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.asymmetric_depolarize

cirq.**asymmetric_depolarize**(*p_x: float*, *p_y: float*, *p_z: float*) → cirq.ops.common_channels.AsymmetricDepolarizingChannel

Returns a AsymmetricDepolarizingChannel with given parameter.

This channel evolves a density matrix via
\rho -> (1 -p_x + p_y + p_z) \rho
+ p_x X \rho X + p_y Y \rho Y + p_z Z \rho Z

Parameters

- **p_x** – The probability that a Pauli X and no other gate occurs.
- **p_y** – The probability that a Pauli Y and no other gate occurs.
- **p_z** – The probability that a Pauli Z and no other gate occurs.

Raises `ValueError` – if the args or the sum of the args are not probabilities.

cirq.AsymmetricDepolarizingChannel

class cirq.**AsymmetricDepolarizingChannel**(*p_x: float*, *p_y: float*, *p_z: float*)

A channel that depolarizes asymmetrically along different directions.

__init__(*p_x: float*, *p_y: float*, *p_z: float*) → None

The asymmetric depolarizing channel.

This channel applies one of four disjoint possibilities: nothing (the identity channel) or one of the three pauli gates. The disjoint probabilities of the three gates are p_x, p_y, and p_z and the identity is done with probability 1 - p_x - p_y - p_z. The supplied probabilities must be valid probabilities and the sum p_x + p_y + p_z must be a valid probability or else this constructor will raise a ValueError.

This channel evolves a density matrix via
\rho -> (1 -p_x + p_y + p_z) \rho
+ p_x X \rho X + p_y Y \rho Y + p_z Z \rho Z

Parameters

- **p_x** – The probability that a Pauli X and no other gate occurs.
- **p_y** – The probability that a Pauli Y and no other gate occurs.
- **p_z** – The probability that a Pauli Z and no other gate occurs.

Raises `ValueError` – if the args or the sum of args are not probabilities.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.AsymmetricDepolarizingChannel.on

AsymmetricDepolarizingChannel.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.AsymmetricDepolarizingChannel.validate_args

AsymmetricDepolarizingChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.bit_flip

cirq.**bit_flip**(*p: Optional[float] = None*) → Union[cirq.ops.common_gates.XPowGate, cirq.ops.common_channels.BitFlipChannel]

Construct a BitFlipChannel that flips a qubit state
with probability of a flip given by p. If p is None, return
a guaranteed flip in the form of an X operation.

This channel evolves a density matrix via
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger

With
M_0 = \sqrt{p} \begin{bmatrix}
1 & 0 \
0 & 1
\end{bmatrix}
M_1 = \sqrt{1-p} \begin{bmatrix}
0 & 1 \
1 & -0
\end{bmatrix}

Parameters **p** – the probability of a bit flip.

Raises ValueError – if p is not a valid probability.

cirq.BitFlipChannel

class cirq.**BitFlipChannel**(*p*)
Probabilistically flip a qubit from 1 to 0 state or vice versa.

__init__(*p*) → None
The bit flip channel.

Construct a channel that flips a qubit with probability p.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \sqrt{p} \begin{bmatrix}
                    1 & 0  \\
                    0 & 1
                \end{bmatrix}
M_1 = \sqrt{1-p} \begin{bmatrix}
                    0 & 1 \\
                    1 & -0
                  \end{bmatrix}
```

Parameters **p** – the probability of a bit flip.

Raises ValueError – if p is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.BitFlipChannel.on

BitFlipChannel.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.BitFlipChannel.validate_args

BitFlipChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.channel

cirq.**channel**(*val: Any, default: Iterable[TDefault] = (array([], dtype=float64),)*) → Union[Tuple[numpy.ndarray], Iterable[TDefault]]
Returns a list of matrices describing the channel for the given value.

```
These matrices are the terms in the operator sum representation of
a quantum channel. If the returned matrices are {A_0,A_1,..., A_{r-1}},
then this describes the channel:
```

ho -> \sum_{k=0}^{r-1} A_0
ho A_0^\dagger
These matrices are required to satisfy the trace preserving condition
\sum_{k=0}^{r-1} A_i^\dagger A_i = I
where I is the identity matrix. The matrices A_i are sometimes called
Krauss or noise operators.

```
Args:
    val: The value to describe by a channel.
    default: Determines the fallback behavior when `val` doesn't have
        a channel. If `default` is not set, a TypeError is raised. If
        default is set to a value, that value is returned.

Returns:
    If `val` has a _channel_ method and its result is not NotImplemented,
    that result is returned. Otherwise, if `val` has a _unitary_ method and
    its result is not NotImplemented a tuple made up of that result is
    returned. Otherwise, if a default value was specified, the default
    value is returned.

Raises:
    TypeError: `val` doesn't have a _channel_ or _unitary_ method (or that
        method returned NotImplemented) and also no default value was
        specified.
```

cirq.depolarize

cirq.**depolarize**(*p: float*) → cirq.ops.common_channels.DepolarizingChannel
Returns a DepolarizingChannel with given probability of error.

This channel applies one of four disjoint possibilities: nothing (the
identity channel) or one of the three pauli gates. The disjoint
probabilities of the three gates are all the same, p / 3, and the
identity is done with probability 1 - p. The supplied probability
must be a valid probability or else this constructor will raise a
ValueError.

This channel evolves a density matrix via
\rho -> (1 - p) \rho
+ (p / 3) X \rho X + (p / 3) Y \rho Y + (p / 3) Z \rho Z

Parameters **p** – The probability that one of the Pauli gates is applied. Each of the Pauli gates is applied independently with probability p / 3.

Raises `ValueError` – if p is not a valid probability.

cirq.DepolarizingChannel

class cirq.**DepolarizingChannel**(*p*)
A channel that depolarizes a qubit.

__init__(*p*) → None
The symmetric depolarizing channel.

This channel applies one of four disjoint possibilities: nothing (the identity channel) or one of the three pauli gates. The disjoint probabilities of the three gates are all the same, p / 3, and the identity is done with probability 1 - p. The supplied probability must be a valid probability or else this constructor will raise a ValueError.

This channel evolves a density matrix via
\rho -> (1 - p) \rho
+ (p / 3) X \rho X + (p / 3) Y \rho Y + (p / 3) Z \rho Z

Parameters **p** – The probability that one of the Pauli gates is applied. Each of the Pauli gates is applied independently with probability p / 3.

Raises `ValueError` – if p is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.DepolarizingChannel.on

DepolarizingChannel.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.DepolarizingChannel.validate_args

DepolarizingChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.generalized_amplitude_damp

cirq.**generalized_amplitude_damp**(*p: float*, *gamma: float*) → cirq.ops.common_channels.GeneralizedAmplitudeDampingChannel

Returns a GeneralizedAmplitudeDampingChannel with the given probabilities gamma and p.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
      + M_2 \rho M_2^\dagger + M_3 \rho M_3^\dagger
```

With:

```
M_0 = \sqrt{p} \begin{bmatrix}
                    1 & 0  \\
                    0 & \sqrt{1 - \gamma}
                \end{bmatrix}

M_1 = \sqrt{p} \begin{bmatrix}
                    0 & \sqrt{\gamma} \\
                    0 & 0
                \end{bmatrix}

M_2 = \sqrt{1-p} \begin{bmatrix}
                    \sqrt{1-\gamma} & 0 \\
                     0 & 1
                  \end{bmatrix}

M_3 = \sqrt{1-p} \begin{bmatrix}
                     0 & 0 \\
                     \sqrt{gamma} & 0
                  \end{bmatrix}
```

Parameters

- **gamma** – the probability of the interaction being dissipative.
- **p** – the probability of the qubit and environment exchanging energy.

Raises `ValueError` – gamma or p is not a valid probability.

cirq.GeneralizedAmplitudeDampingChannel

class cirq.**GeneralizedAmplitudeDampingChannel**(*p: float*, *gamma: float*)

Dampen qubit amplitudes through non ideal dissipation.

This channel models the effect of energy dissipation into the environment as well as the environment depositing energy into the system.

__init__(*p: float*, *gamma: float*) → None
The generalized amplitude damping channel.

Construct a channel to model energy dissipation into the environment as well as the environment depositing energy into the system. The probabilities with which the energy exchange occur are given by gamma, and the probability of the environment being not excited is given by `p`.

The stationary state of this channel is the diagonal density matrix with probability `p` of being |0 and probability `1-p` of being |1.

This channel evolves a density matrix via

$$ \rho \rightarrow M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger + M_2 \rho M_2^\dagger + M_3 \rho M_3^\dagger $$
With

$$ \begin{align} M_0 &= \sqrt{p} \begin{bmatrix} 1 & 0 \newline 0 & \sqrt{1 - \gamma} \end{bmatrix} \newline M_1 &= \sqrt{p} \begin{bmatrix} 0 & \sqrt{\gamma} \newline 0 & 0 \end{bmatrix} \newline M_2 &= \sqrt{1-p} \begin{bmatrix} \sqrt{1-\gamma} & 0 \newline 0 & 1 \end{bmatrix} \newline M_3 &= \sqrt{1-p} \begin{bmatrix} 0 & 0 \newline \sqrt{\gamma} & 0 \end{bmatrix} \end{align} $$

Parameters

- **gamma** – the probability of the interaction being dissipative.
- **p** – the probability of the qubit and environment exchanging energy.

Raises `ValueError` – if gamma or p is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.GeneralizedAmplitudeDampingChannel.on

`GeneralizedAmplitudeDampingChannel`.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.GeneralizedAmplitudeDampingChannel.validate_args

GeneralizedAmplitudeDampingChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.phase_damp

cirq.**phase_damp**(*gamma: float*) → cirq.ops.common_channels.PhaseDampingChannel

Creates a PhaseDampingChannel with damping constant gamma.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \begin{bmatrix}
        1 & 0  \\
        0 & \sqrt{1 - \gamma}
      \end{bmatrix}
M_1 = \begin{bmatrix}
        0 & 0 \\
        0 & \sqrt{\gamma}
      \end{bmatrix}
```

Parameters **gamma** – The damping constant.

Raises ValueError – is gamma is not a valid probability.

cirq.PhaseDampingChannel

class cirq.**PhaseDampingChannel**(*gamma*)

Dampen qubit phase.

This channel models phase damping which is the loss of quantum information without the loss of energy.

__init__(*gamma*) → None

The phase damping channel.

Construct a channel that enacts a phase damping constant gamma.

This channel evolves a density matrix via:
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger

With:

```
M_0 = \begin{bmatrix}
        1 & 0 \\
        0 & \sqrt{1 - \gamma}
      \end{bmatrix}
M_1 = \begin{bmatrix}
        0 & 0 \\
        0 & \sqrt{\gamma}
      \end{bmatrix}
```

Parameters **gamma** – The damping constant.

Raises ValueError – if gamma is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.PhaseDampingChannel.on

PhaseDampingChannel.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.PhaseDampingChannel.validate_args

PhaseDampingChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.phase_flip

cirq.**phase_flip**(*p: Optional[float] = None*) → Union[cirq.ops.common_gates.ZPowGate, cirq.ops.common_channels.PhaseFlipChannel]

Returns a PhaseFlipChannel that flips a qubit's phase with probability p
if p is None, return a guaranteed phase flip in the form of a Z operation.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \sqrt{p} \begin{bmatrix}
                    1 & 0  \\
                    0 & 1
                \end{bmatrix}
M_1 = \sqrt{1-p} \begin{bmatrix}
                    1 & 0 \\
                    0 & -1
                  \end{bmatrix}
```

Parameters **p** – the probability of a phase flip.

Raises ValueError – if p is not a valid probability.

cirq.PhaseFlipChannel

class cirq.**PhaseFlipChannel**(*p*)

Probabilistically flip the sign of the phase of a qubit.

__init__(*p*) → None

The phase flip channel.

Construct a channel to flip the phase with probability p.

This channel evolves a density matrix via:

```
\rho -> M_0 \rho M_0^\dagger + M_1 \rho M_1^\dagger
```

With:

```
M_0 = \sqrt{p} \begin{bmatrix}
                    1 & 0  \\
                    0 & 1
                \end{bmatrix}
M_1 = \sqrt{1-p} \begin{bmatrix}
                    1 & 0 \\
                    0 & -1
                \end{bmatrix}
```

Parameters **p** – the probability of a phase flip.

Raises ValueError – if p is not a valid probability.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.PhaseFlipChannel.on

PhaseFlipChannel.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.PhaseFlipChannel.validate_args

PhaseFlipChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.rotation_error

cirq.**rotation_error**(*eps_x: float*, *eps_y: float*, *eps_z: float*) → cirq.ops.common_channels.RotationErrorChannel

Constructs a RotationErrorChannel that can over/under rotate
a qubit in X, Y, Z by given error angles.

This channel evolves a density matrix via:

```
\rho ->
\exp{-i \epsilon_x \frac{X}{2}} \rho \exp{i \epsilon_x \frac{X}{2}}
+ \exp{-i \epsilon_y \frac{Y}{2}} \rho \exp{i \epsilon_y \frac{Y}{2}}
+ \exp{-i \epsilon_z \frac{Z}{2}} \rho \exp{i \epsilon_z \frac{Z}{2}}
```

Parameters

- **eps_x** – angle to over rotate in x.
- **eps_y** – angle to over rotate in y.
- **eps_z** – angle to over rotate in z.

cirq.RotationErrorChannel

class cirq.**RotationErrorChannel**(*eps_x*, *eps_y*, *eps_z*)
Channel to introduce rotation error in X, Y, Z.

__init__(*eps_x*, *eps_y*, *eps_z*) → None
The rotation error channel.

This channel introduces rotation error by epsilon for
rotations in X, Y and Z that are constant in time.

This channel evolves a density matrix via
\rho ->
\exp{-i \epsilon_x \frac{X}{2}} \rho \exp{i \epsilon_x \frac{X}{2}}

- \exp{-i \epsilon_y \frac{Y}{2}} \rho \exp{i \epsilon_y \frac{Y}{2}}
- \exp{-i \epsilon_z \frac{Z}{2}} \rho \exp{i \epsilon_z \frac{Z}{2}}

Parameters

- **eps_x** – angle to over rotate in x.
- **eps_y** – angle to over rotate in y.
- **eps_z** – angle to over rotate in z.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.RotationErrorChannel.on

RotationErrorChannel.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.RotationErrorChannel.validate_args

RotationErrorChannel.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None

Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

cirq.SupportsChannel

class cirq.**SupportsChannel**(**args*, ***kwargs*)

An object that may be describable as a quantum channel.

__init__(**args*, ***kwargs*)

Methods

—

3.1.16 Work in Progress - Stabilizers

Tools for working with the well-behaved operations from the Clifford+Measurement set.

CircuitDag(can_reorder, ...)	A representation of a Circuit as a directed acyclic graph.
SingleQubitCliffordGate(*, _rotation_map, ...)	Any single qubit Clifford rotation.
Pauli(*, _index, _name)	Represents the X, Y, or Z axis of the Bloch sphere.

Continued on next page

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PauliInteractionGate(pauli0, invert0, ...)	
PauliString(qubit_pauli_map, ...)	
PauliTransform(to, flip)	
Unique(val)	A wrapper for a value that doesn't compare equal to other instances.

cirq.CircuitDag

class cirq.**CircuitDag**(*can_reorder: Callable[[cirq.ops.raw_types.Operation, cirq.ops.raw_types.Operation], bool] = <function _disjoint_qubits>, incoming_graph_data: Any = None, device: cirq.devices.device.Device = cirq.UnconstrainedDevice*)

A representation of a Circuit as a directed acyclic graph.

Nodes of the graph are instances of Unique containing each operation of a circuit.

Edges of the graph are tuples of nodes. Each edge specifies a required application order between two operations. The first must be applied before the second.

The graph is maximalist (transitive completion).

__init__(*can_reorder: Callable[[cirq.ops.raw_types.Operation, cirq.ops.raw_types.Operation], bool] = <function _disjoint_qubits>, incoming_graph_data: Any = None, device: cirq.devices.device.Device = cirq.UnconstrainedDevice*) → None

Initializes a CircuitDag.

Parameters

- **can_reorder** – A predicate that determines if two operations may be reordered. Graph edges are created for pairs of operations where this returns False.

  The default predicate allows reordering only when the operations don't share common qubits.
- **incoming_graph_data** – Data in initialize the graph. This can be any value supported by networkx.DiGraph() e.g. an edge list or another graph.
- **device** – Hardware that the circuit should be able to run on.

Methods

add_edge(u_of_edge, v_of_edge, **attr)	Add an edge between u and v.
add_edges_from(ebunch_to_add, **attr)	Add all the edges in ebunch_to_add.
add_node(node_for_adding, **attr)	Add a single node *node_for_adding* and update node attributes.
add_nodes_from(nodes_for_adding, **attr)	Add multiple nodes.

Continued on next page

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add_weighted_edges_from(ebunch_to_add[, weight])	Add weighted edges in *ebunch_to_add* with specified weight attr
adjacency()	Returns an iterator over (node, adjacency dict) tuples for all nodes.
all_operations()	
append(op)	
clear()	Remove all nodes and edges from the graph.
copy([as_view])	Returns a copy of the graph.
disjoint_qubits(op1, op2)	Returns true only if the operations have qubits in common.
edge_subgraph(edges)	Returns the subgraph induced by the specified edges.
from_circuit(circuit, can_reorder, ...)	
from_ops(*operations, can_reorder, ...)	
get_edge_data(u, v[, default])	Returns the attribute dictionary associated with edge (u, v).
has_edge(u, v)	Returns True if the edge (u, v) is in the graph.
has_node(n)	Returns True if the graph contains the node n.
has_predecessor(u, v)	Returns True if node u has predecessor v.
has_successor(u, v)	Returns True if node u has successor v.
is_directed()	Returns True if graph is directed, False otherwise.
is_multigraph()	Returns True if graph is a multigraph, False otherwise.
make_node(op)	
nbunch_iter([nbunch])	Returns an iterator over nodes contained in nbunch that are also in the graph.
neighbors(n)	Returns an iterator over successor nodes of n.
number_of_edges([u, v])	Returns the number of edges between two nodes.
number_of_nodes()	Returns the number of nodes in the graph.
order()	Returns the number of nodes in the graph.
ordered_nodes()	
predecessors(n)	Returns an iterator over predecessor nodes of n.
remove_edge(u, v)	Remove the edge between u and v.
remove_edges_from(ebunch)	Remove all edges specified in ebunch.
remove_node(n)	Remove node n.
remove_nodes_from(nodes)	Remove multiple nodes.
reverse([copy])	Returns the reverse of the graph.
size([weight])	Returns the number of edges or total of all edge weights.
subgraph(nodes)	Returns a SubGraph view of the subgraph induced on *nodes*.
successors(n)	Returns an iterator over successor nodes of n.
to_circuit()	
to_directed([as_view])	Returns a directed representation of the graph.
to_directed_class()	Returns the class to use for empty directed copies.
to_undirected([reciprocal, as_view])	Returns an undirected representation of the digraph.
to_undirected_class()	Returns the class to use for empty undirected copies.
update([edges, nodes])	Update the graph using nodes/edges/graphs as input.

cirq.CircuitDag.add_edge

CircuitDag.**add_edge**(*u_of_edge*, *v_of_edge*, ***attr*)

Add an edge between u and v.

The nodes u and v will be automatically added if they are not already in the graph.

Edge attributes can be specified with keywords or by directly accessing the edge's attribute dictionary. See examples below.

Parameters

- **v** (*u,*) – Nodes can be, for example, strings or numbers. Nodes must be hashable (and not None) Python objects.
- **attr** (*keyword arguments, optional*) – Edge data (or labels or objects) can be assigned using keyword arguments.

See also:

add_edges_from() add a collection of edges

Notes

Adding an edge that already exists updates the edge data.

Many NetworkX algorithms designed for weighted graphs use an edge attribute (by default *weight*) to hold a numerical value.

Examples

The following all add the edge e=(1, 2) to graph G:

```
>>> G = nx.Graph()   # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> e = (1, 2)
>>> G.add_edge(1, 2)           # explicit two-node form
>>> G.add_edge(*e)             # single edge as tuple of two nodes
>>> G.add_edges_from( [(1, 2)] ) # add edges from iterable container
```

Associate data to edges using keywords:

```
>>> G.add_edge(1, 2, weight=3)
>>> G.add_edge(1, 3, weight=7, capacity=15, length=342.7)
```

For non-string attribute keys, use subscript notation.

```
>>> G.add_edge(1, 2)
>>> G[1][2].update({0: 5})
>>> G.edges[1, 2].update({0: 5})
```

cirq.CircuitDag.add_edges_from

CircuitDag.**add_edges_from**(*ebunch_to_add*, ***attr*)

Add all the edges in ebunch_to_add.

Parameters

- **ebunch_to_add** (*container of edges*) – Each edge given in the container will be added to the graph. The edges must be given as 2-tuples (u, v) or 3-tuples (u, v, d) where d is a dictionary containing edge data.
- **attr** (*keyword arguments, optional*) – Edge data (or labels or objects) can be assigned using keyword arguments.

See also:

add_edge() add a single edge

add_weighted_edges_from() convenient way to add weighted edges

Notes

Adding the same edge twice has no effect but any edge data will be updated when each duplicate edge is added.

Edge attributes specified in an ebunch take precedence over attributes specified via keyword arguments.

Examples

```
>>> G = nx.Graph()    # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.add_edges_from([(0, 1), (1, 2)]) # using a list of edge tuples
>>> e = zip(range(0, 3), range(1, 4))
>>> G.add_edges_from(e) # Add the path graph 0-1-2-3
```

Associate data to edges

```
>>> G.add_edges_from([(1, 2), (2, 3)], weight=3)
>>> G.add_edges_from([(3, 4), (1, 4)], label='WN2898')
```

cirq.CircuitDag.add_node

CircuitDag.**add_node**(*node_for_adding*, ***attr*)

Add a single node *node_for_adding* and update node attributes.

Parameters

- **node_for_adding** (*node*) – A node can be any hashable Python object except None.
- **attr** (*keyword arguments, optional*) – Set or change node attributes using key=value.

See also:

add_nodes_from()

Examples

```
>>> G = nx.Graph()    # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.add_node(1)
>>> G.add_node('Hello')
>>> K3 = nx.Graph([(0, 1), (1, 2), (2, 0)])
```

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```
>>> G.add_node(K3)
>>> G.number_of_nodes()
3
```

Use keywords set/change node attributes:

```
>>> G.add_node(1, size=10)
>>> G.add_node(3, weight=0.4, UTM=('13S', 382871, 3972649))
```

Notes

A hashable object is one that can be used as a key in a Python dictionary. This includes strings, numbers, tuples of strings and numbers, etc.

On many platforms hashable items also include mutables such as NetworkX Graphs, though one should be careful that the hash doesn't change on mutables.

cirq.CircuitDag.add_nodes_from

CircuitDag.**add_nodes_from**(*nodes_for_adding*, ***attr*)

Add multiple nodes.

Parameters

- **nodes_for_adding** (*iterable container*) – A container of nodes (list, dict, set, etc.). OR A container of (node, attribute dict) tuples. Node attributes are updated using the attribute dict.
- **attr** (*keyword arguments, optional (default= no attributes)*) – Update attributes for all nodes in nodes. Node attributes specified in nodes as a tuple take precedence over attributes specified via keyword arguments.

See also:

add_node()

Examples

```
>>> G = nx.Graph()    # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.add_nodes_from('Hello')
>>> K3 = nx.Graph([(0, 1), (1, 2), (2, 0)])
>>> G.add_nodes_from(K3)
>>> sorted(G.nodes(), key=str)
[0, 1, 2, 'H', 'e', 'l', 'o']
```

Use keywords to update specific node attributes for every node.

```
>>> G.add_nodes_from([1, 2], size=10)
>>> G.add_nodes_from([3, 4], weight=0.4)
```

Use (node, attrdict) tuples to update attributes for specific nodes.

```
>>> G.add_nodes_from([(1, dict(size=11)), (2, {'color':'blue'})])
>>> G.nodes[1]['size']
11
>>> H = nx.Graph()
>>> H.add_nodes_from(G.nodes(data=True))
>>> H.nodes[1]['size']
11
```

cirq.CircuitDag.add_weighted_edges_from

CircuitDag.**add_weighted_edges_from**(*ebunch_to_add*, *weight='weight'*, ***attr*)

Add weighted edges in *ebunch_to_add* with specified weight attr

Parameters

- **ebunch_to_add** (*container of edges*) – Each edge given in the list or container will be added to the graph. The edges must be given as 3-tuples (u, v, w) where w is a number.
- **weight** (*string, optional (default= 'weight')*) – The attribute name for the edge weights to be added.
- **attr** (*keyword arguments, optional (default= no attributes)*) – Edge attributes to add/update for all edges.

See also:

add_edge() add a single edge

add_edges_from() add multiple edges

Notes

Adding the same edge twice for Graph/DiGraph simply updates the edge data. For MultiGraph/MultiDiGraph, duplicate edges are stored.

Examples

```
>>> G = nx.Graph()   # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.add_weighted_edges_from([(0, 1, 3.0), (1, 2, 7.5)])
```

cirq.CircuitDag.adjacency

CircuitDag.**adjacency**()

Returns an iterator over (node, adjacency dict) tuples for all nodes.

For directed graphs, only outgoing neighbors/adjacencies are included.

Returns **adj_iter** – An iterator over (node, adjacency dictionary) for all nodes in the graph.

Return type iterator

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> [(n, nbrdict) for n, nbrdict in G.adjacency()]
[(0, {1: {}}), (1, {0: {}, 2: {}}), (2, {1: {}, 3: {}}), (3, {2: {}})]
```

cirq.CircuitDag.all_operations

CircuitDag.**all_operations**() → Iterator[cirq.ops.raw_types.Operation]

cirq.CircuitDag.append

CircuitDag.**append**(*op: cirq.ops.raw_types.Operation*) → None

cirq.CircuitDag.clear

CircuitDag.**clear**()

Remove all nodes and edges from the graph.

This also removes the name, and all graph, node, and edge attributes.

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.clear()
>>> list(G.nodes)
[]
>>> list(G.edges)
[]
```

cirq.CircuitDag.copy

CircuitDag.**copy**(*as_view=False*)

Returns a copy of the graph.

The copy method by default returns an independent shallow copy of the graph and attributes. That is, if an attribute is a container, that container is shared by the original an the copy. Use Python's *copy.deepcopy* for new containers.

If *as_view* is True then a view is returned instead of a copy.

Notes

All copies reproduce the graph structure, but data attributes may be handled in different ways. There are four types of copies of a graph that people might want.

Deepcopy – A "deepcopy" copies the graph structure as well as all data attributes and any objects they might contain. The entire graph object is new so that changes in the copy do not affect the original object. (see Python's copy.deepcopy)

Data Reference (Shallow) – For a shallow copy the graph structure is copied but the edge, node and graph attribute dicts are references to those in the original graph. This saves time and memory but could cause confusion if you change an attribute in one graph and it changes the attribute in the other. NetworkX does not provide this level of shallow copy.

Independent Shallow – This copy creates new independent attribute dicts and then does a shallow copy of the attributes. That is, any attributes that are containers are shared between the new graph and the original. This is exactly what *dict.copy()* provides. You can obtain this style copy using:

```
>>> G = nx.path_graph(5)
>>> H = G.copy()
>>> H = G.copy(as_view=False)
>>> H = nx.Graph(G)
>>> H = G.__class__(G)
```

Fresh Data – For fresh data, the graph structure is copied while new empty data attribute dicts are created. The resulting graph is independent of the original and it has no edge, node or graph attributes. Fresh copies are not enabled. Instead use:

```
>>> H = G.__class__()
>>> H.add_nodes_from(G)
>>> H.add_edges_from(G.edges)
```

View – Inspired by dict-views, graph-views act like read-only versions of the original graph, providing a copy of the original structure without requiring any memory for copying the information.

See the Python copy module for more information on shallow and deep copies, https://docs.python.org/2/library/copy.html.

Parameters **as_view** (*bool, optional (default=False)*) – If True, the returned graph-view provides a read-only view of the original graph without actually copying any data.

Returns **G** – A copy of the graph.

Return type Graph

See also:

to_directed() return a directed copy of the graph.

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> H = G.copy()
```

cirq.CircuitDag.disjoint_qubits

static CircuitDag.**disjoint_qubits**(*op1: cirq.ops.raw_types.Operation*, *op2: cirq.ops.raw_types.Operation*) → bool

Returns true only if the operations have qubits in common.

cirq.CircuitDag.edge_subgraph

CircuitDag.**edge_subgraph**(*edges*)

Returns the subgraph induced by the specified edges.

The induced subgraph contains each edge in *edges* and each node incident to any one of those edges.

Parameters **edges** (*iterable*) – An iterable of edges in this graph.

Returns **G** – An edge-induced subgraph of this graph with the same edge attributes.

Return type Graph

Notes

The graph, edge, and node attributes in the returned subgraph view are references to the corresponding attributes in the original graph. The view is read-only.

To create a full graph version of the subgraph with its own copy of the edge or node attributes, use:

```
>>> G.edge_subgraph(edges).copy()
```

Examples

```
>>> G = nx.path_graph(5)
>>> H = G.edge_subgraph([(0, 1), (3, 4)])
>>> list(H.nodes)
[0, 1, 3, 4]
>>> list(H.edges)
[(0, 1), (3, 4)]
```

cirq.CircuitDag.from_circuit

static CircuitDag.**from_circuit**(*circuit: cirq.circuits.circuit.Circuit, can_reorder: Callable[[cirq.ops.raw_types.Operation, cirq.ops.raw_types.Operation], bool] = <function _disjoint_qubits>*) → cirq.circuits.circuit_dag.CircuitDag

cirq.CircuitDag.from_ops

static CircuitDag.**from_ops**(**operations, can_reorder: Callable[[cirq.ops.raw_types.Operation, cirq.ops.raw_types.Operation], bool] = <function _disjoint_qubits>, device: cirq.devices.device.Device = cirq.UnconstrainedDevice*) → cirq.circuits.circuit_dag.CircuitDag

cirq.CircuitDag.get_edge_data

CircuitDag.**get_edge_data**(*u*, *v*, *default=None*)

Returns the attribute dictionary associated with edge (u, v).

This is identical to *G[u][v]* except the default is returned instead of an exception if the edge doesn't exist.

Parameters

- **v** (*u,*) –
- **default** (*any Python object (default=None)*) – Value to return if the edge (u, v) is not found.

Returns **edge_dict** – The edge attribute dictionary.

Return type dictionary

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G[0][1]
{}
```

Warning: Assigning to *G[u][v]* is not permitted. But it is safe to assign attributes *G[u][v]['foo']*

```
>>> G[0][1]['weight'] = 7
>>> G[0][1]['weight']
7
>>> G[1][0]['weight']
7
```

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.get_edge_data(0, 1)  # default edge data is {}
{}
>>> e = (0, 1)
>>> G.get_edge_data(*e)  # tuple form
{}
>>> G.get_edge_data('a', 'b', default=0)  # edge not in graph, return 0
0
```

cirq.CircuitDag.has_edge

CircuitDag.**has_edge**(*u*, *v*)

Returns True if the edge (u, v) is in the graph.

This is the same as *v in G[u]* without KeyError exceptions.

Parameters **v** (*u,*) – Nodes can be, for example, strings or numbers. Nodes must be hashable (and not None) Python objects.

Returns **edge_ind** – True if edge is in the graph, False otherwise.

Return type bool

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.has_edge(0, 1)  # using two nodes
True
>>> e = (0, 1)
>>> G.has_edge(*e)  #  e is a 2-tuple (u, v)
```

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```
True
>>> e = (0, 1, {'weight':7})
>>> G.has_edge(*e[:2])  # e is a 3-tuple (u, v, data_dictionary)
True
```

The following syntax are equivalent:

```
>>> G.has_edge(0, 1)
True
>>> 1 in G[0]  # though this gives KeyError if 0 not in G
True
```

cirq.CircuitDag.has_node

CircuitDag.**has_node**(*n*)

Returns True if the graph contains the node n.

Identical to *n in G*

Parameters **n** (*node*) –

Examples

```
>>> G = nx.path_graph(3)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.has_node(0)
True
```

It is more readable and simpler to use

```
>>> 0 in G
True
```

cirq.CircuitDag.has_predecessor

CircuitDag.**has_predecessor**(*u*, *v*)

Returns True if node u has predecessor v.

This is true if graph has the edge u<-v.

cirq.CircuitDag.has_successor

CircuitDag.**has_successor**(*u*, *v*)

Returns True if node u has successor v.

This is true if graph has the edge u->v.

cirq.CircuitDag.is_directed

CircuitDag.**is_directed**()

Returns True if graph is directed, False otherwise.

cirq.CircuitDag.is_multigraph

CircuitDag.**is_multigraph**()
Returns True if graph is a multigraph, False otherwise.

cirq.CircuitDag.make_node

static CircuitDag.**make_node**(*op: cirq.ops.raw_types.Operation*) → cirq.circuits.circuit_dag.Unique

cirq.CircuitDag.nbunch_iter

CircuitDag.**nbunch_iter**(*nbunch=None*)
Returns an iterator over nodes contained in nbunch that are also in the graph.

The nodes in nbunch are checked for membership in the graph and if not are silently ignored.

Parameters **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.

Returns **niter** – An iterator over nodes in nbunch that are also in the graph. If nbunch is None, iterate over all nodes in the graph.

Return type iterator

Raises NetworkXError – If nbunch is not a node or or sequence of nodes. If a node in nbunch is not hashable.

See also:

Graph.__iter__()

Notes

When nbunch is an iterator, the returned iterator yields values directly from nbunch, becoming exhausted when nbunch is exhausted.

To test whether nbunch is a single node, one can use "if nbunch in self:", even after processing with this routine.

If nbunch is not a node or a (possibly empty) sequence/iterator or None, a NetworkXError is raised. Also, if any object in nbunch is not hashable, a NetworkXError is raised.

cirq.CircuitDag.neighbors

CircuitDag.**neighbors**(*n*)
Returns an iterator over successor nodes of n.

A successor of n is a node m such that there exists a directed edge from n to m.

Parameters **n** (*node*) – A node in the graph

Raises NetworkXError – If n is not in the graph.

See also:

predecessors()

Notes

neighbors() and successors() are the same.

cirq.CircuitDag.number_of_edges

CircuitDag.**number_of_edges**(*u=None*, *v=None*)

Returns the number of edges between two nodes.

Parameters **v** (*u,*) – If u and v are specified, return the number of edges between u and v. Otherwise return the total number of all edges.

Returns **nedges** – The number of edges in the graph. If nodes *u* and *v* are specified return the number of edges between those nodes. If the graph is directed, this only returns the number of edges from *u* to *v*.

Return type int

See also:

size()

Examples

For undirected graphs, this method counts the total number of edges in the graph:

```
>>> G = nx.path_graph(4)
>>> G.number_of_edges()
3
```

If you specify two nodes, this counts the total number of edges joining the two nodes:

```
>>> G.number_of_edges(0, 1)
1
```

For directed graphs, this method can count the total number of directed edges from *u* to *v*:

```
>>> G = nx.DiGraph()
>>> G.add_edge(0, 1)
>>> G.add_edge(1, 0)
>>> G.number_of_edges(0, 1)
1
```

cirq.CircuitDag.number_of_nodes

CircuitDag.**number_of_nodes**()

Returns the number of nodes in the graph.

Returns **nnodes** – The number of nodes in the graph.

Return type int

See also:

order(), __len__()

Examples

```
>>> G = nx.path_graph(3)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.number_of_nodes()
3
```

cirq.CircuitDag.order

CircuitDag.**order**()

Returns the number of nodes in the graph.

Returns **nnodes** – The number of nodes in the graph.

Return type int

See also:

number_of_nodes(), __len__()

Examples

```
>>> G = nx.path_graph(3)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.order()
3
```

cirq.CircuitDag.ordered_nodes

CircuitDag.**ordered_nodes**() → Iterator[cirq.circuits.circuit_dag.Unique[cirq.ops.raw_types.Operation]]

cirq.CircuitDag.predecessors

CircuitDag.**predecessors**(*n*)

Returns an iterator over predecessor nodes of n.

A predecessor of n is a node m such that there exists a directed edge from m to n.

Parameters **n** (*node*) – A node in the graph

Raises NetworkXError – If n is not in the graph.

See also:

successors()

cirq.CircuitDag.remove_edge

CircuitDag.**remove_edge**(*u*, *v*)

Remove the edge between u and v.

Parameters **v** (*u,*) – Remove the edge between nodes u and v.

Raises NetworkXError – If there is not an edge between u and v.

See also:

remove_edges_from() remove a collection of edges

Examples

```
>>> G = nx.Graph()   # or DiGraph, etc
>>> nx.add_path(G, [0, 1, 2, 3])
>>> G.remove_edge(0, 1)
>>> e = (1, 2)
>>> G.remove_edge(*e) # unpacks e from an edge tuple
>>> e = (2, 3, {'weight':7}) # an edge with attribute data
>>> G.remove_edge(*e[:2]) # select first part of edge tuple
```

cirq.CircuitDag.remove_edges_from

CircuitDag.**remove_edges_from**(*ebunch*)

Remove all edges specified in ebunch.

Parameters **ebunch** (*list or container of edge tuples*) – Each edge given in the list or container will be removed from the graph. The edges can be:

- 2-tuples (u, v) edge between u and v.
- 3-tuples (u, v, k) where k is ignored.

See also:

remove_edge() remove a single edge

Notes

Will fail silently if an edge in ebunch is not in the graph.

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> ebunch = [(1, 2), (2, 3)]
>>> G.remove_edges_from(ebunch)
```

cirq.CircuitDag.remove_node

CircuitDag.**remove_node**(*n*)

Remove node n.

Removes the node n and all adjacent edges. Attempting to remove a non-existent node will raise an exception.

Parameters **n** (*node*) – A node in the graph

Raises NetworkXError – If n is not in the graph.

See also:

remove_nodes_from()

Examples

```
>>> G = nx.path_graph(3)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> list(G.edges)
[(0, 1), (1, 2)]
>>> G.remove_node(1)
>>> list(G.edges)
[]
```

cirq.CircuitDag.remove_nodes_from

CircuitDag.**remove_nodes_from**(*nodes*)

Remove multiple nodes.

Parameters **nodes** (*iterable container*) – A container of nodes (list, dict, set, etc.). If a node in the container is not in the graph it is silently ignored.

See also:

remove_node()

Examples

```
>>> G = nx.path_graph(3)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> e = list(G.nodes)
>>> e
[0, 1, 2]
>>> G.remove_nodes_from(e)
>>> list(G.nodes)
[]
```

cirq.CircuitDag.reverse

CircuitDag.**reverse**(*copy=True*)

Returns the reverse of the graph.

The reverse is a graph with the same nodes and edges but with the directions of the edges reversed.

Parameters **copy** (*bool optional (default=True)*) – If True, return a new DiGraph holding the reversed edges. If False, the reverse graph is created using a view of the original graph.

cirq.CircuitDag.size

CircuitDag.**size**(*weight=None*)

Returns the number of edges or total of all edge weights.

Parameters **weight** (*string or None, optional (default=None)*) – The edge attribute that holds the numerical value used as a weight. If None, then each edge has weight 1.

Returns

size – The number of edges or (if weight keyword is provided) the total weight sum.

If weight is None, returns an int. Otherwise a float (or more general numeric if the weights are more general).

Return type numeric

See also:

number_of_edges()

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.size()
3
```

```
>>> G = nx.Graph()   # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> G.add_edge('a', 'b', weight=2)
>>> G.add_edge('b', 'c', weight=4)
>>> G.size()
2
>>> G.size(weight='weight')
6.0
```

cirq.CircuitDag.subgraph

CircuitDag.**subgraph**(*nodes*)

Returns a SubGraph view of the subgraph induced on *nodes*.

The induced subgraph of the graph contains the nodes in *nodes* and the edges between those nodes.

Parameters **nodes** (*list, iterable*) – A container of nodes which will be iterated through once.

Returns **G** – A subgraph view of the graph. The graph structure cannot be changed but node/edge attributes can and are shared with the original graph.

Return type SubGraph View

Notes

The graph, edge and node attributes are shared with the original graph. Changes to the graph structure is ruled out by the view, but changes to attributes are reflected in the original graph.

To create a subgraph with its own copy of the edge/node attributes use: G.subgraph(nodes).copy()

For an inplace reduction of a graph to a subgraph you can remove nodes: G.remove_nodes_from([n for n in G if n not in set(nodes)])

Subgraph views are sometimes NOT what you want. In most cases where you want to do more than simply look at the induced edges, it makes more sense to just create the subgraph as its own graph with code like:

```
# Create a subgraph SG based on a (possibly multigraph) G
SG = G.__class__()
SG.add_nodes_from((n, G.nodes[n]) for n in largest_wcc)
if SG.is_multigraph:
    SG.add_edges_from((n, nbr, key, d)
        for n, nbrs in G.adj.items() if n in largest_wcc
        for nbr, keydict in nbrs.items() if nbr in largest_wcc
        for key, d in keydict.items())
else:
    SG.add_edges_from((n, nbr, d)
        for n, nbrs in G.adj.items() if n in largest_wcc
        for nbr, d in nbrs.items() if nbr in largest_wcc)
SG.graph.update(G.graph)
```

Examples

```
>>> G = nx.path_graph(4)  # or DiGraph, MultiGraph, MultiDiGraph, etc
>>> H = G.subgraph([0, 1, 2])
>>> list(H.edges)
[(0, 1), (1, 2)]
```

cirq.CircuitDag.successors

CircuitDag.**successors**(*n*)

Returns an iterator over successor nodes of n.

A successor of n is a node m such that there exists a directed edge from n to m.

Parameters **n** (*node*) – A node in the graph

Raises NetworkXError – If n is not in the graph.

See also:

predecessors()

Notes

neighbors() and successors() are the same.

cirq.CircuitDag.to_circuit

CircuitDag.**to_circuit**() → cirq.circuits.circuit.Circuit

cirq.CircuitDag.to_directed

CircuitDag.**to_directed**(*as_view=False*)

Returns a directed representation of the graph.

Returns **G** – A directed graph with the same name, same nodes, and with each edge (u, v, data) replaced by two directed edges (u, v, data) and (v, u, data).

Return type DiGraph

Notes

This returns a "deepcopy" of the edge, node, and graph attributes which attempts to completely copy all of the data and references.

This is in contrast to the similar D=DiGraph(G) which returns a shallow copy of the data.

See the Python copy module for more information on shallow and deep copies, https://docs.python.org/2/library/copy.html.

Warning: If you have subclassed Graph to use dict-like objects in the data structure, those changes do not transfer to the DiGraph created by this method.

Examples

```
>>> G = nx.Graph()  # or MultiGraph, etc
>>> G.add_edge(0, 1)
>>> H = G.to_directed()
>>> list(H.edges)
[(0, 1), (1, 0)]
```

If already directed, return a (deep) copy

```
>>> G = nx.DiGraph()  # or MultiDiGraph, etc
>>> G.add_edge(0, 1)
>>> H = G.to_directed()
>>> list(H.edges)
[(0, 1)]
```

cirq.CircuitDag.to_directed_class

CircuitDag.**to_directed_class**()
Returns the class to use for empty directed copies.

If you subclass the base classes, use this to designate what directed class to use for *to_directed()* copies.

cirq.CircuitDag.to_undirected

CircuitDag.**to_undirected**(*reciprocal=False*, *as_view=False*)
Returns an undirected representation of the digraph.

Parameters

- **reciprocal** (*bool (optional)*) – If True only keep edges that appear in both directions in the original digraph.
- **as_view** (*bool (optional, default=False)*) – If True return an undirected view of the original directed graph.

Returns **G** – An undirected graph with the same name and nodes and with edge (u, v, data) if either (u, v, data) or (v, u, data) is in the digraph. If both edges exist in digraph and their edge data is different, only one edge is created with an arbitrary choice of which edge data to use. You must check and correct for this manually if desired.

Return type Graph

See also:

`Graph()`, *`copy()`*, *`add_edge()`*, *`add_edges_from()`*

Notes

If edges in both directions (u, v) and (v, u) exist in the graph, attributes for the new undirected edge will be a combination of the attributes of the directed edges. The edge data is updated in the (arbitrary) order that the edges are encountered. For more customized control of the edge attributes use add_edge().

This returns a "deepcopy" of the edge, node, and graph attributes which attempts to completely copy all of the data and references.

This is in contrast to the similar G=DiGraph(D) which returns a shallow copy of the data.

See the Python copy module for more information on shallow and deep copies, https://docs.python.org/2/library/copy.html.

Warning: If you have subclassed DiGraph to use dict-like objects in the data structure, those changes do not transfer to the Graph created by this method.

Examples

```
>>> G = nx.path_graph(2)    # or MultiGraph, etc
>>> H = G.to_directed()
>>> list(H.edges)
[(0, 1), (1, 0)]
>>> G2 = H.to_undirected()
>>> list(G2.edges)
[(0, 1)]
```

cirq.CircuitDag.to_undirected_class

`CircuitDag.`**`to_undirected_class`**`()`

Returns the class to use for empty undirected copies.

If you subclass the base classes, use this to designate what directed class to use for *to_directed()* copies.

cirq.CircuitDag.update

`CircuitDag.`**`update`**`(`*edges=None*, *nodes=None*`)`

Update the graph using nodes/edges/graphs as input.

Like dict.update, this method takes a graph as input, adding the graph's nodes and edges to this graph. It can also take two inputs: edges and nodes. Finally it can take either edges or nodes. To specify only nodes the keyword *nodes* must be used.

The collections of edges and nodes are treated similarly to the add_edges_from/add_nodes_from methods. When iterated, they should yield 2-tuples (u, v) or 3-tuples (u, v, datadict).

Parameters

- **edges** (*Graph object, collection of edges, or None*) – The first parameter can be a graph or some edges. If it has attributes *nodes* and *edges*, then it is taken to be a Graph-like object and those attributes are used as collections of nodes and

edges to be added to the graph. If the first parameter does not have those attributes, it is treated as a collection of edges and added to the graph. If the first argument is None, no edges are added.

- **nodes** (*collection of nodes, or None*) – The second parameter is treated as a collection of nodes to be added to the graph unless it is None. If *edges is None* and *nodes is None* an exception is raised. If the first parameter is a Graph, then *nodes* is ignored.

Examples

```
>>> G = nx.path_graph(5)
>>> G.update(nx.complete_graph(range(4,10)))
>>> from itertools import combinations
>>> edges = ((u, v, {'power': u * v})
...          for u, v in combinations(range(10, 20), 2)
...          if u * v < 225)
>>> nodes = [1000]  # for singleton, use a container
>>> G.update(edges, nodes)
```

Notes

It you want to update the graph using an adjacency structure it is straightforward to obtain the edges/nodes from adjacency. The following examples provide common cases, your adjacency may be slightly different and require tweaks of these examples.

```
>>> # dict-of-set/list/tuple
>>> adj = {1: {2, 3}, 2: {1, 3}, 3: {1, 2}}
>>> e = [(u, v) for u, nbrs in adj.items() for v in  nbrs]
>>> G.update(edges=e, nodes=adj)
```

```
>>> DG = nx.DiGraph()
>>> # dict-of-dict-of-attribute
>>> adj = {1: {2: 1.3, 3: 0.7}, 2: {1: 1.4}, 3: {1: 0.7}}
>>> e = [(u, v, {'weight': d}) for u, nbrs in adj.items()
...      for v, d in nbrs.items()]
>>> DG.update(edges=e, nodes=adj)
```

```
>>> # dict-of-dict-of-dict
>>> adj = {1: {2: {'weight': 1.3}, 3: {'color': 0.7, 'weight':1.2}}}
>>> e = [(u, v, {'weight': d}) for u, nbrs in adj.items()
...      for v, d in nbrs.items()]
>>> DG.update(edges=e, nodes=adj)
```

```
>>> # predecessor adjacency (dict-of-set)
>>> pred = {1: {2, 3}, 2: {3}, 3: {3}}
>>> e = [(v, u) for u, nbrs in pred.items() for v in nbrs]
```

```
>>> # MultiGraph dict-of-dict-of-dict-of-attribute
>>> MDG = nx.MultiDiGraph()
>>> adj = {1: {2: {0: {'weight': 1.3}, 1: {'weight': 1.2}}},
...        3: {2: {0: {'weight': 0.7}}}}
>>> e = [(u, v, ekey, d) for u, nbrs in adj.items()
...      for v, keydict in nbrs.items()
```

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```
...       for ekey, d in keydict.items()]
>>> MDG.update(edges=e)
```

See also:

add_edges_from()	add multiple edges to a graph
add_nodes_from()	add multiple nodes to a graph

Attributes

adj	Graph adjacency object holding the neighbors of each node.
degree	A DegreeView for the Graph as G.degree or G.degree().
edges	An OutEdgeView of the DiGraph as G.edges or G.edges().
in_degree	An InDegreeView for (node, in_degree) or in_degree for single node.
in_edges	An InEdgeView of the Graph as G.in_edges or G.in_edges().
name	String identifier of the graph.
nodes	A NodeView of the Graph as G.nodes or G.nodes().
out_degree	An OutDegreeView for (node, out_degree)
out_edges	An OutEdgeView of the DiGraph as G.edges or G.edges().
pred	Graph adjacency object holding the predecessors of each node.
succ	Graph adjacency object holding the successors of each node.

cirq.CircuitDag.adj

CircuitDag.**adj**

Graph adjacency object holding the neighbors of each node.

This object is a read-only dict-like structure with node keys
and neighbor-dict values. The neighbor-dict is keyed by neighbor
to the edge-data-dict. So `G.adj[3][2]['color'] = 'blue'` sets
the color of the edge `(3, 2)` to `"blue"`.

Iterating over G.adj behaves like a dict. Useful idioms include
`for nbr, datadict in G.adj[n].items()`:.

The neighbor information is also provided by subscripting the graph.
So `for nbr, foovalue in G[node].data('foo', default=1)`: works.

For directed graphs, `G.adj` holds outgoing (successor) info.

cirq.CircuitDag.degree

`CircuitDag.`**`degree`**

A DegreeView for the Graph as G.degree or G.degree().

The node degree is the number of edges adjacent to the node. The weighted node degree is the sum of the edge weights for edges incident to that node.

This object provides an iterator for (node, degree) as well as lookup for the degree for a single node.

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **weight** (*string or None, optional (default=None)*) – The name of an edge attribute that holds the numerical value used as a weight. If None, then each edge has weight 1. The degree is the sum of the edge weights adjacent to the node.

Returns

- *If a single node is requested*
- **deg** (*int*) – Degree of the node
- *OR if multiple nodes are requested*
- **nd_iter** (*iterator*) – The iterator returns two-tuples of (node, degree).

See also:

in_degree, *out_degree*

Examples

```
>>> G = nx.DiGraph()   # or MultiDiGraph
>>> nx.add_path(G, [0, 1, 2, 3])
>>> G.degree(0) # node 0 with degree 1
1
>>> list(G.degree([0, 1, 2]))
[(0, 1), (1, 2), (2, 2)]
```

cirq.CircuitDag.edges

`CircuitDag.`**`edges`**

An OutEdgeView of the DiGraph as G.edges or G.edges().

edges(self, nbunch=None, data=False, default=None)

The OutEdgeView provides set-like operations on the edge-tuples
as well as edge attribute lookup. When called, it also provides
an EdgeDataView object which allows control of access to edge
attributes (but does not provide set-like operations).
Hence, `G.edges[u, v]['color']` provides the value of the color
attribute for edge `(u, v)` while
`for (u, v, c) in G.edges.data('color', default='red'):`
iterates through all the edges yielding the color attribute
with default `'red'` if no color attribute exists.

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **data** (*string or bool, optional (default=False)*) – The edge attribute returned in 3-tuple (u, v, ddict[data]). If True, return edge attribute dict in 3-tuple (u, v, ddict). If False, return 2-tuple (u, v).
- **default** (*value, optional (default=None)*) – Value used for edges that don't have the requested attribute. Only relevant if data is not True or False.

Returns **edges** – A view of edge attributes, usually it iterates over (u, v) or (u, v, d) tuples of edges, but can also be used for attribute lookup as *edges[u, v]['foo']*.

Return type OutEdgeView

See also:

in_edges, *out_edges*

Notes

Nodes in nbunch that are not in the graph will be (quietly) ignored. For directed graphs this returns the out-edges.

Examples

```
>>> G = nx.DiGraph()   # or MultiDiGraph, etc
>>> nx.add_path(G, [0, 1, 2])
>>> G.add_edge(2, 3, weight=5)
>>> [e for e in G.edges]
[(0, 1), (1, 2), (2, 3)]
>>> G.edges.data()  # default data is {} (empty dict)
OutEdgeDataView([(0, 1, {}), (1, 2, {}), (2, 3, {'weight': 5})])
>>> G.edges.data('weight', default=1)
OutEdgeDataView([(0, 1, 1), (1, 2, 1), (2, 3, 5)])
>>> G.edges([0, 2])  # only edges incident to these nodes
OutEdgeDataView([(0, 1), (2, 3)])
>>> G.edges(0)  # only edges incident to a single node (use G.adj[0]?)
OutEdgeDataView([(0, 1)])
```

cirq.CircuitDag.in_degree

CircuitDag.**in_degree**

An InDegreeView for (node, in_degree) or in_degree for single node.

The node in_degree is the number of edges pointing to the node.
The weighted node degree is the sum of the edge weights for
edges incident to that node.

This object provides an iteration over (node, in_degree) as well as
lookup for the degree for a single node.

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **weight** (*string or None, optional (default=None)*) – The name of an edge attribute that holds the numerical value used as a weight. If None, then each edge has weight 1. The degree is the sum of the edge weights adjacent to the node.

Returns

- *If a single node is requested*
- **deg** (*int*) – In-degree of the node
- *OR if multiple nodes are requested*
- **nd_iter** (*iterator*) – The iterator returns two-tuples of (node, in-degree).

See also:

degree, *out_degree*

Examples

```
>>> G = nx.DiGraph()
>>> nx.add_path(G, [0, 1, 2, 3])
>>> G.in_degree(0) # node 0 with degree 0
0
>>> list(G.in_degree([0, 1, 2]))
[(0, 0), (1, 1), (2, 1)]
```

cirq.CircuitDag.in_edges

CircuitDag.**in_edges**

An InEdgeView of the Graph as G.in_edges or G.in_edges().

in_edges(self, nbunch=None, data=False, default=None):

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **data** (*string or bool, optional (default=False)*) – The edge attribute returned in 3-tuple (u, v, ddict[data]). If True, return edge attribute dict in 3-tuple (u, v, ddict). If False, return 2-tuple (u, v).
- **default** (*value, optional (default=None)*) – Value used for edges that don't have the requested attribute. Only relevant if data is not True or False.

Returns **in_edges** – A view of edge attributes, usually it iterates over (u, v) or (u, v, d) tuples of edges, but can also be used for attribute lookup as *edges[u, v]['foo']*.

Return type InEdgeView

See also:

edges

cirq.CircuitDag.name

`CircuitDag.`**`name`**

String identifier of the graph.

This graph attribute appears in the attribute dict G.graph keyed by the string `"name"`. as well as an attribute (technically a property) `G.name`. This is entirely user controlled.

cirq.CircuitDag.nodes

`CircuitDag.`**`nodes`**

A NodeView of the Graph as G.nodes or G.nodes().

Can be used as `G.nodes` for data lookup and for set-like operations. Can also be used as `G.nodes(data='color', default=None)` to return a NodeDataView which reports specific node data but no set operations. It presents a dict-like interface as well with `G.nodes.items()` iterating over `(node, nodedata)` 2-tuples and `G.nodes[3]['foo']` providing the value of the `foo` attribute for node `3`. In addition, a view `G.nodes.data('foo')` provides a dict-like interface to the `foo` attribute of each node. `G.nodes.data('foo', default=1)` provides a default for nodes that do not have attribute `foo`.

Parameters

- **data** (*string or bool, optional (default=False)*) – The node attribute returned in 2-tuple (n, ddict[data]). If True, return entire node attribute dict as (n, ddict). If False, return just the nodes n.
- **default** (*value, optional (default=None)*) – Value used for nodes that don't have the requested attribute. Only relevant if data is not True or False.

Returns

Allows set-like operations over the nodes as well as node attribute dict lookup and calling to get a NodeDataView. A NodeDataView iterates over *(n, data)* and has no set operations. A NodeView iterates over *n* and includes set operations.

When called, if data is False, an iterator over nodes. Otherwise an iterator of 2-tuples (node, attribute value) where the attribute is specified in *data*. If data is True then the attribute becomes the entire data dictionary.

Return type NodeView

Notes

If your node data is not needed, it is simpler and equivalent to use the expression `for n in G`, or `list(G)`.

Examples

There are two simple ways of getting a list of all nodes in the graph:

```
>>> G = nx.path_graph(3)
>>> list(G.nodes)
[0, 1, 2]
>>> list(G)
[0, 1, 2]
```

To get the node data along with the nodes:

```
>>> G.add_node(1, time='5pm')
>>> G.nodes[0]['foo'] = 'bar'
>>> list(G.nodes(data=True))
[(0, {'foo': 'bar'}), (1, {'time': '5pm'}), (2, {})]
>>> list(G.nodes.data())
[(0, {'foo': 'bar'}), (1, {'time': '5pm'}), (2, {})]
```

```
>>> list(G.nodes(data='foo'))
[(0, 'bar'), (1, None), (2, None)]
>>> list(G.nodes.data('foo'))
[(0, 'bar'), (1, None), (2, None)]
```

```
>>> list(G.nodes(data='time'))
[(0, None), (1, '5pm'), (2, None)]
>>> list(G.nodes.data('time'))
[(0, None), (1, '5pm'), (2, None)]
```

```
>>> list(G.nodes(data='time', default='Not Available'))
[(0, 'Not Available'), (1, '5pm'), (2, 'Not Available')]
>>> list(G.nodes.data('time', default='Not Available'))
[(0, 'Not Available'), (1, '5pm'), (2, 'Not Available')]
```

If some of your nodes have an attribute and the rest are assumed to have a default attribute value you can create a dictionary from node/attribute pairs using the *default* keyword argument to guarantee the value is never None:

```
>>> G = nx.Graph()
>>> G.add_node(0)
>>> G.add_node(1, weight=2)
>>> G.add_node(2, weight=3)
>>> dict(G.nodes(data='weight', default=1))
{0: 1, 1: 2, 2: 3}
```

cirq.CircuitDag.out_degree

CircuitDag.**out_degree**
An OutDegreeView for (node, out_degree)

The node out_degree is the number of edges pointing out of the node.
The weighted node degree is the sum of the edge weights for
edges incident to that node.

This object provides an iterator over (node, out_degree) as well as
lookup for the degree for a single node.

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **weight** (*string or None, optional (default=None)*) – The name of an edge attribute that holds the numerical value used as a weight. If None, then each edge has weight 1. The degree is the sum of the edge weights adjacent to the node.

Returns

- *If a single node is requested*
- **deg** (*int*) – Out-degree of the node
- *OR if multiple nodes are requested*
- **nd_iter** (*iterator*) – The iterator returns two-tuples of (node, out-degree).

See also:

degree, *in_degree*

Examples

```
>>> G = nx.DiGraph()
>>> nx.add_path(G, [0, 1, 2, 3])
>>> G.out_degree(0) # node 0 with degree 1
1
>>> list(G.out_degree([0, 1, 2]))
[(0, 1), (1, 1), (2, 1)]
```

cirq.CircuitDag.out_edges

CircuitDag.**out_edges**

An OutEdgeView of the DiGraph as G.edges or G.edges().

edges(self, nbunch=None, data=False, default=None)

The OutEdgeView provides set-like operations on the edge-tuples as well as edge attribute lookup. When called, it also provides an EdgeDataView object which allows control of access to edge attributes (but does not provide set-like operations). Hence, `G.edges[u, v]['color']` provides the value of the color attribute for edge `(u, v)` while `for (u, v, c) in G.edges.data('color', default='red'):` iterates through all the edges yielding the color attribute with default `'red'` if no color attribute exists.

Parameters

- **nbunch** (*single node, container, or all nodes (default= all nodes)*) – The view will only report edges incident to these nodes.
- **data** (*string or bool, optional (default=False)*) – The edge attribute returned in 3-tuple (u, v, ddict[data]). If True, return edge attribute dict in 3-tuple (u, v, ddict). If False, return 2-tuple (u, v).
- **default** (*value, optional (default=None)*) – Value used for edges that don't have the requested attribute. Only relevant if data is not True or False.

Returns **edges** – A view of edge attributes, usually it iterates over (u, v) or (u, v, d) tuples of edges, but can also be used for attribute lookup as *edges[u, v]['foo']*.

Return type OutEdgeView

See also:

in_edges, *out_edges*

Notes

Nodes in nbunch that are not in the graph will be (quietly) ignored. For directed graphs this returns the out-edges.

Examples

```
>>> G = nx.DiGraph()   # or MultiDiGraph, etc
>>> nx.add_path(G, [0, 1, 2])
>>> G.add_edge(2, 3, weight=5)
>>> [e for e in G.edges]
[(0, 1), (1, 2), (2, 3)]
>>> G.edges.data()  # default data is {} (empty dict)
OutEdgeDataView([(0, 1, {}), (1, 2, {}), (2, 3, {'weight': 5})])
>>> G.edges.data('weight', default=1)
```

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```
OutEdgeDataView([(0, 1, 1), (1, 2, 1), (2, 3, 5)])
>>> G.edges([0, 2])  # only edges incident to these nodes
OutEdgeDataView([(0, 1), (2, 3)])
>>> G.edges(0)  # only edges incident to a single node (use G.adj[0]?)
OutEdgeDataView([(0, 1)])
```

cirq.CircuitDag.pred

CircuitDag.**pred**
Graph adjacency object holding the predecessors of each node.

This object is a read-only dict-like structure with node keys
and neighbor-dict values. The neighbor-dict is keyed by neighbor
to the edge-data-dict. So `G.pred[2][3]['color'] = 'blue'` sets
the color of the edge `(3, 2)` to `"blue"`.

Iterating over G.pred behaves like a dict. Useful idioms include
`for nbr, datadict in G.pred[n].items()`:. A data-view not provided
by dicts also exists: `for nbr, foovalue in G.pred[node].data('foo')`:
A default can be set via a `default` argument to the `data` method.

cirq.CircuitDag.succ

CircuitDag.**succ**
Graph adjacency object holding the successors of each node.

This object is a read-only dict-like structure with node keys
and neighbor-dict values. The neighbor-dict is keyed by neighbor
to the edge-data-dict. So `G.succ[3][2]['color'] = 'blue'` sets
the color of the edge `(3, 2)` to `"blue"`.

Iterating over G.succ behaves like a dict. Useful idioms include
`for nbr, datadict in G.succ[n].items()`:. A data-view not provided
by dicts also exists: `for nbr, foovalue in G.succ[node].data('foo')`:
and a default can be set via a `default` argument to the `data` method.

The neighbor information is also provided by subscripting the graph.
So `for nbr, foovalue in G[node].data('foo', default=1)`: works.

For directed graphs, `G.adj` is identical to `G.succ`.

cirq.SingleQubitCliffordGate

class cirq.**SingleQubitCliffordGate**(*, _rotation_map: Dict[cirq.ops.pauli.Pauli, cirq.ops.clifford_gate.PauliTransform], _inverse_map: Dict[cirq.ops.pauli.Pauli, cirq.ops.clifford_gate.PauliTransform]*)

Any single qubit Clifford rotation.

__init__(*, _rotation_map: Dict[cirq.ops.pauli.Pauli, cirq.ops.clifford_gate.PauliTransform], _inverse_map: Dict[cirq.ops.pauli.Pauli, cirq.ops.clifford_gate.PauliTransform]*) → None

Initialize self. See help(type(self)) for accurate signature.

Methods

commutes_with(gate_or_pauli, ...)	
commutes_with_pauli(pauli)	
commutes_with_single_qubit_gate(gate)	Tests if the two circuits would be equivalent up to global phase:
decompose_rotation()	Returns ((first_rotation_axis, first_rotation_quarter_turns), ...)
equivalent_gate_before(after)	Returns a SingleQubitCliffordGate such that the circuits
from_double_map(pauli_map_to, ...)	Returns a SingleQubitCliffordGate for the
from_pauli(pauli, sqrt)	
from_quarter_turns(pauli, quarter_turns)	
from_single_map(pauli_map_to, ...)	Returns a SingleQubitCliffordGate for the
from_xz_map(x_to, bool], z_to, bool])	Returns a SingleQubitCliffordGate for the specified transforms.
merged_with(second)	Returns a SingleQubitCliffordGate such that the circuits
on(*qubits)	Returns an application of this gate to the given qubits.
transform(pauli)	
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.SingleQubitCliffordGate.commutes_with

SingleQubitCliffordGate.**commutes_with**(*gate_or_pauli: Union[SingleQubitCliffordGate, cirq.ops.pauli.Pauli]*) → bool

cirq.SingleQubitCliffordGate.commutes_with_pauli

SingleQubitCliffordGate.**commutes_with_pauli**(*pauli: cirq.ops.pauli.Pauli*) → bool

cirq.SingleQubitCliffordGate.commutes_with_single_qubit_gate

SingleQubitCliffordGate.**commutes_with_single_qubit_gate**(*gate: cirq.ops.clifford_gate.SingleQubitCliffordGat* → bool

Tests if the two circuits would be equivalent up to global phase:
–self–gate– and –gate–self–

cirq.SingleQubitCliffordGate.decompose_rotation

SingleQubitCliffordGate.**decompose_rotation**() → Sequence[Tuple[cirq.ops.pauli.Pauli, int]]

Returns ((first_rotation_axis, first_rotation_quarter_turns), ...)

This is a sequence of zero, one, or two rotations.

cirq.SingleQubitCliffordGate.equivalent_gate_before

SingleQubitCliffordGate.**equivalent_gate_before**(*after: cirq.ops.clifford_gate.SingleQubitCliffordGate*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

Returns a SingleQubitCliffordGate such that the circuits
–output–self– and –self–gate–
are equivalent up to global phase.

cirq.SingleQubitCliffordGate.from_double_map

static SingleQubitCliffordGate.**from_double_map**(*pauli_map_to: Optional[Dict[cirq.ops.pauli.Pauli, Tuple[cirq.ops.pauli.Pauli, bool]]] = None*, ***, *x_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*, *y_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*, *z_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

Returns a SingleQubitCliffordGate for the
specified transform with a 90 or 180 degree rotation.

Either pauli_map_to or two of (x_to, y_to, z_to) may be specified.

Parameters

- **pauli_map_to** – A dictionary with two key value pairs describing two transforms.
- **x_to** – The transform from Pauli.X
- **y_to** – The transform from Pauli.Y
- **z_to** – The transform from Pauli.Z

cirq.SingleQubitCliffordGate.from_pauli

static SingleQubitCliffordGate.**from_pauli**(*pauli: cirq.ops.pauli.Pauli*, *sqrt: bool = False*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

cirq.SingleQubitCliffordGate.from_quarter_turns

static SingleQubitCliffordGate.**from_quarter_turns**(*pauli: cirq.ops.pauli.Pauli*, *quarter_turns: int*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

cirq.SingleQubitCliffordGate.from_single_map

static SingleQubitCliffordGate.**from_single_map**(*pauli_map_to: Optional[Dict[cirq.ops.pauli.Pauli, Tuple[cirq.ops.pauli.Pauli, bool]]] = None*, ***, *x_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*, *y_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*, *z_to: Optional[Tuple[cirq.ops.pauli.Pauli, bool]] = None*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

Returns a SingleQubitCliffordGate for the
specified transform with a 90 or 180 degree rotation.

The arguments are exclusive, only one may be specified.

Parameters

- **pauli_map_to** – A dictionary with a single key value pair describing the transform.
- **x_to** – The transform from Pauli.X
- **y_to** – The transform from Pauli.Y
- **z_to** – The transform from Pauli.Z

cirq.SingleQubitCliffordGate.from_xz_map

static SingleQubitCliffordGate.**from_xz_map**(*x_to: Tuple[cirq.ops.pauli.Pauli, bool]*, *z_to: Tuple[cirq.ops.pauli.Pauli, bool]*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

Returns a SingleQubitCliffordGate for the specified transforms.
The Y transform is derived from the X and Z.

Parameters

- **x_to** – Which Pauli to transform X to and if it should negate.
- **z_to** – Which Pauli to transform Z to and if it should negate.

cirq.SingleQubitCliffordGate.merged_with

SingleQubitCliffordGate.**merged_with**(*second: cirq.ops.clifford_gate.SingleQubitCliffordGate*) → cirq.ops.clifford_gate.SingleQubitCliffordGate

Returns a SingleQubitCliffordGate such that the circuits
–output– and –self–second–
are equivalent up to global phase.

cirq.SingleQubitCliffordGate.on

SingleQubitCliffordGate.**on**(**qubits*) → gate_operation.GateOperation
Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.SingleQubitCliffordGate.transform

SingleQubitCliffordGate.**transform**(*pauli: cirq.ops.pauli.Pauli*) → cirq.ops.clifford_gate.PauliTransform

cirq.SingleQubitCliffordGate.validate_args

SingleQubitCliffordGate.**validate_args**(*qubits: Sequence[cirq.ops.raw_types.QubitId]*) → None
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

H
I
X
X_nsqrt
X_sqrt
Y

Continued on next page

Table 148 – continued from previous page

Y_nsqrt
Y_sqrt
Z
Z_nsqrt
Z_sqrt

cirq.SingleQubitCliffordGate.H

SingleQubitCliffordGate.**H = cirq.SingleQubitCliffordGate(X:+Z, Y:-Y, Z:+X)**

cirq.SingleQubitCliffordGate.I

SingleQubitCliffordGate.**I = cirq.SingleQubitCliffordGate(X:+X, Y:+Y, Z:+Z)**

cirq.SingleQubitCliffordGate.X

SingleQubitCliffordGate.**X = cirq.SingleQubitCliffordGate(X:+X, Y:-Y, Z:-Z)**

cirq.SingleQubitCliffordGate.X_nsqrt

SingleQubitCliffordGate.**X_nsqrt = cirq.SingleQubitCliffordGate(X:+X, Y:-Z, Z:+Y)**

cirq.SingleQubitCliffordGate.X_sqrt

SingleQubitCliffordGate.**X_sqrt = cirq.SingleQubitCliffordGate(X:+X, Y:+Z, Z:-Y)**

cirq.SingleQubitCliffordGate.Y

SingleQubitCliffordGate.**Y = cirq.SingleQubitCliffordGate(X:-X, Y:+Y, Z:-Z)**

cirq.SingleQubitCliffordGate.Y_nsqrt

SingleQubitCliffordGate.**Y_nsqrt = cirq.SingleQubitCliffordGate(X:+Z, Y:+Y, Z:-X)**

cirq.SingleQubitCliffordGate.Y_sqrt

SingleQubitCliffordGate.**Y_sqrt = cirq.SingleQubitCliffordGate(X:-Z, Y:+Y, Z:+X)**

cirq.SingleQubitCliffordGate.Z

SingleQubitCliffordGate.**Z = cirq.SingleQubitCliffordGate(X:-X, Y:-Y, Z:+Z)**

cirq.SingleQubitCliffordGate.Z_nsqrt

SingleQubitCliffordGate.**Z_nsqrt = cirq.SingleQubitCliffordGate(X:-Y, Y:+X, Z:+Z)**

cirq.SingleQubitCliffordGate.Z_sqrt

SingleQubitCliffordGate.**Z_sqrt = cirq.SingleQubitCliffordGate(X:+Y, Y:-X, Z:+Z)**

cirq.Pauli

class cirq.**Pauli**(*, *_index: int*, *_name: str*)

Represents the X, Y, or Z axis of the Bloch sphere.

__init__(*, *_index: int*, *_name: str*) → None

Initialize self. See help(type(self)) for accurate signature.

Methods

commutes_with(other)	
difference(second)	
third(second)	

cirq.Pauli.commutes_with

Pauli.**commutes_with**(*other: cirq.ops.pauli.Pauli*) → bool

cirq.Pauli.difference

Pauli.**difference**(*second: cirq.ops.pauli.Pauli*) → int

cirq.Pauli.third

Pauli.**third**(*second: cirq.ops.pauli.Pauli*) → cirq.ops.pauli.Pauli

Attributes

X	
XYZ	
Y	
Z	

cirq.Pauli.X

Pauli.**X = cirq.Pauli.X**

cirq.Pauli.XYZ

Pauli.**XYZ = (cirq.Pauli.X, cirq.Pauli.Y, cirq.Pauli.Z)**

cirq.Pauli.Y

Pauli.**Y = cirq.Pauli.Y**

cirq.Pauli.Z

Pauli.**Z = cirq.Pauli.Z**

cirq.PauliInteractionGate

class cirq.**PauliInteractionGate**(*pauli0: cirq.ops.pauli.Pauli, invert0: bool, pauli1: cirq.ops.pauli.Pauli, invert1: bool, *, exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*)

__init__(*pauli0: cirq.ops.pauli.Pauli, invert0: bool, pauli1: cirq.ops.pauli.Pauli, invert1: bool, *, exponent: Union[cirq.value.symbol.Symbol, float] = 1.0*) → None

Parameters

- **pauli0** – The interaction axis for the first qubit.
- **invert0** – Whether to condition on the +1 or -1 eigenvector of the first qubit's interaction axis.
- **pauli1** – The interaction axis for the second qubit.
- **invert1** – Whether to condition on the +1 or -1 eigenvector of the second qubit's interaction axis.
- **exponent** – Determines the amount of phasing to apply to the vector equal to the tensor product of the two conditions.

Methods

on(*qubits)	Returns an application of this gate to the given qubits.
qubit_index_to_equivalence_group_key(index)	Returns a key that differs between non-interchangeable qubits.
validate_args(qubits)	Checks if this gate can be applied to the given qubits.

cirq.PauliInteractionGate.on

PauliInteractionGate.**on**(**qubits*) → gate_operation.GateOperation

Returns an application of this gate to the given qubits.

Parameters ***qubits** – The collection of qubits to potentially apply the gate to.

cirq.PauliInteractionGate.qubit_index_to_equivalence_group_key

PauliInteractionGate.**qubit_index_to_equivalence_group_key**(*index: int*) → int
Returns a key that differs between non-interchangeable qubits.

cirq.PauliInteractionGate.validate_args

PauliInteractionGate.**validate_args**(*qubits*)
Checks if this gate can be applied to the given qubits.

Does no checks by default. Child classes can override.

Parameters **qubits** – The collection of qubits to potentially apply the gate to.

Throws: ValueError: The gate can't be applied to the qubits.

Attributes

CNOT
CZ
exponent

cirq.PauliInteractionGate.CNOT

PauliInteractionGate.**CNOT = cirq.PauliInteractionGate(cirq.Pauli.Z, False, cirq.Pauli.**

cirq.PauliInteractionGate.CZ

PauliInteractionGate.**CZ = cirq.PauliInteractionGate(cirq.Pauli.Z, False, cirq.Pauli.Z,**

cirq.PauliInteractionGate.exponent

PauliInteractionGate.**exponent**

cirq.PauliString

class cirq.**PauliString**(*qubit_pauli_map: Mapping[cirq.ops.raw_types.QubitId, cirq.ops.pauli.Pauli], negated: bool = False*)

__init__(*qubit_pauli_map: Mapping[cirq.ops.raw_types.QubitId, cirq.ops.pauli.Pauli], negated: bool = False*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

commutes_with(other)
equal_up_to_sign(other)

Continued on next page

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from_single(qubit, pauli)	Creates a PauliString with a single qubit.
get(key[, default])	
items()	
keys()	
map_qubits(qubit_map, ...)	
negate()	
pass_operations_over(ops, after_to_before)	Determines how the Pauli string changes when conjugated by Cliffords.
qubits()	
to_z_basis_ops()	Returns operations to convert the qubits to the computational basis.
values()	
zip_items(other)	
zip_paulis(other)	

cirq.PauliString.commutes_with

PauliString.**commutes_with**(*other: cirq.ops.pauli_string.PauliString*) → bool

cirq.PauliString.equal_up_to_sign

PauliString.**equal_up_to_sign**(*other: cirq.ops.pauli_string.PauliString*) → bool

cirq.PauliString.from_single

static PauliString.**from_single**(*qubit: cirq.ops.raw_types.QubitId*, *pauli: cirq.ops.pauli.Pauli*) → cirq.ops.pauli_string.PauliString

Creates a PauliString with a single qubit.

cirq.PauliString.get

PauliString.**get**(*key: cirq.ops.raw_types.QubitId*, *default=None*)

cirq.PauliString.items

PauliString.**items**() → ItemsView

cirq.PauliString.keys

PauliString.**keys**() → KeysView[cirq.ops.raw_types.QubitId]

cirq.PauliString.map_qubits

PauliString.**map_qubits**(*qubit_map: Dict[cirq.ops.raw_types.QubitId, cirq.ops.raw_types.QubitId]*) → cirq.ops.pauli_string.PauliString

cirq.PauliString.negate

PauliString.**negate**() → cirq.ops.pauli_string.PauliString

cirq.PauliString.pass_operations_over

PauliString.**pass_operations_over**(*ops: Iterable[cirq.ops.raw_types.Operation]*, *after_to_before: bool = False*) → cirq.ops.pauli_string.PauliString

Determines how the Pauli string changes when conjugated by Cliffords.

The output and input pauli strings are related by a circuit equivalence.
In particular, this circuit:

```
———ops———INPUT_PAULI_STRING———
```

will be equivalent to this circuit:

```
———OUTPUT_PAULI_STRING———ops———
```

up to global phase (assuming `after_to_before` is not set).

If ops together have matrix C, the Pauli string has matrix P, and the
output Pauli string has matrix P', then P' == C^-1 P C up to
global phase.

Setting `after_to_before` inverts the relationship, so that the output
is the input and the input is the output. Equivalently, it inverts C.

Parameters

- **ops** – The operations to move over the string.
- **after_to_before** – Determines whether the operations start after the pauli string, instead of before (and so are moving in the opposite direction).

cirq.PauliString.qubits

PauliString.**qubits**() → KeysView[cirq.ops.raw_types.QubitId]

cirq.PauliString.to_z_basis_ops

PauliString.**to_z_basis_ops**() → Union[cirq.ops.raw_types.Operation, Iterable[Any]]

Returns operations to convert the qubits to the computational basis.

cirq.PauliString.values

PauliString.**values**() → ValuesView[cirq.ops.pauli.Pauli]

cirq.PauliString.zip_items

PauliString.**zip_items**(*other: cirq.ops.pauli_string.PauliString*) → Iterator[Tuple[cirq.ops.raw_types.QubitId, Tuple[cirq.ops.pauli.Pauli, cirq.ops.pauli.Pauli]]]

cirq.PauliString.zip_paulis

PauliString.**zip_paulis**(*other: cirq.ops.pauli_string.PauliString*) → Iterator[Tuple[cirq.ops.pauli.Pauli, cirq.ops.pauli.Pauli]]

cirq.PauliTransform

class cirq.**PauliTransform**(*to*, *flip*)

__init__()
Initialize self. See help(type(self)) for accurate signature.

Methods

count(value)	
index(value, [start, [stop]])	Raises ValueError if the value is not present.

cirq.PauliTransform.count

PauliTransform.**count**(*value*) → integer – return number of occurrences of value

cirq.PauliTransform.index

PauliTransform.**index**(*value*[, *start*[, *stop*]]) → integer – return first index of value.
Raises ValueError if the value is not present.

Attributes

flip	Alias for field number 1
to	Alias for field number 0

cirq.PauliTransform.flip

PauliTransform.**flip**
Alias for field number 1

cirq.PauliTransform.to

PauliTransform.**to**
Alias for field number 0

cirq.Unique

class cirq.**Unique**(*val: T*)
A wrapper for a value that doesn't compare equal to other instances.

For example: 5 == 5 but Unique(5) != Unique(5).

Unique is used by CircuitDag to wrap operations because nodes in a graph are considered the same node if they compare equal to each other. X(q0) in one moment of a Circuit and X(q0) in another moment of the Circuit are wrapped by Unique(X(q0)) so they are distinct nodes in the graph.

__init__(*val: T*) → None
Initialize self. See help(type(self)) for accurate signature.

Methods

—

3.1.17 Contrib

Contributed code that requires extra dependencies to be installed, code that may be unstable, and code that may or may not be a fit for the main library. A waiting area.

contrib.acquaintance	Primitives for generalized swap networks.
contrib.jobs	Package for handling a full quantum job.
contrib.paulistring	
contrib.qcircuit	Converts cirq circuits into latex using qcircuit.
contrib.quirk	Converts cirq circuits into quirk circuits.
contrib.tpu	

cirq.contrib.acquaintance

Primitives for generalized swap networks.

cirq.contrib.jobs

Package for handling a full quantum job.

Types and methods related to transforming circuits in preparation of sending them to Quantum Engine. Contains classes to help with adding parameter

sweeps and error simulation.

cirq.contrib.paulistring

cirq.contrib.qcircuit

Converts cirq circuits into latex using qcircuit.

cirq.contrib.quirk

Converts cirq circuits into quirk circuits.

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