Adding a ”no-inline” option to Qiskit Transpiler

Qamp-fall-22 #16

Mentor : Adrien Suau

Mentee : Juon Kim, Pranshi Saxena

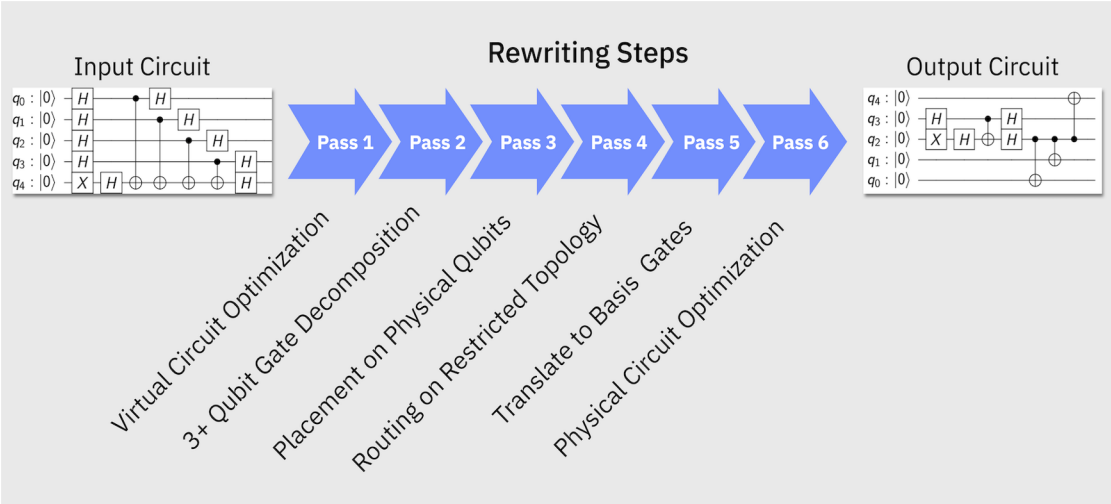
Qiskit Transpilers

Background

- Real Quantum devices can only execute a limited hardware specific quantum gates.
- In the present case of IBM Q devices, the native gate sets are
- ['id', 'rz', 'sx', 'x', 'cx']

Transpilation

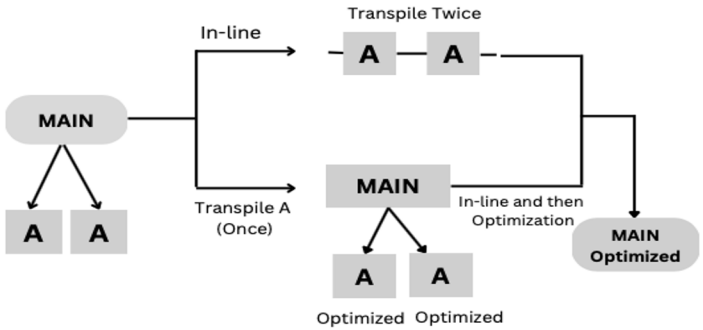
- Rewrites a given circuit to match the topology of a specific quantum device
- Optimize the performance and compensate for the effects of noise, decoherence, errors
- Minimizing the number of SWAP gates in a circuit is a primary goal in the transpilation process



Basic building blocks of a Transpiler

In-line Transpiler vs No In-line Transpiler

In-line Transpiler	No In-line Transpiler
• Optimization by unrolling(inlining in the classical context) the instruction to obtain a flat quantum circuit • "Flat Quantum Circuit - Each part is not interdependent - Limited to reuse the module - Apply all the transpiler passes in each part	• Transpiler capable of working on the hierarchical structure. • "Hierarchical" Quantum Circuit - Circuit is partition into parts and are interconnected - Easy to reuse the module - Apply transpiler pass once and reapply to other part



Project Overview

- Implement classical feedback in the quantum circuit. Set up qiskit code for Transpiler passes to enable transpilation to enable control flow. Table below is an example of compatible transpiler passes and why it adds control flow handling and how it is changed. We analysed each transplier passes whether it is compatible with control flow feedback, and if not how we can change it to make compatible.

Transpiler pass	Definition	Why?	How?
DenseLayout	Choose a layout by finding the most connected subset of qubitS	DenseLayout pass is heuristic, so control flow is not exactly correct	Count the number of measurement and cx gates per qubit
VF2Layout	Choose a layout of a circuit onto a coupling graph	To solve the subgraph isomorphism problem	Score the control flow operation which is transparent in the pass
CheckMap	Check if a DAG circuit is mapped to a coupling map	More complicated to check if there is no control flow blocks	Control flow blocks are not in outer circuits but inner qubits that reference the root register
Unroll3qOrMore	Expands 3q+ gates repeatedly until the circuit contains 2q or 1q qubits	To make repeated operations recursive	Modify control flow operations in a depth-first pass before running the circuit

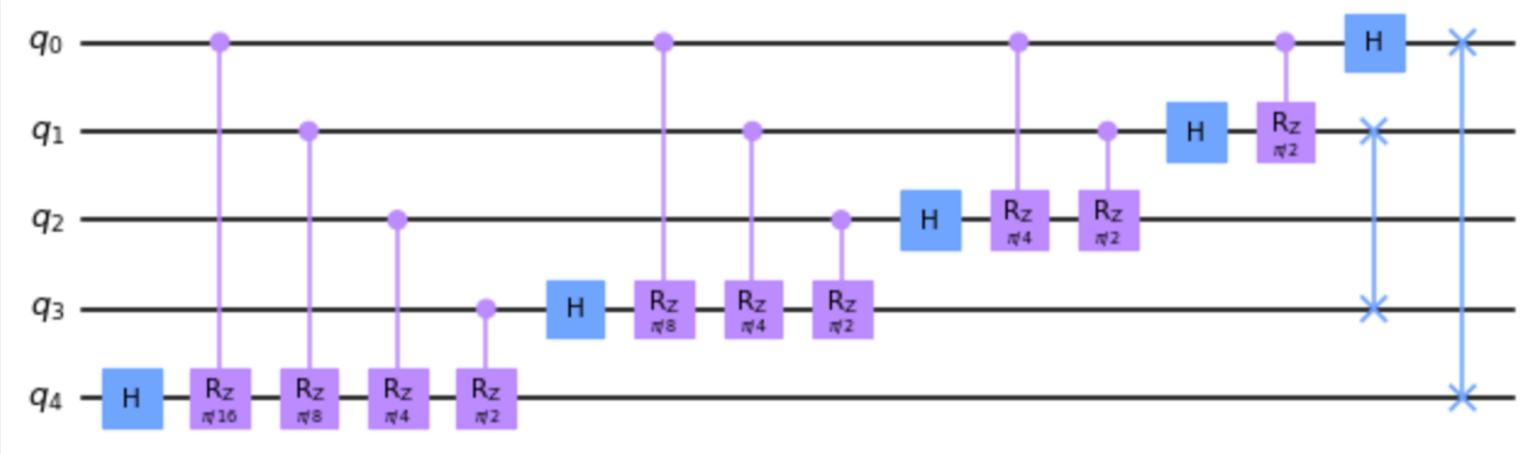
- Implement no-inline transpiler that can instances containing classical-feedback features and that does not systematically unroll the subroutines found in the circuit. This was implemented by making changing in the Transpiler passes and passmanger for different optimization levels.
- In addition, Reviewed Research paper “Tackling the Qubit Mapping For NISQ - Era Quantum Devices”. The qubit mapping algorithm presented in this paper, called SABRE, can be used with NISQ devices that have any number of connections between qubits. The study of such mapping algorithm is important as we expect these algorithms to be a major issue in making the transpiler “no-inline”.

Implementation

QFT(Quantum Fourier Transform)

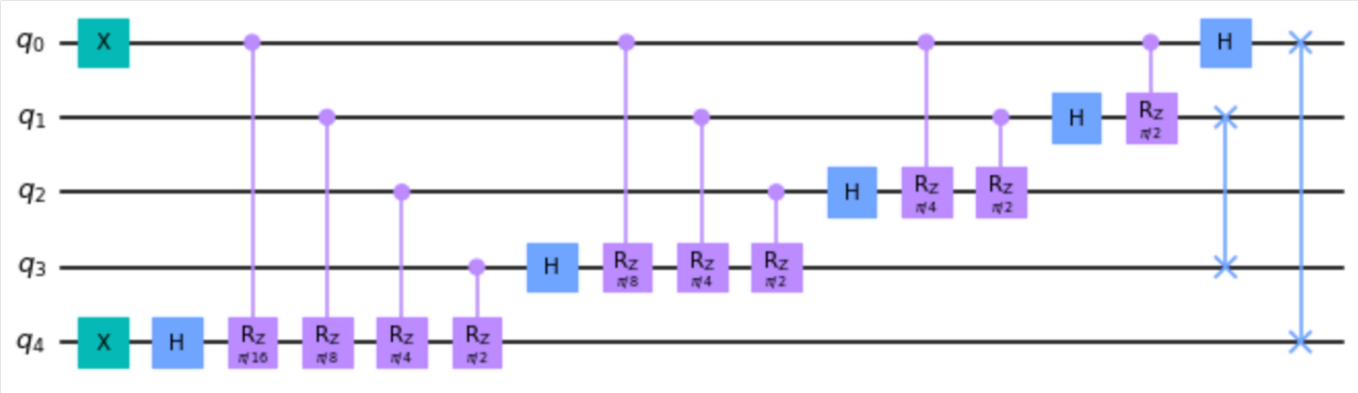
: A linear transformation on quantum bits, and is the quantum analogue of the discrete Fourier transform

- Structurally easy to divide into subroutines
- Repeat similar motions with the same gate in each subroutine



Implementation

Example) Convert the number 17 (10001)



Apply the inverse of QFT function

- To measure a binary output
- To see the distinguishable result with plot histogram

Implementation

1. Inline circuit

- Implement → Transpile

1. No-Inline circuit - Case 1

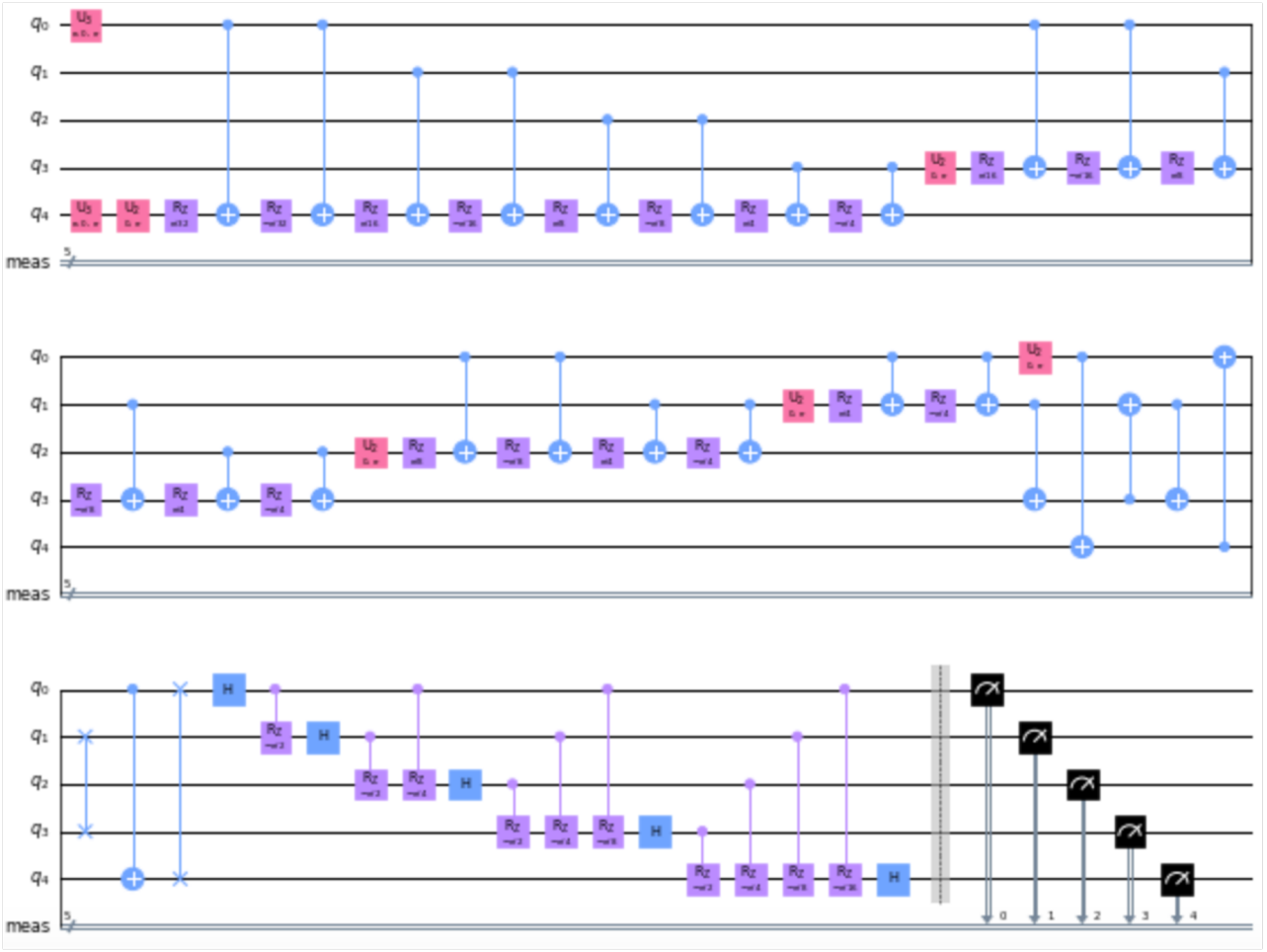
- Transpile → Implement
- Transpile each subroutines and combine them

1. No-Inline circuit - Case 2

- Implement → Transpile
- Optimize the circuit to minimize the depth and transpile it

Implementation 1

- Inline circuit

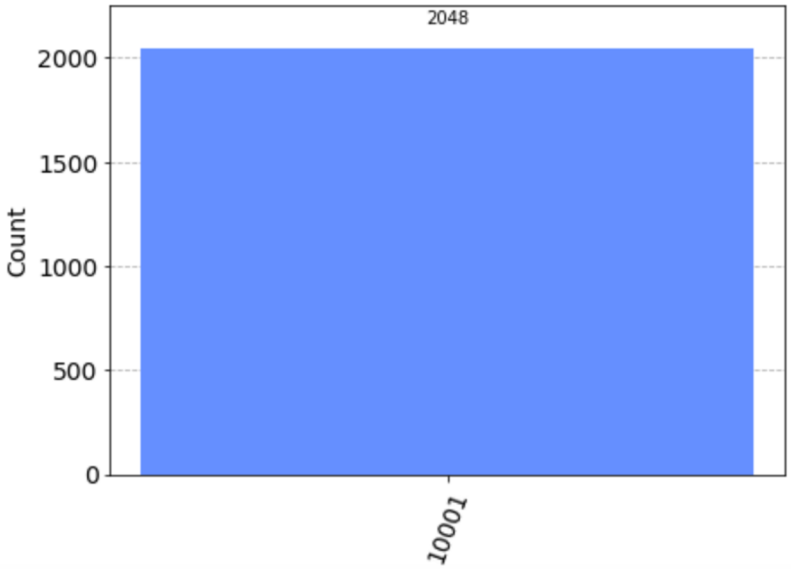


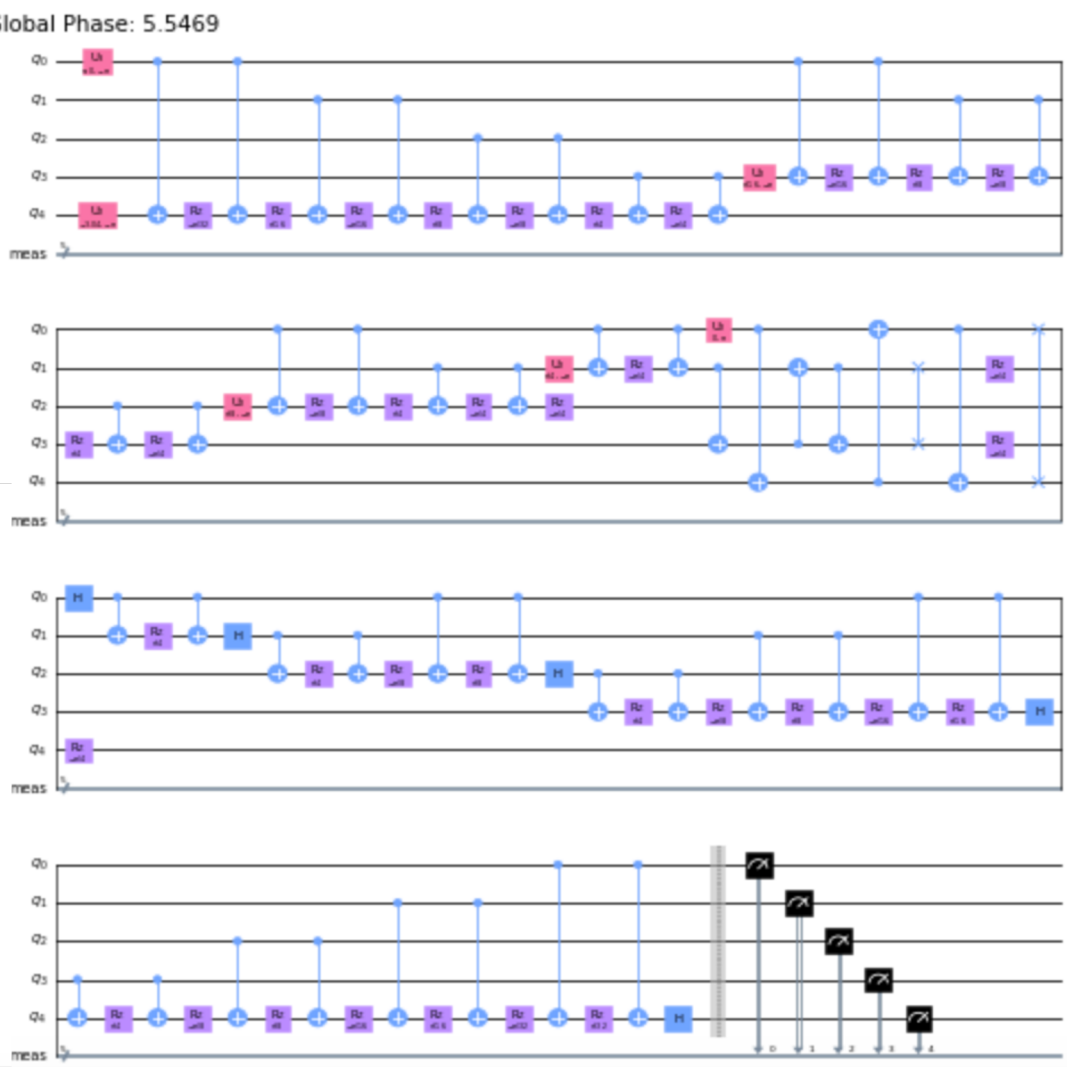
Implementation 1

- Transpiled Inline circuit

Optimization_level=3

Result :



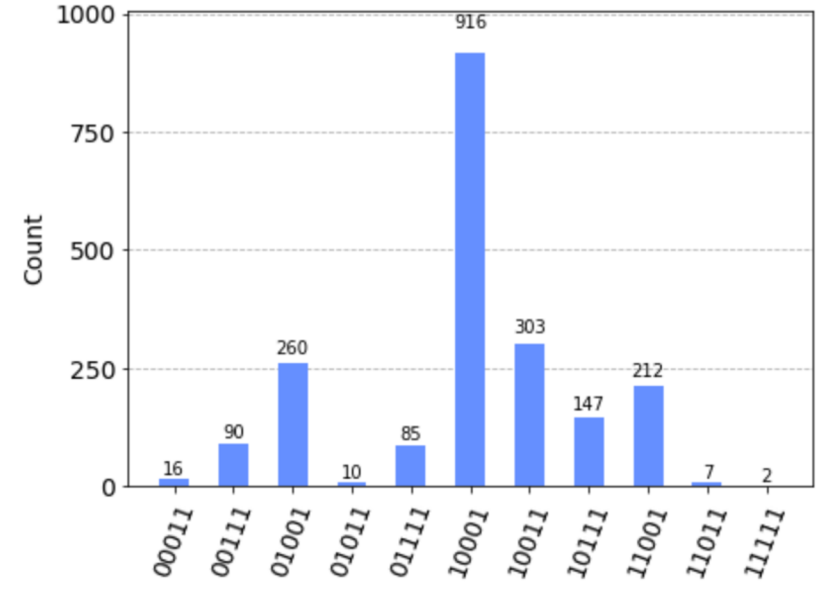


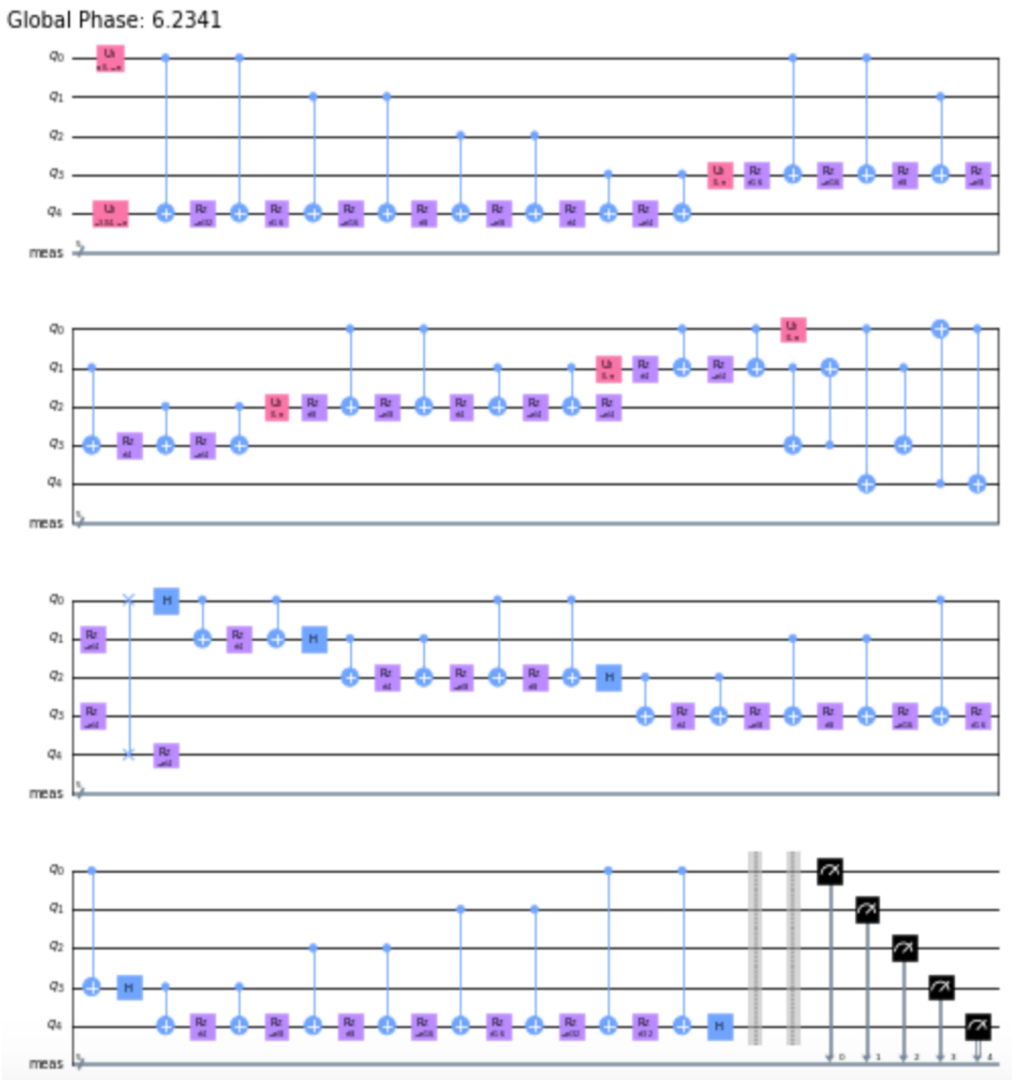
Implementation 2

- Transpiled No-Inline circuit

Transpile each subroutines and combine them

Result :

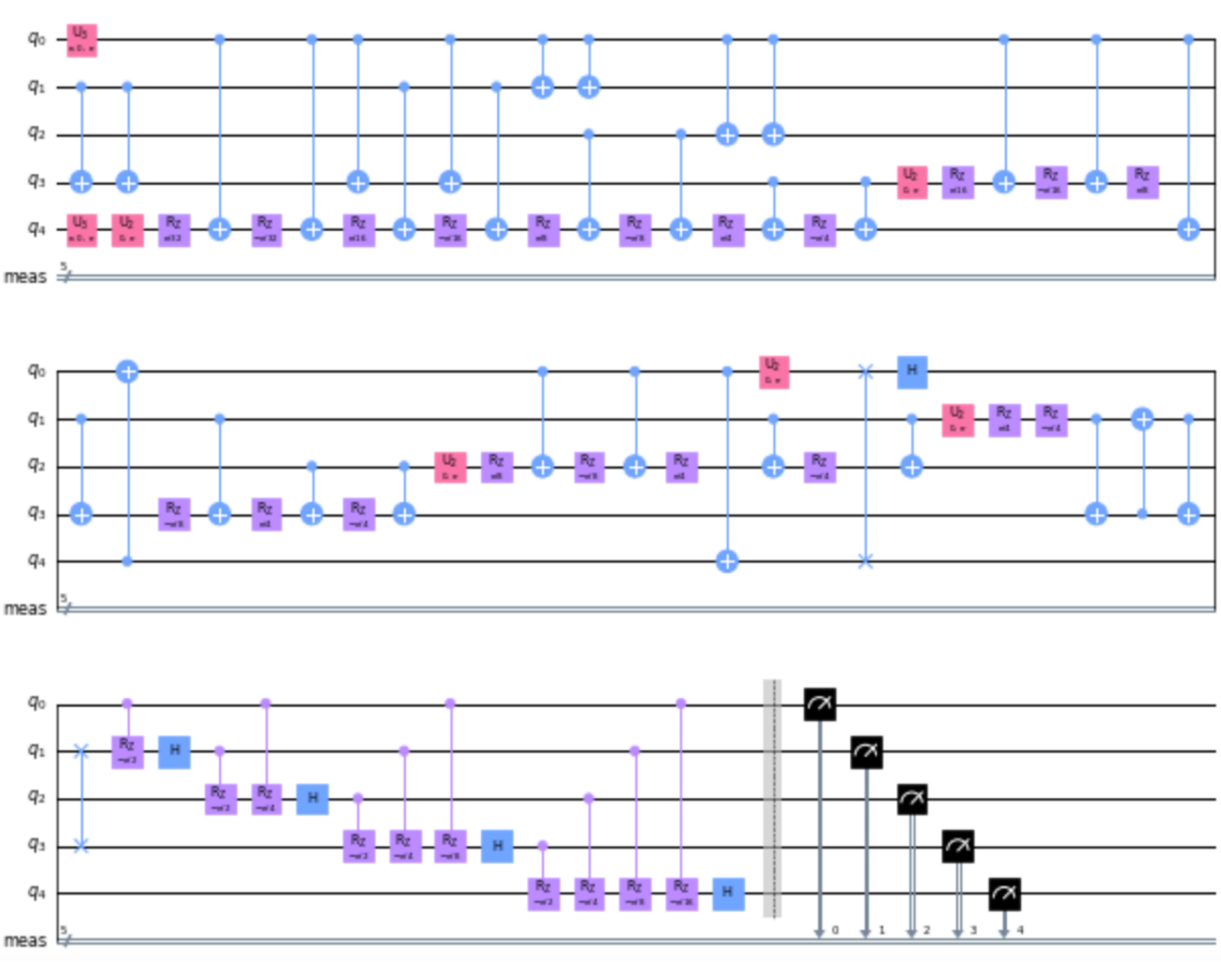




Implementation 3

- No-Inline circuit

Optimize the circuit to minimize the depth and transpile it

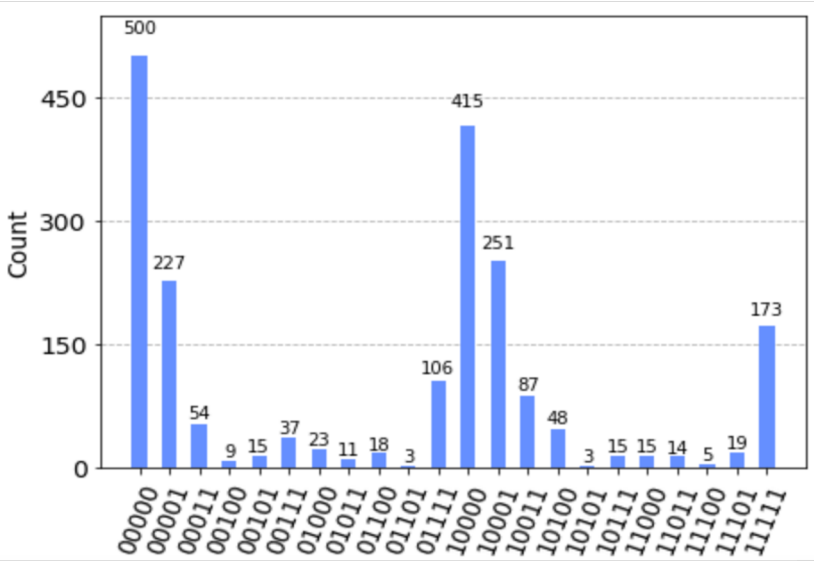


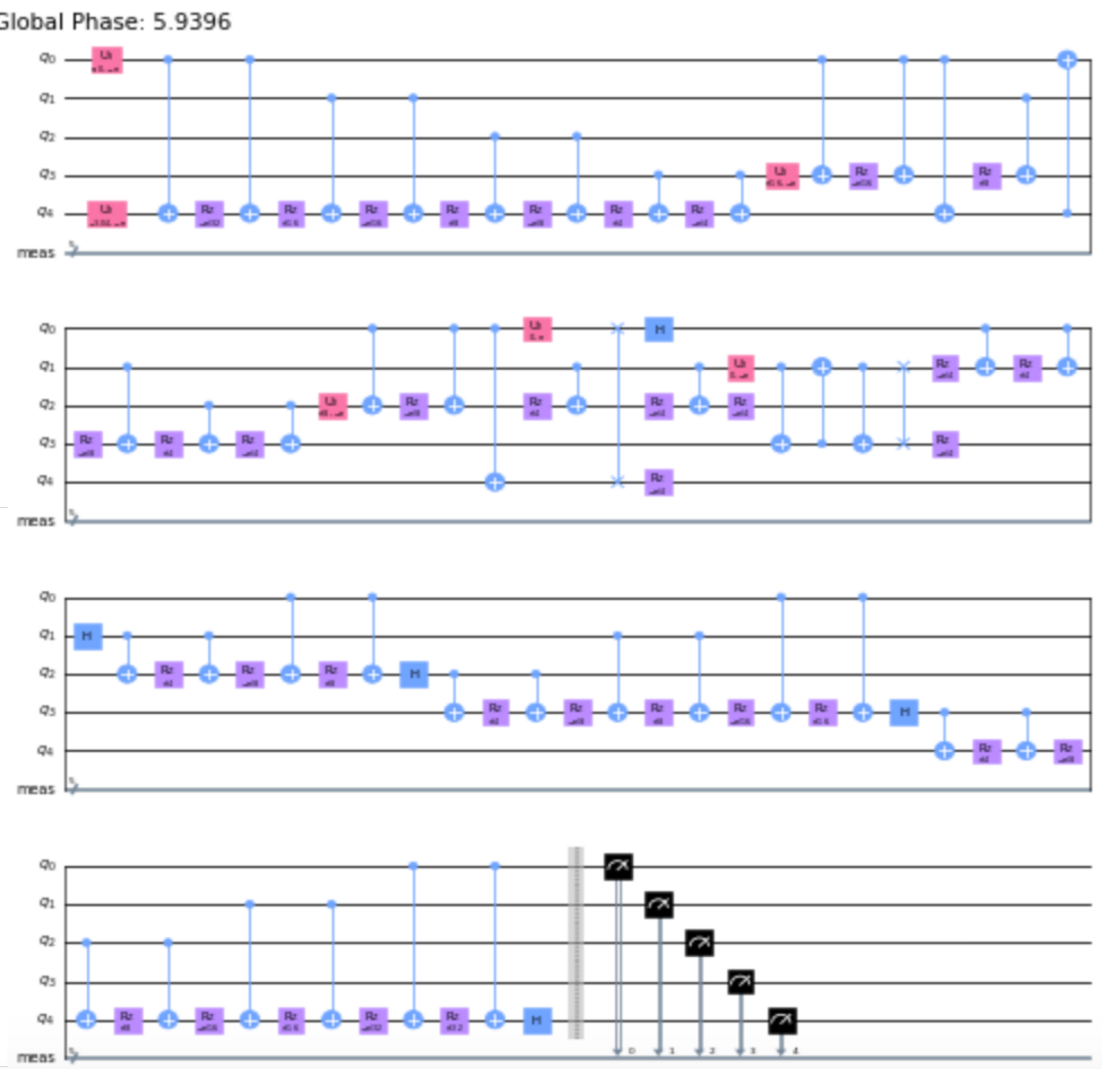
Implementation 3

- Transpiled No-Inline circuit

Optimize the circuit to minimize the depth and transpile it

Result :





Future Work

- Make changes in more passes
- Implement no-inline for complex circuits
- Supplement the 2nd case
- Increase the accuracy when measuring the circuit

Thank You

References:

- https://github.com/qiskit-advocate/qamp-fall-22/issues/16
- https://github.com/Qiskit/qiskit-terra
- https://arxiv.org/abs/1809.02573
- https://github.com/Qiskit/qiskit-terra/issues/8630
- https://qiskit.org/textbook/ch-algorithms/quantum-fourier-transform.html