

# Code Concatenation

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# Introduction

# Problem statement

## Problem

The Threshold Theorem theoretically enables Quantum Error Correction, and the multiple concatenation of codes formulates the theorem itself. Compiling the quantum circuits results after code concatenation is challenging because: a) there will be many qubits involved in the final circuit; b) each code used within the concatenation might have its own supported gate set (logical operators)

# Methods

## Implementation of Steane code

- 1 Create Bloqs required to encode the Steane code
- 2 Create a Bloq to encode the Steane code in Qualtran
- 3 Enable concatenation of the Steane code with itself
- 4 Draw diagrams for the level of concatenations
  - 1 Plot qubits and operation growth

## Logical error rates for Steane code

- 1 Convert Bloqs to stim circuits
- 2 Extend circuit with syndrome extraction
- 3 Add noise and detectors to the circuit
- 4 Decode circuit via pymatching
- 5 Plot logical error rates

# Results



# Results

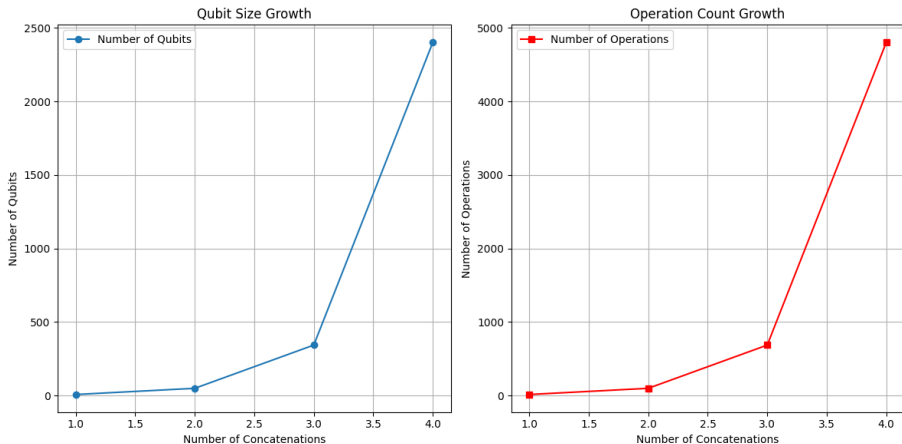


Figure: Qubit and Operation growth

# Results

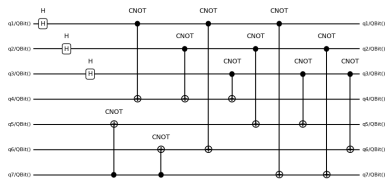


Figure: Musical score representation

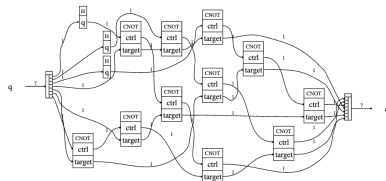


Figure: Bloq graph representation

# Results

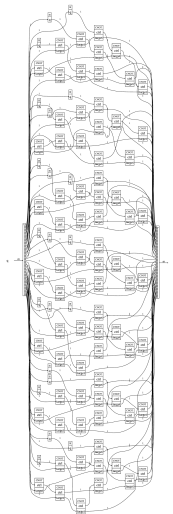


Figure: Concatenated Steane code graph representation

# Results

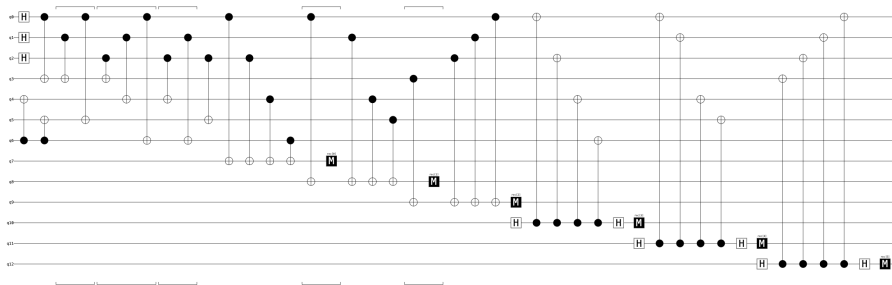


Figure: Steane code encoding and syndrome extraction circuit

# Results

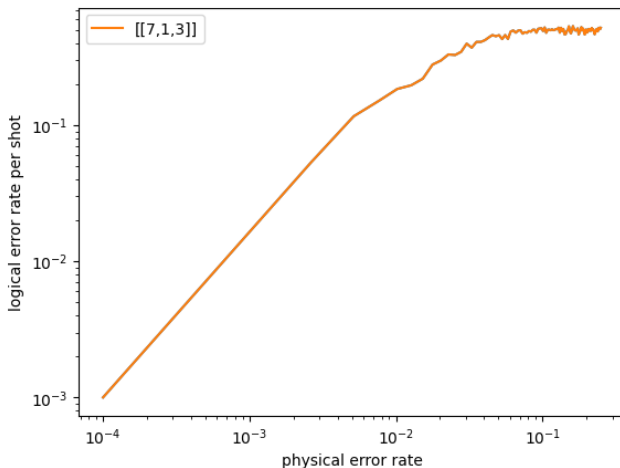
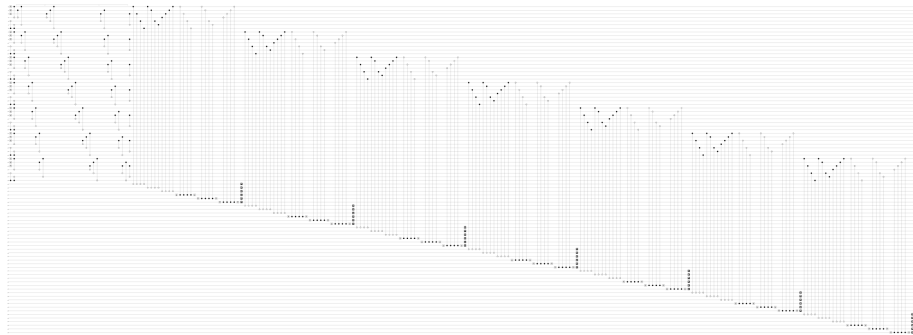


Figure: Steane code logical error rate

# Results



**Figure:** Concatenated Steane code syndrome extraction circuit

# Conclusion

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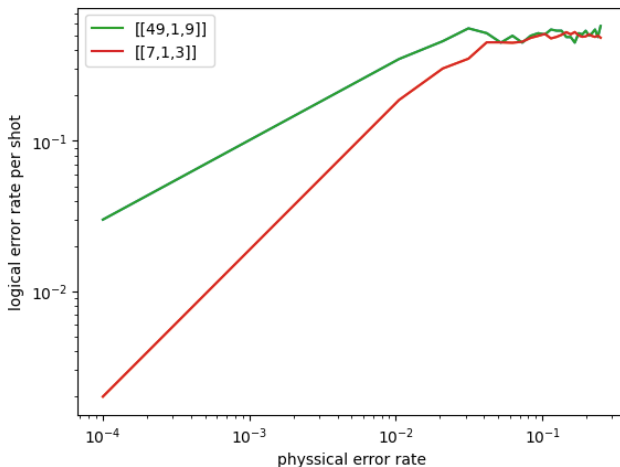


Figure: Logical error rates of  $[[7,1,3]]$  and  $[[49,1,9]]$