



# **QAMP 15: Building out Qiskit-QEC: XP Formalism**

**Final Showcase**

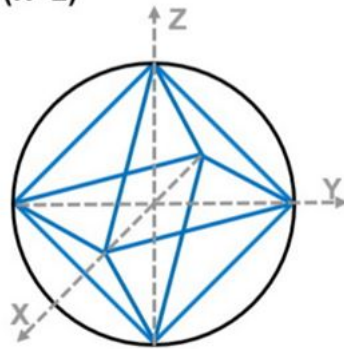
Team members: Dhruv Bhatnagar & Ruihao Li

Mentors: Drew Vandeth & Grace Harper

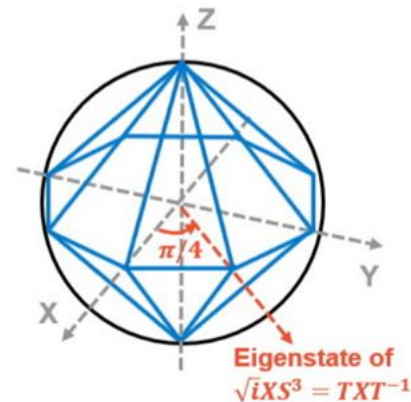
# Recap on XP stabilizer formalism

Ref: M. A. Webster, B. J. Brown, and S. D. Bartlett. Quantum 6, 815 (2022).

Pauli Stabiliser Formalism  
(N=2)



XS Formalism (N=4)



Pauli Stabilizer Formalism:  $\langle iI, X, Z \rangle^{\otimes n}$


XP Formalism: To construct new quantum error correcting codes using fractional Z rotations to generate the stabilizer group

$$\langle iI, X, P \rangle^{\otimes n}, \omega = e^{i\pi/N}, P = \text{diag}(1, \omega^2)$$

# Adding the new class: BaseXPPauli (DB)

- Understood structure of BasePauli class and pauli\_rep module in qiskit-qec
- Created BaseXPPauli and xp\_pauli\_rep
- Added empty methods with placeholders in BaseXPPauli and xp\_pauli\_rep


## Issue 258 basexppauli class skeleton #259

 Merged dhruvbhq merged 5 commits into [Issue-257/XP\\_Formalism](#) from [258-basexppauli-class-skeleton](#) on Oct 18

 Conversation 12

 Commits 5

 Checks 0

 Files changed 5



dhruvbhq commented on Oct 11

Collaborator  

### Summary

Fix for issue [#258](#) . Added skeleton class `BaseXPPauli` and methods `xp_pauli_rep.py`

### Details and comments

- Added skeleton class and methods in `qiskit_qec/operators` and `qiskit_qec/utils`
- Most function declarations from `BasePauli` and `pauli_rep.py` have been retained as of now. Functions are empty. There are placeholders for future documentation.
- Locally disabled lint warnings for newly added files

# Developing the new classes: BaseXPPauli, XPPauli and XPPauliList (DB)

- Developed classes `XPPauli` and `XPPauliList` derived from `BaseXPPauli`
- Implemented following methods for XP operator algebra, based on Mark's original code:
  - `XPSetN` (`rescale_precision`)
  - `XPDistance` (`weight`)
  - `XPisDiag` (`is_diagonal`)
  - `XPDegree` (`degree`)
  - `XPPower` (`power`)
  - `XPMul` (`compose`)
  - `XPRound` (`unique_vector_rep`)
  - `XP` (`antisymmetric_op`)

## 274 building xppauli classes (part of 257) #281

Merged

grace-harper-ibm merged 30 commits into [Issue-257/XP\\_Formalism](#) from [274-building-xppauli-classes](#) 23 days ago

Conversation 20

Commits 30

Checks 0

Files changed 9



dhruvbhq commented on Oct 31

Collaborator



### Summary

Partial fix for #274 (part of #257). This PR contains an initial implementation of `XPPauli` and `XPPauliList` classes.

# Developing xp\_pauli\_rep [WIP] (DB)

Currently implementing the following string representations for XP operators:

- INDEX\_SYNTAX: 'XP8 ((w, 12) (XP4) 2 (X) 1 (X) 0) '
- XP\_SYMPLECTIC\_SYNTAX: 'XP8 (12|1 1 1 0 0 0 0|0 0 4 0 0 0 0) '
- PRODUCT\_SYNTAX: 'XP8 ((w, 12) (I) (I) (I) (I) (XP4) (X) (X)) '
- LATEX\_SYNTAX: 'XP\_{8} ((w, 12) (XP^{4}) \_{2} (X) \_{1} (X) \_{0}) '


296 xp pauli rep (part of 257) #305

 Draft dhruvbjh wants to merge 2 commits into [Issue-257/XP\\_Formalism](#) from [296-xp-pauli-rep](#) 

 Conversation **0**  Commits **2**  Checks **0**  Files changed **3**



dhruvbjh commented yesterday

Collaborator 

## Summary

WIP, initial implementation of `xp_pauli_rep.py`.

## Details and comments

This is a WIP, initial implementation of `xp_symplectic2str` in `xp_pauli_rep.py`. Currently, as per the notation in the XP Formalism paper, there is one phase encoding implemented: "w" (representing  $\omega$ , the complex number  $e^{i\pi/N}$ ), and one tensor encoding: "XP". I've also added a new syntax `XP_SYMPLECTIC_SYNTAX` for the  $XP_N(p|x|z)$  notation used in the paper and the XPF package.

# Continuation of XP algebra (RL)

This includes the implementation of the following methods (based on Mark's original implementation):

- `XPInverse` (`inverse`):  $A^{-1}$
- `XPConjugate` (`conjugate`):  $A_1 A_2 A_1^{-1}$
- `XPCommutator` (`commutator`):  $A_1 A_2 A_1^{-1} A_2^{-1}$
- `XPFundamentalPhase` (`fundamental_phase`):  $q$  such that  $A^{\deg(A)} = \omega^q I$
- `XPSetEval` (`reset_eigenvalue`): returns XP operator with +1 being an eigenvalue

## 294 continue xp algebra #304



ruihao-li wants to merge 9 commits into [Issue-257/XP\\_Formalism](#) from [294-continue-xp-algebra](#)

Conversation 0

Commits 9

Checks 0

Files changed 5



ruihao-li commented 22 hours ago

Collaborator

### Summary

PR for Issue [#294](#). It includes implementation of several XP algebra methods in `BaseXPPauli`, `XPPauli`, and `XPPauliList` classes. See details below.

# Modular arithmetic & Howell matrix form (RL)

Modular arithmetics on ring  $Z/nZ$ : reside in `qiskit_qec/arithmetic/modn.py`

- Extended Euclidean algorithm for finding the greatest common divisor (`gcd_ext`)
- Quotient (`quo`)
- Divisor (`div`)

## 273 howell matrix form #279

 Merged grace-harper-ibm merged 10 commits into [Issue-257/XP\\_Formalism](#) from [273-howell-matrix-form](#)  23 days ago

 Conversation 21

 Commits 10

 Checks 0

 Files changed 5



ruihao-li commented on Oct 28 • edited

Collaborator  

### Summary

Implementation for Issue [#273](#), part of Issue [#257](#) (XP formalism).

### Details and comments

- Added functions for modular arithmetic and `howell`, which outputs the Howell matrix form, the transformation matrix, and the kernel. All functions were added to `qiskit_qec/linear/matrix.py`
- Added unit tests under `tests/linear/test_matrix.py`

# Post-QAMP



- We plan to continue working on XP formalism implementation in Qiskit-qec



- String representation for XP operators
- Functionality for XP codespace
- Examples/Tutorials