Quantstamp

Executive Summary

This audit report was prepared by Quantstamp, the leader in blockchain security.

Type	Lending Protocol
Timeline	2024-03-04 through 2024-03-26
Language	Solidity
Methods	Architecture Review, Unit Testing, Functional Testing, Computer-Aided Verification, Manual Review
Specification	Public Documentation 🔗 🔗
Source Code	• Secured-Finance/contracts 🔗 #f1c6276 🔗
Auditors	• Michael Boyle Auditing Engineer • Valerian Callens Senior Auditing Engineer • Mustafa Hasan Senior Auditing Engineer

Documentation quality	Medium	
Test quality	Medium	
Total Findings	14	Fixed: 9 Acknowledged: 5
High severity findings ⓘ	0	
Medium severity findings ⓘ	2	Fixed: 2
Low severity findings ⓘ	7	Fixed: 4 Acknowledged: 3
Undetermined severity findings ⓘ	0	
Informational findings ⓘ	5	Fixed: 3 Acknowledged: 2

Summary of Findings

This audit report presents a differential analysis, underscoring the modifications between the former audit at commit `#92f4e85` and the current state at commit `#f1c62764`. Key updates include the integration of ZCTokens, enabling users to tokenize their Zero Coupon Bonds (lending positions) and facilitate their transfer beyond the Secured Finance protocol.

The diff audit resulted in 14 findings: 0 high, 2 medium, 7 low, and 5 informational. During the audit, the client identified and highlighted several concerns, which are detailed in this report. These concerns are specifically related to SF-1, SF-2, SF-5, SF-6, and SF-10.

Regarding testing, a significant number of tests fail due to an issue with an iterative test that fails a quarter of the way through. We highly recommend fixing the testing suite by ensuring that all tests pass. The project implements code coverage metrics. It shows 87.19% of branch coverage. We also recommend improving the branch coverage to a minimum of 95% and adding new tests to cover the proposed fixes.

Fix Review: The Secured Finance team has either fixed or acknowledged all issues found within the report, and provided a new commit containing fixes for the issues found. The test suite has been improved to have 2044 passing tests, no failures, and slightly improved coverage.

ID	DESCRIPTION	SEVERITY	STATUS
SF-1	**Partial Withdrawal Requests of `ZCTokens` Results in Withdrawing More than What Is Requested**	• Medium ⓘ	Fixed
SF-2	**Non-Perpetual `ZCTokens` Are Deployed with an Incorrect Amount of Decimals**	• Medium ⓘ	Fixed
SF-3	**Deposits with Permits Can Be Delayed by Front-Running the Approval**	• Low ⓘ	Acknowledged
SF-4	**Incorrect Value Used when Emitting `LiquidatorFeeRateUpdated` Events**	• Low ⓘ	Fixed
SF-5	`OrderBookId` **Can Overflow**	• Low ⓘ	Fixed

ID	DESCRIPTION	SEVERITY	STATUS
SF-6	The Compound Factor Can Cause Overflows in Scenarios with High Interest Rates over Long Periods	• Low ⓘ	Fixed
SF-7	Haircuts in Deployed Contract Have Zero Values for All Currencies	• Low ⓘ	Acknowledged
SF-8	Missing Input Validation	• Low ⓘ	Fixed
SF-9	Privileged Roles and Ownership	• Low ⓘ	Acknowledged
SF-10	`ZCTokens` May Use More Decimals than Is Supported by Third-Party Applications	• Informational ⓘ	Fixed
SF-11	Semantical Mismatch Between Function's Name and Behavior	• Informational ⓘ	Fixed
SF-12	Borrowing Users Increase Their Liquidation Risk when Minting `ZCTokens`	• Informational ⓘ	Acknowledged
SF-13	Some Erc20 Tokens Do Not Support Transfers with Permission Signatures	• Informational ⓘ	Acknowledged
SF-14	Dead Code	• Informational ⓘ	Fixed

Assessment Breakdown

Quantstamp's objective was to evaluate the repository for security-related issues, code quality, and adherence to specification and best practices.

> ⓘ **Disclaimer**
>
> Only features that are contained within the repositories at the commit hashes specified on the front page of the report are within the scope of the audit and fix review. All features added in future revisions of the code are excluded from consideration in this report.

Possible issues we looked for included (but are not limited to):

- Transaction-ordering dependence
- Timestamp dependence
- Mishandled exceptions and call stack limits
- Unsafe external calls
- Integer overflow / underflow
- Number rounding errors
- Reentrancy and cross-function vulnerabilities
- Denial of service / logical oversights
- Access control
- Centralization of power
- Business logic contradicting the specification
- Code clones, functionality duplication
- Gas usage
- Arbitrary token minting

Methodology

1. Code review that includes the following
   1. Review of the specifications, sources, and instructions provided to Quantstamp to make sure we understand the size, scope, and functionality of the smart contract.
   2. Manual review of code, which is the process of reading source code line-by-line in an attempt to identify potential vulnerabilities.
   3. Comparison to specification, which is the process of checking whether the code does what the specifications, sources, and instructions provided to Quantstamp describe.
2. Testing and automated analysis that includes the following:
   1. Test coverage analysis, which is the process of determining whether the test cases are actually covering the code and how much code is exercised when we run those test cases.
   2. Symbolic execution, which is analyzing a program to determine what inputs cause each part of a program to execute.

3. Best practices review, which is a review of the smart contracts to improve efficiency, effectiveness, clarity, maintainability, security, and control based on the established industry and academic practices, recommendations, and research.
4. Specific, itemized, and actionable recommendations to help you take steps to secure your smart contracts.

Scope

Files Included

Repo: `https://github.com/Secured-Finance/contracts(f1c62764ccf9782b2ff2de5088abc439566b7a0b)` Files: `contracts/protocol/*`

Findings

SF-1
Partial Withdrawal Requests of `ZCTokens` Results in Withdrawing More than What Is Requested

● Medium ⓘ   Fixed

> ✅ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `3e8bda875a75cd8991ede8d0c35dff322166aad5` .

File(s) affected: `LendingMarketUserLogic.sol`

Description: Users have the capability to withdraw a specified `_amount` of ZC tokens using the `_withdrawZCToken()` and `_withdrawZCPerpetualToken()` functions. However, the presence of the `isAll` flag, as determined by the `_getWithdrawableZCTokenAmount()` function, indicates that users can withdraw their entire position for a specific maturity. This functionality effectively eliminates the option for partial withdrawals. Specifically, based on the `isAll` value, either `0` or the `_amount` specified will be forwarded to the `lock()` function. The `lock()` function interprets an amount of `0` as an instruction to lock the user's total balance or the specified amount. Consequently, if `isAll` is set to `true` for a user intending to withdraw only `8` out of `10` tokens, all `10` tokens will be locked, not just the `8` requested. This could inadvertently impact the user's risk management strategies, as it differs from their initial withdrawal intent.

Note: This issue was raised by the client during the audit process.

Recommendation: Consider updating the code to support partial withdrawals of ZC Tokens.

SF-2
Non-Perpetual `ZCTokens` Are Deployed with an Incorrect Amount of Decimals

● Medium ⓘ   Fixed

> ✅ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `f533c161fa2ad8e1e120ae77ff4d8b8406e2087e` . The client provided the following explanation:
>
> > "To keep our protocol for a long time even with extremely high interest rates, we need to set additional decimals for ZC Tokens but some protocol and third-party tools can't support 36 as token decimals. So we use 6 as additional decimals instead of 18."

> ℹ️ **Update**
>
> We highly recommend conducting comprehensive testing on all edge cases, including conversions between FV and GV, as well as the minting and burning processes for both perpetual and non-perpetual ZC tokens. It is crucial to examine scenarios involving extreme decimal values (ranging from 0 to 44) and amounts (spanning from 1 wei to 50% of the total supply). Additionally, it's important to verify that the system accurately manages any loss of precision.

File(s) affected: `LendingMarketUserLogic.sol`

Description: The function `LendingMarketOperationLogic.createZCToken()` is used to deploy two types of ZC Tokens: perpetual and non-perpetual.

- Non-perpetual ZC Tokens for an underlying token `T` should have a number of decimals that match the amount of decimal of `T` .
- Perpetual ZC Tokens for this same underlying token `T` should have a number of decimals that matches the number of decimals of the genesis value of `T` , which should have 18 additional decimals.

However, all ZCTokens are deployed with 18 additional decimals to match the genesis value amount. As a result, users withdrawing non-perpetual ZC Tokens may think that they received 1e18 times less than expected.

Note: This issue was raised by the client during the audit process.

Recommendation: Consider setting the number of decimals based on the maturity (0 for perpetual, non-zero for non-perpetuals).

SF-3
Deposits with Permits Can Be Delayed by Front-Running the Approval   • Low ⓘ   Acknowledged

> ℹ️ **Update**
>
> Marked as "Acknowledged" by the client. The client provided the following explanation:
>
> > This is a general behavior of ERC2612. We can accept this.

Description: When a user calls a function that uses permit signatures to approve the tokens for deposit, the signature parameters can be pulled from the the mempool and used to approve the token directly. Since the permit signature uses nonce protection, the original function call would fail if someone else used the signature first. This affects all functions that use `permit()` to approve tokens before transferring them.

Exploit Scenario:
1. Alice wants to perform the operation `OP1` : `TokenVault.depositWithPermitTo()` in order to deposit 3 BTC for BOB. The permit signature `PS` is a permission of 3 BTC from Alice to the TokenVault contract.
2. Attacker, Cameron, takes `PS` and consumes it on the BTC contract `permit()` function to front-run Alice's call, so `OP1` will fail because the nonce of this signature is now used in the BTC contract.
3. While funds are not at risk, it could be a way for Cameron to delay BOB from getting an emergency refill of his position that would prevent a liquidation.

Recommendation: Consider documenting that Alice can be front-run when calling functions that involve a permit signature. Users can avoid this by using a private relay to submit transactions. In addition, consider adding a `try-catch` block to revert with a custom error if the call to `permit()` reverts.

SF-4 Incorrect Value Used when Emitting `LiquidatorFeeRateUpdated` Events   • Low ⓘ   Fixed

> ✅ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `a50c4b39147d482bf3e44b38281655958d531715` .

File(s) affected: `MixinLiquidationConfiguration.sol`

Description: The event `LiquidatorFeeRateUpdated` is defined as follows:

```
event LiquidatorFeeRateUpdated(uint256 previousRate, uint256 ratio);
```

However, when the value of `Storage.slot().liquidatorFeeRate` is updated in the function `_updateLiquidationConfiguration()` , the event will use for both fields the new value, instead of using the old and the new value:

```
if (_liquidatorFeeRate != Storage.slot().liquidatorFeeRate) {
    Storage.slot().liquidatorFeeRate = _liquidatorFeeRate;
    emit LiquidatorFeeRateUpdated(Storage.slot().liquidatorFeeRate, _liquidatorFeeRate);
}
```

This can negatively impact external observers of the protocol.

Recommendation: Consider inverting the lines used to update the value and to emit the events.

SF-5 `OrderBookId` Can Overflow   • Low ⓘ   Fixed

> ✅ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `ab9197c1a9f38956b049145b3ee42c9e163af117` .

File(s) affected: `OrderBookLogic.sol`

Description: Order book IDs are stored in `uint8` variables that hold a maximum value of 255. Each time a new order book is created, the previous ID will be incremented by 1. Given the expected rate of a new order book every 3 months, it will take approximately 63 years before new order books cannot be created due to overflow, effectively freezing the protocol.

Note: This issue was raised by the client during the audit process.

Recommendation: Consider reusing previous `orderBookId` values from 1 after 255 has been reached.

SF-6

The Compound Factor Can Cause Overflows in Scenarios with High Interest Rates over Long Periods • Low ⓘ Fixed

> ✅ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `dd25a0a57de312a0e67de447f86e52519fcb07d2` .

File(s) affected: `GenesisValueVault.sol`

Description: In rare cases, the compound factor can become very large and cause an overflow when converting from genesis value to future value. This only happens in circumstances of high interest rates for extended periods such as 200% APR for 197 years.

Note: This issue was raised by the client during the audit process.

Recommendation: Consider using a math library to avoid overflows.

SF-7

Haircuts in Deployed Contract Have Zero Values for All Currencies • Low ⓘ Acknowledged

> ℹ️ **Update**
>
> Marked as "Acknowledged" by the client. The client provided the following explanation:
>
>> This is what we intended. To reduce liquidation risk at the beginning, we had set 0 for all haircuts to avoid users using ZC Bonds as collateral between different currencies.

File(s) affected: `FundManagementLogic.sol` , `LendingMarketUserLogic.sol`

Description: The functions `LendingMarketUserLogic._getWithdrawableAmount()` and `FundManagementLogic.calculateFunds()` apply haircuts to values, which are stored in the `CurrencyController` contract. However, all the currencies in the deployed contract at `0x7dca6b6BF30cd28ADe83e86e21e82e3F852bF2DC` (address taken from the docs) have zero values as their haircuts. This may lead to unwanted consequences when risk management is required while valuing user assets.

Recommendation: Add haircuts for all currencies to avoid volatility in currency prices and potential risks for the platform.

SF-8 Missing Input Validation • Low ⓘ Fixed

> ✅ **Update**
>
> Marked as "Mitigated" by the client. Addressed in: `7ccb862ca858e70667ed157acdbb26691c883fff` . The client provided the following explanation:
>
>> In our protocol, any heartbeats can be acceptable.
>
> Item 1 is fixed. Item 2 is working as expected.

File(s) affected: `MixinLiquidationConfiguration.sol`

Description: It is important to validate inputs, even if they only come from trusted addresses, to avoid human error:

In `MixinLiquidationConfiguration.sol` :

1. In the function `_updateLiquidationConfiguration()` , there is no check making sure that `fullLiquidationThresholdRate < liquidationThresholdRate` .

In `CurrencyController.sol` :

1. In the function `_updatePriceFeed()` , there is no minimum and maximum check for the value of the heartbeats.

Recommendation: We recommend adding the relevant checks.

SF-9 Privileged Roles and Ownership

• **Low** ⓘ   Acknowledged

> ⓘ **Update**
>
> Marked as "Acknowledged" by the client. The client provided the following explanation:
>
> > Understood. We will remove this function to be used for only migration.

File(s) affected: `LendingMarketController.sol`

Description: In addition to the roles described in the previous audit report, the owner can create new ZCTokens.

Recommendation: Consider making users aware of the privileged roles via documentation.

SF-10
`ZCTokens` May Use More Decimals than Is Supported by Third-Party Applications

• **Informational** ⓘ   Fixed

> ✓ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `f533c161fa2ad8e1e120ae77ff4d8b8406e2087e`. The client provided the following explanation:
>
> > Fixed together with SF-2.

Description: Some `ZCTokens` are expected to have as many as 36 decimals. While this does not create any issues within Secured Finance, third-party applications, such as wallets, can have issues supporting tokens with too many decimals.

Note: This issue was raised by the client during the audit process.

Recommendation: Consider reducing the number of decimals used for `ZCTokens`.

SF-11
Semantical Mismatch Between Function's Name and Behavior

• **Informational** ⓘ   Fixed

> ✓ **Update**
>
> Marked as "Fixed" by the client. Addressed in: `466aec13fe018c088f1af5d971dd9ca5619e084b`.

File(s) affected: `LendingMarketController.sol`

Description: In the contract `LendingMarketController`, the modifier `ifValidMaturity()` contains the following line of code:

```
if (isValidMaturity(_ccy, _maturity)) revert InvalidMaturity();
```

This line is a contradiction but still works because the function `isValidMaturity()` returns `true` if the maturity does not exist, and false if the maturity does exist. As a result, this adds confusion for external readers of the code.

Recommendation: Consider removing the confusion from this portion of the code by aligning the name and the behavior of the function `isValidMaturity()`.

SF-12
Borrowing Users Increase Their Liquidation Risk when Minting `ZCTokens`

• **Informational** ⓘ   Acknowledged

File(s) affected: `LendingMarketUserLogic.sol`

Description: Users can become close to being liquidated if they have ZC bonds that are used as collateral and convert their maximum balance of the withdrawable amount. In this extreme case, a liquidation can happen in the next block if a slight update of the price happens.

Recommendation: Consider documenting this risk to end-users, and adding to the front end an option for users to use a security threshold between 0 and 100% to manually manage their risk of liquidation.

SF-13
Some Erc20 Tokens Do Not Support Transfers with Permission Signatures

● **Informational** ⓘ   `Acknowledged`

File(s) affected: `TokenVault.sol`

Description: The new version of the codebase brings two additional functions letting users deposit tokens to the contract using permission signatures (ERC2612). However, not all tokens support this feature. Worse, few ERC20 tokens such as WETH can offer a `fallback()` function that will lead to any attempt to execute the function `permit()` on this contract to silently fail (concept of phantom functions). Even if right now, no concrete impact was found since only `msg.sender` can originate a signature that will transfer tokens from its address, silent failures should be avoided.

Recommendation: Consider adding a whitelist of token addresses that support transfers with a permission signature, and only allow these tokens to be transferred by the functions `depositWithPermitTo()` and `depositWithPermitFrom()`.

SF-14   Dead Code

● **Informational** ⓘ   `Fixed`

Description: "Dead" code refers to code that is never executed and hence makes no impact on the final result of running a program. Dead code raises a concern, since either the code is unnecessary or the necessary code's results were ignored.

`_calculatePVFromFV()` is an overloaded function. One version takes two `uint256` as input and the other takes one `uint256` and one `int256`. The version that takes two `uint256` is not called.

Recommendation: Remove or refactor the abovementioned code statements.

Definitions

- **High severity** – High-severity issues usually put a large number of users' sensitive information at risk, or are reasonably likely to lead to catastrophic impact for client's reputation or serious financial implications for client and users.

- **Medium severity** – Medium-severity issues tend to put a subset of users' sensitive information at risk, would be detrimental for the client's reputation if exploited, or are reasonably likely to lead to moderate financial impact.

- **Low severity** – The risk is relatively small and could not be exploited on a recurring basis, or is a risk that the client has indicated is low impact in view of the client's business circumstances.

- **Informational** – The issue does not post an immediate risk, but is relevant to security best practices or Defence in Depth.

- **Undetermined** – The impact of the issue is uncertain.

- **Fixed** – Adjusted program implementation, requirements or constraints to eliminate the risk.

- **Mitigated** – Implemented actions to minimize the impact or likelihood of the risk.

- **Acknowledged** – The issue remains in the code but is a result of an intentional business or design decision. As such, it is supposed to be addressed outside the programmatic means, such as: 1) comments, documentation, README, FAQ; 2) business processes; 3) analyses showing that the issue shall have no negative consequences in practice (e.g., gas analysis, deployment settings).

Toolset

The notes below outline the setup and steps performed in the process of this audit.

Setup

Tool Setup:
- Slither ☒ v0.10.1

Steps taken to run the tools:
1. Install the Slither tool: `pip3 install slither-analyzer`
2. Run Slither from the project directory: `npm run security:slither`

Automated Analysis

Slither

Slither was used to get a static analysis of the repository. All the issues and recommendations are discussed in this report or classified as false positives.

Test Suite Results

The test suite has 1424 passing tests and 600 failing tests. The failing tests are a part of the auto-roll tests which iterate 800 times. The first 200 tests pass and then it fails on the 201st time. All subsequent calls fail. The test suite should be updated to ensure all tests are passing.

Fix Review: The test suite has been improved and now has 2044 passing tests.

```
> @secured-finance/contracts@1.1.0-beta.2 test
> DOTENV_CONFIG_PATH=.env.test hardhat test

Compiled 34 Solidity files successfully

  Integration Test: Auto-rolls
    Execute auto-roll with orders on the single market
      ✓ Fill an order
      ✓ Execute auto-roll (1st time)
      ✓ Execute auto-roll (2nd time)
    Execute auto-roll with orders on the multiple markets
      ✓ Fill an order on the closest maturity market
      ✓ Fill an order on the second closest maturity market
      ✓ Check total PVs
      ✓ Execute auto-roll
      ✓ Clean orders
    Execute auto-rolls with users who has open orders and filled orders.
      ✓ Fill an order
      ✓ Execute auto-roll
    Execute auto-rolls more times than the number of markets using the past auto-roll price
      ✓ Fill an order
      ✓ Execute auto-roll (1st time)
      ✓ Execute auto-roll (2nd time)
      ✓ Execute auto-roll (3rd time)
      ✓ Execute auto-roll (4th time)
      ✓ Execute auto-roll (5th time)
      ✓ Execute auto-roll (6th time)
      ✓ Execute auto-roll (7th time)
      ✓ Execute auto-roll (8th time)
      ✓ Execute auto-roll (9th time)
      ✓ Execute auto-roll (10th time)
    Execute auto-roll with many orders, Check the FV and GV
      ✓ Fill an order
      ✓ Check future values
      ✓ Execute auto-roll, Check genesis values
```

```
Execute auto-roll well past maturity
  ✓ Fill an order
  ✓ Advance time
  ✓ Fail to create an order due to market closure
  ✓ Execute auto-roll


Integration Test: Calculations
  Order Estimations
    Estimate a borrowing order result to be filled
      ✓ Deposit ETH
      ✓ Place a lending order on the ETH market
      ✓ Estimate a borrowing order result
    Estimate a lending order result to be filled
      ✓ Place a borrowing order on the ETH market
      ✓ Deposit ETH
      ✓ Estimate a lending order result
    Estimate a borrowing order result to be placed
      ✓ Deposit ETH
      ✓ Estimate a borrowing order result
    Estimate a borrowing order result to be placed with unit price less than min debt unit prices
      ✓ Deposit ETH
      ✓ Estimate a borrowing order result
    Estimate a lending order result to be placed
      ✓ Deposit ETH
      ✓ Estimate a lending order result
  Borrowable Amount Calculations
    Calculate the borrowable amount with deposit
      ✓ Deposit ETH
      ✓ Calculate the borrowable amount in ETH
      ✓ Calculate the borrowable amount in WFIL
    Calculate the borrowable amount with borrowing position (Haircut: 0)
      ✓ Deposit ETH
      ✓ Fill an order to get a borrowing position
      ✓ Calculate the borrowable amount in ETH(1)
      ✓ Calculate the borrowable amount in WFIL(1)
      ✓ Fill an order to partially use the borrowing position
      ✓ Calculate the borrowable amount in ETH(2)
      ✓ Calculate the borrowable amount in WFIL(2)
      ✓ Fill an order to use the whole borrowing position
      ✓ Calculate the borrowable amount in ETH(3)
      ✓ Calculate the borrowable amount in WFIL(3)
    Calculate the borrowable amount with borrowing position (Haircut: 5000)
      ✓ Deposit ETH
      ✓ Fill an order to get a borrowing position
      ✓ Calculate the borrowable amount in ETH(1)
      ✓ Calculate the borrowable amount in WFIL(1)
      ✓ Fill an order to partially use the borrowing position
      ✓ Calculate the borrowable amount in ETH(2)
      ✓ Calculate the borrowable amount in WFIL(2)
      ✓ Fill an order to use the whole borrowing position
      ✓ Calculate the borrowable amount in ETH(3)
      ✓ Calculate the borrowable amount in WFIL(3)
    Calculate the borrowable amount with borrowing position (Haircut: 9600)
      ✓ Deposit ETH
      ✓ Fill an order to get a borrowing position
      ✓ Calculate the borrowable amount in ETH(1)
      ✓ Calculate the borrowable amount in WFIL(1)
      ✓ Fill an order to partially use the borrowing position
      ✓ Calculate the borrowable amount in ETH(2)
      ✓ Calculate the borrowable amount in WFIL(2)
      ✓ Fill an order to use the whole borrowing position
      ✓ Calculate the borrowable amount in ETH(3)
      ✓ Calculate the borrowable amount in WFIL(3)
    Calculate the borrowable amount with deposit & borrowing position
      ✓ Deposit ETH
      ✓ Fill an order to get a borrowing position
      ✓ Calculate the borrowable amount in ETH
      ✓ Calculate the borrowable amount in WFIL


Integration Test: Deposit
  Deposit ETH, Withdraw all collateral
    ✓ Deposit ETH
```

      ✓ Withdraw all collateral
      ✓ Clean up funds
    Deposit WBTC, Withdraw all collateral
      ✓ Deposit WBTC
      ✓ Withdraw all collateral
      ✓ Clean up funds
    Deposit ETH twice, Withdraw all collateral
      ✓ Deposit ETH
      ✓ Withdraw partially
      ✓ Withdraw with over amount input
      ✓ Clean up funds
    Deposit multiple currency, Withdraw all collateral
      ✓ Deposit ETH (Non-ERC20 collateral currency)
      ✓ Deposit FIL (ERC20 non-collateral currency)
      ✓ Withdraw ETH with over amount input
      ✓ Clean up funds
      ✓ Deposit USDC (ERC20 collateral currency)
      ✓ Deposit WBTC (ERC20 collateral currency)
      ✓ Withdraw FIL (ERC20 non-collateral currency) with over amount input
      ✓ Clean up funds
    Deposit by multiple users
      ✓ Deposit FIL
      ✓ Withdraw by one user
      ✓ Withdraw from empty deposit
    Deposit by another user
      ✓ Deposit FIL
      ✓ Withdraw by caller
      ✓ Withdraw by the deposited user
    Deposit without prior approval
      ✓ Deposit USDC without prior approval
      ✓ Withdraw by one user
    Deposit new currency as collateral
      ✓ Register new currency as collateral
      ✓ Deposit TestToken
      ✓ Place an order
    Fill an borrowing order, Withdraw collateral
      ✓ Fill an order(WBTC)
      ✓ Fill an order(WFIL)
      ✓ Withdraw by borrower
      ✓ Withdraw by lender(empty deposit)
    Fill an lending order, Withdraw collateral
      ✓ Fill an order
      ✓ Withdraw by borrower
      ✓ Withdraw by lender(empty deposit)
    Fill orders on multiple markets, Withdraw collateral
      ✓ Fill an order on the FIL market
      ✓ Fill an order on the ETH market
      ✓ Withdraw by Alice
    Place orders, Withdraw collateral
      ✓ Deposit ETH
      ✓ Place orders
      ✓ Check withdrawable amount
      ✓ Withdraw ETH
    Withdraw non-collateral currencies while a active lending order exists
      ✓ Place lending orders for non-collateral currencies, WFIL and WBTC
      ✓ Withdraw all WFIL and WBTC deposit of bob and get deposit amount again
    Deposit and withdraw wFIL using MixinWallet
      ✓ Deposit wFIL on ReserveFund contract
      ✓ Withdraw all wFIL deposit on ReserveFund contract
      ✓ Deposit wFIL on ReserveFund contract using wallet transactions
      ✓ Withdraw all wFIL deposit on ReserveFund contract using wallet transaction
      ✓ Deposit wFIL on Liquidator contract
      ✓ Withdraw all wFIL deposit on Liquidator contract
      ✓ Deposit wFIL on Liquidator contract using wallet transactions
      ✓ Withdraw all wFIL deposit on liquidator contract using wallet transaction
    Fill an orders under min debt unit price, Withdraw collateral
      ✓ Fill an order with amount with over the min debt unit price
      ✓ Fill an order with amount with under the min debt unit price
      ✓ Check the withdrawable collateral amount of borrower
      ✓ Withdraw by borrower

  Integration Test: Emergency terminations

```
    Execute emergency termination & redemption
      Including only healthy users
        ✓ Fill an order on the ETH market with depositing ETH
        ✓ Fill an order on the FIL market with depositing USDC
        ✓ Execute emergency termination
        ✓ Execute forced redemption
        ✓ Withdraw all collateral
      Including an auto-rolled position
        ✓ Fill an order on the ETH market with depositing ETH
        ✓ Execute auto-roll
        ✓ Execute emergency termination
        ✓ Execute forced redemption
      Including a liquidation user
        ✓ Fill an order on the ETH market with depositing ETH
        ✓ Fill an order on the FIL market with depositing USDC
        ✓ Update a price feed to change the wFIL price
        ✓ Execute emergency termination
        ✓ Execute forced redemption
      Including an insolvent user
        ✓ Fill an order on the ETH market with depositing ETH
        ✓ Fill an order on the FIL market with depositing USDC
        ✓ Fill an order for a huge amount to store fees in the reserve funds
        ✓ Update a price feed to change the wFIL price
        ✓ Execute emergency termination
        ✓ Execute forced redemption
        ✓ Withdraw all collateral

  Integration Test: Itayose (ERC20)
    Execute Itayose including pre-orders without prior approval
      ✓ Fill an order
      ✓ Crate pre-orders without prior approval
      ✓ Execute auto-roll
      ✓ Check the expected result before Itayose execution
      ✓ Execute Itayose with pre-order

  Integration Test: Itayose
    Execute Itayose on the single market without pre-order
      ✓ Fill an order
      ✓ Execute auto-roll
      ✓ Check the expected result before Itayose execution
      ✓ Execute Itayose without pre-order
    Execute Itayose with pre-order
      ✓ Fill an order
      ✓ Crate pre-orders
      ✓ Execute auto-roll
      ✓ Check the expected result before Itayose execution
      ✓ Execute Itayose with pre-order
    Execute Itayose with pre-order and execute clearing order process
      ✓ Crate pre-orders
      ✓ Check if clearing order process takes the opening price into accounts
    Execute Itayose with pre-order in same amount and execute clearing order process
      ✓ Crate pre-orders
      ✓ Check if clearing order process takes the opening price into accounts

  Integration Test: Liquidations
    Liquidations on FIL(non-collateral currency) market by ETH
      Increase FIL exchange rate, Execute liquidation once, Manage reserve funds
        ✓ Create orders
        ✓ Withdraw
```
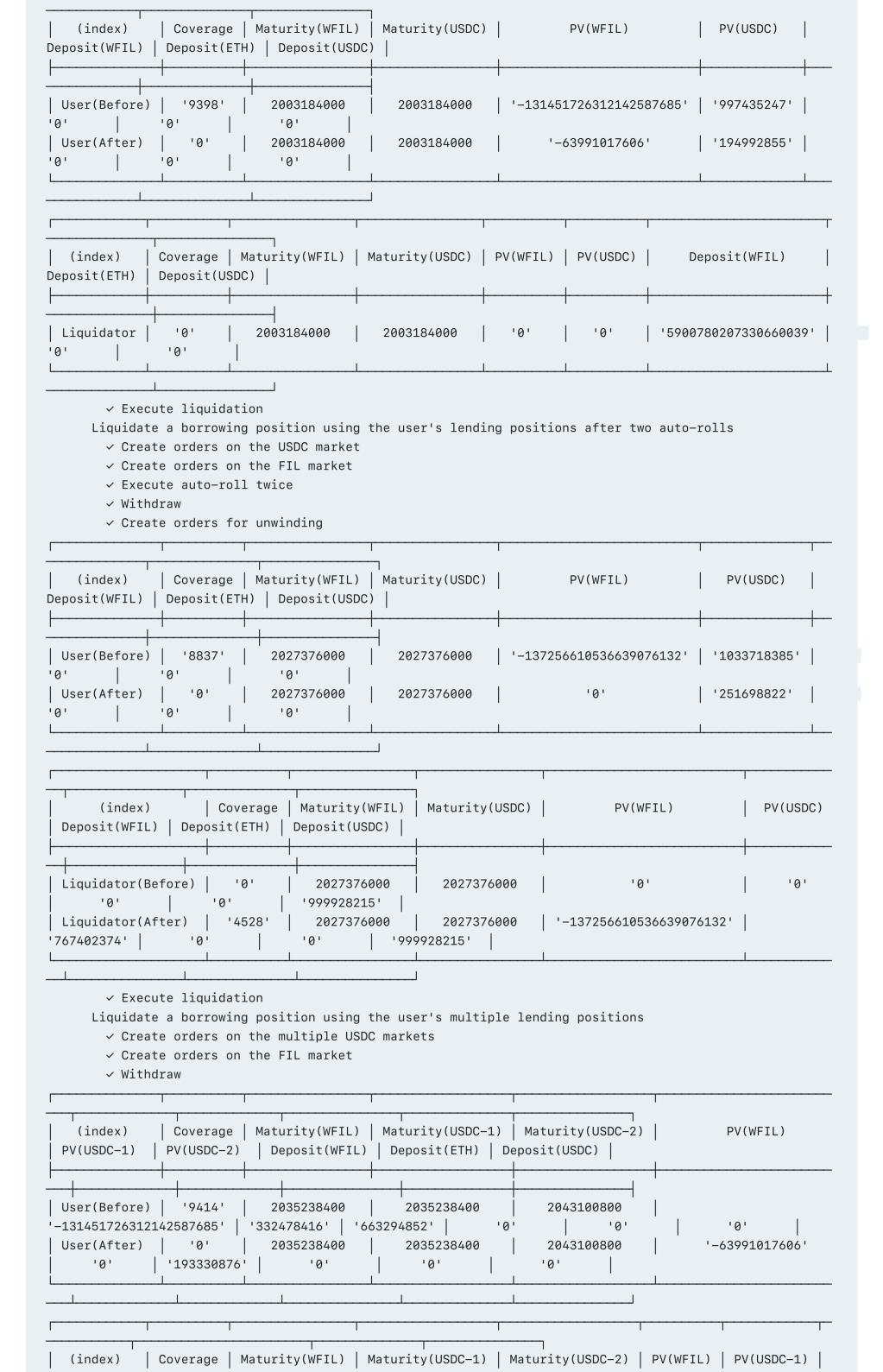
(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'8368'	1948147200	'-2000000000000000000000'	'0'	'1000000000000000000'	'0'
After	'7575'	1948147200	'-9999999999999999999'	'0'	'552307134710000000'	'0'

```
        ✓ Execute liquidation
```

Increase FIL exchange rate, Execute full liquidation
    ✓ Create orders
    ✓ Withdraw

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'8748'	1956009600	'-200000000000000000000'	'0'	'1000000000000000000'	'0'
After	'0'	1956009600	'0'	'0'	'63914918030000000'	'0'

    ✓ Execute full liquidation
  Execute auto-roll a borrowing position, Execute liquidation after auto-roll
    ✓ Create orders
    ✓ Withdraw
    ✓ Execute auto-roll

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'8340'	1971734400	'-219273561643835616511'	'0'	'1000000000000000000'	'0'
After	'7530'	1971734400	'-109636780822474227243'	'0'	'553785413208300000'	'0'

    ✓ Execute liquidation
  Liquidate partially due to insufficient collateral
    ✓ Create orders
    ✓ Withdraw

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'22822'	1979596800	'-200000000000000000000'	'0'	'1000000000000000000'	'0'
After	'115792089237316195423570985008687907853269984665640564039457584007913129639935'	1979596800	'-106545413228416482157'	'0'	'0'	'0'

    ✓ Execute liquidation
    ✓ Withdraw funds on Liquidator contract
  Liquidate partially due to insufficient collateral without the reserve fund after auto-roll
    ✓ Create orders
    ✓ Withdraw
    ✓ Execute auto-roll

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'23825'	1995321600	'-208936073059360073092'	'0'	'1000000000000000000'	'0'
After	'115792089237316195423570985008687907853269984665640564039457584007913129639935'	1995321600	'-125332193774416969805'	'0'	'0'	'0'

    ✓ Execute liquidation
  Liquidate a borrowing position using the user's deposits and lending positions
    ✓ Create orders on the USDC market
    ✓ Create orders on the FIL market
    ✓ Withdraw

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
User(Before)	'9398'	2003184000	2003184000	'-13145172631214 2587685'	'997435247'	'0'	'0'	'0'
User(After)	'0'	2003184000	2003184000	'-63991017606'	'194992855'	'0'	'0'	'0'

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Liquidator	'0'	2003184000	2003184000	'0'	'0'	'5900780207330660039'	'0'	'0'

    ✓ Execute liquidation
   Liquidate a borrowing position using the user's lending positions after two auto-rolls
    ✓ Create orders on the USDC market
    ✓ Create orders on the FIL market
    ✓ Execute auto-roll twice
    ✓ Withdraw
    ✓ Create orders for unwinding

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
User(Before)	'8837'	2027376000	2027376000	'-13725661053666390 76132'	'1033718385'	'0'	'0'	'0'
User(After)	'0'	2027376000	2027376000	'0'	'251698822'	'0'	'0'	'0'

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Liquidator(Before)	'0'	2027376000	2027376000	'0'	'0'	'0'	'0'	'999928215'
Liquidator(After)	'4528'	2027376000	2027376000	'-1372566105366390 76132'	'767402374'	'0'	'0'	'999928215'

    ✓ Execute liquidation
   Liquidate a borrowing position using the user's multiple lending positions
    ✓ Create orders on the multiple USDC markets
    ✓ Create orders on the FIL market
    ✓ Withdraw

(index)	Coverage	Maturity(WFIL)	Maturity(USDC-1)	Maturity(USDC-2)	PV(WFIL)	PV(USDC-1)	PV(USDC-2)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
User(Before)	'9414'	2035238400	2035238400	2043100800	'-13145172631214 2587685'	'332478416'	'663294852'	'0'	'0'	'0'
User(After)	'0'	2035238400	2035238400	2043100800	'-63991017606'	'0'	'193330876'	'0'	'0'	'0'

(index)	Coverage	Maturity(WFIL)	Maturity(USDC-1)	Maturity(USDC-2)	PV(WFIL)	PV(USDC-1)	

PV(USDC-2)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)

| Liquidator | '0' | 2035238400 | 2035238400 | 2043100800 | '0' | '0' | '0' | '5703437537353127956' | '0' | '0' |

      ✓ Execute liquidation
    Liquidates a borrowing position of users with open orders in the currency used for collateral
      ✓ Create a lending order on the USDC market
      ✓ Create orders on the FIL market
      ✓ Execute liquidation

(index)	Coverage		Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
User(Before)	'20000'		2050963200	'-262903452624285175371'	'262903452624285175371'	'0'	'1999856430'
User(After)	'115792089237316195423570985008687907853269984665640564039457584007913129639935'		2050963200	'-88118373118276409783'	'262903452624285175371'	'0'	'0'
User(After2)	'26813'		2050963200	'-88118373118276409783'	'262903452624285175371'	'0'	'499964107'

      ✓ Cancel an order
    Liquidations on multiple market

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before1	'7775'	2066688000	2066688000	'-2000000000000000000000'	'-600000000'	'0'	'1750000000000000000'	'0'
Before2	'8210'	2066688000	2066688000	'-2000000000000000000000'	'-600000000'	'0'	'1750000000000000000'	'0'
After	'7321'	2066688000	2066688000	'-28293910964595707418'	'-600000000'	'0'	'981284090120000000'	'0'

      ✓ Take orders from both FIL & USDC markets, Liquidate the larger position

(index)	Coverage	Maturity(WFIL)	Maturity(USDC)	PV(WFIL)	PV(USDC)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before1	'7775'	2074550400	2074550400	'-2000000000000000000000'	'-600000000'	'0'	'1750000000000000000'	'0'
Before2	'8210'	2074550400	2074550400	'-2000000000000000000000'	'-600000000'	'0'	'1750000000000000000'	'0'
After	'7552'	2074550400	2074550400	'-2000000000000000000000'	'0'	'0'	'1107953910820000000'	'0'

      ✓ Take orders from both FIL & USDC markets, Liquidate the smaller position
    Delisting
    Repay and redeem positions
      ✓ Create orders
      ✓ Delist a currency

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'3803'	2082412800	'-2000000000000000000000'	'2000000000000000000000'	'2000000000000000000'	'0'
After	'0'	2082412800	'0'	'0'	'2000000000000000000'	'0'

```
              └───────────┴───────────┴───────────┘
       ✓ Execute repayment & redemption
     Force a repayment of a borrowing position
         ✓ Create orders
         ✓ Withdraw
```

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'3803'	2090275200	'-2000000000000000000000'	'0'	'2000000000000000000'	'0'
After	'0'	2090275200	'0'	'0'	'1152096846041666667'	'0'

```
       ✓ Execute forced repayment
     Force a repayment of a insolvent borrowing position
         ✓ Create orders
         ✓ Withdraw
```

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'11411'	2098137600	'-2000000000000000000000'	'0'	'2000000000000000000'	'0'
After	'115792089237316195423570985008687907853269984665640564039457584007913129639935'	2098137600	'-39754086019483321679'	'0'	'0'	'0'

```
       ✓ Execute forced repayment
     Force a repayment of a borrowing position after auto-roll
         ✓ Create orders
         ✓ Withdraw
         ✓ Execute auto-roll
```

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'3574'	2113862400	'-1879487767123287671216'	'0'	'2000000000000000000'	'0'
After	'0'	2113862400	'0'	'0'	'1203188237867920378'	'0'

```
       ✓ Execute forced repayment
     Force a repayment of a insolvent borrowing position after auto-roll
         ✓ Create orders
         ✓ Withdraw
         ✓ Execute auto-roll
```

(index)	Coverage	Maturity(WFIL)	PV(WFIL)	Deposit(WFIL)	Deposit(ETH)	Deposit(USDC)
Before	'11914'	2129587200	'-2088319634703319634690'	'0'	'2000000000000000000'	'0'
After	'115792089237316195423570985008687907853269984665640564039457584007913129639935'	2129587200	'-48586049489802956384'	'0'	'0'	'0'

```
       ✓ Execute forced repayment

  Integration Test: Order Book
    Market orders
```

Add orders using the same currency as the collateral, Fill the order, Unwind the ETH borrowing
order
        ✓ Create orders
        ✓ Deposit ETH
        ✓ Fill an order on the ETH market
        ✓ Check collateral
        ✓ Unwind all positions
    Add orders using the different currency as the collateral, Fill the order, Unwind the non-ETH
borrowing order
        ✓ Deposit ETH
        ✓ Fill an order on the FIL market
        ✓ Check collateral
        ✓ Unwind all positions
    Fill the order, Unwind the lending order
        ✓ Deposit ETH
        ✓ Fill an order on the FIL market
        ✓ Check lending position
        ✓ Unwind a lending position
    Fill orders in multiple markets, Unwind partially
        ✓ Deposit ETH
        ✓ Fill an order on the FIL market
        ✓ Fill an order on the ETH market
        ✓ Check collateral
        ✓ Unwind positions partially
    Fill multiple orders on different order sides in multiple markets
        ✓ Deposit ETH
        ✓ Fill an order on the ETH market(1)
        ✓ Fill an order on the ETH market(2)
    Fill orders, Trigger circuit breakers by one order
        ✓ Fill an order to determine the market unit price
        ✓ Deposit ETH
        ✓ Fill orders on the FIL market
    Fill orders, Trigger circuit breakers by multiple orders
        ✓ Deposit ETH
        ✓ Fill an order to determine the market unit price
        ✓ Fill orders on the FIL market
    Unwind lending position used as collateral
        ✓ Deposit ETH
        ✓ Fill an order on the FIL market(1)
        ✓ Fill an order on the FIL market(2)
        ✓ Fail to unwind positions due to insufficient collateral
    Fill orders without prior approval
        ✓ Deposit ETH
        ✓ Fill an order without prior approval
    Fail to execute order due to not enough deposit
        ✓ Fail to execute order due to no deposit in the selected currency
        ✓ Deposit ETH
        ✓ Fail to execute order due to double spend
  Limit orders
    Fill a borrowing order with the same amount
        ✓ Create users
        ✓ Fill an order
        ✓ Check orders
    Fill a borrowing order with less amount
        ✓ Create users
        ✓ Fill an order
        ✓ Check orders
    Fill a borrowing order with greater amount
        ✓ Create users
        ✓ Fill an order
        ✓ Check orders
    Fill a lending order with the same amount
        ✓ Create users
        ✓ Fill an order
        ✓ Check orders
    Fill a lending order with less amount
        ✓ Create users
        ✓ Fill an order
        ✓ Check orders
    Fill a lending order with greater amount
        ✓ Create users
        ✓ Fill an order

```
                    ✓ Check orders
        Order Cancellation
          Place a borrowing order, Cancel orders
            ✓ Deposit ETH
            ✓ Place a borrowing order on the FIL market
            ✓ Cancel an order
          Place a lending order by a user who has a deposit, Cancel orders
            ✓ Deposit ETH
            ✓ Place a lending order on the FIL market
            ✓ Cancel an order


  Integration Test: Tokenization
    Settings
      ✓ Check ZC token info of ETH
      ✓ Check ZC perpetual token info of ETH
      ✓ Check ZC token info of USDC
      ✓ Check ZC perpetual token info of USDC
    Deposit and Withdraw(ETH)
      Withdraw and deposit ZC tokens by the same user
        ✓ Fill an order
        ✓ Withdraw ZC token
        ✓ Deposit ZC token
      Withdraw and deposit ZC tokens by the different user
        ✓ Fill an order
        ✓ Withdraw ZC token
        ✓ Transfer ZC token
        ✓ Deposit ZC token
      Withdraw and deposit ZC perpetual tokens by the same user
        ✓ Fill an order
        ✓ Execute auto roll
        ✓ Withdraw ZC perpetual token
        ✓ Deposit ZC perpetual token
      Withdraw and deposit ZC perpetual tokens by the different user
        ✓ Fill an order
        ✓ Execute auto roll
        ✓ Withdraw ZC perpetual token
        ✓ Transfer ZC perpetual token
        ✓ Deposit ZC perpetual token
      Deposit ZC tokens after maturity date
        ✓ Fill an order
        ✓ Withdraw ZC token
        ✓ Execute auto roll
        ✓ Deposit ZC token
        ✓ Withdraw ZC token
      Withdraw ZC tokens with deposits after using as collateral
        ✓ Fill an order
        ✓ Fill an order using ZC bonds
        ✓ Withdraw ZC token
      Withdraw ZC tokens with additional deposits after using as collateral
        ✓ Fill an order
        ✓ Fill an order using ZC bonds
        ✓ Deposit additional collateral
        ✓ Withdraw ZC token
      Withdraw ZC tokens without deposits after using as collateral
        ✓ Fill an order
        ✓ Fill an order using ZC bonds
        ✓ Withdraw borrowed collateral
        ✓ Withdraw ZC token
      Deposit ZC tokens after the emergency termination
        ✓ Fill an order
        ✓ Withdraw ZC token
        ✓ Execute emergency termination
        ✓ Deposit ZC token
        ✓ Fail to withdraw ZC token
        ✓ Execute forced redemption
    Deposit and Withdraw(USDC)
      Withdraw and deposit ZC tokens by the same user
        ✓ Fill an order
        ✓ Withdraw ZC token
        ✓ Deposit ZC token
      Withdraw and deposit ZC perpetual tokens by the same user
        ✓ Fill an order
```

✓ Execute auto roll
✓ Withdraw ZC perpetual token
✓ Deposit ZC perpetual token

Performance Test: Auto-rolls
  Execute auto-rolls for 200 years
    ✓ Fill an order
    ✓ Execute auto-roll (1st time)
    ✓ Execute auto-roll (2nd time)
    ✓ Execute auto-roll (3rd time)
    ✓ Execute auto-roll (4th time)
    ✓ Execute auto-roll (5th time)
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✓ Execute auto-roll (757th time)
✓ Execute auto-roll (758th time)
✓ Execute auto-roll (759th time)
✓ Execute auto-roll (760th time)
✓ Execute auto-roll (761st time)
✓ Execute auto-roll (762nd time)
✓ Execute auto-roll (763rd time)
✓ Execute auto-roll (764th time)
✓ Execute auto-roll (765th time)
✓ Execute auto-roll (766th time)
✓ Execute auto-roll (767th time)
✓ Execute auto-roll (768th time)
✓ Execute auto-roll (769th time)
✓ Execute auto-roll (770th time)
✓ Execute auto-roll (771st time)
✓ Execute auto-roll (772nd time)
✓ Execute auto-roll (773rd time)
✓ Execute auto-roll (774th time)
✓ Execute auto-roll (775th time)
✓ Execute auto-roll (776th time)
✓ Execute auto-roll (777th time)
✓ Execute auto-roll (778th time)
✓ Execute auto-roll (779th time)
✓ Execute auto-roll (780th time)
✓ Execute auto-roll (781st time)
✓ Execute auto-roll (782nd time)
✓ Execute auto-roll (783rd time)
✓ Execute auto-roll (784th time)
✓ Execute auto-roll (785th time)
```

```
        ✓ Execute auto-roll (786th time)
        ✓ Execute auto-roll (787th time)
        ✓ Execute auto-roll (788th time)
        ✓ Execute auto-roll (789th time)
        ✓ Execute auto-roll (790th time)
        ✓ Execute auto-roll (791st time)
        ✓ Execute auto-roll (792nd time)
        ✓ Execute auto-roll (793rd time)
        ✓ Execute auto-roll (794th time)
        ✓ Execute auto-roll (795th time)
        ✓ Execute auto-roll (796th time)
        ✓ Execute auto-roll (797th time)
        ✓ Execute auto-roll (798th time)
        ✓ Execute auto-roll (799th time)
        ✓ Execute auto-roll (800th time)
      ✓ Check the orders
      ✓ Clean up orders
      ✓ Fill an order

  Performance Test: Order Book
    Fill orders without the order cleaning
      ETH market
        Ordered: 0
[K        Ordered: 0/1
[K        ✓ 1 orders
        Ordered: 0
[K        Ordered: 0/10
[K        Ordered: 1/10
[K        Ordered: 2/10
[K        Ordered: 3/10
[K        Ordered: 4/10
[K        Ordered: 5/10
[K        Ordered: 6/10
[K        Ordered: 7/10
[K        Ordered: 8/10
[K        Ordered: 9/10
[K        ✓ 10 orders
        Ordered: 0
[K        Ordered: 0/100
[K        Ordered: 1/100
[K        Ordered: 2/100
[K        Ordered: 3/100
[K        Ordered: 4/100
[K        Ordered: 5/100
[K        Ordered: 6/100
[K        Ordered: 7/100
[K        Ordered: 8/100
[K        Ordered: 9/100
[K        Ordered: 10/100
[K        Ordered: 11/100
[K        Ordered: 12/100
[K        Ordered: 13/100
[K        Ordered: 14/100
[K        Ordered: 15/100
[K        Ordered: 16/100
[K        Ordered: 17/100
[K        Ordered: 18/100
[K        Ordered: 19/100
[K        Ordered: 20/100
[K        Ordered: 21/100
[K        Ordered: 22/100
[K        Ordered: 23/100
[K        Ordered: 24/100
[K        Ordered: 25/100
[K        Ordered: 26/100
[K        Ordered: 27/100
[K        Ordered: 28/100
[K        Ordered: 29/100
[K        Ordered: 30/100
[K        Ordered: 31/100
[K        Ordered: 32/100
[K        Ordered: 33/100
```

```
[K         Ordered: 34/100
[K         Ordered: 35/100
[K         Ordered: 36/100
[K         Ordered: 37/100
[K         Ordered: 38/100
[K         Ordered: 39/100
[K         Ordered: 40/100
[K         Ordered: 41/100
[K         Ordered: 42/100
[K         Ordered: 43/100
[K         Ordered: 44/100
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[K         Ordered: 91/100
[K         Ordered: 92/100
[K         Ordered: 93/100
[K         Ordered: 94/100
[K         Ordered: 95/100
[K         Ordered: 96/100
[K         Ordered: 97/100
[K         Ordered: 98/100
[K         Ordered: 99/100
[K         ✓ 100 orders
      USDC market
        Ordered: 0
[K         Ordered: 0/1
[K         ✓ 1 orders
        Ordered: 0
```

```
[K        Ordered: 0/10
[K        Ordered: 1/10
[K        Ordered: 2/10
[K        Ordered: 3/10
[K        Ordered: 4/10
[K        Ordered: 5/10
[K        Ordered: 6/10
[K        Ordered: 7/10
[K        Ordered: 8/10
[K        Ordered: 9/10
[K        ✓ 10 orders
       Ordered: 0
[K        Ordered: 0/100
[K        Ordered: 1/100
[K        Ordered: 2/100
[K        Ordered: 3/100
[K        Ordered: 4/100
[K        Ordered: 5/100
[K        Ordered: 6/100
[K        Ordered: 7/100
[K        Ordered: 8/100
[K        Ordered: 9/100
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[K        Ordered: 51/100
[K        Ordered: 52/100
[K        Ordered: 53/100
[K        Ordered: 54/100
[K        Ordered: 55/100
[K        Ordered: 56/100
[K        Ordered: 57/100
[K        Ordered: 58/100
[K        Ordered: 59/100
```

```
[K        Ordered: 60/100
[K        Ordered: 61/100
[K        Ordered: 62/100
[K        Ordered: 63/100
[K        Ordered: 64/100
[K        Ordered: 65/100
[K        Ordered: 66/100
[K        Ordered: 67/100
[K        Ordered: 68/100
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[K        Ordered: 90/100
[K        Ordered: 91/100
[K        Ordered: 92/100
[K        Ordered: 93/100
[K        Ordered: 94/100
[K        Ordered: 95/100
[K        Ordered: 96/100
[K        Ordered: 97/100
[K        Ordered: 98/100
[K        Ordered: 99/100
[K        ✓ 100 orders
      Show results
```

(index)	GasCosts(ETH)	GasCosts(USDC)
1	854025	951688
10	539392	670265
100	1487429	1614031

```
        ✓ Gas Costs
    Place an order with the order cleaning
      USDC market
        Ordered: 0
[K        Ordered: 0/1
[K        ✓ 1 markets
        Ordered: 0
[K        Ordered: 0/2
[K        Ordered: 1/2
[K        ✓ 2 markets
        Ordered: 0
[K        Ordered: 0/8
[K        Ordered: 1/8
[K        Ordered: 2/8
[K        Ordered: 3/8
[K        Ordered: 4/8
[K        Ordered: 5/8
[K        Ordered: 6/8
[K        Ordered: 7/8
[K        ✓ 8 markets
      Show results
```

(index)	GasCosts

1	526210
2	692385
8	852112

      ✓ Gas Costs
   Place an order with active orders
    USDC market
     ✓ Deposit
     ✓ Active orders: 0
     ✓ Active orders: 1
     ✓ Active orders: 2
     ✓ Active orders: 3
     ✓ Active orders: 4
     ✓ Active orders: 5
     ✓ Active orders: 6
     ✓ Active orders: 7
     ✓ Active orders: 8
     ✓ Active orders: 9
     ✓ Active orders: 10
     ✓ Active orders: 11
     ✓ Active orders: 12
     ✓ Active orders: 13
     ✓ Active orders: 14
     ✓ Active orders: 15
     ✓ Active orders: 16
     ✓ Active orders: 17
     ✓ Active orders: 18
     ✓ Active orders: 19
    Show results

(index)	GasCosts(USDC)
0	793440
1	611658
2	702897
3	669726
4	732100
5	739975
6	788125
7	823340
8	838254
9	839309
10	912532
11	914224
12	949622
13	952597
14	1014394
15	1050281
16	1074832
17	1122170
18	1125787
19	1140967

      ✓ Gas Costs

  AddressResolver
   Ownership
    ✓ Transfer ownership
    ✓ Renounce ownership
    ✓ Fail to renounce ownership due to execution by non-owner
    ✓ Fail to transfer ownership due execution by non-owner
    ✓ Fail to transfer ownership due to zero address
   Initialization
    ✓ Fail to call initialization due to duplicate execution
    ✓ Fail to call initialization due to execution by non-proxy contract
   Address importing
    ✓ Import empty array
    ✓ Import an address
    ✓ Import multiple addresses
    ✓ Import an addresses multiple times with different contract
    ✓ Fail to import an addresses due to unmatched inputs

      ✓ Fail to import an addresses due to execution by non-owner
    Imported address check
      ✓ Get an empty address
      ✓ Get a imported address
      ✓ Get multiple imported addresses
      ✓ Fail to get a imported address due to non-exist contract

  BeaconProxyController
    Initialization
      ✓ Check if the contract addresses are cached in the resolver
      ✓ Fail to call initialization due to duplicate execution
      ✓ Fail to call initialization due to execution by non-proxy contract
    Get data
      ✓ Get the required contracts
      ✓ Fail to get the beacon proxy address due to empty address
    FutureValueVault implementation
      ✓ Set an implementation contract and deploy the contract
      ✓ Set an implementation contract twice
      ✓ Fail to set an implementation contract due to execution by non-owner
      ✓ Fail to deploy the contract due to execution by non-accepted contract
      ✓ Fail to deploy the contract due to non-existence of beacon proxy contract
    LendingMarket implementation
      ✓ Set an implementation contract and deploy the contract
      ✓ Set an implementation contract twice
      ✓ Fail to set an implementation contract due to execution by non-owner
      ✓ Fail to deploy the contract due to execution by non-accepted contract
      ✓ Fail to deploy the contract due to non-existence of beacon proxy contract
    Change Admin
      ✓ Successfully change admins of a beacon proxy contract
      ✓ Fail to change admins of a beacon proxy contract due to execution by non-owner

  CurrencyController
    Initialization
      ✓ Add a currency except for ETH as a supported currency
      ✓ Fail to add a currency due to the invalid price
      ✓ Fail to add a currency due to the invalid decimals
      ✓ Fail to add a currency due to the mismatch of price feeds decimals with the base currency
      ✓ Fail to add a currency due to empty price feed
      ✓ Fail to add a currency due to input array length mismatch
      ✓ Fail to add a currency due to execution by non-owner
      ✓ Fail to call initialization due to duplicate execution
      ✓ Fail to call initialization due to execution by non-proxy contract
    Update
      ✓ Update a currency support
      ✓ Update a haircut
      ✓ Update a price feed
      ✓ Update multiple price feeds
      ✓ Update multiple data using multicall
      ✓ Fail to update the haircut due to overflow
      ✓ Fail to update the haircut due to invalid currency
      ✓ Fail to update the price feed due to invalid currency
      ✓ Fail to update the price feed due to input array length mismatch
      ✓ Fail to remove the currency due to execution by non-owner
      ✓ Fail to update the haircut due to execution by non-owner
      ✓ Fail to update the price feed due to execution by non-owner
      ✓ Fail to update the price feed due to stale price feed with old timestamp
      ✓ Fail to update the price feed due to stale price feed with zero price
    Convert
      ✓ Get the converted amount(int256) in the base currency
      ✓ Get the converted amount(uint256) in the base currency
      ✓ Get the array of converted amounts(uint256[]) in the base currency
      ✓ Get the converted amount(uint256) in the selected currency
      ✓ Get the converted amount(uint256) in the selected currency
      ✓ Get the converted amount in the selected currency from another selected currency
      ✓ Get the converted amounts in the selected currency from another selected currency
      ✓ Get the converted amounts in the selected currency from another selected currency from 0
      ✓ Fail to get the converted amount due to stale price feed with old timestamp
      ✓ Fail to get the converted amount due to stale price feed with zero price

  FutureValueVault
    Initialization
      ✓ Fail to call initialization due to duplicate execution

✓ Fail to call initialization due to execution by non-beacon proxy contract
    Update balance
        ✓ Increase user balance
        ✓ Decrease user balance
        ✓ Fail to increase balance due to execution by non-accepted contract
        ✓ Fail to decrease balance due to execution by non-accepted contract
        ✓ Fail to increase balance due to invalid user address
        ✓ Fail to decrease balance due to invalid user address
    Lock and unlock balance
        ✓ Lock user balance
        ✓ Unlock user balance
        ✓ Fail to lock user balance if balance is minus
        ✓ Fail to lock user balance if balance is 0
        ✓ Fail to unlock user balance if total unlock balance is insufficient
        ✓ Fail to lock balance due to execution by non-accepted contract
        ✓ Fail to unlock balance due to execution by non-accepted contract
    Transfer balance
        ✓ Transfer balance to another user
        ✓ Fail to transfer balance because sender has balance in the past maturity
        ✓ Fail to transfer balance because receiver has balance in the past maturity
        ✓ Fail to transfer balance due to execution by non-accepted contract
    Reset balance
        ✓ Force reset a user's empty balance with amount
        ✓ Force reset a user's balance with amount
        ✓ Force reset a user's empty balance without amount
        ✓ Force reset a user's balance with amount
        ✓ Fail to force reset a user's balance due to lending amount mismatch
        ✓ Fail to force reset a user's balance due to borrowing amount mismatch
        ✓ Fail to force reset a user's balance with amount due to execution by non-accepted contract
        ✓ Fail to force reset a user's balance without amount due to execution by non-accepted contract

GenesisValueVault
    Initialize
        ✓ Initialize contract settings
        ✓ Fail to call initialization due to duplicate execution
        ✓ Fail to call initialization due to execution by non-proxy contract
        ✓ Fail to initialize the currency setting due to execution by non-accepted contract
        ✓ Fail to update the initial compound factor due to execution by non-accepted contract
        ✓ Fail to initialize the currency setting due to zero compound factor
        ✓ Fail to initialize the currency setting due to the initialized
        ✓ Fail to update the initial compound factor due to the finalized
    Balance
        Calculate balance
            ✓ Convert balance to selected maturity from another maturity
            ✓ Convert 0 to selected maturity from another maturity
            ✓ Convert balance to selected maturity from same maturity
            ✓ Calculate amount in FV from positive amount in GV
            ✓ Calculate amount in FV from negative amount in GV
            ✓ Fail to calculate amount in FV from amount in GV due to no compound factor
            ✓ Fail to calculate amount in GV from amount in FV due to no compound factor
        Update balance
            ✓ Update the genesis value
            ✓ Update the genesis value after auto-rolls
            ✓ Update the genesis value with residual amount
            ✓ Update the genesis value from a positive amount to a negative amount
            ✓ Update the genesis value from a negative amount to a positive amount
            ✓ Fail to update the genesis value due to execution by non-accepted contract
            ✓ Fail to update the genesis value with residual amount due to execution by non-accepted contract
        Lock and unlock balance
            ✓ Lock user balance
            ✓ Unlock user balance
            ✓ Fail to lock user balance if balance is minus
            ✓ Fail to lock user balance if balance is 0
            ✓ Fail to unlock user balance if if total unlock balance is insufficient
            ✓ Fail to lock user balance due to execution by non-accepted contract
            ✓ Fail to unlock user balance due to execution by non-accepted contract
        Transfer balance
            ✓ Transfer balance to another user
            ✓ Fail to transfer balance to another user due to execution by non-accepted contract
        Reset balance
            ✓ Force reset a user's empty balance with amount
            ✓ Force reset a user's empty balance with small amount

       ✓ Force reset a user's empty balance without amount
       ✓ Fail to force reset a user's balance due to lending amount mismatch
       ✓ Fail to force reset a user's balance due to borrowing amount mismatch
       ✓ Fail to force reset a user's balance without amount due to execution by non-accepted contract
       ✓ Fail to force reset a user's balance with amount due to execution by non-accepted contract
    Clean up balance
       ✓ Clean up a user balance
       ✓ Clean up a user balance with fluctuation
       ✓ Fail to clean up a user balance due to execution by non-accepted contract
  Auto-roll
    ✓ Execute auto-roll
    ✓ Calculate the balance fluctuation of auto-rolls by on the current maturity
    ✓ Calculate the balance fluctuation of auto-rolls by on the future maturity
    ✓ Calculate the balance fluctuation of auto-rolls by on the past maturity
    ✓ Calculate the balance fluctuation of auto-rolls with invalid maturity
    ✓ Fail to execute auto-roll due to duplicate execution
    ✓ Fail to execute auto-roll due to execution by non-accepted contract
    ✓ Fail to execute auto-roll due to invalid order fee rate
    ✓ Fail to execute auto-roll due to zero unit price
    ✓ Fail to execute auto-roll due to invalid maturity

LendingMarket − Auto-rolls
  ✓ Execute an auto-roll
  ✓ Fail to execute an auto-roll due to invalid caller
  ✓ Fail to execute an auto-roll due to invalid caller

LendingMarket − Calculations
  ✓ Calculate the filled amount from one lending order
  ✓ Calculate the filled amount from one borrowing order
  ✓ Calculate the filled amount from multiple lending order
  ✓ Calculate the filled amount from multiple borrowing order
  ✓ Calculate the blocked order amount by the circuit breaker

LendingMarket − Circuit Breakers
  Get circuit breaker thresholds
    ✓ Get circuit breaker thresholds without the last block price
    ✓ Get circuit breaker thresholds with the last block price
  Borrow orders
    ✓ Fill an order partially until the circuit breaker threshold using the market order
    ✓ Fill an order partially until the circuit breaker threshold using the limit order
    ✓ Execute multiple transactions to fill orders in one block with the circuit breaker triggered
    ✓ Fill an order in different blocks after the circuit breaker has been triggered
    ✓ Fill an order in the same block after the circuit breaker has been triggered
    ✓ Fail to place a second market order in the same block due to no filled amount
    ✓ Fail to place a second limit order in the same block due to over the circuit breaker threshold
    ✓ Fill an order within the circuit breaker minimum rage
    ✓ Fill an order outside the circuit breaker minimum rage
    ✓ Fill an order within the circuit breaker that has reached min unit price
  Lend orders
    ✓ Fill an order partially until the circuit breaker threshold using the market order
    ✓ Fill an order partially until the circuit breaker threshold using the limit order
    ✓ Execute multiple transactions to fill orders in one block with the circuit breaker triggered
    ✓ Fill an order in different blocks after the circuit breaker has been triggered
    ✓ Fill an order in the same block after the circuit breaker has been triggered
    ✓ Fail to place a second market order in the same block due to no filled amount
    ✓ Fail to place a second limit order in the same block due to over the circuit breaker threshold
    ✓ Fill an order within the circuit breaker minimum rage
    ✓ Fill an order outside the circuit breaker minimum rage
    ✓ Fill an order within the circuit breaker that has reached max unit price
  Unwind positions
    ✓ Unwind a position partially until the circuit breaker threshold
    ✓ Unwind no position due to circuit breaker

LendingMarket − Initialization
  ✓ Deploy Lending Market
  ✓ Create an order book
  ✓ Fail to deploy Lending Market with circuit breaker range more than equal to 10000
  ✓ Fail to create an order book due to invalid caller

LendingMarket − Itayose
  ✓ Execute Itayose call(Case 1)
  ✓ Execute Itayose call(Case 2)

✓ Execute Itayose call(Case 3)
✓ Execute Itayose call(Case 4)
✓ Execute Itayose call(Case 5)
✓ Execute Itayose call(Case 6)
✓ Execute Itayose call(Case 7)
✓ Execute Itayose call(Case 8)
✓ Execute Itayose call without pre-orders
✓ Fail to create a pre-order due to an existing order with a past maturity
✓ Fail to create a pre-order due to not in the pre-order period
✓ Fail to cancel a pre-order due to in the Itayose period
✓ Fail to execute the Itayose call due to not in the Itayose period
✓ Fail to execute the Itayose call due to invalid caller

LendingMarket - Operations
✓ Pause and unpause the lending market
✓ Fail to update the order fee rate due to invalid caller
✓ Fail to update the circuit breaker limit range due to invalid caller

LendingMarket - Orders
  Check the block unit price
    ✓ Check with a single order
    ✓ Check with multiple orders in the same block
    ✓ Check with multiple orders in the different block
    ✓ Check with 5 orders in the different block
    ✓ Check with over 5 orders in the different block
    ✓ Check with unwinding
    ✓ Check with an order less than the reliable amount
    ✓ Check with an order equal to the reliable amount
  Execute orders
    ✓ Fail to create a order due to the matured order book
    ✓ Fail to unwind the position due to the matured order book
    ✓ Fail to create an order due to invalid caller
    ✓ Fail to cancel the order due to invalid caller
    ✓ Fail to unwind the position due to invalid caller
    ✓ Fail to create a order due to an existing order with a past maturity
  Execute pre-orders
    ✓ Fail to create a lending pre-order due to opposite order existing
    ✓ Fail to create a borrowing pre-order due to opposite order existing
    ✓ Fail to create a pre-order due to invalid caller
  Clean up orders
    ✓ Clean up a lending order
    ✓ Clean up a borrowing order
    ✓ Fail to clean up orders due to invalid caller

LendingMarketController - Calculations
  Total Funds Calculations
    ✓ Calculate total funds without positions
    ✓ Calculate total funds with positions
    ✓ Calculate total funds with additional lent amount exceeded deposit amount
  Order Estimations
    ✓ Get an borrowing order estimation from one lending order on the order book
    ✓ Get an lending order estimation from one borrowing order on the order book
    ✓ Get an order estimation from multiple order on the order book
    ✓ Get an order estimation blocked by the circuit breaker
    ✓ Get an borrowing order estimation on the empty order book
    ✓ Get an lending order estimation on the empty order book

LendingMarketController - Itayose
  ✓ Get Itayose estimation with no pre-orders
  ✓ Execute Itayose call on the initial markets, the opening price become the same as the lending order
  ✓ Execute Itayose call on the initial markets, the opening price become the same as the borrowing order
  ✓ Fill a borrowing pre-order whose unit price is lower than the opening price after Itayose call
  ✓ Fill a lending pre-order whose unit price is higher than the opening price after Itayose call.
  ✓ Execute Itayose call after auto-rolling
  ✓ Fill orders that are not filled with Itayose call and not the same as the opening unit price
  ✓ Fill orders that are not filled with Itayose call and the same as the opening unit price
  ✓ Filled pre-order should be returned as inactive orders with opening unit price
  ✓ Crete a pre-order with permit
  ✓ Fail to create an order due to too many orders
  ✓ Fail to create an pre-order due to invalid maturity
  ✓ Fail to create an pre-order and deposit token due to invalid maturity

✓ Fail to create an pre-order and deposit token with permit due to invalid maturity

LendingMarketController — Liquidations
  External liquidator
    ✓ Fail to execute liquidation call due to non-operator
    ✓ Fail to execute liquidation call due to invalid maturity
    ✓ Fail to execute liquidation call due to non-collateral currency selected
    ✓ Fail to execute forced repayment due to non-operator
    ✓ Fail to execute forced repayment due to invalid maturity
    ✓ Fail to execute forced repayment due to non-collateral currency selected
    ✓ Fail to execute operations for collateral due to non lending market controller
    ✓ Fail to execute operations for debt due to non lending market controller
  Liquidations
    ✓ Liquidate less than 50% borrowing position in case the one position doesn't cover liquidation amount
    ✓ Liquidate 50% borrowing position in case the one position cover liquidation amount
    ✓ Liquidate borrowing position using zero-coupon bonds
    ✓ Liquidate insolvent user using the reserve fund
    ✓ Liquidate insolvent user without using the reserve fund
    ✓ Liquidate borrowing position after auto-roll
    ✓ Fail to liquidate a borrowing position due to no debt
    ✓ Fail to liquidate a borrowing position due to no liquidation amount
    ✓ Fail to liquidate a borrowing position due to insufficient collateral
  Delisting
    ✓ Execute repayment & redemption
    ✓ Execute repayment & redemption after auto-roll
    ✓ Force repayment of overdue borrowing positions
    ✓ Force a insolvent user to repay in the first market
    ✓ Force a insolvent user to repay in the seconde market
    ✓ Force a insolvent user to repay after auto roll using 1000000 as a compound factor
    ✓ Force a insolvent user to repay after auto roll using 1000000000000000000 as a compound factor
    ✓ Force a insolvent user to repay after auto roll using 1000000000000000000000000000000000000 as a compound factor
    ✓ Fail to repay due to active market
    ✓ Fail to repay due to active currency
    ✓ Fail to redeem due to active market
    ✓ Fail to redeem due to under repayment period
    ✓ Fail to repay due to invalid maturity
    ✓ Fail to redeem due to invalid maturity

LendingMarketController — Operations
  Operations
    Order books
      ✓ Get the lending market detail with empty order book
      ✓ Get the lending market detail with non-empty order book
      ✓ Get the multiple lending market details
    Pause/Unpause
      ✓ Pause lending markets
      ✓ Change the operator
    Protocol updates
      ✓ Get the min debt unit price
      ✓ Update the min debt unit price
      ✓ Get the current min debt unit price
      ✓ Update the order fee rate
      ✓ Update the circuit breaker limit range
      ✓ Update beacon proxy implementations and calculate Genesis value
      ✓ Fail to update the order fee rate due to execution by non-owner
      ✓ Fail to update the circuit breaker limit range due to execution by non-owner
      ✓ Fail to update the min debt unit price due to execution by non-owner
      ✓ Fail to update the min debt unit price due to invalid value
    Calculation

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'0'	'0'	'0'	'0'	'0'	'0'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1259380451830791474314 2830'	'0'	'3116418537544390000 0000'	'31164185375443900000000'	'0'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1259380451830791474314 2830'	'0'	'938045183079147431 42830'	'1259380451830791474314 2830'	'12593804518307914743142830'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1259380451830791474314 2830'	'0'	'938045183079147431 42830'	'1259380451830791474314 2830'	'12593804518307914743142830'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1265675797548421840874 8511'	'0'	'938045183079147431 42830'	'1259380451830791474314 2830'	'12593804518307914743142830'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1272002612213865561431 5939'	'0'	'2200261221386556143 15939'	'1272002612213865561431 5939'	'12720026122138565614315939'

(index)	Alice	Bob	Carol	ReserveFund	TotalLendingSupply	TotalBorrowingSupply
GenesisValue	'12500000000000000000000000'	'-1272002612213865561431 5939'	'0'	'2200261221386556143 15939'	'1272002612213865561431 5939'	'12720026122138565614315939'

✓ Calculate the genesis value per maturity
✓ Calculate the total funds from inactive lending order list
✓ Calculate the total funds from inactive borrowing order list
✓ Calculate the total funds with open orders less than min debt unit price
✓ Calculate the total funds with position less than min debt unit price

LendingMarketController — Orders
  Initialization
✓ Initialize the lending market
✓ Fail to initialize the lending market due to invalid currency
✓ Fail to initialize the lending market due to execution by non-owner
✓ Fail to initialize the lending market due to too many token decimals
✓ Get genesisDate
✓ Get beacon proxy implementations
✓ Fail to get beacon proxy implementations
✓ Create a order book

(index)	Maturity	Maturity(Unixtime)

0	'September 25, 2285 12:00 AM'	'9963561600'
1	'December 25, 2285 12:00 AM'	'9971424000'
2	'March 26, 2286 12:00 AM'	'9979286400'
3	'June 25, 2286 12:00 AM'	'9987148800'
4	'September 24, 2286 12:00 AM'	'9995011200'
5	'December 31, 2286 12:00 AM'	'10003478400'
6	'March 25, 2287 12:00 AM'	'10010736000'
7	'June 24, 2287 12:00 AM'	'10018598400'
8	'September 30, 2287 12:00 AM'	'10027065600'

✓ Create multiple lending markets
✓ Fail to create a order book because market is not initialized
✓ Fail to create a order book because currency does not exist
✓ Fail to create a order book due to invalid pre-opening date
✓ Fail to create a order book due to execution by non-owner
  Orders
✓ Get a market currency data
✓ Add orders and check rates

(index)	Alice	Bob	Carol	ReserveFund
TotalPresentValue	'100000000000000000'	'0'	'-100249310977929985'	'249310977929985'
FutureValue(9963561600)	'114678899082568807'	'0'	'-114964806167350900'	'285907084782093'
FutureValue(9971424000)	'0'	'0'	'0'	'0'
GenesisValue	'0'	'0'	'0'	'0'

(index)	Alice	Bob	Carol	ReserveFund
TotalPresentValue	'140000000000000000'	'-40099726002029427'	'-100249310977929985'	'349036979959412'
FutureValue(9963561600)	'114678899082568807'	'0'	'-114964806167350900'	'285907084782093'
FutureValue(9971424000)	'458715596330275523'	'-45985924314253930'	'0'	'114364681226407'
GenesisValue	'0'	'0'	'0'	'0'

(index)	Alice	Bob	Carol	ReserveFund
TotalPresentValue	'154442736772314282'	'-40099726002029427'	'-115227928355188252'	'385044308246323'
FutureValue(9963561600)	'0'	'0'	'0'	'0'
FutureValue(9971424000)	'177113230243479681'	'-45985924314253930'	'-132142119673381023'	'441564573676976'
GenesisValue	'114678899082568807000000000'	'0'	'-115465710974983022839056248'	'285907084782093000000'

(index)	Alice	Bob	Carol	ReserveFund
TotalPresentValue	'154442736772314282'	'-40099726002029427'	'-115227928355188252'	'385044308246323'
FutureValue(9963561600)	'0'	'0'	'0'	'0'
FutureValue(9971424000)	'177113230243479681'	'-45985924314253930'	'-132142119673381023'	'441564573676976'
GenesisValue	'114678899082568807000000000'	'0'		

(index)	'-1154657109749830228395 6248'	'28590708478209300000000'

(index) ReserveFund	Alice	Bob	Carol
TotalPresentValue	'154442736772314282'	'-40099726002029427' '-115227928355188252'	'884917584903398'
FutureValue(9963561600)	'0'	'0'	'0' '0'
FutureValue(9971424000)	'177113230243479681'	'-45985924314253930' '-132142119673381023'	'1014813744155273'
GenesisValue	'114678899082568807000 00000'	'0' '-1154657109749830228395 6248'	'78681189241421583956248'

(index) ReserveFund	Alice	Bob	Carol
TotalPresentValue	'154442736772314282'	'-40099726002029427' '-115227928355188252'	'884917584903398'
FutureValue(9963561600)	'0'	'0'	'0' '0'
FutureValue(9971424000)	'177113230243479681'	'-45985924314253930' '-132142119673381023'	'1014813744155273'
GenesisValue	'114678899082568807000 00000'	'0' '-1154657109749830228395 6248'	'78681189241421583956248'

✓ Add orders and rotate markets
✓ Deposit and add an order
✓ Deposit and add an order(payable)
✓ Add multiple orders using multicall
✓ Get an order
✓ Cancel an order
✓ Get an active order from one market
✓ Get active orders from multiple markets
✓ Get active orders from multiple currencies
✓ Get active orders and inactive orders
✓ Get an empty order list
✓ Get an active position from one market
✓ Get active positions of a user who has both side position
✓ Get active positions from multiple markets
✓ Get active positions from multiple currencies
✓ Get an active position after auto-rolls
✓ Get an empty position list of a user who has an open order
✓ Get an empty position list of a user who has no open order

(index)	Total	Market0	Market1	Market2
PresentValue(Alice)	'-50000000000000000'	'-50000000000000000'	'0'	'0'

(index)	Total	Market0	Market1	Market2
PresentValue(Alice)	'-100000000000000000'	'-50000000000000000'	'-50000000000000000'	'0'

(index)	Total	Market0	Market1	Market2
PresentValue(Alice)	'-20000000000000000'	'-50000000000000000'	'-50000000000000000'	'80000000000000000'

```
       └
        ✓ Fill lending orders and check the total present value
        ✓ Calculate the funds of users who have a large lending position and a small borrowing position
        ✓ Calculate the funds of users who have a small lending position and a large borrowing position
        ✓ Fill lending orders and partially fill own order.
        ✓ Fill lending orders including own order
        ✓ Fill borrowing orders including own order
        ✓ Fill lending orders including another user's order for unwinding
        ✓ Fill multiple lending orders without partially filled orders
      Limit Order
        ✓ Fill all lending orders at one rate
        ✓ Fill all borrowing orders at one rate
        ✓ Fill orders partially at one rate
        ✓ Fill orders at one rate with a partial amount with limit rate
        ✓ Fill orders at one rate with a over amount with limit rate
        ✓ Fill an own order
        ✓ Fill multiple lending order at different rates with limit rate
        ✓ Fill multiple borrowing order at different rates with limit rate
        ✓ Fill multiple lending order at different rates with limit rate
        ✓ Fill multiple borrowing order at different rates with limit rate
        ✓ Fill an order partially out of the orders held
        ✓ Fill multiple orders partially out of the orders held
        ✓ Fill 100 orders in same rate
        ✓ Fill 100 orders in different rate
        ✓ Deposit and place a lending order with permit
      Market Order
        ✓ Fail to place a borrow market order
        ✓ Fail to place a lend market order
      Unwinding
        ✓ Unwind a lending order
        ✓ Unwind a borrowing order
        ✓ Unwind a order at the order book that don't has enough orders
        ✓ Unwind a order ta the order book that don't has any orders
        ✓ Fail to execute unwinding due to insufficient collateral
        ✓ Fail to execute unwinding due to no future values user has
        ✓ Fail to execute unwinding due to invalid maturity
      Order Book
        ✓ Get all borrow orders
        ✓ Get all lend orders
        ✓ Get all borrow orders in multiple calls
        ✓ Get all lend orders in multiple calls
        ✓ Get borrow orders starting from a non-existent unit price
        ✓ Get lend orders starting from a non-existent unit price
        ✓ Get borrow orders starting from the minimum unit price
        ✓ Get borrow orders starting from the maximum unit price
      Failure
        ✓ Fail to create an order due to insufficient collateral
        ✓ Fail to create an order due to too many orders
        ✓ Fail to create an order due to invalid maturity
        ✓ Fail to create an order and deposit token due to invalid maturity
        ✓ Fail to create an order and deposit token with permit due to invalid maturity
        ✓ Fail to cancel an order due to invalid maturity
        ✓ Fail to rotate lending markets due to pre-maturity
        ✓ Fail to cancel an order due to execution by non-maker
        ✓ Fail to cancel an order due to invalid order

  LendingMarketController - Rotations
    General order books
      ✓ Rotate markets multiple times under condition without lending position
```

(index)	Alice	Bob
GenesisValue(10027065600)	'125000000000000000000000000'	'-125841709644168599933542624'
GenesisValue(10034928000)	'-19225179923187053358752599'	'17601249095710850975592713'
GenesisValue(10042790400)	'147036324887937376434137799'	'-150572400532587990700042501'
GenesisValue(10050652800)	'-46545465373652190633570201'	'40875103903848847647907024'

```
      ✓ Rotate markets multiple times under condition where users have lending positions that are offset
  after the auto-rolls every time
      ✓ Rotate markets using the unit price average(only one order) during the observation period
      ✓ Rotate markets using the unit price average(multiple orders) during the observation period
      ✓ Rotate markets using the estimated auto-roll price
```

✓ Rotate markets using the past auto-roll price as an order is filled on dates too old
    ✓ Rotate markets using the past auto-roll price as no orders are filled
    ✓ Rotate markets including one market that has orders adjusted by with the residual amount.
    ✓ Fail to rotate order books due to no currency
    ✓ Fail to rotate order books due to no order book
    ✓ Fail to rotate order books due to no zc token
  Pre-open order books
    ✓ Rotate markets including one market that has pre-orders adjusted by with the residual amount.
    ✓ Rotate markets including one market that has pre-orders partially filled and adjusted by with the residual amount.

LendingMarketController - Terminations
  Terminations
    ✓ Get the termination status
    ✓ Execute an emergency termination without an order and check all inactivated functions
    ✓ Execute an emergency termination with orders of single market
    ✓ Execute an emergency termination with orders of multiple markets
    ✓ Execute an emergency termination with orders after auto-rolls
    ✓ Execute an emergency termination with paused markets
    ✓ Fail to redeem due to a insolvent user
    ✓ Fail to redeem due to 2nd execution
    ✓ Fail to execute the emergency termination due to execution by non-owner
    ✓ Fail to initialize the lending market due to the market being already initialized
    ✓ Fail to execute the emergency settlement due to no markets terminated

LendingMarketController - Tokenization
  Token Deployments
    ✓ Create a new zc perpetual token
    ✓ Create a new zc token with maturity
    ✓ Create a new zc token with maturity(+ 9 month)
    ✓ Create a new zc token manually
    ✓ Fail to migrate a lending market manually if it already exists
    ✓ Fail to migrate a lending market manually if the maturity is invalid
    ✓ Fail to migrate a lending market manually if the caller is not owner
    ✓ Fail to migrate a lending market manually due to too many token decimals
  Withdraw and Deposit
    ✓ Withdraw zc tokens without used collaterals
    ✓ Withdraw zc tokens used as discounted collateral
    ✓ Withdraw zc tokens used as discounted collateral and allocated collateral as is
    ✓ Withdraw all zc tokens used as discounted collateral and allocated collateral as is
    ✓ Withdraw zc perpetual tokens without allocated collaterals
    ✓ Withdraw zc perpetual tokens used as discounted collateral
    ✓ Withdraw zc perpetual tokens used as discounted collateral and allocated collateral as is
    ✓ Withdraw zc tokens partially
    ✓ Withdraw zc perpetual tokens partially
    ✓ Deposit zc tokens
    ✓ Deposit zc tokens with exceeded amount
    ✓ Deposit zc perpetual tokens
    ✓ Deposit zc perpetual tokens with exceeded amount
    ✓ Fail to withdraw zc tokens if the maturity is invalid
    ✓ Fail to deposit zc tokens if the maturity is invalid
    ✓ Fail to withdraw zc tokens if the caller has no balance of zc tokens
    ✓ Fail to deposit zc tokens if the caller has no balance of zc tokens
    ✓ Fail to withdraw zc tokens if the caller has no balance of zc perpetual tokens
    ✓ Fail to deposit zc tokens if the caller has no balance of zc perpetual tokens

LendingMarketOperationLogic
  Testing calculateNextMaturity()
    ✓ Get the last Friday after 3 months
    ✓ Get the date 1 week later

OrderStatisticsTree - drop values
  Dropping
    Lending market orders
      Drop nodes from the tree by one action
        1 nodes in the tree
          ✓ Fill 1 node partially: Target amount is 50000000
          ✓ Drop all nodes: Target amount is 100000000
          ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
        2 nodes in the tree
          ✓ Fill 1 node partially: Target amount is 100000000
          ✓ Drop 1 node: Target amount is 300000000

✓ Drop 1 node, Fill 1 node partially: Target amount is 350000000
✓ Drop all nodes: Target amount is 400000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
3 nodes in the tree
✓ Fill 1 node partially: Target amount is 300000000
✓ Drop 1 node: Target amount is 500000000
✓ Drop 1 node, Fill 1 node partially: Target amount is 600000000
✓ Drop 2 nodes: Target amount is 800000000
✓ Drop all nodes: Target amount is 900000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
3 nodes with multiple orders in the tree
✓ Fill 1 node partially, Remove 4 order with a unfilled amount: Target amount is 350000000
✓ Fill 1 node partially, Remove 4 order without a unfilled amount: Target amount is 400000000
✓ Drop 1 node: Target amount is 500000000
✓ Drop 1 node, Fill 1 node partially: Target amount is 580000000
✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 620000000
✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 700000000
✓ Drop 2 nodes: Target amount is 800000000
✓ Drop 2 nodes, Fill 1 node partially: Target amount is 820000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 830000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 850000000
✓ Drop all nodes: Target amount is 900000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
Many nodes in the tree
✓ Fill 1 node partially: Target amount is 50000000
✓ Drop 1 node: Target amount is 100000000
✓ Drop multiple nodes less than the root: Target amount is 400000000
✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 6000000000
✓ Drop multiple nodes less than or equal to the root: Target amount is 6600000000
✓ Drop multiple nodes across the root: Target amount is 7000000000
✓ Drop all nodes: Target amount is 7500000000
✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Drop nodes from the tree by multiple actions
1 nodes in the tree
✓ Fill 1 node partially: Target amount is 50000000
✓ Drop all nodes: Target amount is 100000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
2 nodes in the tree
✓ Fill 1 node partially: Target amount is 100000000
✓ Drop 1 node: Target amount is 300000000
✓ Drop 1 node, Fill 1 node partially: Target amount is 350000000
✓ Drop all nodes: Target amount is 400000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
3 nodes in the tree
✓ Fill 1 node partially: Target amount is 300000000
✓ Drop 1 node: Target amount is 500000000
✓ Drop 1 node, Fill 1 node partially: Target amount is 600000000
✓ Drop 2 nodes: Target amount is 800000000
✓ Drop all nodes: Target amount is 900000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
3 nodes with multiple orders in the tree
✓ Fill 1 node partially, Remove 4 order with a unfilled amount: Target amount is 350000000
✓ Fill 1 node partially, Remove 4 order without a unfilled amount: Target amount is 400000000
✓ Drop 1 node: Target amount is 500000000
✓ Drop 1 node, Fill 1 node partially: Target amount is 580000000
✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 620000000
✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 700000000
✓ Drop 2 nodes: Target amount is 800000000
✓ Drop 2 nodes, Fill 1 node partially: Target amount is 820000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 830000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 850000000
✓ Drop all nodes: Target amount is 900000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000

Many nodes in the tree
  ✓ Fill 1 node partially: Target amount is 50000000
  ✓ Drop 1 node: Target amount is 100000000
  ✓ Drop multiple nodes less than the root: Target amount is 400000000
  ✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 6000000000
  ✓ Drop multiple nodes less than or equal to the root: Target amount is 6600000000
  ✓ Drop multiple nodes across the root: Target amount is 7000000000
  ✓ Drop all nodes: Target amount is 7500000000
  ✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Drop nodes from the tree by repeated inserting and dropping
  1 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop all nodes: Target amount is 100000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  2 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 100000000
    ✓ Drop 1 node: Target amount is 300000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 350000000
    ✓ Drop all nodes: Target amount is 400000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 300000000
    ✓ Drop 1 node: Target amount is 500000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 600000000
    ✓ Drop 2 nodes: Target amount is 800000000
    ✓ Drop all nodes: Target amount is 900000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes with multiple orders in the tree
    ✓ Fill 1 node partially, Remove 4 order with a unfilled amount: Target amount is 350000000
    ✓ Fill 1 node partially, Remove 4 order without a unfilled amount: Target amount is 400000000
    ✓ Drop 1 node: Target amount is 500000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 580000000
    ✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 620000000
    ✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 700000000
    ✓ Drop 2 nodes: Target amount is 800000000
    ✓ Drop 2 nodes, Fill 1 node partially: Target amount is 820000000
    ✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 830000000
    ✓ Drop 2 nodes, Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 850000000
    ✓ Drop all nodes: Target amount is 900000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  Many nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop multiple nodes less than the root: Target amount is 400000000
    ✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 6000000000
    ✓ Drop multiple nodes less than or equal to the root: Target amount is 6600000000
    ✓ Drop multiple nodes across the root: Target amount is 7000000000
    ✓ Drop all nodes: Target amount is 7500000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Lending limit orders
  Drop nodes from the tree
    1 nodes in the tree
      ✓ Drop all nodes: Target amount is 100000000, Limit value 9800
      ✓ Drop all nodes by limitValue: Target amount is 200000000, Limit value 9800
    2 nodes in the tree
      ✓ Drop 1 node: Target amount is 300000000, Limit value 9801
      ✓ Drop 1 node by limitValue: Target amount is 350000000, Limit value 9801
      ✓ Drop 1 node, Fill 1 node partially: Target amount is 350000000, Limit value 9800
      ✓ Drop all nodes: Target amount is 400000000, Limit value 9800
      ✓ Drop all nodes by limitValue: Target amount is 1000000000, Limit value 9800
    3 nodes in the tree
      ✓ Drop 1 node: Target amount is 500000000, Limit value 9802
      ✓ Drop 1 node by limitValue: Target amount is 600000000, Limit value 9802
      ✓ Drop 1 node, Fill 1 node partially: Target amount is 600000000, Limit value 9801
      ✓ Drop 2 nodes: Target amount is 800000000, Limit value 9801
      ✓ Drop 2 nodes by limitValue: Target amount is 900000000, Limit value 9801

          ✓ Drop all nodes: Target amount is 900000000, Limit value 9800
          ✓ Drop all nodes by limitValue: Target amount is 1000000000, Limit value 9800
       3 discontinuous nodes in the tree
          ✓ Drop 1 node: Target amount is 1000000000, Limit value 9803
          ✓ Drop 1 node, Fill 1 node partially: Target amount is 700000000, Limit value 9801
          ✓ Drop 2 node: Target amount is 1000000000, Limit value 9801
          ✓ Drop all nodes: Target amount is 1000000000, Limit value 9799
     Lending unwind orders
       Drop nodes from the tree
         1 nodes in the tree
          ✓ Fill 1 node partially: Unwind future value 125000000
          ✓ Drop all nodes: Unwind future value 250000000
          ✓ Drop all nodes without limits and amounts: Unwind future value 0
          ✓ Drop all nodes by an exceeding amount: Unwind future value 300000000
         2 nodes in the tree
          ✓ Fill 1 node partially: Unwind future value 125000000
          ✓ Drop 1 node: Unwind future value 250000000
          ✓ Drop 1 node, Fill 1 node partially: Unwind future value 350000000
          ✓ Drop all nodes: Unwind future value 1250000000
          ✓ Drop all nodes without limits and amounts: Unwind future value 0
          ✓ Drop all nodes by an exceeding amount: Unwind future value 2000000000
         3 nodes in the tree
          ✓ Fill 1 node partially: Unwind future value 125000000
          ✓ Drop 1 node: Unwind future value 250000000
          ✓ Drop 1 node, Fill 1 node partially: Unwind future value 350000000
          ✓ Drop 2 nodes: Unwind future value 1250000000
          ✓ Drop 2 nodes, Fill 1 node partially: Unwind future value 1350000000
          ✓ Drop all nodes: Unwind future value 2250000000
          ✓ Drop all nodes without limits and amounts: Unwind future value 0
          ✓ Drop all nodes by an exceeding amount: Unwind future value 3000000000
     Borrowing market orders
       Drop nodes from the tree by one action
         1 nodes in the tree
          ✓ Fill 1 node partially: Target amount is 50000000
          ✓ Drop all nodes: Target amount is 100000000
          ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
         2 nodes in the tree
          ✓ Fill 1 node partially: Target amount is 50000000
          ✓ Drop 1 node: Target amount is 100000000
          ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
          ✓ Drop all nodes: Target amount is 400000000
          ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
         3 nodes in the tree
          ✓ Fill 1 node partially: Target amount is 50000000
          ✓ Drop 1 node: Target amount is 100000000
          ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
          ✓ Drop 2 nodes: Target amount is 400000000
          ✓ Drop all nodes: Target amount is 900000000
          ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
         3 nodes with multiple orders in the tree
          ✓ Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 25000000
          ✓ Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 50000000
          ✓ Drop 1 node: Target amount is 100000000
          ✓ Drop 1 node, Fill 1 node partially: Target amount is 150000000
          ✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 280000000
          ✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 300000000
          ✓ Drop 2 nodes: Target amount is 400000000
          ✓ Drop 2 nodes, Fill 1 node partially: Target amount is 450000000
          ✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order with a unfilled amount: Target amount is 650000000
          ✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order without a unfilled amount: Target amount is 700000000
          ✓ Drop all nodes: Target amount is 900000000
          ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
         Many nodes in the tree
          ✓ Fill 1 node partially: Target amount is 50000000
          ✓ Drop 1 node: Target amount is 100000000
          ✓ Drop multiple nodes less than the root: Target amount is 400000000
          ✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 1300000000

✓ Drop multiple nodes less than or equal to the root: Target amount is 1600000000
✓ Drop multiple nodes across the root: Target amount is 3000000000
✓ Drop all nodes: Target amount is 7500000000
✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Drop nodes from the tree by multiple actions
  1 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop all nodes: Target amount is 100000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  2 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
    ✓ Drop all nodes: Target amount is 400000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
    ✓ Drop 2 nodes: Target amount is 400000000
    ✓ Drop all nodes: Target amount is 900000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes with multiple orders in the tree
    ✓ Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 25000000
    ✓ Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 150000000
    ✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 280000000
    ✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 300000000
    ✓ Drop 2 nodes: Target amount is 400000000
    ✓ Drop 2 nodes, Fill 1 node partially: Target amount is 450000000
    ✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order with a unfilled amount: Target amount is 650000000
    ✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order without a unfilled amount: Target amount is 700000000
    ✓ Drop all nodes: Target amount is 900000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  Many nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop multiple nodes less than the root: Target amount is 400000000
    ✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 1300000000
    ✓ Drop multiple nodes less than or equal to the root: Target amount is 1600000000
    ✓ Drop multiple nodes across the root: Target amount is 3000000000
    ✓ Drop all nodes: Target amount is 7500000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Drop nodes from the tree by repeated inserting and dropping
  1 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop all nodes: Target amount is 100000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  2 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
    ✓ Drop all nodes: Target amount is 400000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes in the tree
    ✓ Fill 1 node partially: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000
    ✓ Drop 2 nodes: Target amount is 400000000
    ✓ Drop all nodes: Target amount is 900000000
    ✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
  3 nodes with multiple orders in the tree
    ✓ Fill 1 node partially, Remove 1 order with a unfilled amount: Target amount is 25000000
    ✓ Fill 1 node partially, Remove 1 order without a unfilled amount: Target amount is 50000000
    ✓ Drop 1 node: Target amount is 100000000
    ✓ Drop 1 node, Fill 1 node partially: Target amount is 150000000

✓ Drop 1 node, Fill 1 node partially, Remove 2 order with a unfilled amount: Target amount is 280000000
✓ Drop 1 node, Fill 1 node partially, Remove 2 order without a unfilled amount: Target amount is 300000000
✓ Drop 2 nodes: Target amount is 400000000
✓ Drop 2 nodes, Fill 1 node partially: Target amount is 450000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order with a unfilled amount: Target amount is 650000000
✓ Drop 2 nodes, Fill 1 node partially, Remove 3 order without a unfilled amount: Target amount is 700000000
✓ Drop all nodes: Target amount is 900000000
✓ Drop all nodes using an exceeding amount: Target amount is 1000000000
Many nodes in the tree
✓ Fill 1 node partially: Target amount is 50000000
✓ Drop 1 node: Target amount is 100000000
✓ Drop multiple nodes less than the root: Target amount is 400000000
✓ Drop multiple nodes less than the root, Fill root node partially: Target amount is 1300000000
✓ Drop multiple nodes less than or equal to the root: Target amount is 1600000000
✓ Drop multiple nodes across the root: Target amount is 3000000000
✓ Drop all nodes: Target amount is 7500000000
✓ Drop all nodes using an exceeding amount: Target amount is 10000000000
Borrowing limit orders
Drop nodes from the tree
1 nodes in the tree
✓ Drop all nodes: Target amount is 100000000, Limit value 9800
✓ Drop all nodes by limitValue: Target amount is 200000000, Limit value 9800
2 nodes in the tree
✓ Drop 1 node: Target amount is 100000000, Limit value 9800
✓ Drop 1 node by limitValue: Target amount is 200000000, Limit value 9800
✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000, Limit value 9801
✓ Drop all nodes: Target amount is 400000000, Limit value 9801
✓ Drop all nodes by limitValue: Target amount is 1000000000, Limit value 9801
3 nodes in the tree
✓ Drop 1 node: Target amount is 100000000, Limit value 9800
✓ Drop 1 node by limitValue: Target amount is 200000000, Limit value 9800
✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000, Limit value 9801
✓ Drop 2 nodes: Target amount is 400000000, Limit value 9801
✓ Drop 2 nodes by limitValue: Target amount is 900000000, Limit value 9801
✓ Drop all nodes: Target amount is 900000000, Limit value 9802
✓ Drop all nodes by limitValue: Target amount is 1000000000, Limit value 9802
3 discontinuous nodes in the tree
✓ Drop 1 node: Target amount is 1000000000, Limit value 9801
✓ Drop 1 node, Fill 1 node partially: Target amount is 200000000, Limit value 9803
✓ Drop 2 node: Target amount is 1000000000, Limit value 9803
✓ Drop all nodes: Target amount is 1000000000, Limit value 9805
Borrowing unwind orders
Drop nodes from the tree
1 nodes in the tree
✓ Fill 1 node partially: Unwind future value 125000000
✓ Drop all nodes: Unwind future value 250000000
✓ Drop all nodes without limits and amounts: Unwind future value 0
✓ Drop all nodes by an exceeding amount: Unwind future value 300000000
2 nodes in the tree
✓ Fill 1 node partially: Unwind future value 125000000
✓ Drop 1 node: Unwind future value 250000000
✓ Drop 1 node, Fill 1 node partially: Unwind future value 375000000
✓ Drop all nodes: Unwind future value 800000000
✓ Drop all nodes without limits and amounts: Unwind future value 0
✓ Drop all nodes by an exceeding amount: Unwind future value 1000000000
3 nodes in the tree
✓ Fill 1 node partially: Unwind future value 125000000
✓ Drop 1 node: Unwind future value 250000000
✓ Drop 1 node, Fill 1 node partially: Unwind future value 375000000
✓ Drop 2 nodes: Unwind future value 800000000
✓ Drop 2 nodes, Fill 1 node partially: Unwind future value 1000000000
✓ Drop all nodes: Unwind future value 1200000000
✓ Drop all nodes without limits and amounts: Unwind future value 0
✓ Drop all nodes by an exceeding amount: Unwind future value 2000000000
Drop and Insert
✓ Insert a lend order to the dropped node
✓ Insert a borrow order to the dropped node

Estimation
    Estimate the dropped amount from the lending tree
        Estimate the dropped FV amount by PV amount
            ✓ Drop 1 node partially
            ✓ Drop 1 node
            ✓ Drop 1 node, Fill 1 node partially
            ✓ Drop 2 nodes, Fill 1 node partially
        Estimate the dropped PV amount by FV amount
            ✓ Drop 1 node partially
            ✓ Drop 1 node
            ✓ Drop 1 node, Fill 1 node partially
            ✓ Drop 2 nodes, Fill 1 node partially
    Estimate the dropped amount from the borrowing tree
        Estimate the dropped FV amount by PV amount
            ✓ Drop 1 node partially
            ✓ Drop 1 node
            ✓ Drop 1 node, Fill 1 node partially
            ✓ Drop 2 nodes, Fill 1 node partially
        Estimate the dropped PV amount by FV amount
            ✓ Drop 1 node partially
            ✓ Drop 1 node
            ✓ Drop 1 node, Fill 1 node partially
            ✓ Drop 2 nodes, Fill 1 node partially

  OrderStatisticsTree — insert and delete
Number of steps: 214
element, orderCount
    4827 0
    1299 0
    5193 0
    287 0
    7688 0
    5427 0
    2447 0
    9023 0
    4457 0
    9057 0
    7168 0
    9373 0
    1290 0
    6498 0
    7076 0
    2191 0
    1234 0
    3971 0
    1113 0
    7367 0
    4370 0
    4366 0
    1580 0
    7946 0
    2760 0
    4816 0
    5782 0
    7919 0
    7248 0
    4438 0
    6426 0
    8751 0
    9202 0
    4669 0
    4574 0
    6952 0
    8246 0
    9558 0
    2386 0
    4680 0
    4584 0
    4760 0
    4311 0
    4888 0
    5753 0

```
544 0
3471 0
2915 0
1760 0
797 0
4251 0
7509 0
5429 0
1815 0
8971 0
4641 0
412 0
6180 0
7897 0
8118 0
7940 0
641 0
6497 0
3082 0
6918 0
1005 0
1105 0
9416 0
23 0
396 0
637 0
467 0
7096 0
8187 0
6517 0
6479 0
8779 0
3696 0
4116 0
2283 0
4817 0
1741 0
6465 0
2750 0
9414 0
1505 0
9757 0
627 0
969 0
500 0
3277 0
2316 0
8343 0
6151 0
7609 0
7603 0
8419 0
3148 0
8626 0
4042 0
246 0
6016 0
9136 0
5044 0
9843 0
8382 0
1715 0
4827 0
1299 0
5193 0
287 0
7688 0
5427 0
2447 0
9023 0
4457 0
9057 0
```

```
7168 0
9373 0
1290 0
6498 0
7076 0
2191 0
1234 0
3971 0
1113 0
7367 0
4370 0
4366 0
1580 0
7946 0
2760 0
4816 0
5782 0
7919 0
7248 0
4438 0
6426 0
8751 0
9202 0
4669 0
4574 0
6952 0
8246 0
9558 0
2386 0
4680 0
4584 0
4760 0
4311 0
4888 0
5753 0
544 0
3471 0
2915 0
1760 0
797 0
4251 0
7509 0
5429 0
1815 0
8971 0
4641 0
412 0
6180 0
7897 0
8118 0
7940 0
641 0
6497 0
3082 0
6918 0
1005 0
1105 0
9416 0
23 0
396 0
637 0
467 0
7096 0
8187 0
6517 0
6479 0
8779 0
3696 0
4116 0
2283 0
4817 0
1741 0
```

```
        6465 0
        2750 0
        9414 0
        1505 0
        9757 0
        627 0
        969 0
        500 0
        3277 0
        2316 0
        8343 0
        6151 0
        7609 0
        7603 0
        8419 0
        3148 0
        8626 0
        4042 0
        246 0
        6016 0
        9136 0
        5044 0
        9843 0
        8382 0
        1715 0
Tree Properties
    Root Count 0
    First 0
    Last 0
    Root Value 0
Node Details, (crawled in order), value, parent, left, right, red, head, tail, orderCounter

See if values exists
value, exists
    4827 false
    1299 false
    5193 false
    287 false
    7688 false
    5427 false
    2447 false
    9023 false
    4457 false
    9057 false
    7168 false
    9373 false
    1290 false
    6498 false
    7076 false
    2191 false
    1234 false
    3971 false
    1113 false
    7367 false
    4370 false
    4366 false
    1580 false
    7946 false
    2760 false
    4816 false
    5782 false
    7919 false
    7248 false
    4438 false
    6426 false
    8751 false
    9202 false
    4669 false
    4574 false
    6952 false
    8246 false
    9558 false
```

```
2386 false
4680 false
4584 false
4760 false
4311 false
4888 false
5753 false
544 false
3471 false
2915 false
1760 false
797 false
4251 false
7509 false
5429 false
1815 false
8971 false
4641 false
412 false
6180 false
7897 false
8118 false
7940 false
641 false
6497 false
3082 false
6918 false
1005 false
1105 false
9416 false
23 false
396 false
637 false
467 false
7096 false
8187 false
6517 false
6479 false
8779 false
3696 false
4116 false
2283 false
4817 false
1741 false
6465 false
2750 false
9414 false
1505 false
9757 false
627 false
969 false
500 false
3277 false
2316 false
8343 false
6151 false
7609 false
7603 false
8419 false
3148 false
8626 false
4042 false
246 false
6016 false
9136 false
5044 false
9843 false
8382 false
1715 false
4827 false
1299 false
5193 false
```

287 false
7688 false
5427 false
2447 false
9023 false
4457 false
9057 false
7168 false
9373 false
1290 false
6498 false
7076 false
2191 false
1234 false
3971 false
1113 false
7367 false
4370 false
4366 false
1580 false
7946 false
2760 false
4816 false
5782 false
7919 false
7248 false
4438 false
6426 false
8751 false
9202 false
4669 false
4574 false
6952 false
8246 false
9558 false
2386 false
4680 false
4584 false
4760 false
4311 false
4888 false
5753 false
544 false
3471 false
2915 false
1760 false
797 false
4251 false
7509 false
5429 false
1815 false
8971 false
4641 false
412 false
6180 false
7897 false
8118 false
7940 false
641 false
6497 false
3082 false
6918 false
1005 false
1105 false
9416 false
23 false
396 false
637 false
467 false
7096 false
8187 false
6517 false

```
6479 false
8779 false
3696 false
4116 false
2283 false
4817 false
1741 false
6465 false
2750 false
9414 false
1505 false
9757 false
627 false
969 false
500 false
3277 false
2316 false
8343 false
6151 false
7609 false
7603 false
8419 false
3148 false
8626 false
4042 false
246 false
6016 false
9136 false
5044 false
9843 false
8382 false
1715 false
```
    ✓ Insert all orders and delete after

ProxyController
  Initialize
    ✓ Deploy a ProxyController contract
  Register contracts
    ✓ Register a CurrencyController contract
    ✓ Fail to set a contract due to invalid caller
    ✓ Update a CurrencyController contract
    ✓ Fail to set a contract due to invalid input
    ✓ Register multiple contracts using multicall
    ✓ Fail to register contracts due to execution by non-owner
  Get contract address
    ✓ Successfully get a proxy address
    ✓ Fail to get a proxy address due to empty data
    ✓ Fail to call a contract due to missing address
  Use contracts through the Proxy
    ✓ Successfully call a CurrencyController contract
    ✓ Fail to call a CurrencyController contract due to direct access
  Change Admin
    ✓ Successfully change admins of a proxy contract
    ✓ Fail to change admins of a proxy contract due to execution by non-owner

ReserveFund
  Initialize
    ✓ Fail to call initialization due to duplicate execution
    ✓ Fail to call initialization due to execution by non-proxy contract
  Pause
    ✓ Pause and Unpause
    ✓ Change the operator
    ✓ Remove operator role from another user
    ✓ Fail to pause due to non-operator caller
    ✓ Fail to unpause due to non-operator caller
    ✓ Fail to revoke role due to own role
    ✓ Fail to renounce role due to not allowed access
  Deposit
    ✓ Deposit ERC20 token
    ✓ Deposit ETH
    ✓ Fail to deposit token due to execution by non-owner
  Withdraw

```
        ✓ Withdraw funds
        ✓ Fail to withdraw token due to execution by non-owner
      Execute transaction
        ✓ Execute emergency settlement
        ✓ Execute a deposit transaction
        ✓ Fail to execute a transaction due to execution by non-owner
        ✓ Fail to execute transactions due to execution by non-owner
        ✓ Fail to execute transactions due to empty inputs
        ✓ Fail to execute transactions due to input array length mismatch: _data
        ✓ Fail to execute transactions due to input array length mismatch: _values

  BokkyPooBahsDateTimeContract
    Test functions library functions
      Test basic read time functions
        ✓ timestampToDate
        ✓ getDaysInMonth
        ✓ getDayOfWeek
        ✓ getYear
        ✓ getMonth
        ✓ getDay
        ✓ getHour
        ✓ getMinute
      Test basic time addition functions
        ✓ addedYears
        ✓ addMonths
        ✓ addDays
        ✓ addHours
        ✓ addMinutes
      Test basic time subtraction functions
        ✓ subYears
        ✓ subMonths
        ✓ subDays
        ✓ subHours
        ✓ subMinutes
      Test basic time difference functions
        ✓ diffYears
        ✓ diffMonths
        ✓ diffDays
        ✓ diffHours
        ✓ diffMinutes

  TokenVault
    Initialize
      ✓ Get liquidation threshold rate
      ✓ Update the liquidation configuration
      ✓ Fail to call updateLiquidationConfiguration due to invalid rate
      ✓ Fail to call initialization due to duplicate execution
      ✓ Fail to call initialization due to execution by non-proxy contract
    Currencies
      ✓ Register currency
      ✓ Update collateral currency to non-collateral currency
      ✓ Register non-collateral currency to collateral currency
      ✓ Fail to receive ETH due to execution by non-WETH contract
      ✓ Fail to register currency due to execution by non-owner
      ✓ Fail to update currency due to execution by non-owner
      ✓ Fail to register currency due to nonexistent currency
      ✓ Fail to register currency due to duplicate registration
      ✓ Fail to register currency due to zero address
      ✓ Fail to register currency due to market termination
      ✓ Fail to update currency due to market termination
    Coverage
      ✓ Calculate the coverage without deposit
      ✓ Calculate the coverage with deposit
      ✓ Calculate the coverage for borrowing orders
      ✓ Calculate the coverage for lending orders
      ✓ Calculate the coverage for lending orders that exceed the deposit amount.
    Deposit & Withdraw
      ✓ Deposit ERC20 token
      ✓ Deposit ETH
      ✓ Deposit ETH to another user
      ✓ Deposit multiple tokens using multicall
      ✓ Deposit to another user with permit
```

- ✓ Deposit from another user with permit
- ✓ Get the withdrawable amount with the working orders & Withdraw collateral
- ✓ Get the withdrawable amount with the borrowed amount
- ✓ Get the withdrawable amount with with the debt amount
- ✓ Add and remove the collateral amount
- ✓ Reset the collateral amount
- ✓ Add an amount in a currency that is not accepted as collateral
- ✓ Get the withdrawable amount per currency
- ✓ Get the withdrawable amount per currency with the borrowing working orders
- ✓ Get the withdrawable amount per currency with the lending working orders
- ✓ Get the liquidation amount
- ✓ Get the liquidation amount decreased by a maximum
- ✓ Get the liquidation fees
- ✓ Get liquidation amount with no collateral
- ✓ Get liquidation amount with no used collateral
- ✓ Fail to deposit token due to unregistered currency
- ✓ Fail to withdraw token due to unregistered currency
- ✓ Fail to call addDepositAmount due to unregistered currency
- ✓ Fail to call removeDepositAmount due to unregistered currency
- ✓ Fail to call executeForcedReset due to unregistered currency
- ✓ Fail to call transferFrom due to unregistered currency
- ✓ Fail to call addDepositAmount due to invalid caller
- ✓ Fail to call removeDepositAmount due to invalid caller
- ✓ Fail to call executeForcedReset due to invalid caller
- ✓ Fail to call transferFrom due to invalid caller
- ✓ Fail to call depositWithPermitFrom due to invalid caller
- ✓ Fail to call addDepositAmount due to invalid amount
- ✓ Fail to call deposit due to zero amount
- ✓ Fail to call withdraw due to zero amount
- ✓ Fail to call deposit due to no transfer of native token
- ✓ Fail to deposit token due to transfer of native token
- ✓ Fail to call deposit due to lending market termination
- ✓ Fail to withdraw due to redemption required
- ✓ Fail to withdraw due to insolvency
- ✓ Deposit funds from Alice
- ✓ Withdraw funds from Alice
- ✓ Fail to call depositFrom due to lending market termination
- ✓ Fail to call depositWithPermitTo due to lending market termination
- ✓ Fail to depositWithPermitFrom due to lending market termination

Transfer
- ✓ Transfer from Alice to Bob
- ✓ Transfer from Alice to Bob with over amount
- ✓ Transfer the deposit amount of Alice, who has a lent amount..
- ✓ Fail to transfer deposits due to invalid caller

Pause/Unpause operations
- ✓ Pause token vault
- ✓ Unpause token vault
- ✓ Change the operator

Borrowable amount calculations
- ✓ Without collateral
- ✓ With collateral, unused
- ✓ With collateral, partially used
- ✓ With collateral, totally used
- ✓ Without collateral, has claimable amount
- ✓ With collateral, has claimable amount
- ✓ With collateral, has funds (claimable > collateral)
- ✓ With collateral, has funds (claimable == collateral)

ZCToken
  Initialization
  - ✓ Get correct name, symbol, asset, and maturity
  Minting and Burning
  - ✓ Mint tokens successfully
  - ✓ Burn tokens successfully
  - ✓ Fail to mint tokens by non-authorized addresses
  - ✓ Fail to burn tokens by non-authorized addresses
  Permit
  - ✓ Get domain separator
  - ✓ Accept owner signature
  - ✓ Reject reused signature
  - ✓ Reject other signature
  - ✓ Reject other signature

```
·----------------------------------------------------------|---------------------------|-------------|----------------------------·
|                          Solc version: 0.8.19            ·  Optimizer enabled: true  ·  Runs: 200  ·  Block limit: 30000000 gas  |
···········································|···························|·············|·······························|
|  Methods                                                                                                                          |
···········································|···························|·············|·····················|·····················|·············
|  Contract                  ·  Method                    ·  Min        ·  Max        ·  Avg       ·  # calls      ·  usd (avg)  |
···········································|···························|·············|··········|·············|·············
|  AddressResolver               ·  importAddresses            ·  35714      ·  491154     ·  319082    ·  120        ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyController         ·  changeBeaconProxyAdmins     ·  −          ·  −          ·  40561     ·  1          ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyController         ·  multicall                  ·  190332     ·  1037566    ·  559194    ·  3          ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyController         ·  setFutureValueVaultImpl     ·  48875      ·  346234     ·  337614    ·  69         ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyController         ·  setLendingMarketImpl        ·  48800      ·  346159     ·  329638    ·  54         ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyController         ·  setZCTokenImpl             ·  346189     ·  346201     ·  346199    ·  45         ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyControllerCaller   ·  deployFutureValueVault     ·  −          ·  −          ·  472341    ·  2          ·  −          |
···········································|···························|·············|··········|·············|·············
|  BeaconProxyControllerCaller   ·  deployLendingMarket        ·  −          ·  −          ·  576781    ·  1          ·  −          |
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|  CurrencyController            ·  addCurrency                ·  79628      ·  305417     ·  252293    ·  105        ·  −          |
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|  CurrencyController            ·  removeCurrency             ·  36672      ·  36682      ·  36675     ·  7          ·  −          |
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|  CurrencyController            ·  updateHaircut              ·  33389      ·  55313      ·  39751     ·  8          ·  −          |
···········································|···························|·············|··········|·············|·············
|  CurrencyController            ·  updatePriceFeed            ·  78923      ·  157785     ·  118354    ·  4          ·  −          |
···········································|···························|·············|··········|·············|·············
|  ERC20                         ·  transfer                   ·  −          ·  −          ·  57382     ·  1          ·  −          |
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|  FutureValueVaultCaller        ·  decrease                   ·  −          ·  −          ·  112258    ·  4          ·  −          |
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|  FutureValueVaultCaller        ·  deployFutureValueVault      ·  −          ·
```

Contract	Method	Min	Max	Avg	# calls
			472756		27
FutureValueVaultCaller	executeForcedReset	43701	47130	45416	4
FutureValueVaultCaller	executeForcedReset	42810	46013	44412	4
FutureValueVaultCaller	increase	112064	112076	112075	11
FutureValueVaultCaller	lock	–	–	66696	4
FutureValueVaultCaller	transferFrom	–	–	92526	2
FutureValueVaultCaller	unlock	–	–	68965	2
GenesisValueVaultCaller	cleanUpBalance	40274	121920	81097	4
GenesisValueVaultCaller	executeAutoRoll	171382	171494	171484	18
GenesisValueVaultCaller	executeForcedReset	49447	54222	51835	4
GenesisValueVaultCaller	executeForcedReset	–	–	37997	2
GenesisValueVaultCaller	initializeCurrencySetting	240643	240655	240654	46
GenesisValueVaultCaller	lock	–	–	66230	4
GenesisValueVaultCaller	transferFrom	–	–	61245	2
GenesisValueVaultCaller	unlock	–	–	65362	2
GenesisValueVaultCaller	updateGenesisValueWithFutureValue	65999	137614	123850	28
GenesisValueVaultCaller	updateGenesisValueWithResidualAmount	–	–	107844	1
GenesisValueVaultCaller	updateInitialCompoundFactor	–	–	70755	1
LendingMarket	pause			52116	

Contract	Method	Min	Max	Avg	# calls
		52503	52227		7
LendingMarket	unpause	30249	30611	30352	7
LendingMarketCaller	cleanUpOrders	86268	86308	86288	4
LendingMarketCaller	createOrderBook	81039	186456	148939	579
LendingMarketCaller	deployLendingMarket	576978	576990	576984	14
LendingMarketCaller	executeAutoRoll	49823	70116	49869	511
LendingMarketCaller	executeItayoseCall	95518	307048	189394	20
LendingMarketCaller	executeOrder	123572	395310	266631	206
LendingMarketCaller	executePreOrder	340586	403113	369038	57
LendingMarketCaller	pause	–	–	63189	1
LendingMarketCaller	unpause	–	–	41299	1
LendingMarketCaller	unwindPosition	95806	159191	139917	5
LendingMarketController	cancelOrder	123205	143504	125455	25
LendingMarketController	cleanUpAllFunds	145164	731232	344851	26
LendingMarketController	createOrderBook	1026889	1086599	1054406	1344
LendingMarketController	depositAndExecuteOrder	588142	1242019	883588	229
LendingMarketController	depositAndExecutesPreOrder	642620	853037	800427	4
LendingMarketController	depositWithPermitAndExecuteOrder	593668	940565	839979	4
LendingMarketController	depositWithPermitAndExecutePreOrder	584280			

Contract	Method	Min	Max	Avg	# calls
			881826	683462	3
LendingMarketController	depositZCToken	181716	309321	217459	16
LendingMarketController	executeEmergencySettlement	278134	707185	449484	36
LendingMarketController	executeEmergencyTermination	213984	472202	322206	24
LendingMarketController	executeForcedRepayment	430490	566784	494189	9
LendingMarketController	executeItayoseCall	119947	460843	127326	901
LendingMarketController	executeLiquidationCall	613368	1133269	722364	14
LendingMarketController	executeOrder	263813	1641072	717474	3168
LendingMarketController	executePreOrder	341329	749290	549509	99
LendingMarketController	executeRedemption	227505	275076	252072	5
LendingMarketController	executeRepayment	318787	437707	366530	5
LendingMarketController	initializeLendingMarket	2021323	2046731	2037125	269
LendingMarketController	migrateLendingMarket	811874	815064	812672	4
LendingMarketController	pauseLendingMarket	–	–	76424	3
LendingMarketController	rotateOrderBooks	1284096	1585840	1417656	938
LendingMarketController	unpauseLendingMarket	–	–	54593	2
LendingMarketController	unwindPosition	460664	650500	545114	15
LendingMarketController	updateCircuitBreakerLimitRange	–	–	52761	2
LendingMarketController	updateMinDebtUnitPrice	–			

Contract	Method	Min	Max	Avg	# calls
			41298		1
LendingMarketController	updateOrderFeeRate	–		59531	2
LendingMarketController	withdrawZCToken	464549	846228	566968	34
Liquidator	addOperator	56526	56614	56578	4
Liquidator	deposit	59234	206597	161701	1128
Liquidator	executeForcedRepayment	1075575	1179112	1120205	8
Liquidator	executeLiquidationCall	1733439	3296266	2111931	21
Liquidator	executeTransaction	43254	600260	299929	14
Liquidator	executeTransactions	65599	131966	108106	9
Liquidator	removeOperator	34690	34747	34728	3
Liquidator	renounceOwnership	–		28815	1
Liquidator	revokeRole	–		35182	1
Liquidator	transferOwnership	–		34224	1
Liquidator	withdraw	58241	670917	325162	70
MigrationAddressResolver	buildCaches	72006	433840	171084	104
MockERC20	approve	–		46302	1
MockERC20	permit	–		92372	2
MockERC20	transfer	–		46656	1
MockUniswapRouter	setToken	44189			

Contract	Method	Min	Max	Avg	# calls	usd (avg)
		44201	44197		3	—
MockUSDC	approve	26702	46602	44584	120	—
MockUSDC	transfer	51396	51456	51431	161	—
MockV3Aggregator	updateAnswer	102972	105808	104511	46	—
MockWBTC	approve	—	—	46266	8	—
MockWBTC	transfer	51420	51432	51431	26	—
MockWFIL	approve	29214	46602	46255	891	—
MockWFIL	transfer	34368	51480	51392	962	—
OrderStatisticsTreeContract	dropValuesFromFirst	36226	182465	84911	215	—
OrderStatisticsTreeContract	dropValuesFromLast	36247	215352	86547	215	—
OrderStatisticsTreeContract	insertAmountValue	95653	325118	169546	2573	—
OrderStatisticsTreeContract	removeAmountValue	59914	206332	117150	107	—
ProxyController	changeProxyAdmins	—	—	35374	1	—
ProxyController	multicall	—	—	761601	2	—
ProxyController	setAddressResolverImpl	392728	392740	392739	136	—
ProxyController	setBeaconProxyControllerImpl	406227	406239	406238	202	—
ProxyController	setCurrencyControllerImpl	54431	383156	351546	52	—
ProxyController	setGenesisValueVaultImpl	381726	381738	381737	74	—
ProxyController	setLendingMarketControllerImpl	478468				

Contract	Method	Min	Max	Avg	# calls	usd (avg)
		478480	478479	·	70	–
ProxyController	setReserveFundImpl	481544	481556	481553	36	–
ProxyController	setTokenVaultImpl	578931	578943	578940	36	–
TokenVault	depositTo	163297	180520	174779	3	–
TokenVault	depositWithPermitTo	96064	201924	163334	4	–
TokenVault	registerCurrency	80240	154507	109183	142	–
TokenVault	updateCurrency	48294	112778	99483	35	–
TokenVault	updateLiquidationConfiguration	38526	47657	39931	13	–
TokenVaultCaller	addDepositAmount	51163	132772	113030	5	–
TokenVaultCaller	cleanUpFunds	78264	578485	238871	48	–
TokenVaultCaller	cleanUpUsedCurrencies	–	–	47078	1	–
TokenVaultCaller	depositFrom	123428	170801	158958	4	–
TokenVaultCaller	depositWithPermitFrom	–	–	180915	2	–
TokenVaultCaller	executeForcedReset	–	–	49884	1	–
TokenVaultCaller	removeDepositAmount	44370	49134	46752	2	–
TokenVaultCaller	transferFrom	137334	160082	152191	7	–
ZCTokenCaller	burn	–	–	43111	2	–
ZCTokenCaller	deployZCToken	727903	727915	727914	10	–
ZCTokenCaller	mint					–

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–   ·        86647   ·                    [90m3 [39m   ·              [32m [90m– [32m [39m   |
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|    [32m [1mDeployments [22m [39m                                                            ·
·  [1m% of limit [22m    ·               |
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|   AddressResolver                                                    ·         –  ·          –  ·
852927   ·         [90m2.8 % [39m   ·              [32m [90m– [32m [39m   |
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|   BeaconProxyController                                              ·         –  ·          –  ·
2512625   ·         [90m8.4 % [39m   ·              [32m [90m– [32m [39m   |
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|   BeaconProxyControllerCaller                                        ·         [36m221760 [39m   ·
[31m221772 [39m   ·      221771   ·         [90m0.7 % [39m   ·              [32m [90m– [32m [39m   |
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|   BokkyPooBahsDateTimeContract                                       ·         –  ·          –  ·
1304957   ·         [90m4.3 % [39m   ·              [32m [90m– [32m [39m   |
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|   CurrencyController                                                 ·         –  ·          –  ·
2237966   ·         [90m7.5 % [39m   ·              [32m [90m– [32m [39m   |
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|   DepositManagementLogic                                            ·         –  ·          –  ·
2101416   ·         [90m7 % [39m   ·              [32m [90m– [32m [39m   |
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|   FundManagementLogic                                               ·         [36m4527096 [39m   ·
[31m4527108 [39m   ·     4527107   ·         [90m15.1 % [39m   ·              [32m [90m– [32m [39m   |
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|   FutureValueVault                                                  ·         –  ·          –  ·
1707829   ·         [90m5.7 % [39m   ·              [32m [90m– [32m [39m   |
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|   FutureValueVaultCaller                                            ·         [36m508145 [39m   ·
[31m508169 [39m   ·      508167   ·         [90m1.7 % [39m   ·              [32m [90m– [32m [39m   |
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|   GenesisValueVault                                                 ·         –  ·          –  ·
2728739   ·         [90m9.1 % [39m   ·              [32m [90m– [32m [39m   |
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|   GenesisValueVaultCaller                                           ·         –  ·          –  ·
530108   ·         [90m1.8 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarket                                                     ·         [36m3004222 [39m   ·
[31m3004534 [39m   ·     3004505   ·         [90m10 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarketCaller                                               ·         [36m869433 [39m   ·
[31m869445 [39m   ·      869445   ·         [90m2.9 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarketController                                           ·         [36m5002393 [39m   ·
[31m5002597 [39m   ·     5002567   ·         [90m16.7 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarketOperationLogic                                       ·         –  ·          –  ·
3535721   ·         [90m11.8 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarketReader                                               ·         [36m2650315 [39m   ·
[31m2650327 [39m   ·     2650326   ·         [90m8.8 % [39m   ·              [32m [90m– [32m [39m   |
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|   LendingMarketUserLogic                                            ·         [36m2857194 [39m   ·
```

Contract	Min	Max	Avg	% of limit	
	2857410	2857397	9.5 %	–	
LiquidationLogic	2039702	2039870	2039860	6.8 %	–
Liquidator	2764932	2767155	2765575	9.2 %	–
MigrationAddressResolver	–	192897	0.6 %	–	
MockERC20	–	1750145	5.8 %	–	
MockUniswapRouter	–	1420951	4.7 %	–	
MockUSDC	1796892	1797000	1796956	6 %	–
MockV3Aggregator	663084	663120	663103	2.2 %	–
MockWBTC	1796928	1797036	1796961	6 %	–
MockWETH9	–	559075	1.9 %	–	
MockWFIL	1797174	1797294	1797265	6 %	–
OrderActionLogic	4400638	4400686	4400683	14.7 %	–
OrderBookLogic	–	3104881	10.3 %	–	
OrderReaderLogic	–	1761226	5.9 %	–	
OrderStatisticsTreeContract	–	2623359	8.7 %	–	
ProxyController	1723035	1750788	1723231	5.7 %	–
QuickSort	–	294449	1 %	–	
ReserveFund	–	1923568	6.4 %	–	
TokenVault	3876672				

[31m3876924 [39m   ·   3876911   ·   [90m12.9 % [39m   ·   [32m [90m– [32m [39m |
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| TokenVaultCaller   ·   – ·   – ·
844077   ·   [90m2.8 % [39m   ·   [32m [90m– [32m [39m |
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| ZCToken   ·   – ·   – ·
1903105   ·   [90m6.3 % [39m   ·   [32m [90m– [32m [39m |
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| ZCTokenCaller   ·   – ·   – ·
329036   ·   [90m1.1 % [39m   ·   [32m [90m– [32m [39m |
·---|-------------|-------------|---
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   2044 passing (1h)

Code Coverage

While line and statement coverage metrics are high, we highly recommend improving the branch coverage to a minimum of 95%.

Fix Review: The test coverage has been slightly improved across the board. We continue to recommend improving branch coverage to a minimum of 95%.

File	% Stmts	% Branch	% Funcs	% Lines	Uncovered Lines
migration/	100	50	100	100	
MigrationAddressResolver.sol	100	50	100	100	
protocol/	98.83	91.8	97.87	99.01	
AddressResolver.sol	100	100	100	100	
BeaconProxyController.sol	100	88.46	100	100	
CurrencyController.sol	100	100	100	100	
FutureValueVault.sol	98	94.12	94.12	98.92	44
GenesisValueVault.sol	99.06	94.74	97.5	98.79	57,432
LendingMarket.sol	98.18	93.55	98.08	98.46	174
LendingMarketController.sol	97.8	83.82	96.67	98.08	138,146
ProxyController.sol	100	92.31	100	100	
ReserveFund.sol	100	100	100	100	
TokenVault.sol	98.33	92.31	97.67	98.73	163
ZCToken.sol	100	75	100	100	
protocol/interfaces/	100	100	100	100	
IAddressResolver.sol	100	100	100	100	

File	% Stmts	% Branch	% Funcs	% Lines	Uncovered Lines
IBeaconProxyController.sol	100	100	100	100	
ICurrencyController.sol	100	100	100	100	
IFutureValueVault.sol	100	100	100	100	
IGenesisValueVault.sol	100	100	100	100	
ILendingMarket.sol	100	100	100	100	
ILendingMarketController.sol	100	100	100	100	
ILiquidationReceiver.sol	100	100	100	100	
INativeToken.sol	100	100	100	100	
IProxyController.sol	100	100	100	100	
IReserveFund.sol	100	100	100	100	
ITokenVault.sol	100	100	100	100	
IZCToken.sol	100	100	100	100	
protocol/libraries/	94.9	83.11	89.63	94.44	
AddressResolverLib.sol	100	100	100	100	
BokkyPooBahsDateTimeLibrary.sol	83.05	54.17	71.79	76.86	... 407,458,459
Constants.sol	100	100	100	100	
Contracts.sol	100	100	100	100	
OrderBookLib.sol	100	94.53	100	100	
OrderStatisticsTreeLib.sol	95.08	87.73	95.65	95.6	... 3,1052,1053
QuickSort.sol	93.33	75	100	100	
TransferHelper.sol	96	69.23	90.91	96.15	14
protocol/libraries/logics/	99.46	91.97	100	98.99	
DepositManagementLogic.sol	97.56	94.44	100	95.45	... 376,379,382
FundManagementLogic.sol	100	94.19	100	99.07	614,1046,1052
LendingMarketOperationLogic.sol	100	93.75	100	100	
LendingMarketUserLogic.sol	99.2	94.05	100	99.35	706
LiquidationLogic.sol	100	82.26	100	98.97	374

File	% Stmts	% Branch	% Funcs	% Lines	Uncovered Lines
OrderActionLogic.sol	100	89.47	100	100	
OrderBookLogic.sol	100	86.36	100	100	
OrderReaderLogic.sol	97.22	94.44	100	100	
protocol/libraries/math/	100	80	100	100	
RoundingInt256.sol	100	83.33	100	100	
RoundingUint256.sol	100	75	100	100	
protocol/mixins/	95.52	90.38	88.24	96.43	
MixinAccessControl.sol	100	100	100	100	
MixinAddressResolver.sol	85.71	75	69.23	88	73,81,89
MixinLendingMarketConfiguration.sol	100	100	100	100	
MixinLiquidationConfiguration.sol	100	95	100	100	
MixinWallet.sol	100	87.5	100	100	
protocol/storages/	100	100	100	100	
AddressResolverStorage.sol	100	100	100	100	
BeaconProxyControllerStorage.sol	100	100	100	100	
CurrencyControllerStorage.sol	100	100	100	100	
FutureValueVaultStorage.sol	100	100	100	100	
GenesisValueVaultStorage.sol	100	100	100	100	
LendingMarketControllerStorage.sol	100	100	100	100	
LendingMarketStorage.sol	100	100	100	100	
ReserveFundStorage.sol	100	100	100	100	
TokenVaultStorage.sol	100	100	100	100	
ZCTokenStorage.sol	100	100	100	100	
protocol/storages/libraries/	100	100	100	100	
TransferHelperStorage.sol	100	100	100	100	

File	% Stmts	% Branch	% Funcs	% Lines	Uncovered Lines
protocol/storages/mixins/	100	100	100	100	
MixinAddressResolverStorage.sol	100	100	100	100	
protocol/storages/utils/	100	100	100	100	
AccessControlStorage.sol	100	100	100	100	
EIP712UpgradeableStorage.sol	100	100	100	100	
ERC20PermitUpgradeableStorage.sol	100	100	100	100	
ERC20UpgradeableStorage.sol	100	100	100	100	
OwnableStorage.sol	100	100	100	100	
PausableStorage.sol	100	100	100	100	
protocol/types/	100	100	100	100	
ProtocolTypes.sol	100	100	100	100	
protocol/utils/	74.19	56.1	84.21	78.18	
AccessControl.sol	61.11	35.71	69.23	63.64	... 216,217,218
EIP712Upgradeable.sol	66.67	50	80	84.62	57,113
ERC20PermitUpgradeable.sol	100	100	100	100	
ERC20Upgradeable.sol	58.33	36.36	68.42	64.52	... 305,306,307
LockAndMsgSender.sol	100	50	100	83.33	17
Ownable.sol	100	100	100	100	
Pausable.sol	100	87.5	100	100	
Proxyable.sol	100	100	100	100	
UpgradeabilityBeaconProxy.sol	71.43	33.33	83.33	75	15,20
UpgradeabilityProxy.sol	85.71	50	100	87.5	15
UpgradeableBeacon.sol	100	50	100	100	
All files	96.47	87.69	94.84	96.46	

Changelog

About Quantstamp

Quantstamp is a global leader in blockchain security. Founded in 2017, Quantstamp's mission is to securely onboard the next billion users to Web3 through its best-in-class Web3 security products and services.

Quantstamp's team consists of cybersecurity experts hailing from globally recognized organizations including Microsoft, AWS, BMW, Meta, and the Ethereum Foundation. Quantstamp engineers hold PhDs or advanced computer science degrees, with decades of combined experience in formal verification, static analysis, blockchain audits, penetration testing, and original leading-edge research.

To date, Quantstamp has performed more than 500 audits and secured over $200 billion in digital asset risk from hackers. Quantstamp has worked with a diverse range of customers, including startups, category leaders and financial institutions. Brands that Quantstamp has worked with include Ethereum 2.0, Binance, Visa, PayPal, Polygon, Avalanche, Curve, Solana, Compound, Lido, MakerDAO, Arbitrum, OpenSea and the World Economic Forum.

Quantstamp's collaborations and partnerships showcase our commitment to world-class research, development and security. We're honored to work with some of the top names in the industry and proud to secure the future of web3.

Notable Collaborations & Customers:
- Blockchains: Ethereum 2.0, Near, Flow, Avalanche, Solana, Cardano, Binance Smart Chain, Hedera Hashgraph, Tezos
- DeFi: Curve, Compound, Maker, Lido, Polygon, Arbitrum, SushiSwap
- NFT: OpenSea, Parallel, Dapper Labs, Decentraland, Sandbox, Axie Infinity, Illuvium, NBA Top Shot, Zora
- Academic institutions: National University of Singapore, MIT

Timeliness of content

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