



March 31st 2021 — Quantstamp Verified

## Saddle Finance VirtualSwap

This security assessment was prepared by Quantstamp, the leader in blockchain security

### Executive Summary

Type	Bridge and SynthSwap Contracts						
Auditors	Ed Zulkoski, Senior Security Engineer Jose Ignacio Orlicki, Senior Engineer						
Timeline	2021-02-22 through 2021-03-30						
EVM	Muir Glacier						
Languages	Solidity						
Methods	Architecture Review, Unit Testing, Functional Testing, Computer-Aided Verification, Manual Review						
Specification	<a href="#">Virtual Swap Design Doc</a> <a href="#">SIP-89</a>						
Documentation Quality	<div><div></div>High</div>						
Test Quality	<div><div></div>Medium</div>						
Source Code	<table><tr><th>Repository</th><th>Commit</th></tr><tr><td><a href="#">saddle-contract</a></td><td><a href="#">5452b15 (initial report)</a></td></tr><tr><td><a href="#">saddle-contract</a></td><td><a href="#">b0c731c (final report)</a></td></tr></table>	Repository	Commit	<a href="#">saddle-contract</a>	<a href="#">5452b15 (initial report)</a>	<a href="#">saddle-contract</a>	<a href="#">b0c731c (final report)</a>
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Total Issues	5 (5 Resolved)
High Risk Issues	0 (0 Resolved)
Medium Risk Issues	1 (1 Resolved)
Low Risk Issues	0 (0 Resolved)
Informational Risk Issues	2 (2 Resolved)
Undetermined Risk Issues	2 (2 Resolved)



⚠ High Risk	The issue puts a large number of users' sensitive information at risk, or is reasonably likely to lead to catastrophic impact for client's reputation or serious financial implications for client and users.
⚠ Medium Risk	The issue puts a subset of users' sensitive information at risk, would be detrimental for the client's reputation if exploited, or is reasonably likely to lead to moderate financial impact.
✓ Low Risk	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.
ℳ 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.
⬮ Unresolved	Acknowledged the existence of the risk, and decided to accept it without engaging in special efforts to control it.
⬮ 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).
⬮ Resolved	Adjusted program implementation, requirements or constraints to eliminate the risk.
⬮ Mitigated	Implemented actions to minimize the impact or likelihood of the risk.

## Summary of Findings

This audit only pertains to the VirtualSwap [Bridge](#) and [SynthSwapper](#) contracts. The Saddle VirtualSwap contracts appear to be well-architected and properly documented. During our audit, several issues of ranging severity were uncovered, including a mismatch between the inline specification and code, as well as potential access-control issues. We recommend addressing all issues before deploying to mainnet.

Inline documentation and tests are in general of high quality. We recommend adding coverage scripts for the VirtualSwap contracts, however we acknowledge that the mainnet dependency for this test suite makes this non-trivial.

**Update:** all issues have been resolved as of commit [b0c731ce](#).

ID	Description	Severity	Status
QSP-1	Mismatch between inline specification and <code>withdraw</code> function	^ Medium	Fixed
QSP-2	Unchecked function return values	o Informational	Fixed
QSP-3	Settle cloned swappers can be destroyed	o Informational	Fixed
QSP-4	<code>completeToSynth</code> is callable by any user	? Undetermined	Fixed
QSP-5	States <code>ReadyToSettle</code> , <code>PartiallyCompleted</code> and <code>Completed</code> are never checked and can lead to abnormal calls.	? Undetermined	Fixed

## Quantstamp Audit Breakdown

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

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

The Quantstamp auditing process follows a routine series of steps:

1. Code review that includes the following
  - i. Review of the specifications, sources, and instructions provided to Quantstamp to make sure we understand the size, scope, and functionality of the smart contract.
  - ii. Manual review of code, which is the process of reading source code line-by-line in an attempt to identify potential vulnerabilities.
  - iii. 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:
  - i. 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.
  - ii. 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, clarify, 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.

### Toolset

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

#### Setup

Tool Setup:

- [Slither](#) v0.6.14
- [Mythril](#) v0.22.16

Steps taken to run the tools:

1. Installed the Slither tool: `pip install slither-analyzer`
2. Run Slither from the project directory: `slither .`
3. Installed the Mythril tool from Pypi: `pip3 install mythril`
4. Ran the Mythril tool on each contract: `myth -x path/to/contract`



## Findings

### QSP-1 Mismatch between inline specification and `withdraw` function

Severity: *Medium Risk*

Status: Fixed

File(s) affected: `Bridge.sol`

Description: The comment on L275-276 states: "Reverts if the given `itemId` does not represent a `synthToToken` or a `tokenToSynth` swap." However, the function checks `swapType > PendingSwapType.TokenToSynth`, which allows either `SynthToToken` or `TokenToToken` swap types.

Recommendation: Revise either the `require` statement or the inline comment.

### QSP-2 Unchecked function return values

Severity: *Informational*

Status: Fixed

File(s) affected: `SynthSwapper.sol`

Description: In order to ensure that the functions updated state properly, it should be checked that `transfer` calls in `swapSynthToToken` and `withdraw` return true.

Recommendation: Since some tokens are not strictly ERC20-compliant and may not return a boolean, consider using OpenZeppelin's [SafeERC20](#).

### QSP-3 Settle cloned swappers can be destroyed

Severity: *Informational*

Status: Fixed

File(s) affected: `SynthSwapper.sol`, `synthetix/contracts/ExchangeState.sol`

Description: To save some gas on settlement and storage in general (in case of backup or migration), a cloned `SynthSwapper` that has already been used for settled swaps, can be destroyed. You can also remove the swaps from the pending list.

Recommendation: Use `selfdestruct()` to destruct the `SynthSwapper` contracts after the `_settle()` settlement, as the last thing to do, on functions `withdraw()`, `completeToSynth()` and `completeToToken()`. Optionally, you can also remove the completed swaps from the pending list `pendingSynthSwaps`.

### QSP-4 `completeToSynth` is callable by any user

Severity: *Undetermined*

Status: Fixed

File(s) affected: `Bridge.sol`

Description: The function `completeToSynth` is callable by any user after the `maxSecsLeftInWaitingPeriod`. Although the `synth` will be sent to the correct `nftOwner` regardless of `msg.sender`, this could have impact on external contracts that rely upon calling `completeToSynth`. For example, suppose some contract has a function of the form:

```
function getSynthAndTransfer(...) {
    Bridge.completeToSynth(id);
    synth.transfer(external_addr);
}
```

If another arbitrary user invokes `completeToSynth` before the contract invokes it, the funds could be locked forever (assuming the contract did not have sufficient "retrieval" functions).

Recommendation: Consider adding a `require(nftOwner == msg.sender, "not owner");` in `completeToSynth`.

### QSP-5 States `ReadyToSettle`, `PartiallyCompleted` and `Completed` are never checked and can lead to abnormal calls.

Severity: *Undetermined*

Status: Fixed

File(s) affected: `Bridge.sol`, `SynthSwapper.sol`

Description: These pending swap states are set but never checked anywhere; this must be due to implicit assumptions on the state of swaps, but opens the door for duplicated calls to, for example, `completeToToken()`. A second duplicated call to `completeToToken()` might be possible with `swapAmount = 0` even if it was completed before.

Recommendation: Use checks for pending swaps states and also check that `swapAmount` is greater than zero. Similar for `synthInAmount` and `tokenInAmount`, and all functions that depend on swap states.

## Automated Analyses

### Slither

Slither warns that `_setPendingSwapState` performs multiplication on the result of division, however this is intended semantics for the function and no precision issues will occur.

### Mythril

Myth warned of several calls to user-supplied token addresses in `SynthSwapper.sol`, however since this contract is restricted to only be called from the `Bridge`, these were classified as false positives.

Adherence to Specification

The code appears to adhere to provided specifications.

Code Documentation

- [Fixed] It should be noted that `Bridge._setPendingSwapType` should not be called after `Bridge._setPendingSwapState` for an `itemId`, as it would erase the state. While this does not happen in the code currently, it may be worth adding a comment to these functions In order to mitigate future issues.
- [Fixed] In `Bridge.sol` on L517, `TokenToSynth` should be `SynthToToken`.

Adherence to Best Practices

- [Fixed] The function `Bridge._settle` invokes `maxSecsLeftInWaitingPeriod`. While this is fine as is, it appears that `exchanger._internalSettle` also invokes `maxSecsLeftInWaitingPeriod`, and therefore some gas could potentially be saved by removing the duplicate check. Note however that this check could be desirable if the `exchanger` is updated to not include the check.
- [Fixed] Consider improving compressed variables and field names such as `pstss` and `ss`.

Test Results

Test Suite Results

Allowlist setPoolCap, getPoolCap deployed USD pool clone (targeting "SwapFlashLoan") at 0x856e4424f806D16E8CBC702B3c0F2ede5468eae5		
(index)	0	1
0	'Allowlist'	'0x5FbDB2315678afecb367fE032d93F642f64180aa3'
1	'MathUtils'	'0xe7f1725E7734CE288F8367e18b143E90bb3F0512'
2	'SwapUtilsGuarded'	'0x9fE46736679d2D9a65F0992F2272dE9f3c7fa6e0'
3	'SwapUtils'	'0xCf7Ed3AccA5a467e9e704C705E8D87F634fB0Fc9'
4	'SwapDeployer'	'0xDc64a140Aa3E981100a9becA4E685f962f0cF6C9'
5	'Swap'	'0x5FC8d32690cc91D4c39d9d3abcBD16989F875707'
6	'SwapFlashLoan'	'0x0165878A594ca255338adfa4d48449f69242Eb8F'
7	'TBTC'	'0xa513E6E4b8f2a923D98304ec87F64353C4D5C853'
8	'WBTC'	'0x8A791620dd6260079BF849Dc5567aDC3F2FdC318'
9	'RENBTC'	'0xB7f88C63BbcaD18155201308C8f3540b07f84F5e'
10	'SBTC'	'0x0DCd1Bf9A1b36cE34237eEaFef2209328468CD82'
11	'SaddleBTCPool'	'0x0B306BF915C4d645ff596e518fAf3F9669b97016'
12	'SaddleBTCPoolLPToken'	'0x524F04724632eED237cbA3c37272e018b3A7967e'
13	'DAI'	'0x9A9f2CCfdE556A7E9Ff0848998Aa4a0CFD8863AE'
14	'USDC'	'0x3Aa5ebB10DC797CAC828524e59A333d0A371443c'
15	'USDT'	'0x59b670e9fa9D0A427751Af201D676719a970857b'
16	'SaddleUSDPool'	'0x856e4424f806D16E8CBC702B3c0F2ede5468eae5'
17	'SaddleUSDPoolLPToken'	'0x63f84713F52422Af2F8E18b56703b0f80CCcCBcE'

✓ Emits PoolCap event

✓ Reverts when the pool address is 0x0

✓ Reverts when non-owner tries to set the pool cap

✓ Sets and gets pool cap

setPoolAccountLimit and getPoolAccountLimit

✓ Emits PoolAccountLimit event

✓ Reverts when the pool address is 0x0

✓ Reverts when non-owner tries to set the pool account limit

✓ Sets and gets pool account limit

verifyAddress() & isAccountVerified()

✓ Returns true when proof and address are correct

✓ Returns true when merkleProof is empty but the account has been verified

✓ Returns true when merkleProof is wrong but the account has been verified

✓ Returns false when merkleProof is empty and the account has NOT been verified

✓ Returns false when address is wrong

updateMerkleRoot

✓ Emits NewMerkleRoot event

✓ Updates merkleRoot successfully

✓ Reverts when called by non-owner

Swap Flashloan

✓ Reverts when the borrower does not have enough to pay back

✓ Reverts when flashloan debt is not paid

✓ Reverts when calling re-entering swap contract via 'addLiquidity'

✓ Reverts when calling re-entering swap contract via 'swap'

✓ Reverts when calling re-entering swap contract via 'removeLiquidity'

✓ Reverts when calling re-entering swap contract via 'removeLiquidityOneToken'

✓ Succeeds when fee is paid off

setFlashLoanFees

✓ Reverts when called by non-owner

✓ Reverts when fees are not in the range

✓ Succeeds when fees are in the valid range

GenericERC20

✓ Reverts when minting 0

LPToken

✓ Reverts when minting 0

MathUtils

within1

✓ Returns true when a > b and a - b <= 1

✓ Returns false when a > b and a - b > 1

✓ Returns true when a <= b and b - a <= 1

✓ Returns false when a <= b and b - a > 1

✓ Reverts during an integer overflow

difference

✓ Returns correct difference when a > b

✓ Returns correct difference when a <= b

✓ Reverts during an integer overflow

StakeableTokenWrapper

✓ Reverts when staking 0

✓ Emits an event on staking

✓ Emits an event on withdrawing

✓ Only allows staked funds to be withdrawn

✓ Returns correct staked balances

✓ Returns correct total supply

Swap

swapStorage

lpToken

✓ Returns correct lpTokenName

✓ Returns correct lpTokenSymbol

✓ Returns true after successfully calling transferFrom

A

✓ Returns correct A value

fee

✓ Returns correct fee value



```
adminFee
  ✓ Returns correct adminFee value
getToken
  ✓ Returns correct addresses of pooled tokens
  ✓ Reverts when index is out of range
getTokenIndex
  ✓ Returns correct token indexes
  ✓ Reverts when token address is not found
getTokenBalance
  ✓ Returns correct balances of pooled tokens
  ✓ Reverts when index is out of range
getA
  ✓ Returns correct value
addLiquidity
  ✓ Reverts when contract is paused
  ✓ Reverts with 'Amounts must match pooled tokens'
  ✓ Reverts with 'Cannot withdraw more than available'
  ✓ Reverts with 'Must supply all tokens in pool'
  ✓ Succeeds with expected output amount of pool tokens
  ✓ Succeeds with actual pool token amount being within ±0.1% range of calculated pool token
  ✓ Succeeds with correctly updated tokenBalance after imbalanced deposit
addLiquidity: Expected 2997459774673651937, got 2997459774673651937
  ✓ Returns correct minted lpToken amount
  ✓ Reverts when minToMint is not reached due to front running
  ✓ Reverts when block is mined after deadline
  ✓ Emits addLiquidity event
removeLiquidity
  ✓ Reverts with 'Cannot exceed total supply'
  ✓ Reverts with 'minAmounts must match poolTokens'
  ✓ Succeeds even when contract is paused
  ✓ Succeeds with expected return amounts of underlying tokens
addLiquidity: Expected 2997459774673651937, got 2997459774673651937
removeLiquidity: Expected 1199593357354995187, got 1199593357354995187
removeLiquidity: Expected 1799390036032492780, got 1799390036032492780
  ✓ Returns correct amounts of received tokens
  ✓ Reverts when user tries to burn more LP tokens than they own
  ✓ Reverts when minAmounts of underlying tokens are not reached due to front running
  ✓ Reverts when block is mined after deadline
  ✓ Emits removeLiquidity event
removeLiquidityImbalance
  ✓ Reverts when contract is paused
  ✓ Reverts with 'Amounts should match pool tokens'
  ✓ Reverts with 'Cannot withdraw more than available'
  ✓ Succeeds with calculated max amount of pool token to be burned (±0.1%)
addLiquidity: Expected 2997459774673651937, got 2997459774673651937
removeLiquidityImbalance: Expected 1110205039594566418, got 1110205039594566418
  ✓ Returns correct amount of burned lpToken
  ✓ Reverts when user tries to burn more LP tokens than they own
  ✓ Reverts when minAmounts of underlying tokens are not reached due to front running
  ✓ Reverts when block is mined after deadline
  ✓ Emits RemoveLiquidityImbalance event
removeLiquidityOneToken
  ✓ Reverts when contract is paused.
  ✓ Reverts with 'Token index out of range'
  ✓ Reverts with 'Withdraw exceeds available'
  ✓ Reverts with 'Token not found'
  ✓ Succeeds with calculated token amount as minAmount
addLiquidity: Expected 2997459774673651937, got 2997459774673651937
removeLiquidityOneToken: Expected 1864597634420375471, got 1864597634420375471
  ✓ Returns correct amount of received token
  ✓ Reverts when user tries to burn more LP tokens than they own
  ✓ Reverts when minAmount of underlying token is not reached due to front running
  ✓ Reverts when block is mined after deadline
  ✓ Emits RemoveLiquidityOne event
swap
  ✓ Reverts when contract is paused
  ✓ Reverts with 'Token index out of range'
  ✓ Reverts with 'Cannot swap more than you own'
  ✓ Succeeds with expected swap amounts
  ✓ Reverts when minDy (minimum amount token to receive) is not reached due to front running
  ✓ Succeeds when using lower minDy even when transaction is front-ran
addLiquidity: Expected 2997459774673651937, got 2997459774673651937
swap: Expected 999000000000000000, got 999000000000000000
  ✓ Returns correct amount of received token
  ✓ Reverts when block is mined after deadline
  ✓ Emits TokenSwap event
getVirtualPrice
  ✓ Returns expected value after initial deposit
  ✓ Returns expected values after swaps
  ✓ Returns expected values after imbalanced withdrawal
  ✓ Value is unchanged after balanced deposits
  ✓ Value is unchanged after balanced withdrawals
setSwapFee
  ✓ Emits NewSwapFee event
  ✓ Reverts when called by non-owners
  ✓ Reverts when fee is higher than the limit
  ✓ Succeeds when fee is within the limit
setAdminFee
  ✓ Emits NewAdminFee event
  ✓ Reverts when called by non-owners
  ✓ Reverts when adminFee is higher than the limit
  ✓ Succeeds when adminFee is within the limit
getAdminBalance
  ✓ Reverts with 'Token index out of range'
  ✓ Is always 0 when adminFee is set to 0
  ✓ Returns expected amounts after swaps when adminFee is higher than 0
withdrawAdminFees
  ✓ Reverts when called by non-owners
  ✓ Succeeds when there are no fees withdrawn
  ✓ Succeeds with expected amount of fees withdrawn
  ✓ Withdrawing admin fees has no impact on users' withdrawal
Test withdrawal fees on removeLiquidity
  ✓ Removing liquidity immediately after deposit
  ✓ Removing liquidity 2 weeks after deposit
  ✓ Removing liquidity 4 weeks after deposit
Test withdrawal fees on removeLiquidityOne
  ✓ Removing liquidity immediately after deposit
  ✓ Removing liquidity 2 weeks after deposit
  ✓ Removing liquidity 4 weeks after deposit
Test withdrawal fees on removeLiquidityImbalance
  ✓ Removing liquidity immediately after deposit
  ✓ Removing liquidity 2 weeks after deposit
  ✓ Removing liquidity 4 weeks after deposit
Verify changing withdraw fee works as expected
  ✓ Increase withdraw fee from 0% to 0.5%, immediately after last deposit
  ✓ Increase withdraw fee from 0% to 0.5%, 2 weeks after last deposit
  ✓ Increase withdraw fee from 0% to 0.5%, 4 weeks after last deposit
  ✓ Increase withdraw fee from 0.5% to 1%
  ✓ Decrease withdraw fee from 0.5% to 0%
  ✓ Decrease withdraw fee from 1% to 0.5%
updateUserWithdrawFee
  ✓ Reverts with 'Only callable by pool token'
  ✓ Test adding liquidity, and once again at 2 weeks mark then removing all deposits at 4 weeks mark
  ✓ Verify withdraw fees are updated on transfer
setDefaultWithdrawFee
  ✓ Emits NewWithdrawFee event
  ✓ Setting the withdraw fee affects past deposits as well
  ✓ Reverts when fee is too high
rampA
  ✓ Emits RampA event
  ✓ Succeeds to ramp upwards
  ✓ Succeeds to ramp downwards
  ✓ Reverts when non-owner calls it
  ✓ Reverts with 'Wait 1 day before starting ramp'
  ✓ Reverts with 'Insufficient ramp time'
  ✓ Reverts with 'futureA_ must be > 0 and < MAX_A'
  ✓ Reverts with 'futureA_ is too small'
  ✓ Reverts with 'futureA_ is too large'
stopRampA
  ✓ Emits StopRampA event
  ✓ Stop ramp succeeds
  ✓ Reverts with 'Ramp is already stopped'
Check for timestamp manipulations
  ✓ Check for maximum differences in A and virtual price when A is increasing
  ✓ Check for maximum differences in A and virtual price when A is decreasing
Check for attacks while A is ramping upwards
  When tokens are priced equally: attacker creates massive imbalance prior to A change, and resolves it after
    ✓ Attack fails with 900 seconds between blocks
    ✓ Attack fails with 2 weeks between transactions (mimics rapid A change)
  When token price is unequal: attacker 'resolves' the imbalance prior to A change, then recreates the imbalance.
```

```

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```

```

Swap with 4 tokens
addLiquidity
    ✓ Add liquidity succeeds with pool with 4 tokens
swap
    ✓ Swap works between tokens with different decimals
removeLiquidity
    ✓ Remove Liquidity succeeds
Check for timestamp manipulations
    ✓ Check for maximum differences in A and virtual price when increasing
    ✓ Check for maximum differences in A and virtual price when decreasing
Check for attacks while A is ramping upwards
When tokens are priced equally: attacker creates massive imbalance prior to A change, and resolves it after
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```

```

Swap
swapStorage#constructor
    ✓ Reverts with '_pooledTokens.length <= 1'
    ✓ Reverts with '_pooledTokens.length > 32'
    ✓ Reverts with '_pooledTokens decimals mismatch'
    ✓ Reverts with 'Duplicate tokens'
    ✓ Reverts with 'The 0 address isn't an ERC-20'
    ✓ Reverts with 'Token decimals exceeds max'
    ✓ Reverts with '_a exceeds maximum'
    ✓ Reverts with '_fee exceeds maximum'
    ✓ Reverts with '_adminFee exceeds maximum'
    ✓ Reverts with '_withdrawFee exceeds maximum'

```

```

Virtual swap bridge [ @skip-on-coverage ]
setSynthIndex
network block skew detected; skipping block events
deployed USD pool clone (targeting "SwapFlashLoan") at 0x8aCd85898458400f7Db866d53FCFF6f0D49741FF

```

(index)	0	1
0	'Allowlist'	'0x5FC8d32690cc91D4c39d9d3abc8D16989F875707'
1	'MathUtils'	'0x0165878A594ca255338adfa4d48449f69242Eb8F'
2	'SwapUtilsGuarded'	'0xa513E6E4b8f2a923D98304ec87F64353C4D5C853'
3	'SwapUtils'	'0x2279B7A0a67DB372996a5FaB50D91eAA73d2eBe6'
4	'SwapDeployer'	'0x8A791620dd6260079BF849Dc5567aDC3F2FdC318'
5	'Swap'	'0x610178dA211FEF7D417bC0e6FeD39F05609AD788'
6	'SwapFlashLoan'	'0xB7f88C638bcaD18155201308C8f3540b07f84F5e'
7	'tBTC'	'0xA51c1fc2f0D1a1b8494Ed1FE312d7C3a78Ed91C0'
8	'WBTC'	'0x9A676e781A523b5d0C0e43731313A708CB607508'
9	'RENBTC'	'0x959922bE3CAee4b8Cd9a407cc3ac1C251C2007B1'
10	'sBTC'	'0x68B1D87F95878fE058998F19b66F4baba5De1aed'
11	'SaddleBTCPool'	'0xc6e7DF5E7b4f2A278906862b61205850344D4e7d'
12	'SaddleBTCPoolLPToken'	'0x553BED26A78b94862e53945941e4ad6E4F2497da'
13	'DAI'	'0x4ed7c70f96B899c776995fB64377f0d4aB3B0e1C1'
14	'USDC'	'0xa85233C63b9Ee964Add6F2cffe00Fd84eb32338F'
15	'USDT'	'0x7a2088a1bFc9d81c55368AE168C2C02570cB814F'
16	'SaddleUSDPool'	'0x8aCd85898458400f7Db866d53FCFF6f0D49741FF'
17	'SaddleUSDPoolLPToken'	'0xe4c278D3211848BFB72e4e59e16a953b68638EF'

```

    ✓ Emits SynthIndex event
    ✓ Succeeds with correct currencyKey
    ✓ Reverts when currencyKey do not match
    ✓ Reverts when given index is not a synth
calcTokenToSynth
    ✓ Succeeds to calculate wBTC -> sUSD
    ✓ Succeeds to calculate wBTC -> sDEFI
tokenToSynth
    ✓ Reverts when minAmount is not reached
    ✓ Succeeds to swap wBTC -> sUSD then settle it
    ✓ Succeeds to swap wBTC -> sDEFI then settle it
    ✓ Reverts when minAmount is not reached
calcSynthToToken
    ✓ Succeeds to calculate sUSD -> tBTC
    ✓ Succeeds to calculate sDEFI -> tBTC
synthToToken
    ✓ Reverts when minMediumSynthAmount is not reached
    ✓ Succeeds to swap sUSD -> sBTC -> tBTC
calcTokenToToken
    ✓ Succeeds to calculate tBTC -> sBTC -> sUSD -> USDC
    ✓ Succeeds to calculate USDC -> sUSD -> sBTC -> WBTC
tokenToToken
    ✓ Reverts when minMediumSynthAmount is not reached
Initiate a cross asset swap: tBTC -> sBTC -> sUSD -> USDC
completeToToken
    ✓ Succeeds with the full amount
    ✓ Succeeds with partial amounts
    ✓ Reverts when not reached minAmount
withdraw
    ✓ Succeeds to withdraw the synth in full amount
    ✓ Succeeds to withdraw in partial amounts
    ✓ Reverts when trying to withdraw more than the synth balance

```

Solc version: 0.6.12		Optimizer enabled: true		Runs: 10000	Block limit: 950000 gas	
Methods						
Contract	Method	Min	Max	Avg	# calls	usd (avg)
Allowlist	setPoolAccountLimit	-	-	44098	4	-
Allowlist	setPoolCap	-	-	44097	4	-
Allowlist	updateMerkleRoot	-	-	28761	3	-
Allowlist	verifyAddress	23109	46012	33592	28	-
Bridge	completeToSynth	210061	217548	213805	4	-
Bridge	completeToToken	335141	404236	347224	6	-



Bridge	· setSynthIndex	· 96359	· 96371	· 96368	· 31	· -
Bridge	· synthToToken	· -	· -	· 1109719	· 1	· -
Bridge	· tokenToSynth	· 1210381	· 1284395	· 1247388	· 4	· -
Bridge	· tokenToToken	· -	· -	· 1225585	· 6	· -
Bridge	· withdraw	· 151901	· 216725	· 195109	· 3	· -
ERC20	· approve	· 44379	· 66895	· 54120	· 21	· -
ERC20	· transfer	· 23949	· 168560	· 71976	· 9	· -
FlashLoanBorrowerExample	· flashLoan	· -	· -	· 64796	· 3	· -
GenericERC20	· approve	· 28998	· 44358	· 44063	· 62	· -
GenericERC20	· mint	· 51664	· 66736	· 58638	· 93	· -
GenericERC20	· transfer	· 51023	· 51035	· 51032	· 4	· -
LPToken	· approve	· 25158	· 44358	· 29526	· 45	· -
LPToken	· transfer	· 62059	· 104737	· 83398	· 2	· -
LPToken	· transferFrom	· -	· -	· 106260	· 1	· -
StakeableTokenWrapper	· stake	· 40008	· 76008	· 71722	· 7	· -
StakeableTokenWrapper	· withdraw	· -	· -	· 33827	· 2	· -
Swap	· addLiquidity	· 199698	· 534628	· 278620	· 98	· -
Swap	· initialize	· 1548026	· 1678305	· 1613178	· 4	· -
Swap	· pause	· -	· -	· 44992	· 5	· -
Swap	· rampA	· 75293	· 76079	· 75502	· 38	· -
Swap	· removeLiquidity	· 71038	· 169886	· 102181	· 20	· -
Swap	· removeLiquidityImbalance	· 189639	· 223228	· 207785	· 8	· -
Swap	· removeLiquidityOneToken	· 160930	· 168639	· 164422	· 6	· -
Swap	· setAdminFee	· 45428	· 45440	· 45433	· 7	· -
Swap	· setDefaultWithdrawFee	· 15368	· 45416	· 41661	· 24	· -
Swap	· setSwapFee	· -	· -	· 30451	· 3	· -
Swap	· stopRampA	· -	· -	· 50146	· 2	· -
Swap	· swap	· 145049	· 178589	· 163023	· 83	· -
Swap	· unpause	· -	· -	· 15005	· 1	· -
Swap	· withdrawAdminFees	· 40048	· 74212	· 62824	· 3	· -
SwapDeployer	· deploy	· 1713760	· 1737449	· 1718503	· 5	· -
SwapFlashLoan	· addLiquidity	· -	· -	· 454095	· 1	· -
SwapFlashLoan	· initialize	· -	· -	· 1720181	· 1	· -
SwapFlashLoan	· setFlashLoanFees	· -	· -	· 32670	· 1	· -
SwapGuarded	· disableGuard	· -	· -	· 14033	· 4	· -
TestSwapReturnValues	· test_addLiquidity	· -	· -	· 300724	· 5	· -
TestSwapReturnValues	· test_removeLiquidity	· -	· -	· 169982	· 1	· -
TestSwapReturnValues	· test_removeLiquidityImbalance	· -	· -	· 234593	· 1	· -
TestSwapReturnValues	· test_removeLiquidityOneToken	· -	· -	· 226557	· 1	· -
TestSwapReturnValues	· test_swap	· -	· -	· 183726	· 1	· -
Deployments					· % of limit	
Allowlist		· -	· -	· 815750	· 8.6 %	· -
Bridge		· -	· -	· 5534221	· 58.3 %	· -
FlashLoanBorrowerExample		· -	· -	· 653938	· 6.9 %	· -
GenericERC20		· 1072566	· 1072722	· 1072619	· 11.3 %	· -
LPToken		· -	· -	· 1300284	· 13.7 %	· -
MathUtils		· -	· -	· 114689	· 1.2 %	· -
StakeableTokenWrapper		· -	· -	· 578238	· 6.1 %	· -
Swap		· 4394640	· 4394904	· 4394902	· 46.3 %	· -
SwapDeployer		· -	· -	· 650763	· 6.9 %	· -
SwapFlashLoan		· -	· -	· 5102072	· 53.7 %	· -
SwapGuarded		· -	· -	· 4172840	· 43.9 %	· -
SwapUtils		· -	· -	· 4044110	· 42.6 %	· -
SwapUtilsGuarded		· -	· -	· 4213392	· 44.4 %	· -
TestSwapReturnValues		· -	· -	· 1701825	· 17.9 %	· -
225 passing (3m)						

## Code Coverage

The code coverage scripts do not currently handle the VirtualSwap contracts due to a mainnet dependency.

# Appendix

## File Signatures

The following are the SHA-256 hashes of the reviewed files. A file with a different SHA-256 hash has been modified, intentionally or otherwise, after the security review. You are cautioned that a different SHA-256 hash could be (but is not necessarily) an indication of a changed condition or potential vulnerability that was not within the scope of the review.

### Contracts

e38ac7efbdcf842db9d90c3fea11e98c9661e14b5e99744be2fabd34fd765f10 ./contracts/SwapFlashLoan.sol

aa5a611727bc5fa1ee6e3286182846909eeaed8a0a58dd15840927271ae415e3 ./contracts/MathUtils.sol

f4d79582b67df36d82648a8b7af60b14850e46713c5886acd2350f07677b0a28 ./contracts/SwapDeployer.sol

c44affe35f4a86bcfc1c3e55330ecab8c7d279aceb37a4f7ff67810f9a19aa81 ./contracts/OwnerPausableUpgradeable.sol

fab569ac64d66193f05f7de14d021c57751a1a6ed8eee3493589dc65a684825a ./contracts/StakeableTokenWrapper.sol

8616297461c3dfc01f214f0eea9170e3157d089254c1008b3b117b9911b41854 ./contracts/LPToken.sol

3aab4d2301bf13631af13d2f9125afd9d129b36379d47570508496831d6d79d8 ./contracts/Swap.sol

9812c5a9c2e8a242cad31e4739e6641ea10566af47398ab5542a75b17f57d5b2 ./contracts/SwapUtils.sol

7b96876fc12505f74729a70aaa63e8cf78742474837f97b2b32604842c8761d4 ./contracts/interfaces/IFlashLoanReceiver.sol

7ff1e26341789a794ee6542cc9507b0200225d3797f96b478ad4a2ca4bf4e8e4 ./contracts/interfaces/IAllowlist.sol

22ee52c76ac29947b7a510086ac31b270c4d5ca80e20018cff30e771e02a7342 ./contracts/interfaces/ISwap.sol

9dae47c485ff6988fc457389ff7fe8a1de8d2de0ce285b5ecbfd55217e700ae3 ./contracts/interfaces/ISwapFlashLoan.sol

077ec0265ad29bf6133fd5181219938829932e4e4296f1c868d1db5b99b1bf8e ./contracts/interfaces/ISwapGuarded.sol

764ddb44a85a4a852974cab654d7801fa4f0f577af4c0f0b67ff07b9ad79709 ./contracts/helper/FlashLoanBorrowerExample.sol

0f6f94dd4e8b44b36d18b6e56804a28b8e3719cc0d6041c69aacabd6a254d586 ./contracts/helper/GenericERC20.sol

5187d232f17e9d54930a79c71703f4cccd2c38a3cfee2a590ea05891e390490e ./contracts/helper/test/TestSwapReturnValues.sol

a155b4381e1a6b5801e616bbfc4b5696f77cf55bead2f98951651f84638ca415 ./contracts/VirtualSwap/Bridge.sol

11531f51926013e586e9832b6865333c8ac1e69ded363d72afcca39a342f177b ./contracts/VirtualSwap/SynthSwapper.sol

1a695d67c0222c095ca5d7f83d1f025e0378dc0504afe21cbeea1e77403e2c9f ./contracts/guarded/OwnerPausable.sol

79836cd81df43f5a3891db79f315496dee6b05f345353f0b06438c320d00cdab ./contracts/guarded/SwapUtilsGuarded.sol

ffe4c2282fe44a009faa0c577d2e2caa8f1000b5cf4b88d2c94bbcc39f98b355 ./contracts/guarded/Allowlist.sol

30b25e55fc8686bee317e23824f11f6c0f3b3503687bf000fc39470bc973bb48 ./contracts/guarded/SwapGuarded.sol

005cfd5763bcdff308ca7a2674f790e43ed2f9be3405d25c03d499057c56a3026 ./contracts/guarded/LPTokenGuarded.sol

### Tests

6f157630b4ccd0279a0887b3e9bd62e72e8f2dec8c1e640824d24fdab4882c0f ./test/lpToken.ts

8dd00cadbb4d99ea3be0ecbe062575e8c0c871726aa4edd4d592cf4758486d55 ./test/virtualBridge.ts

be4cac1ab2bb9ba97ee0863993fe92fc0d64686e362231ec2f63ff718a0de428 ./test/mathUtils.ts

ac81a3ae6ae442bfe3e0797c3dae8a823fa2aadf56ded535d23ff2056ada64d1 ./test/swapInitialize.ts

0949108ab466b3b02385aae84ebbe0ce6df4dfa1fd01588e5d39543611e73e3b ./test/allowlist.ts

02a5d923537e1a467e8f6fa36454730e587356bfcc55f31239ec772343fb8e0f ./test/genericERC20.ts

a77b97808fa8cc34d3c2baa157fd1ba9414f89f0a21ae84206c4663b27006b7c ./test/flashloan.ts

dec49dd70632839d1378b227a1a24e4758a59e6aa2d830a39de11effe8d5c62b ./test/swapDeployer.ts

d5fcbbc87915c8b24ee245734331addf0d9d35f63c4df8e2a573f83cb11b8639a ./test/testUtils.ts

fccf2e590957110c8f249ace44adfacc7b35853ae16644ec3f0d7698b1c182da9 ./test/swap.ts

8e57a0121443812df3e8f5739fb450c134ce0cfe302c440db19f00d4c6aca0ea ./test/stakeableTokenWrapper.ts

dbc1c37cc026bb74351fb554e6cfbf2ef8aa7bc977f4f500a420f1eac623cefa ./test/swap4tokens.ts

## Changelog

- 2021-03-07 - Initial report
- 2021-03-29 - Updated report based on commit [b0c731ce](#)



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With over 1000 Google scholar citations and numerous published papers, Quantstamp’s team has decades of combined experience in formal verification, static analysis, and software verification. Quantstamp has also developed a protocol to help smart contract developers and projects worldwide to perform cost-effective smart contract security scans.

To date, Quantstamp has protected \$5B in digital asset risk from hackers and assisted dozens of blockchain projects globally through its white glove security assessment services. As an evangelist of the blockchain ecosystem, Quantstamp assists core infrastructure projects and leading community initiatives such as the Ethereum Community Fund to expedite the adoption of blockchain technology.

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