



AAVE

# **Aave v3.0.1 & v3.0.2 Contract Review**

*Version: 3.0*

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## Introduction

Sigma Prime was commercially engaged to perform a time-boxed security review of the Aave smart contracts. The review focused solely on the security aspects of the Solidity implementation of the contract, though general recommendations and informational comments are also provided.

## Disclaimer

Sigma Prime makes all effort but holds no responsibility for the findings of this security review. Sigma Prime does not provide any guarantees relating to the function of the smart contract. Sigma Prime makes no judgements on, or provides any security review, regarding the underlying business model or the individuals involved in the project.

## Document Structure

The first section provides an overview of the functionality of the Aave smart contracts contained within the scope of the security review. A summary followed by a detailed review of the discovered vulnerabilities is then given which assigns each vulnerability a severity rating (see [Vulnerability Severity Classification](#)), an *open/closed/resolved* status and a recommendation. Additionally, findings which do not have direct security implications (but are potentially of interest) are marked as *informational*.

Outputs of automated testing that were developed during this assessment are also included for reference (in the Appendix: [Test Suite](#)).

The appendix provides additional documentation, including the severity matrix used to classify vulnerabilities within the Aave smart contracts.

## Overview

Aave `v3.0.1` is an update to the [aave-v3-core](#) repository. The following are a list of changes implemented in `v3.0.1`:

- ATokens transfer events have been updated to be ERC20 compliant.
- Patch to prevent reentrancy on withdrawals and liquidations, only applies to reentrant tokens (e.g. ERC777).
- Allows borrows and repays to occur in the same block.
- Adds a return value for `backUnbacked()`.
- Adds a configuration parameter to a reserve to disable flash loans for a collateral.
- Fix edge case for liquidations if protocol fee is greater than user balance.
- Patches a bug when reserve factor is 100%.
- Optimises state updates if the timestamp is unchanged.
- AToken function `handleRepayment()` adds the `onBehalfOf` parameter.
- Unbacked tokens are always accounted for when calculating interest rates.

The upgrade `v3.0.2` consists of the following changes.

- Prevent LTV zero asset from being enabled as collateral.
- Do not automatically enable collateral in isolation mode.
- Add the role `ISOLATED_COLLATERAL_SUPPLIER`.
- Fix flashloan premium amount when borrow occurs.

## Security Assessment Summary

This review was conducted on the files hosted on the [aave-v3-core repository](#) and assessed updates from v3.0.0 to v3.0.1 as seen in PR [#701 @ 428e258](#).

An additional review was performed on updates from v3.0.1 to v3.0.2 as seen in PR [#820](#) and PR [#822](#). No new findings were found in the review of v3.0.2.

*Note: the OpenZeppelin libraries and dependencies were excluded from the scope of this assessment.*

The manual code review section of the report is focused on identifying any and all issues/vulnerabilities associated with the business logic implementation of the contracts. This includes their internal interactions, intended functionality and correct implementation with respect to the underlying functionality of the Ethereum Virtual Machine (for example, verifying correct storage/memory layout). Additionally, the manual review process focused on all known Solidity anti-patterns and attack vectors. These include, but are not limited to, the following vectors: re-entrancy, front-running, integer overflow/underflow and correct visibility specifiers. For a more thorough, but non-exhaustive list of examined vectors, see [\[1, 2\]](#).

To support this review, the testing team used the following automated testing tools:

- Mythril: <https://github.com/ConsenSys/mythril>
- Slither: <https://github.com/trailofbits/slither>
- Surya: <https://github.com/ConsenSys/surya>

Output for these automated tools is available upon request.

## Findings Summary

The testing team identified a total of 2 issues during this assessment. Categorised by their severity:

- Informational: 2 issues.

## Detailed Findings

This section provides a detailed description of the vulnerabilities identified within the Aave smart contracts. Each vulnerability has a severity classification which is determined from the likelihood and impact of each issue by the matrix given in the Appendix: [Vulnerability Severity Classification](#).

A number of additional properties of the contracts, including gas optimisations, are also described in this section and are labelled as “informational”.

Each vulnerability is also assigned a **status**:

- **Open:** the issue has not been addressed by the project team.
- **Resolved:** the issue was acknowledged by the project team and updates to the affected contract(s) have been made to mitigate the related risk.
- **Closed:** the issue was acknowledged by the project team but no further actions have been taken.

# Summary of Findings

| ID       | Description                                     | Severity      | Status   |
|----------|---|---------------|----------|
| AV301-01 | Mint Event Is Emitted When Zero Value Is Minted | Informational | Resolved |
| AV301-02 | Miscellaneous General Comments                  | Informational | Resolved |

|                 |   |
|-----------------|---|
| <b>AV301-01</b> | Mint Event Is Emitted When Zero Value Is Minted |
| Asset           | ScaledBalanceTokenBase.sol                      |
| Status          | <b>Resolved:</b> See <a href="#">Resolution</a> |
| Rating          | Informational                                   |

## Description

Scaled balance tokens such as `aTokens` accrue interest and increase in value. When these tokens are transferred both the sender's and receiver's balances are checked for a balance increase. `Mint` events are always emitted for the sender and only for the receiver if there has been a balance increase.

```

138 function _transfer(
139     address sender,
140     address recipient,
141     uint256 amount,
142     uint256 index
143 ) internal {
144     uint256 senderScaledBalance = super.balanceOf(sender);
145     uint256 senderBalanceIncrease = senderScaledBalance.rayMul(index) -
146         senderScaledBalance.rayMul(_userState[sender].additionalData);
147     uint256 recipientScaledBalance = super.balanceOf(recipient);
148     uint256 recipientBalanceIncrease = recipientScaledBalance.rayMul(index) -
149         recipientScaledBalance.rayMul(_userState[recipient].additionalData);
150     _userState[sender].additionalData = index.toUint128();
151     _userState[recipient].additionalData = index.toUint128();
152
153     super._transfer(sender, recipient, amount.rayDiv(index).toUint128());
154
155     emit Transfer(address(0), sender, senderBalanceIncrease);
156     emit Mint(_msgSender(), sender, senderBalanceIncrease, senderBalanceIncrease, index);
157
158     if (recipientBalanceIncrease > 0) {
159         emit Transfer(address(0), recipient, recipientBalanceIncrease);
160         emit Mint(_msgSender(), recipient, recipientBalanceIncrease, recipientBalanceIncrease, index);
161     }

```

It is expected for the case where `senderBalanceIncrease = 0` to occur if a sender makes multiple actions in the same block. One example is making two transfers as the first transfer will update the `_userState[sender].additionalData` to the current `index`. The second transfer will then have `_userState[sender].additionalData = index` and hence `senderBalanceIncrease` will be zero.

The impact of the issue is informational. Emitting zero value events will increase gas costs and increase the load of processing events off-chain. There are no funds at risk and the events will always display the correct values.

## Recommendations

The issue may be resolved by only emitting the `Mint` event if the `senderBalanceIncrease` is non-zero.



## Resolution

The issue is resolved in PR [#745](#) by adding the following check.

```
if (senderBalanceIncrease > 0) {  
    emit Transfer(address(o), sender, senderBalanceIncrease);  
    emit Mint(msgSender(), sender, senderBalanceIncrease, senderBalanceIncrease, index);  
}
```

|                 |   |
|-----------------|---|
| <b>AV301-02</b> | Miscellaneous General Comments                  |
| Asset           | contracts/*                                     |
| Status          | <b>Resolved:</b> See <a href="#">Resolution</a> |
| Rating          | Informational                                   |

## Description

This section details miscellaneous findings discovered by the testing team that do not have direct security implications:

### 1. `ReserveCache.currLiquidityIndex` is no longer necessary.

The variable `currLiquidityIndex` is cached in `ReserveCache` to help minimise storage load operations. This variable is only ever used in `_updateIndexes()`. It is safe to remove this variable and instead use `nextLiquidityIndex` during `_updateIndexes()`.

### 2. Camel Case inconsistencies in the use of `flashLoan` and `flashloan`.

Consider updating the the following types to have an upper-case "L":

- `ValidationLogic.validateFlashloanSimple()`
- `DataTypes.FlashloanSimpleParams`
- `ValidationLogic.validateFlashloan()`
- `DataTypes.FlashloanParams`
- `Pool.updateFlashloanPremiums()` and `IPool.updateFlashloanPremiumTotal()`
- `IPoolConfigurator.FlashloanPremiumTotalUpdated` event and parameters `oldFlashloanPremiumTotal` and `newFlashloanPremiumTotal`
- `IPoolConfigurator.FlashloanPremiumToProtocolUpdated` event and parameters `oldFlashloanPremiumTotal` and `newFlashloanPremiumTotal`
- `IPoolConfigurator` and `PoolConfigurator` function `updateFlashloanPremiumTotal()` function (also parameters and local variables for this function)
- `IPoolConfigurator` and `PoolConfigurator` function `updateFlashloanPremiumToProtocol()` function (also parameters and local variables for this function)

## Recommendations

Ensure that the comments are understood and acknowledged, and consider implementing the suggestions above.

## Resolution

The development team have opted not to remove `currLiquidityIndex`. The reason is that the current logic matches `currVariableBorrowIndex` and `nextVariableBorrowIndex`, modifying `currLiquidityIndex` will cause inconsistencies between these two variables and complicate the code base.

The discrepancies between `flashloan` and `flashLoan` require changes to interfaces which impact users of the smart contracts. Changes will not be made in a minor patch and will be implemented in a future update.

## Appendix A Test Suite

A non-exhaustive list of tests were constructed to aid this security review and are provided alongside this document. The `brownie` framework was used to perform these tests and the output is given below.

|  |        |       |
|--|--------|-------|
| test_borrow  | PASSED | [0%]  |
| test_borrow_isolation_mode                           | PASSED | [1%]  |
| test_repay   | PASSED | [2%]  |
| test_repay_isolation_mode                            | PASSED | [2%]  |
| test_rebalance_stable_borrow_rate                    | PASSED | [3%]  |
| test_swap_borrow_rate_mode_stable                    | PASSED | [4%]  |
| test_swap_borrow_rate_mode_variable                  | PASSED | [4%]  |
| test_mint_unbacked                                   | PASSED | [5%]  |
| test_mint_unbacked_supply_and_borrows                | PASSED | [6%]  |
| test_mint_unbacked_cap                               | PASSED | [6%]  |
| test_mint_unbacked_zero                              | PASSED | [7%]  |
| test_only_bridge_modifier                            | PASSED | [8%]  |
| test_back_unbacked                                   | PASSED | [8%]  |
| test_back_unbacked_erc20_fails                       | PASSED | [9%]  |
| test_set_user_emode                                  | PASSED | [10%] |
| test_flashloan_repay                                 | PASSED | [11%] |
| test_flashloan_borrow                                | PASSED | [11%] |
| test_flashloan_simple                                | PASSED | [12%] |
| test_liquidation_call                                | PASSED | [13%] |
| test_linear_interest                                 | PASSED | [13%] |
| test_linear_interest_one_year                        | PASSED | [14%] |
| test_linear_interest_max_values                      | PASSED | [15%] |
| test_linear_interest_zero                            | PASSED | [15%] |
| test_compound_interest                               | PASSED | [16%] |
| test_compound_interest_overflows                     | PASSED | [17%] |
| test_compound_interest_zero                          | PASSED | [17%] |
| test_percent_mul                                     | PASSED | [18%] |
| test_percent_mul_zero                                | PASSED | [19%] |
| test_percent_mul_overflow                            | PASSED | [20%] |
| test_percent_div                                     | PASSED | [20%] |
| test_percent_div_zero                                | PASSED | [21%] |
| test_percent_div_overflow                            | PASSED | [22%] |
| test_init_reserves                                   | PASSED | [22%] |
| test_drop_reserve                                    | PASSED | [23%] |
| test_update_atoken                                   | PASSED | [24%] |
| test_update_stable_debt_token                        | PASSED | [24%] |
| test_update_variable_debt_token                      | PASSED | [25%] |
| test_set_reserve_borrowing                           | PASSED | [26%] |
| test_configure_reserve_as_collateral                 | PASSED | [26%] |
| test_configure_reserve_as_collateral_large_ltv       | PASSED | [27%] |
| test_configure_reserve_as_collateral_non_zero_bonus  | PASSED | [28%] |
| test_configure_reserve_as_collateral_excessive_bonus | PASSED | [28%] |
| test_configure_reserve_as_collateral_small_bonus     | PASSED | [29%] |
| test_configure_reserve_as_collateral_supply          | PASSED | [30%] |
| test_set_reserve_stable_rate_borrowing               | PASSED | [31%] |
| test_set_reserve_active                              | PASSED | [31%] |
| test_set_reserve_active_atokens                      | PASSED | [32%] |
| test_set_reserve_freeze                              | PASSED | [33%] |
| test_set_borrowable_in_isolation                     | PASSED | [33%] |
| test_set_reserve_pause                               | PASSED | [34%] |
| test_set_reserve_factor                              | PASSED | [35%] |
| test_set_debt_ceiling                                | PASSED | [35%] |
| test_set_borrow_cap                                  | PASSED | [36%] |
| test_set_supply_cap                                  | PASSED | [37%] |
| test_set_liquidation_protocol_fee                    | PASSED | [37%] |
| test_set_emode_category                              | PASSED | [38%] |
| test_set_emode_category_invalid_cases                | PASSED | [39%] |
| test_set_emode_category_below_asset                  | PASSED | [40%] |
| test_set_asset_emode_category                        | PASSED | [40%] |
| test_set_asset_emode_category_invalid_threshold      | PASSED | [41%] |
| test_set_unbacked_mint_cap                           | PASSED | [42%] |
| test_set_pool_paused                                 | PASSED | [42%] |

|  |        |       |
|--|--------|-------|
| test_update_bridge_protocol_fee                        | PASSED | [43%] |
| test_update_flash_loan_premium_total                   | PASSED | [44%] |
| test_update_flash_loan_premium_to_protocol             | PASSED | [44%] |
| test_only_pool_admin                                   | PASSED | [45%] |
| test_only_emergency_admin                              | PASSED | [46%] |
| test_only_emergency_or_pool_admin                      | PASSED | [46%] |
| test_only_asset_listing_or_pool_admins                 | PASSED | [47%] |
| test_only_risk_or_pool_admins                          | PASSED | [48%] |
| test_supply  | PASSED | [48%] |
| test_withdraw  | PASSED | [49%] |
| test_withdraw_bad_hf                                   | PASSED | [50%] |
| test_finalize_transfer                                 | PASSED | [51%] |
| test_finalize_transfer_bad_hf                          | PASSED | [51%] |
| test_set_user_use_reserve_as_collateral                | PASSED | [52%] |
| test_set_user_use_reserve_as_collateral_bad_hf         | PASSED | [53%] |
| test_set_user_use_reserve_as_collateral_twice          | PASSED | [53%] |
| test_set_user_use_reserve_as_collateral_isolation_mode | PASSED | [54%] |
| test_validate_supply_paused                            | PASSED | [55%] |
| test_validate_supply_frozen                            | PASSED | [55%] |
| test_validate_supply_active                            | PASSED | [56%] |
| test_validate_supply_amount_zero                       | PASSED | [57%] |
| test_validate_supply_cap                               | PASSED | [57%] |
| test_validate_withdraw_paused                          | PASSED | [58%] |
| test_validate_withdraw_frozen                          | PASSED | [59%] |
| test_validate_withdraw_amount_zero                     | PASSED | [60%] |
| test_validate_withdraw_insufficient_balance            | PASSED | [60%] |
| test_validate_borrow_paused                            | PASSED | [61%] |
| test_validate_borrow_frozen                            | PASSED | [62%] |
| test_validate_borrow_amount_zero                       | PASSED | [62%] |
| test_validate_borrow_borrowing_disabled                | PASSED | [63%] |
| test_validate_borrow_price_oracle_sentinel_disallowed  | PASSED | [64%] |
| test_validate_borrow_interest_rate_mode                | PASSED | [64%] |
| test_validate_borrow_borrow_cap                        | PASSED | [65%] |
| test_validate_borrow_isolation_not_borrowable          | PASSED | [66%] |
| test_validate_borrow_isolation_debt_ceiling            | PASSED | [66%] |
| test_validate_borrow_emode_category                    | PASSED | [67%] |
| test_validate_borrow_zero_collateral                   | PASSED | [68%] |
| test_validate_borrow_bad_hf                            | PASSED | [68%] |
| test_validate_borrow_insufficient_collateral           | PASSED | [69%] |
| test_validate_borrow_stable_disabled                   | PASSED | [70%] |
| test_validate_borrow_collateral_currency               | PASSED | [71%] |
| test_validate_borrow_stable_max_size                   | PASSED | [71%] |
| test_validate_repay_paused                             | PASSED | [72%] |
| test_validate_repay_amount_zero                        | PASSED | [73%] |
| test_validate_repay_same_block_stable                  | PASSED | [73%] |
| test_validate_repay_same_block_variable                | PASSED | [74%] |
| test_validate_repay_no_debt                            | PASSED | [75%] |
| test_validate_repay_max_on_behalf_of                   | PASSED | [75%] |
| test_validate_swap_rate_mode_paused                    | PASSED | [76%] |
| test_validate_swap_rate_mode_frozen                    | PASSED | [77%] |
| test_validate_swap_rate_mode_no_stable_debt            | PASSED | [77%] |
| test_validate_swap_rate_mode_no_variable_debt          | PASSED | [78%] |
| test_validate_swap_rate_mode_stable_disabled           | PASSED | [79%] |
| test_validate_swap_rate_mode_stable_collateral         | PASSED | [80%] |
| test_validate_rebalance_stable_borrow_rate_paused      | PASSED | [80%] |
| test_validate_rebalance_stable_borrow_rate_criteria    | PASSED | [81%] |
| test_validate_set_use_reserve_as_collateral_paused     | PASSED | [82%] |
| test_validate_set_use_reserve_as_collateral_no_balance | PASSED | [82%] |
| test_validate_flash_loan_paused                        | PASSED | [83%] |
| test_validate_flash_loan_simple_paused                 | PASSED | [84%] |
| test_validate_flash_loan_disabled                      | PASSED | [84%] |
| test_validate_liquidation_call_paused                  | PASSED | [85%] |
| test_validate_liquidation_call_sentinel                | PASSED | [86%] |
| test_validate_liquidation_call_health_factor           | PASSED | [86%] |
| test_validate_liquidation_call_collateral_not_enabled  | PASSED | [87%] |
| test_validate_liquidation_call_no_debt                 | PASSED | [88%] |
| test_validate_health_factor                            | PASSED | [88%] |
| test_validate_hf_and_ltv                               | PASSED | [89%] |
| test_validate_transfer                                 | PASSED | [90%] |
| test_validate_drop_reserve_zero_address                | PASSED | [91%] |

|  |        |        |
|--|--------|--------|
| test_validate_drop_reserve_invalid_asset               | PASSED | [91%]  |
| test_validate_drop_reserve_atoken                      | PASSED | [92%]  |
| test_validate_drop_reserve_stable                      | PASSED | [93%]  |
| test_validate_drop_reserve_variable                    | PASSED | [93%]  |
| test_validate_set_user_emode_invalid_category          | PASSED | [94%]  |
| test_validate_set_user_emode_category_match_borrowings | PASSED | [95%]  |
| test_getters   | PASSED | [95%]  |
| test_wad_mul   | PASSED | [96%]  |
| test_wad_div   | PASSED | [97%]  |
| test_ray_mul   | PASSED | [97%]  |
| test_ray_div   | PASSED | [98%]  |
| test_ray_to_wad  | PASSED | [99%]  |
| test_ray_mul_div_rounding                              | PASSED | [100%] |

## Appendix B Vulnerability Severity Classification

This security review classifies vulnerabilities based on their potential impact and likelihood of occurrence. The total severity of a vulnerability is derived from these two metrics based on the following matrix.

|        |        |            |        |          |
|--------|--------|------------|--------|----------|
| Impact | High   | Medium     | High   | Critical |
|        | Medium | Low        | Medium | High     |
|        | Low    | Low        | Low    | Medium   |
|        |        | Low        | Medium | High     |
|        |        | Likelihood |        |          |

Table 1: Severity Matrix - How the severity of a vulnerability is given based on the *impact* and the *likelihood* of a vulnerability.

## References

- [1] Sigma Prime. Solidity Security. Blog, 2018, Available: <https://blog.sigmaprime.io/solidity-security.html>. [Accessed 2018].
- [2] NCC Group. DASP - Top 10. Website, 2018, Available: <http://www.dasp.co/>. [Accessed 2018].

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