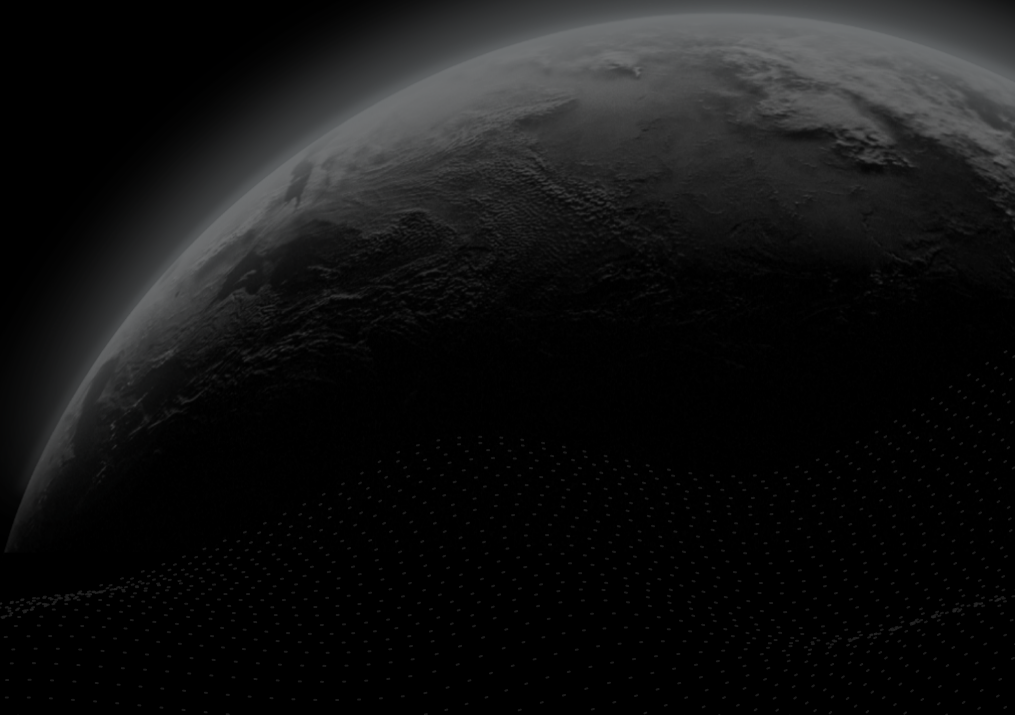




Preliminary Comments

COMBO

CertiK Verified on Apr 28th, 2023





Certik Verified on Apr 28th, 2023

COMBO

These preliminary comments were prepared by Certik, the leader in Web3.0 security.

Executive Summary

TYPES

DeFi

ECOSYSTEM

Ethereum (ETH)

METHODS

Formal Verification, Manual Review, Static Analysis

LANGUAGE

Solidity

TIMELINE

Delivered on 04/28/2023

KEY COMPONENTS

N/A

CODEBASE

<https://github.com/ComboLabs/ComboToken/>[...View All](#)

COMMITTS

[d4b8a5c0d45cc0634ac18036883b9e28f1b38c49](#)[fcb723ee0d082fec0cf292fbeb34f3b4004f3518](#)[...View All](#)

Vulnerability Summary



3

Total Findings

1

Resolved

0

Mitigated

0

Partially Resolved

1

Acknowledged

0

Declined

1

Unresolved

0 Critical

Critical risks are those that impact the safe functioning of a platform and must be addressed before launch. Users should not invest in any project with outstanding critical risks.

1 Major

1 Unresolved

Major risks can include centralization issues and logical errors. Under specific circumstances, these major risks can lead to loss of funds and/or control of the project.

0 Medium

Medium risks may not pose a direct risk to users' funds, but they can affect the overall functioning of a platform.

1 Minor

1 Resolved

Minor risks can be any of the above, but on a smaller scale. They generally do not compromise the overall integrity of the project, but they may be less efficient than other solutions.

1 Informational

1 Acknowledged

Informational errors are often recommendations to improve the style of the code or certain operations to fall within industry best practices. They usually do not affect the overall functioning of the code.

0 Discussion

The impact of the issue is yet to be determined, hence requires further clarifications from the project team.

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CTT-04 : Unclear Purpose Of `withdrawFromContract()` and `transfer()`

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CODEBASE | COMBO

Repository

<https://github.com/ComboLabs/ComboToken/>

Commit

[d4b8a5c0d45cc0634ac18036883b9e28f1b38c49](#)

[fcb723ee0d082fec0cf292fbeb34f3b4004f3518](#)

AUDIT SCOPE COMBO

1 file audited 1 file with Unresolved findings

ID	File	SHA256 Checksum
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CTT	contracts/ComboToken.sol	826d67a99fc2cc4527a1843fc60e6811e748eb5b1add7e8b72bd9dbf6928e216
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APPROACH & METHODS | COMBO

This report has been prepared for Combo Network to discover issues and vulnerabilities in the source code of the COMBO project as well as any contract dependencies that were not part of an officially recognized library. A comprehensive examination has been performed, utilizing Static Analysis and Manual Review techniques.

The auditing process pays special attention to the following considerations:

- Testing the smart contracts against both common and uncommon attack vectors.
- Assessing the codebase to ensure compliance with current best practices and industry standards.
- Ensuring contract logic meets the specifications and intentions of the client.
- Cross referencing contract structure and implementation against similar smart contracts produced by industry leaders.
- Thorough line-by-line manual review of the entire codebase by industry experts.

The security assessment resulted in findings that ranged from critical to informational. We recommend addressing these findings to ensure a high level of security standards and industry practices. We suggest recommendations that could better serve the project from the security perspective:

- Testing the smart contracts against both common and uncommon attack vectors;
- Enhance general coding practices for better structures of source codes;
- Add enough unit tests to cover the possible use cases;
- Provide more comments per each function for readability, especially contracts that are verified in public;
- Provide more transparency on privileged activities once the protocol is live.

FINDINGS | COMBO



3

Total Findings

0

Critical

1

Major

0

Medium

1

Minor

1

Informational

0

Discussion

This report has been prepared to discover issues and vulnerabilities for COMBO. Through this audit, we have uncovered 3 issues ranging from different severity levels. Utilizing the techniques of Static Analysis & Manual Review to complement rigorous manual code reviews, we discovered the following findings:

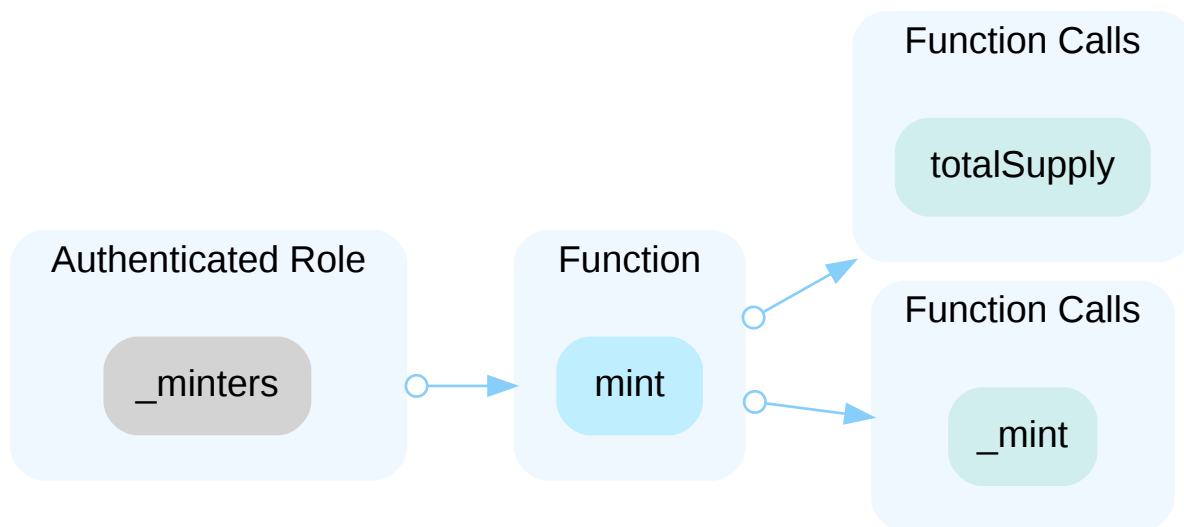
ID	Title	Category	Severity	Status
CTT-05	Centralization Risks In ComboToken.Sol	Centralization / Privilege	Major	Unresolved
CTT-02	Incorrect Whitelist And Blacklist Check In <code>_transfer()</code> Function	Logical Issue	Minor	Resolved
CTT-04	Unclear Purpose Of <code>withdrawFromContract()</code> And <code>_transfer()</code>	Logical Issue	Informational	Acknowledged

CTT-05 | CENTRALIZATION RISKS IN COMBOTOKEN.SOL

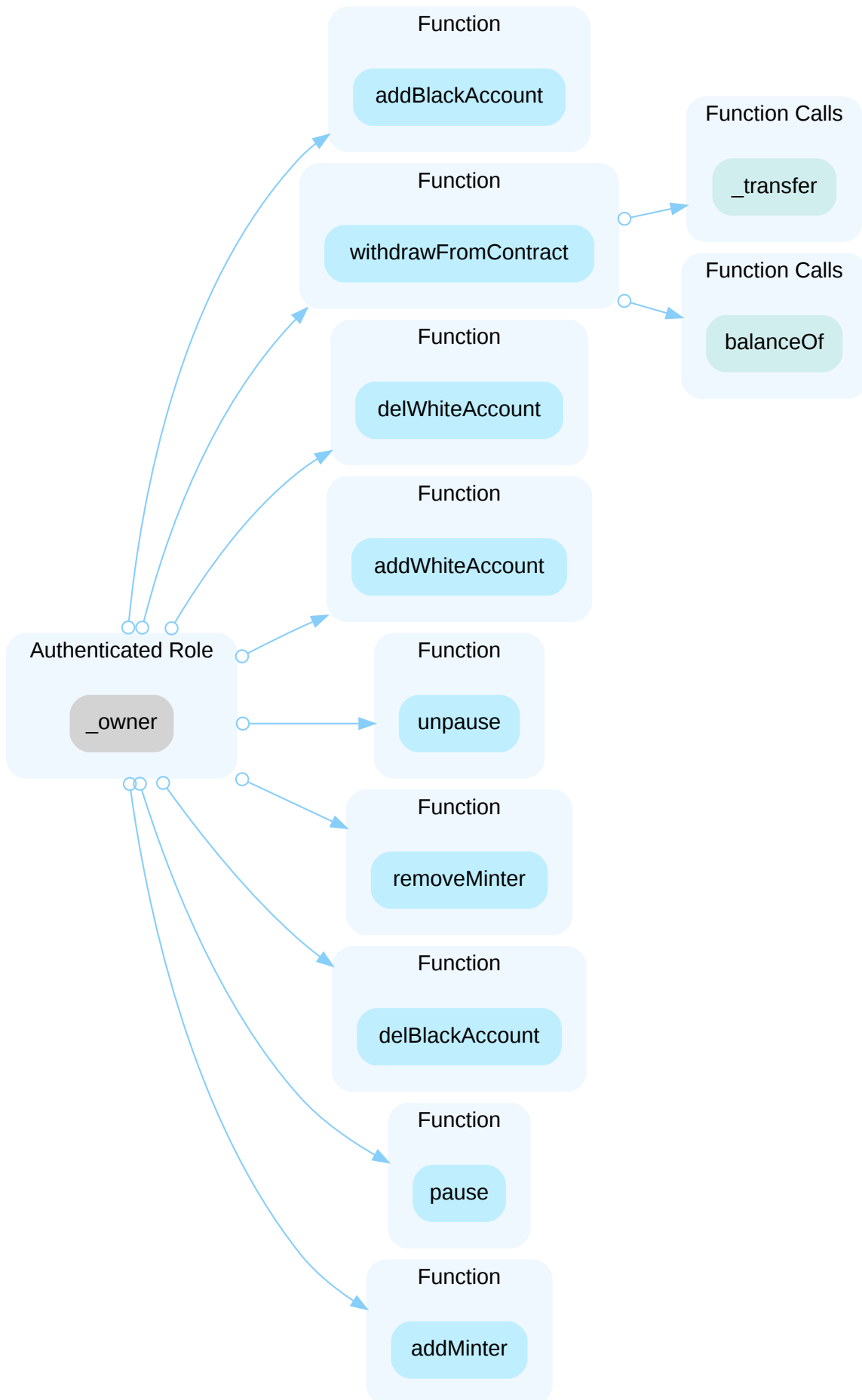
Category	Severity	Location	Status
Centralization / Privilege	Major	contracts/ComboToken.sol: 65, 87, 97, 101, 108, 121, 127, 133, 141, 149, 157	Pending

Description

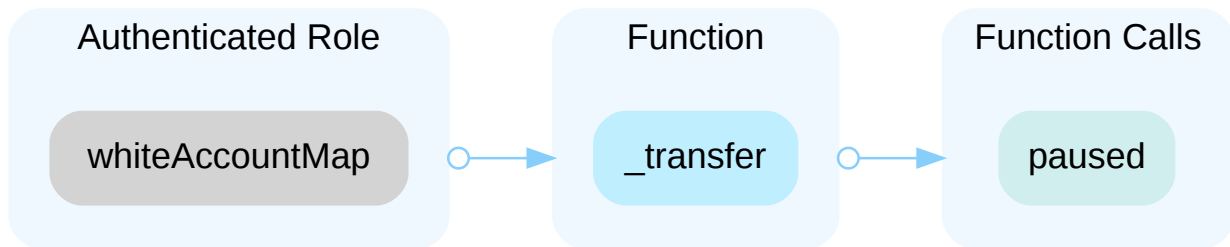
In the contract `ComboToken` the role `_minters` has authority over the functions shown in the diagram below.



In the contract `ComboToken` the role `_owner` has authority over the functions shown in the diagram below.



In the contract `ComboToken` the role `whiteAccountMap` has authority over the functions shown in the diagram below.



Any compromise to the privileged account may allow the hacker to take advantage of this authority:

1. `withdrawFromContract()` - Allows the **owner** to withdraw tokens accidentally sent to the contract address.
2. `pause()` - Allows the **owner** to pause the contract, restricting token transfers for non-whitelisted accounts.
3. `unpause()` - Allows the **owner** to unpause the contract, resuming token transfers for all non-blacklisted accounts.
4. `mint()` - Allows **minters** to mint new tokens and add them to the specified account's balance.
5. `addMinter()` - Allows the **owner** to add a new minter address.
6. `removeMinter()` - Allows the **owner** to remove a minter address.
7. `addWhiteAccount()` - Allows the **owner** to add an account to the whitelist, allowing token transfers during a pause.
8. `delWhiteAccount()` - Allows the **owner** to remove an account from the whitelist.
9. `addBlackAccount()` - Allows the **owner** to add an account to the blacklist, restricting token transfers even when the contract is not paused.
10. `delBlackAccount()` - Allows the **owner** to remove an account from the blacklist.
11. `_transfer()` - Allows the **whiteAccountMap** role to transfer tokens.

Recommendation

The risk describes the current project design and potentially makes iterations to improve in the security operation and level of decentralization, which in most cases cannot be resolved entirely at the present stage. We advise the client to carefully manage the privileged account's private key to avoid any potential risks of being hacked. In general, we strongly recommend centralized privileges or roles in the protocol be improved via a decentralized mechanism or smart-contract-based accounts with enhanced security practices, e.g., multisignature wallets. Indicatively, here are some feasible suggestions that would also mitigate the potential risk at a different level in terms of short-term, long-term and permanent:

Short Term:

Timelock and Multi sign ($\frac{2}{3}$, $\frac{3}{5}$) combination *mitigate* by delaying the sensitive operation and avoiding a single point of key management failure.

- Time-lock with reasonable latency, e.g., 48 hours, for awareness on privileged operations;
- AND

- Assignment of privileged roles to multi-signature wallets to prevent a single point of failure due to the private key compromised;
AND
- A medium/blog link for sharing the timelock contract and multi-signers addresses information with the public audience.

Long Term:

Timelock and DAO, the combination, *mitigate* by applying decentralization and transparency.

- Time-lock with reasonable latency, e.g., 48 hours, for awareness on privileged operations;
AND
- Introduction of a DAO/governance/voting module to increase transparency and user involvement.
AND
- A medium/blog link for sharing the timelock contract, multi-signers addresses, and DAO information with the public audience.

Permanent:

Renouncing the ownership or removing the function can be considered *fully resolved*.

- Renounce the ownership and never claim back the privileged roles.
OR
- Remove the risky functionality.

CTT-02 | INCORRECT WHITELIST AND BLACKLIST CHECK IN `_transfer()` FUNCTION

Category	Severity	Location	Status
Logical Issue	Minor	contracts/ComboToken.sol: 87	Resolved

Description

The whitelist and blacklist checks in the `_transfer()` function are incorrect. The code that checks the whitelist and blacklist should verify whether the `from` addresses are in the whitelist or blacklist, rather than checking whether `msg.sender` is in the whitelist or blacklist.

Recommendation

We recommend making the following update to check the whitelist and blacklist correctly:

```
65 function _transfer(  
66     address from,  
67     address to,  
68     uint256 value  
69 ) internal override {  
70     if (paused() == true) {  
71         // only white list pass  
72         require(whiteAccountMap[from], "'from' is not in the whitelist list");  
73     } else {  
74         // check black list  
75         require(!blackAccountMap[from], "'from' is in the black list");  
76     }  
77     super._transfer(from, to, value);  
78 }
```

Alleviation

[COMBO] : The team heeded the advice and resolved the finding in the commit [9a57b3eeb3c67f088f070604a99391339fe8bdae](#)

CTT-04 | UNCLEAR PURPOSE OF `withdrawFromContract()` AND `_transfer()`

Category	Severity	Location	Status
Logical Issue	● Informational	contracts/ComboToken.sol: 93	● Acknowledged

Description

In function `withdrawFromContract()`, current implementation would help transfer a certain amount `contractBalance` of token from `address(this)` to `_to` by invoking the `_transfer()` function. This function can only be called by `owner` role account. However there are validations in `_transfer()` to check if `msg.sender` would be in a whitelist or a blacklist. Since the `owner` would be the only caller and only potential `msg.sender` address, having whitelist/blacklist for a `owner` address cannot explicitly reveal the intentional design of the project.

Recommendation

We would like to confirm with the client about the design/purpose of the `withdrawFromContract()`, `_transfer()` and `whiteAccountMap` / `blackAccountMap()` use scenarios. These two functions would be reviewed again once the design has been clarified.

Alleviation

[COMBO] : To avoid errors in transferring to the token contract address, tokens transferred to the token contract address can be transferred out again.



OPTIMIZATIONS | COMBO

ID	Title	Category	Severity	Status
CTT-01	Comparison To A Boolean Constant	Gas Optimization	Optimization	● Resolved
CTT-03	Unnecessary Use Of SafeMath	Gas Optimization	Optimization	● Resolved

CTT-01 | COMPARISON TO A BOOLEAN CONSTANT

Category	Severity	Location	Status
Gas Optimization	● Optimization	contracts/ComboToken.sol: 70	● Resolved

Description

A boolean is compared to a boolean constant as shown below:

```
70      if (paused() == true) {
```

Boolean constants can be used directly and do not need to be compared to true or false.

Recommendation

We advise removing the comparison to the boolean constant.

Alleviation

[certik]: The team heeded the advice and resolved the finding in [fcb723ee0d082fec0cf292fbeb34f3b4004f3518](#)

CTT-03 | UNNECESSARY USE OF SAFEMATH

Category	Severity	Location	Status
Gas Optimization	● Optimization	contracts/ComboToken.sol: 114	● Resolved

Description

The `SafeMath` library is used unnecessarily. With Solidity compiler versions 0.8.0 or newer, arithmetic operations will automatically revert in case of integer overflow or underflow.

```
13     using SafeMath for uint256;
```

- `SafeMath` library is used for `uint256` type in `ComboToken` contract.

```
114     uint256 newMintSupply = totalSupply().add(amount);
```

- `SafeMath.add` is called in `mint` function of `ComboToken` contract.

Recommendation

We advise removing the usage of `SafeMath` library and using the built-in arithmetic operations provided by the Solidity programming language.

Alleviation

[certik]: The team heeded the advice and resolved the finding in [fcb723ee0d082fec0cf292fbeb34f3b4004f3518](#)

FORMAL VERIFICATION | COMBO

Formal guarantees about the behavior of smart contracts can be obtained by reasoning about properties relating to the entire contract (e.g. contract invariants) or to specific functions of the contract. Once such properties are proven to be valid, they guarantee that the contract behaves as specified by the property. As part of this audit, we applied automated formal verification (symbolic model checking) to prove that well-known functions in the smart contracts adhere to their expected behavior.

Considered Functions And Scope

In the following, we provide a description of the properties that have been used in this audit. They are grouped according to the type of contract they apply to.

Verification of ERC-20 Compliance

We verified properties of the public interface of those token contracts that implement the ERC-20 interface. This covers

- Functions `transfer` and `transferFrom` that are widely used for token transfers,
- functions `approve` and `allowance` that enable the owner of an account to delegate a certain subset of her tokens to another account (i.e. to grant an allowance), and
- the functions `balanceOf` and `totalSupply`, which are verified to correctly reflect the internal state of the contract.

The properties that were considered within the scope of this audit are as follows:

Property Name	Title
erc20-transfer-correct-amount	<code>transfer</code> Transfers the Correct Amount in Non-self Transfers
erc20-transfer-revert-zero	<code>transfer</code> Prevents Transfers to the Zero Address
erc20-transfer-succeed-normal	<code>transfer</code> Succeeds on Admissible Non-self Transfers
erc20-transfer-succeed-self	<code>transfer</code> Succeeds on Admissible Self Transfers
erc20-transfer-correct-amount-self	<code>transfer</code> Transfers the Correct Amount in Self Transfers
erc20-transfer-change-state	<code>transfer</code> Has No Unexpected State Changes
erc20-transfer-exceed-balance	<code>transfer</code> Fails if Requested Amount Exceeds Available Balance
erc20-transfer-false	If <code>transfer</code> Returns <code>false</code> , the Contract State Is Not Changed
erc20-transfer-never-return-false	<code>transfer</code> Never Returns <code>false</code>
erc20-transferfrom-revert-from-zero	<code>transferFrom</code> Fails for Transfers From the Zero Address

Property Name	Title
erc20-transfer-recipient-overflow	<code>transfer</code> Prevents Overflows in the Recipient's Balance
erc20-transferfrom-revert-to-zero	<code>transferFrom</code> Fails for Transfers To the Zero Address
erc20-transferfrom-correct-amount	<code>transferFrom</code> Transfers the Correct Amount in Non-self Transfers
erc20-transferfrom-correct-amount-self	<code>transferFrom</code> Performs Self Transfers Correctly
erc20-transferfrom-succeed-self	<code>transferFrom</code> Succeeds on Admissible Self Transfers
erc20-transferfrom-succeed-normal	<code>transferFrom</code> Succeeds on Admissible Non-self Transfers
erc20-transferfrom-correct-allowance	<code>transferFrom</code> Updated the Allowance Correctly
erc20-transferfrom-fail-exceed-balance	<code>transferFrom</code> Fails if the Requested Amount Exceeds the Available Balance
erc20-transferfrom-fail-exceed-allowance	<code>transferFrom</code> Fails if the Requested Amount Exceeds the Available Allowance
erc20-transferfrom-false	If <code>transferFrom</code> Returns <code>false</code> , the Contract's State Is Unchanged
erc20-transferfrom-change-state	<code>transferFrom</code> Has No Unexpected State Changes
erc20-transferfrom-never-return-false	<code>transferFrom</code> Never Returns <code>false</code>
erc20-totalsupply-succeed-always	<code>totalSupply</code> Always Succeeds
erc20-totalsupply-correct-value	<code>totalSupply</code> Returns the Value of the Corresponding State Variable
erc20-totalsupply-change-state	<code>totalSupply</code> Does Not Change the Contract's State
erc20-balanceof-succeed-always	<code>balanceOf</code> Always Succeeds
erc20-transferfrom-fail-recipient-overflow	<code>transferFrom</code> Prevents Overflows in the Recipient's Balance
erc20-balanceof-correct-value	<code>balanceOf</code> Returns the Correct Value
erc20-balanceof-change-state	<code>balanceOf</code> Does Not Change the Contract's State
erc20-allowance-succeed-always	<code>allowance</code> Always Succeeds
erc20-allowance-correct-value	<code>allowance</code> Returns Correct Value
erc20-allowance-change-state	<code>allowance</code> Does Not Change the Contract's State

Property Name	Title
erc20-approve-revert-zero	<input type="button" value="approve"/> Prevents Approvals For the Zero Address
erc20-approve-succeed-normal	<input type="button" value="approve"/> Succeeds for Admissible Inputs
erc20-approve-correct-amount	<input type="button" value="approve"/> Updates the Approval Mapping Correctly
erc20-approve-change-state	<input type="button" value="approve"/> Has No Unexpected State Changes
erc20-approve-false	If <input type="button" value="approve"/> Returns <input type="button" value="false"/> , the Contract's State Is Unchanged
erc20-approve-never-return-false	<input type="button" value="approve"/> Never Returns <input type="button" value="false"/>

Verification Results

In the remainder of this section, we list all contracts where model checking of at least one property was not successful. There are several reasons why this could happen:

- Model checking reports a counterexample that violates the property. Depending on the counterexample, this occurs if
 - The specification of the property is too generic and does not accurately capture the intended behavior of the smart contract. In that case, the counterexample does not indicate a problem in the underlying smart contract. We report such instances as being "inapplicable".
 - The property is applicable to the smart contract. In that case, the counterexample showcases a problem in the smart contract and a correspond finding is reported separately in the Findings section of this report. In the following tables, we report such instances as "invalid". The distinction between spurious and actual counterexamples is done manually by the auditors.
- The model checking result is inconclusive. Such a result does not indicate a problem in the underlying smart contract. An inconclusive result may occur if
 - The model checking engine fails to construct a proof. This can happen if the logical deductions necessary are beyond the capabilities of the automated reasoning tool. It is a technical limitation of all proof engines and cannot be avoided in general.
 - The model checking engine runs out of time or memory and did not produce a result. This can happen if automatic abstraction techniques are ineffective or of the state space is too big.

Detailed Results For Contract ComboToken (contracts/ComboToken.sol) In Commit d4b8a5c0d45cc0634ac18036883b9e28f1b38c49

Verification of ERC-20 Compliance

Detailed results for function `transfer`

Property Name	Final Result	Remarks
erc20-transfer-correct-amount	True	
erc20-transfer-revert-zero	True	
erc20-transfer-succeed-normal	False	
erc20-transfer-succeed-self	False	
erc20-transfer-correct-amount-self	True	
erc20-transfer-change-state	True	
erc20-transfer-exceed-balance	True	
erc20-transfer-false	True	
erc20-transfer-never-return-false	True	
erc20-transfer-recipient-overflow	Inapplicable	Context not considered




Detailed results for function `transferFrom`

Property Name	Final Result	Remarks
erc20-transferfrom-revert-from-zero	● True	
erc20-transferfrom-revert-to-zero	● True	
erc20-transferfrom-correct-amount	● True	
erc20-transferfrom-correct-amount-self	● True	
erc20-transferfrom-succeed-self	● False	
erc20-transferfrom-succeed-normal	● False	
erc20-transferfrom-correct-allowance	● True	
erc20-transferfrom-fail-exceed-balance	● True	
erc20-transferfrom-fail-exceed-allowance	● True	
erc20-transferfrom-false	● True	
erc20-transferfrom-change-state	● True	
erc20-transferfrom-never-return-false	● True	
erc20-transferfrom-fail-recipient-overflow	● Inapplicable	Context not considered




Detailed results for function `totalSupply`

Property Name	Final Result	Remarks
erc20-totalsupply-succeed-always	● True	
erc20-totalsupply-correct-value	● True	
erc20-totalsupply-change-state	● True	







Detailed results for function `balanceOf`

Property Name	Final Result	Remarks
erc20-balanceof-succeed-always	 True	
erc20-balanceof-correct-value	 True	
erc20-balanceof-change-state	 True	

Detailed results for function `allowance`

Property Name	Final Result	Remarks
erc20-allowance-succeed-always	 True	
erc20-allowance-correct-value	 True	
erc20-allowance-change-state	 True	

Detailed results for function `approve`

Property Name	Final Result	Remarks
erc20-approve-revert-zero	 True	
erc20-approve-succeed-normal	 True	
erc20-approve-correct-amount	 True	
erc20-approve-change-state	 True	
erc20-approve-false	 True	
erc20-approve-never-return-false	 True	

APPENDIX | COMBO

Finding Categories

Categories	Description
Centralization / Privilege	Centralization / Privilege findings refer to either feature logic or implementation of components that act against the nature of decentralization, such as explicit ownership or specialized access roles in combination with a mechanism to relocate funds.
Gas Optimization	Gas Optimization findings do not affect the functionality of the code but generate different, more optimal EVM opcodes resulting in a reduction on the total gas cost of a transaction.
Logical Issue	Logical Issue findings detail a fault in the logic of the linked code, such as an incorrect notion on how block.timestamp works.

Checksum Calculation Method

The "Checksum" field in the "Audit Scope" section is calculated as the SHA-256 (Secure Hash Algorithm 2 with digest size of 256 bits) digest of the content of each file hosted in the listed source repository under the specified commit.

The result is hexadecimal encoded and is the same as the output of the Linux "sha256sum" command against the target file.

Details on Formal Verification

Some Solidity smart contracts from this project have been formally verified using symbolic model checking. Each such contract was compiled into a mathematical model which reflects all its possible behaviors with respect to the property. The model takes into account the semantics of the Solidity instructions found in the contract. All verification results that we report are based on that model.

Technical Description

The model also formalizes a simplified execution environment of the Ethereum blockchain and a verification harness that performs the initialization of the contract and all possible interactions with the contract. Initially, the contract state is initialized non-deterministically (i.e. by arbitrary values) and over-approximates the reachable state space of the contract throughout any actual deployment on chain. All valid results thus carry over to the contract's behavior in arbitrary states after it has been deployed.

Assumptions and Simplifications

The following assumptions and simplifications apply to our model:

- Gas consumption is not taken into account, i.e. we assume that executions do not terminate prematurely because they run out of gas.
- The contract's state variables are non-deterministically initialized before invocation of any function. That ignores contract invariants and may lead to false positives. It is, however, a safe over-approximation.
- The verification engine reasons about unbounded integers. Machine arithmetic is modeled using modular arithmetic based on the bit-width of the underlying numeric Solidity type. This ensures that over- and underflow characteristics are faithfully represented.
- Certain low-level calls and inline assembly are not supported and may lead to a contract not being formally verified.
- We model the semantics of the Solidity source code and not the semantics of the EVM bytecode in a compiled contract.

Formalism for Property Specification

All properties are expressed in linear temporal logic (LTL). For that matter, we treat each invocation of and each return from a public or an external function as a discrete time step. Our analysis reasons about the contract's state upon entering and upon leaving public or external functions.

Apart from the Boolean connectives and the modal operators "always" (written \Box) and "eventually" (written \Diamond), we use the following predicates as atomic propositions. They are evaluated on the contract's state whenever a discrete time step occurs:

- `started(f, [cond])` Indicates an invocation of contract function `f` within a state satisfying formula `cond`.
- `willSucceed(f, [cond])` Indicates an invocation of contract function `f` within a state satisfying formula `cond` and considers only those executions that do not revert.
- `finished(f, [cond])` Indicates that execution returns from contract function `f` in a state satisfying formula `cond`. Here, formula `cond` may refer to the contract's state variables and to the value they had upon entering the function (using the `old` function).
- `reverted(f, [cond])` Indicates that execution of contract function `f` was interrupted by an exception in a contract state satisfying formula `cond`.

The verification performed in this audit operates on a harness that non-deterministically invokes a function of the contract's public or external interface. All formulas are analyzed w.r.t. the trace that corresponds to this function invocation.

Description of the Analyzed ERC-20 Properties

The specifications are designed such that they capture the desired and admissible behaviors of the ERC-20 functions `transfer`, `transferFrom`, `approve`, `allowance`, `balanceOf`, and `totalSupply`. In the following, we list those property specifications.

Properties related to function `transfer`

`erc20-transfer-revert-zero`

`transfer` Prevents Transfers to the Zero Address. Any call of the form `transfer(recipient, amount)` must fail if the

recipient address is the zero address. Specification:

```
[](started(contract.transfer(to, value), to == address(0)) ==>
  <>(reverted(contract.transfer) || finished(contract.transfer(to, value), return
    == false)))
```

erc20-transfer-succeed-normal

`transfer` Succeeds on Admissible Non-self Transfers. All invocations of the form `transfer(recipient, amount)` must succeed and return `true` if

- the `recipient` address is not the zero address,
- `amount` does not exceed the balance of address `msg.sender`,
- transferring `amount` to the `recipient` address does not lead to an overflow of the recipient's balance, and
- the supplied gas suffices to complete the call. Specification:

```
[](started(contract.transfer(to, value), to != address(0) && to != msg.sender &&
  value >= 0 && value <= _balances[msg.sender] && _balances[to] + value <
  0x10000000000000000000000000000000000000000000000000000000000000000 &&
  _balances[to] >= 0 && _balances[msg.sender] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transfer(to, value), return == true)))
```

erc20-transfer-succeed-self

`transfer` Succeeds on Admissible Self Transfers. All self-transfers, i.e. invocations of the form `transfer(recipient, amount)` where the `recipient` address equals the address in `msg.sender` must succeed and return `true` if

- the value in `amount` does not exceed the balance of `msg.sender` and
- the supplied gas suffices to complete the call. Specification:

```
[](started(contract.transfer(to, value), to != address(0) && to == msg.sender &&
  value >= 0 && value <= _balances[msg.sender] && _balances[msg.sender] >= 0 &&
  _balances[msg.sender] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transfer(to, value), return == true)))
```

erc20-transfer-correct-amount

`transfer` Transfers the Correct Amount in Non-self Transfers. All non-reverting invocations of `transfer(recipient, amount)` that return `true` must subtract the value in `amount` from the balance of `msg.sender` and add the same value to the balance of the `recipient` address. Specification:

erc20-transfer-correct-amount-self

erc20-transfer-change-state

erc20-transfer-exceed-balance

erc20-transfer-recipient-overflow

transfer	Prevents Overflows in the Recipient's Balance. Any invocation of <code>transfer(recipient, amount)</code>
----------	-----------------------------------------------------------------------------------------------------------

[illegible]

erc20-transfer-false

If `transfer` Returns `false`, the Contract State Is Not Changed. If the `transfer` function in contract `contract` fails by returning `false`, it must undo all state changes it incurred before returning to the caller. Specification:

```

[] (willSucceed(contract.transfer(to, value)) ==> <> (finished(contract.transfer(to,
value), return == false ==> (_balances == old(_balances) && _totalSupply ==
old(_totalSupply) && _allowances == old(_allowances) &&
other_state_variables == old(other_state_variables))))

```

erc20-transfer-never-return-false

`transfer` Never Returns `false`. The transfer function must never return `false` to signal a failure. Specification:

```
[ ](! (finished(contract.transfer, return == false)))
```

Properties related to function `transferFrom`

erc20-transferfrom-revert-from-zero

`transferFrom` Fails for Transfers From the Zero Address. All calls of the form `transferFrom(from, dest, amount)` where the `from` address is zero, must fail. Specification:

```

[](started(contract.transferFrom(from, to, value), from == address(0)) ==>
  <-(reverted(contract.transferFrom) || finished(contract.transferFrom, return ==
    false)))

```

erc20-transferfrom-revert-to-zero

`transferFrom` Fails for Transfers To the Zero Address. All calls of the form `transferFrom(from, dest, amount)` where the `dest` address is zero, must fail. Specification:

```

[](started(contract.transferFrom(from, to, value), to == address(0)) ==>
  <>(reverted(contract.transferFrom) || finished(contract.transferFrom, return ==
    false)))

```

erc20-transferfrom-succeed-normal

`transferFrom` Succeeds on Admissible Non-self Transfers. All invocations of `transferFrom(from, dest, amount)` must succeed and return `true` if

- the value of `amount` does not exceed the balance of address `from`,
- the value of `amount` does not exceed the allowance of `msg.sender` for address `from`,
- transferring a value of `amount` to the address in `dest` does not lead to an overflow of the recipient's balance, and
- the supplied gas suffices to complete the call. Specification:

```

[](started(contract.transferFrom(from, to, value), from != address(0) && to !=
  address(0) && from != to && value <= _balances[from] && value <=
  _allowances[from][msg.sender] && _balances[to] + value <
  0x10000000000000000000000000000000000000000000000000000000000000000 && value >=
  0 && _balances[to] >= 0 && _balances[from] >= 0 && _balances[from] <
  0x10000000000000000000000000000000000000000000000000000000000000000 &&
  _allowances[from][msg.sender] >= 0 && _allowances[from][msg.sender] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transferFrom(from, to, value), return == true)))

```

erc20-transferfrom-succeed-self

`transferFrom` Succeeds on Admissible Self Transfers. All invocations of `transferFrom(from, dest, amount)` where the `dest` address equals the `from` address (i.e. self-transfers) must succeed and return `true` if:

- The value of `amount` does not exceed the balance of address `from`,
- the value of `amount` does not exceed the allowance of `msg.sender` for address `from`, and
- the supplied gas suffices to complete the call. Specification:

```

[](started(contract.transferFrom(from, to, value), from != address(0) && from == to
  && value <= _balances[from] && value <= _allowances[from][msg.sender] && value
  >= 0 && _balances[from] <
  0x10000000000000000000000000000000000000000000000000000000000000000 &&
  _allowances[from][msg.sender] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transferFrom(from, to, value), return == true)))

```

erc20-transferfrom-correct-amount

```

[] (willSucceed(contract.transferFrom(from, to, value), from != to && value >= 0 &&
    _balances[from] >= 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] + value <
    0x10000000000000000000000000000000000000000000000000000000000000000) ==>
<> (finished(contract.transferFrom(from, to, value), return == true ==>
    _balances[from] == old(_balances[from]) - value && _balances[to] ==
    old(_balances[to] + value))))

```

```
[](willSucceed(contract.transferFrom(from, to, value), from == to && value >= 0 &&  
    value < 0x10000000000000000000000000000000000000000000000000000000000000000 &&  
    _balances[from] >= 0 && _balances[from] <  
        0x1000000000000000000000000000000000000000000000000000000000000000) ==>  
<>(finished(contract.transferFrom(from, to, value), return == true ==>  
    _balances[from] == old(_balances[from]))))
```

[illegible]

erc20-transferfrom-change-state

`transferFrom` Has No Unexpected State Changes. All non-reverting invocations of `transferFrom(from, dest, amount)` that return `true` may only modify the following state variables:

- The balance entry for the address in `dest`,
- The balance entry for the address in `from`,
- The allowance for the address in `msg.sender` for the address in `from`. Specification:

```

[] (willSucceed(contract.transferFrom(from, to, amount), p1 != from && p1 != to &&
    (p2 != from || p3 != msg.sender)) ==> <> (finished(contract.transferFrom(from,
    to, amount), return == true ==> (_totalSupply == old(_totalSupply) &&
    _balances[p1] == old(_balances[p1]) && _allowances[p2][p3] ==
    old(_allowances[p2][p3]) && other_state_variables ==
    old(other_state_variables))))))

```

erc20-transferfrom-fail-exceed-balance

`transferFrom` Fails if the Requested Amount Exceeds the Available Balance. Any call of the form `transferFrom(from, dest, amount)` with a value for `amount` that exceeds the balance of address `from` must fail. Specification:

```

[](started(contract.transferFrom(from, to, value), value > _balances[from] &&
    _balances[from] >= 0 && _balances[from] <
        0x10000000000000000000000000000000000000000000000000000000000000000) ==>
    <>(reverted(contract.transferFrom) || finished(contract.transferFrom, return ==
        false)))

```

erc20-transferfrom-fail-exceed-allowance

`transferFrom` Fails if the Requested Amount Exceeds the Available Allowance. Any call of the form `transferFrom(from, dest, amount)` with a value for `amount` that exceeds the allowance of address `msg.sender` must fail. Specification:

```

[] (started(contract.transferFrom(from, to, value), msg.sender != from && value >
    _allowances[from][msg.sender] && _allowances[from][msg.sender] >= 0 && value <
    0x10000000000000000000000000000000000000000000000000000000000000000) ==>
    <(>(reverted(contract.transferFrom) || finished(contract.transferFrom(from, to,
        value), return == false)))

```

erc20-transferfrom-fail-recipient-overflow

`transferFrom` Prevents Overflows in the Recipient's Balance. Any call of `transferFrom(from, dest, amount)` with a value in `amount` whose transfer would cause an overflow of the balance of address `dest` must fail. Specification:

erc20-transferfrom-false

erc20-transferfrom-never-return-false

erc20-totalsupply-succeed-always

erc20-totalsupply-change-state

`totalSupply` Does Not Change the Contract's State. The `totalSupply` function in contract contract must not change any state variables. Specification:

```
[](willSucceed(contract.totalSupply) ==> <>(finished(contract.totalSupply,
  _totalSupply == old(_totalSupply) && _balances == old(_balances) &&
  _allowances == old(_allowances) && other_state_variables ==
  old(other_state_variables))))
```

Properties related to function `balanceOf`

erc20-balanceof-succeed-always

`balanceOf` Always Succeeds. Function `balanceOf` must always succeed if it does not run out of gas. Specification:

```
[](started(contract.balanceOf) ==> <>(finished(contract.balanceOf)))
```

erc20-balanceof-correct-value

`balanceOf` Returns the Correct Value. Invocations of `balanceOf(owner)` must return the value that is held in the contract's balance mapping for address `owner`. Specification:

```
[](willSucceed(contract.balanceOf) ==> <>(finished(contract.balanceOf(owner),
  return == _balances[owner])))
```

erc20-balanceof-change-state

`balanceOf` Does Not Change the Contract's State. Function `balanceOf` must not change any of the contract's state variables. Specification:

```
[](willSucceed(contract.balanceOf) ==> <>(finished(contract.balanceOf(owner),
  _totalSupply == old(_totalSupply) && _balances == old(_balances) &&
  _allowances == old(_allowances) && other_state_variables ==
  old(other_state_variables))))
```

Properties related to function `allowance`

erc20-allowance-succeed-always

`allowance` Always Succeeds. Function `allowance` must always succeed, assuming that its execution does not run out of gas. Specification:

```
[](started(contract.allowance) ==> <>(finished(contract.allowance)))
```

erc20-allowance-correct-value

allowance Returns Correct Value. Invocations of `allowance(owner, spender)` must return the allowance that address `spender` has over tokens held by address `owner`. Specification:

```
[(willSucceed(contract.allowance(owner, spender)) ==>
  <>(finished(contract.allowance(owner, spender), return ==
    _allowances[owner][spender])))]
```

erc20-allowance-change-state

allowance Does Not Change the Contract's State. Function `allowance` must not change any of the contract's state variables. Specification:

```
[(willSucceed(contract.allowance(owner, spender)) ==>
  <>(finished(contract.allowance(owner, spender), _totalSupply == old(_totalSupply)
    && _balances == old(_balances) && _allowances == old(_allowances) &&
    other_state_variables == old(other_state_variables))))]
```

Properties related to function `approve`

erc20-approve-revert-zero

approve Prevents Approvals For the Zero Address. All calls of the form `approve(spender, amount)` must fail if the address in `spender` is the zero address. Specification:

```
[(started(contract.approve(spender, value), spender == address(0)) ==>
  <>(reverted(contract.approve) || finished(contract.approve(spender, value),
    return == false)))]
```

erc20-approve-succeed-normal

approve Succeeds for Admissible Inputs. All calls of the form `approve(spender, amount)` must succeed, if

- the address in `spender` is not the zero address and
- the execution does not run out of gas. Specification:

```
[(started(contract.approve(spender, value), spender != address(0)) ==>
  <>(finished(contract.approve(spender, value), return == true)))]
```

erc20-approve-correct-amount

approve Updates the Approval Mapping Correctly. All non-reverting calls of the form `approve(spender, amount)` that return `true` must correctly update the allowance mapping according to the address `msg.sender` and the values of `spender` and `amount`. Specification:

```

[] (willSucceed(contract.approve(spender, value), spender != address(0) && value >=
    0 && value <
    0x10000000000000000000000000000000000000000000000000000000000000000) ==>
    <> (finished(contract.approve(spender, value), return == true ==>
        _allowances[msg.sender][spender] == value)))

```

erc20-approve-change-state

`approve` Has No Unexpected State Changes. All calls of the form `approve(spender, amount)` must only update the allowance mapping according to the address `msg.sender` and the values of `spender` and `amount` and incur no other state changes. Specification:

```

[] (willSucceed(contract.approve(spender, value), spender != address(0) && (p1 !=
    msg.sender || p2 != spender)) ==> <> (finished(contract.approve(spender,
    value), return == true ==> _totalSupply == old(_totalSupply) && _balances
    == old(_balances) && _allowances[p1][p2] == old(_allowances[p1][p2]) &&
    other_state_variables == old(other_state_variables))))

```

erc20-approve-false

If `approve` Returns `false`, the Contract's State Is Unchanged. If function `approve` returns `false` to signal a failure, it must undo all state changes that it incurred before returning to the caller. Specification:

```

[] (willSucceed(contract.approve(spender, value)) ==>
    <> (finished(contract.approve(spender, value), return == false ==> (_balances ==
        old(_balances) && _totalSupply == old(_totalSupply) && _allowances ==
        old(_allowances) && other_state_variables == old(other_state_variables)))))

```

erc20-approve-never-return-false

`approve` Never Returns `false`. The function `approve` must never returns `false`. Specification:

```

[] (!(finished(contract.approve, return == false)))

```

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