CERTIK

# Security Assessment

# WARRIOR

CertiK Verified on Feb 11th, 2023


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# WARRIOR

The security assessment was prepared by CertiK, the leader in Web3.0 security.

## Executive Summary

| TYPES | ECOSYSTEM | METHODS |
|---|---|---|
| ERC-20 | Binance Smart Chain (BSC) | Formal Verification, Manual Review, Static Analysis |

| LANGUAGE | TIMELINE | KEY COMPONENTS |
|---|---|---|
| Solidity | Delivered on 02/11/2023 | N/A |

CODEBASE

https://bscscan.com/address/0xd6edbb510af7901b2c049ce778b65a740c4aeb7f

...View All

## Vulnerability Summary

| 4 | 0 | 0 | 0 | 4 | 0 | 0 |
|---|---|---|---|---|---|---|
| Total Findings | Resolved | Mitigated | Partially Resolved | Acknowledged | Declined | 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. |
| 2 | Major | 2 Acknowledged | 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. |
| 0 | Minor | | 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. |
| 2 | Informational | 2 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. |

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# CODEBASE | WARRIOR

## Repository

https://bscscan.com/address/0xd6edbb510af7901b2c049ce778b65a740c4aeb7f

# AUDIT SCOPE | WARRIOR

1 file audited ● 1 file with Acknowledged findings

| ID | File | SHA256 Checksum |
| --- | --- | --- |
| ● WAR | WARRIOR.sol | a82adb27a2c145eadf29da1119c247b2b08eefc4e8b46b623e8eba69223956e5 |

# APPROACH & METHODS | WARRIOR

This report has been prepared for WARRIOR to discover issues and vulnerabilities in the source code of the WARRIOR 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 | WARRIOR

| 4 | 0 | 2 | 0 | 0 | 2 |
|---|---|---|---|---|---|
| Total Findings | Critical | Major | Medium | Minor | Informational |

This report has been prepared to discover issues and vulnerabilities for WARRIOR. Through this audit, we have uncovered 4 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:

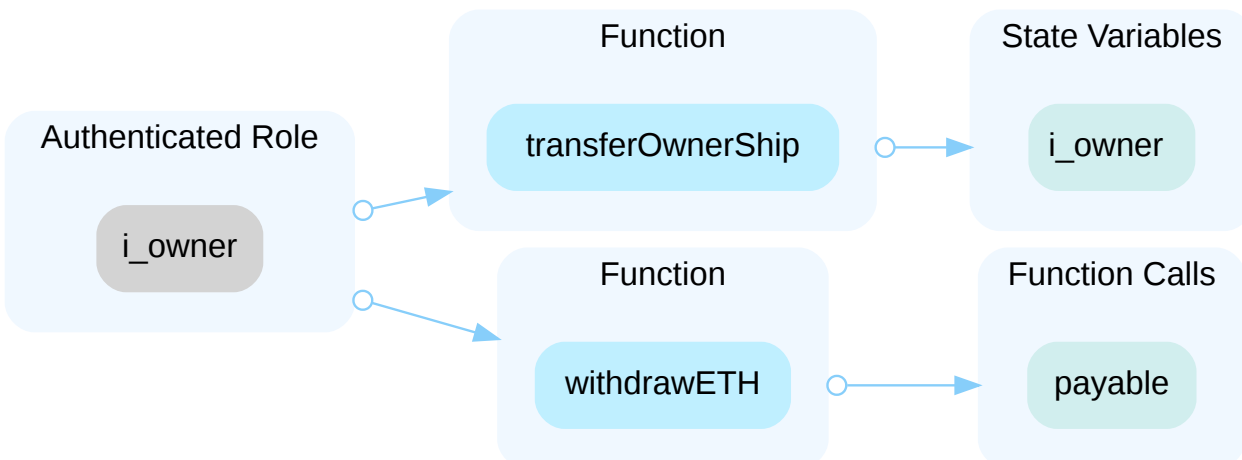
| ID | Title | Category | Severity | Status |
|---|---|---|---|---|
| **WAR-01** | **Centralization Risks In WARRIOR.Sol** | **Centralization / Privilege** | **Major** | **Acknowledged** |
| **WAR-02** | **Initial Token Distribution** | **Centralization / Privilege** | **Major** | **Acknowledged** |
| WAR-03 | Different Solidity Versions | Language Specific | Informational | Acknowledged |
| WAR-04 | Missing Emit Events | Language Specific | Informational | Acknowledged |

# WAR-01 | CENTRALIZATION RISKS IN WARRIOR.SOL

| Category | Severity | Location | Status |
|---|---|---|---|
| **Centralization / Privilege** | **Major** | **WARRIOR.sol: 555, 560** | **Acknowledged** |

## Description

In the contract `WARRIOR` the role `i_owner` has authority over the functions shown in the diagram below. Any compromise to the `i_owner` account may allow the hacker to take advantage of this authority.




## 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 (⅔, ⅗) 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.

## Alleviation

`[CertiK]` : The team acknowledged this issue and will leave it as it is for now.

# WAR-02 | INITIAL TOKEN DISTRIBUTION

| Category | Severity | Location | Status |
| --- | --- | --- | --- |
| **Centralization / Privilege** | **Major** | **WARRIOR.sol: 546** | **Acknowledged** |

## Description

Any amount of **WARRIOR** tokens can be sent to the contract deployer when deploying the contract. This is a potential centralization risk as the deployer can distribute **WARRIOR** tokens without the consensus of the community.

## Recommendation

We recommend transparency through providing a breakdown of the intended initial token distribution in a public location. We also recommend the team make an effort to restrict the access of the corresponding private key.

## Alleviation

`[CertiK]` : The team acknowledged this issue and will leave it as it is for now.

# WAR-03 | DIFFERENT SOLIDITY VERSIONS

| Category | Severity | Location | Status |
| --- | --- | --- | --- |
| Language Specific | Informational | WARRIOR.sol: 20, 132, 162, 542 | Acknowledged |

## Description

Multiple Solidity versions are used in the codebase.

Versions used: `^0.8.0`, `^0.8.1`

`^0.8.0` is used in WARRIOR.sol file.

```
542  pragma solidity ^0.8.0;
```

`^0.8.1` is used in WARRIOR.sol file.

```
20  pragma solidity ^0.8.1;
```

## Recommendation

We recommend using one Solidity version.

## Alleviation

`[CertiK]`: The team acknowledged this issue and will leave it as it is for now.

# WAR-04 | MISSING EMIT EVENTS

| Category | Severity | Location | Status |
| --- | --- | --- | --- |
| Language Specific | Informational | WARRIOR.sol: 562 | Acknowledged |

## Description

One or more state changes do not emit events to pass the changes out of chain.

```
562         i_owner  = newOwner;
```

## Recommendation

We recommend declaring and emitting corresponding events for all the essential state variables that are possible to be changed during runtime.

## Alleviation

`[CertiK]`: The team acknowledged this issue and will leave it as it is for now.

# FORMAL VERIFICATION | WARRIOR

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-totalsupply-succeed-always | Function `totalSupply` Always Succeeds |
| erc20-transferfrom-fail-recipient-overflow | Function `transferFrom` Prevents Overflows in the Recipient's Balance |
| erc20-transferfrom-false | If Function `transferFrom` Returns `false`, the Contract's State Has Not Been Changed |
| erc20-transferfrom-never-return-false | Function `transferFrom` Never Returns `false` |
| erc20-totalsupply-correct-value | Function `totalSupply` Returns the Value of the Corresponding State Variable |
| erc20-balanceof-succeed-always | Function `balanceOf` Always Succeeds |
| erc20-totalsupply-change-state | Function `totalSupply` Does Not Change the Contract's State |
| erc20-balanceof-correct-value | Function `balanceOf` Returns the Correct Value |
| erc20-balanceof-change-state | Function `balanceOf` Does Not Change the Contract's State |

| Property Name | Title |
| --- | --- |
| erc20-allowance-succeed-always | Function `allowance` Always Succeeds |
| erc20-allowance-change-state | Function `allowance` Does Not Change the Contract's State |
| erc20-allowance-correct-value | Function `allowance` Returns Correct Value |
| erc20-approve-revert-zero | Function `approve` Prevents Giving Approvals For the Zero Address |
| erc20-approve-correct-amount | Function `approve` Updates the Approval Mapping Correctly |
| erc20-approve-succeed-normal | Function `approve` Succeeds for Admissible Inputs |
| erc20-approve-change-state | Function `approve` Has No Unexpected State Changes |
| erc20-approve-false | If Function `approve` Returns `false`, the Contract's State Has Not Been Changed |
| erc20-approve-never-return-false | Function `approve` Never Returns `false` |
| erc20-transfer-revert-zero | Function `transfer` Prevents Transfers to the Zero Address |
| erc20-transfer-succeed-normal | Function `transfer` Succeeds on Admissible Non-self Transfers |
| erc20-transfer-succeed-self | Function `transfer` Succeeds on Admissible Self Transfers |
| erc20-transfer-correct-amount | Function `transfer` Transfers the Correct Amount in Non-self Transfers |
| erc20-transfer-correct-amount-self | Function `transfer` Transfers the Correct Amount in Self Transfers |
| erc20-transfer-change-state | Function `transfer` Has No Unexpected State Changes |
| erc20-transfer-exceed-balance | Function `transfer` Fails if Requested Amount Exceeds Available Balance |
| erc20-transfer-recipient-overflow | Function `transfer` Prevents Overflows in the Recipient's Balance |
| erc20-transfer-false | If Function `transfer` Returns `false`, the Contract State Has Not Been Changed |
| erc20-transfer-never-return-false | Function `transfer` Never Returns `false` |
| erc20-transferfrom-revert-from-zero | Function `transferFrom` Fails for Transfers From the Zero Address |
| erc20-transferfrom-revert-to-zero | Function `transferFrom` Fails for Transfers To the Zero Address |
| erc20-transferfrom-succeed-normal | Function `transferFrom` Succeeds on Admissible Non-self Transfers |

| Property Name | Title |
| --- | --- |
| erc20-transferfrom-succeed-self | Function `transferFrom` Succeeds on Admissible Self Transfers |
| erc20-transferfrom-correct-amount | Function `transferFrom` Transfers the Correct Amount in Non-self Transfers |
| erc20-transferfrom-correct-amount-self | Function `transferFrom` Performs Self Transfers Correctly |
| erc20-transferfrom-fail-exceed-balance | Function `transferFrom` Fails if the Requested Amount Exceeds the Available Balance |
| erc20-transferfrom-change-state | Function `transferFrom` Has No Unexpected State Changes |
| erc20-transferfrom-correct-allowance | Function `transferFrom` Updated the Allowance Correctly |
| erc20-transferfrom-fail-exceed-allowance | Function `transferFrom` Fails if the Requested Amount Exceeds the Available Allowance |

## Verification Results

For the following contracts, model checking established that each of the properties that were in scope of this audit (see scope) are valid:

### Detailed Results For Contract ERC20 (WARRIOR.sol)

#### Verification of ERC-20 Compliance

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 `transferFrom`

| Property Name | Final Result | Remarks |
|---|---|---|
| erc20-transferfrom-fail-recipient-overflow | True | |
| erc20-transferfrom-false | True | |
| erc20-transferfrom-never-return-false | True | |
| erc20-transferfrom-revert-from-zero | True | |
| erc20-transferfrom-revert-to-zero | True | |
| erc20-transferfrom-succeed-normal | True | |
| erc20-transferfrom-correct-amount | True | |
| erc20-transferfrom-correct-amount-self | True | |
| erc20-transferfrom-succeed-self | True | |
| erc20-transferfrom-fail-exceed-balance | True | |
| erc20-transferfrom-fail-exceed-allowance | True | |
| erc20-transferfrom-correct-allowance | True | |
| erc20-transferfrom-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-change-state | True | |
| erc20-allowance-correct-value | True | |

Detailed results for function `approve`

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

Detailed results for function `transfer`

| Property Name | Final Result | Remarks |
|---|---|---|
| erc20-transfer-revert-zero | True | |
| erc20-transfer-succeed-self | True | |
| erc20-transfer-succeed-normal | True | |
| erc20-transfer-correct-amount | True | |
| erc20-transfer-correct-amount-self | True | |
| erc20-transfer-change-state | True | |
| erc20-transfer-exceed-balance | True | |
| erc20-transfer-recipient-overflow | True | |
| erc20-transfer-false | True | |
| erc20-transfer-never-return-false | True | |

### Detailed Results For Contract WARRIOR (WARRIOR.sol)

**Verification of ERC-20 Compliance**

Detailed results for function `transfer`

| Property Name | Final Result | Remarks |
|---|---|---|
| erc20-transfer-revert-zero | True | |
| erc20-transfer-succeed-normal | True | |
| erc20-transfer-succeed-self | True | |
| erc20-transfer-correct-amount | True | |
| erc20-transfer-correct-amount-self | True | |
| erc20-transfer-change-state | True | |
| erc20-transfer-exceed-balance | True | |
| erc20-transfer-recipient-overflow | True | |
| erc20-transfer-false | True | |
| erc20-transfer-never-return-false | True | |

Detailed results for function `transferFrom`

| Property Name | Final Result | Remarks |
|---|---|---|
| erc20-transferfrom-revert-from-zero | True | |
| erc20-transferfrom-revert-to-zero | True | |
| erc20-transferfrom-succeed-normal | True | |
| erc20-transferfrom-succeed-self | True | |
| erc20-transferfrom-correct-amount | True | |
| erc20-transferfrom-correct-amount-self | True | |
| erc20-transferfrom-fail-exceed-balance | True | |
| erc20-transferfrom-change-state | True | |
| erc20-transferfrom-correct-allowance | True | |
| erc20-transferfrom-fail-exceed-allowance | True | |
| erc20-transferfrom-never-return-false | True | |
| erc20-transferfrom-fail-recipient-overflow | True | |
| erc20-transferfrom-false | True | |

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-never-return-false | True | |
| erc20-approve-false | True | |

# APPENDIX | WARRIOR

## 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. |
| Language Specific | Language Specific findings are issues that would only arise within Solidity, i.e. incorrect usage of private or delete. |

## 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 `[]`) and "eventually" (written `<>`), 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

Function `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

Function `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

Function `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

Function `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:

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

#### erc20-transfer-correct-amount-self

Function `transfer` Transfers the Correct Amount in Self Transfers. All non-reverting invocations of `transfer(recipient, amount)` that return `true` and where the `recipient` address equals `msg.sender` (i.e. self-transfers) must not change the balance of address `msg.sender`. Specification:

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

#### erc20-transfer-change-state

Function `transfer` Has No Unexpected State Changes. All non-reverting invocations of `transfer(recipient, amount)` that return `true` must only modify the balance entries of the `msg.sender` and the `recipient` addresses. Specification:

```
[](willSucceed(contract.transfer(to, value), p1 != msg.sender && p1 != to) ==>
  <>(finished(contract.transfer(to, value), return == true ==> (_totalSupply ==
        old(_totalSupply) && _allowances == old(_allowances) && _balances[p1] ==
        old(_balances[p1]) && other_state_variables ==
        old(other_state_variables)))))
```

#### erc20-transfer-exceed-balance

Function `transfer` Fails if Requested Amount Exceeds Available Balance. Any transfer of an amount of tokens that exceeds the balance of `msg.sender` must fail. Specification:

```
[](started(contract.transfer(to, value), value > _balances[msg.sender] &&
    _balances[msg.sender] >= 0 && value <
    0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(reverted(contract.transfer) || finished(contract.transfer(to, value), return
      == false)))
```

#### erc20-transfer-recipient-overflow

Function `transfer` Prevents Overflows in the Recipient's Balance. Any invocation of `transfer(recipient, amount)` must fail if it causes the balance of the `recipient` address to overflow. Specification:

```
[](started(contract.transfer(to, value), to != msg.sender && _balances[to] + value
    >= 0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[msg.sender] <
    0x10000000000000000000000000000000000000000000000000000000000000000 && value >
    0 && value <= _balances[msg.sender]) ==> <>(reverted(contract.transfer) ||
    finished(contract.transfer(to, value), return == false) ||
    finished(contract.transfer(to, value), _balances[to] > old(_balances[to]) +
      value -
      0x10000000000000000000000000000000000000000000000000000000000000000)))
```

#### erc20-transfer-false

If Function `transfer` Returns `false` , the Contract State Has Not Been 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

Function `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

Function `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

Function `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

Function `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

Function `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

Function `transferFrom` Transfers the Correct Amount in Non-self Transfers. All invocations of `transferFrom(from, dest, amount)` that succeed and that return `true` subtract the value in `amount` from the balance of address `from` and add the same value to the balance of address `dest`. Specification:

```
[](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))))
```

#### erc20-transferfrom-correct-amount-self

Function `transferFrom` Performs Self Transfers Correctly. All non-reverting invocations of `transferFrom(from, dest, amount)` that return `true` and where the address in `from` equals the address in `dest` (i.e. self-transfers) do not change the balance entry of the `from` address (which equals `dest`). Specification:

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

#### erc20-transferfrom-correct-allowance

Function `transferFrom` Updated the Allowance Correctly. All non-reverting invocations of `transferFrom(from, dest, amount)` that return `true` must decrease the allowance for address `msg.sender` over address `from` by the value in `amount`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, value), value >= 0 && value <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[from] >= 0 && _balances[from] <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _allowances[from][msg.sender] >= 0 && _allowances[from][msg.sender] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transferFrom(from, to, value), return == true ==>
      ((_allowances[from][msg.sender] == old(_allowances[from][msg.sender]) -
      value) || (_allowances[from][msg.sender] ==
      old(_allowances[from][msg.sender]) && (from == msg.sender ||
        old(_allowances[from][msg.sender]) ==
        0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF))))))
```

**erc20-transferfrom-change-state**

Function `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**

Function `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] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(reverted(contract.transferFrom) || finished(contract.transferFrom, return ==
      false)))
```

**erc20-transferfrom-fail-exceed-allowance**

Function `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), value >
    _allowances[from][msg.sender] && _allowances[from][msg.sender] >= 0 && value <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(reverted(contract.transferFrom) || finished(contract.transferFrom(from, to,
       value), return == false) || finished(contract.transferFrom(from, to,
       value), return == true && (msg.sender == from ||
       _allowances[from][msg.sender] ==
       0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF))))
```

#### erc20-transferfrom-fail-recipient-overflow

Function `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:

```
[](started(contract.transferFrom(from, to, value), from != to && _balances[to] +
    value >= 0x1000000000000000000000000000000000000000000000000000000000000000 &&
    value < 0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(reverted(contract.transferFrom) || finished(contract.transferFrom(from, to,
       value), return == false) || finished(contract.transferFrom(from, to,
       value), _balances[to] > old(_balances[to]) + value -
     0x1000000000000000000000000000000000000000000000000000000000000000)))
```

#### erc20-transferfrom-false

If Function `transferFrom` Returns `false`, the Contract's State Has Not Been Changed. If `transferFrom` returns `false` to signal a failure, it must undo all incurred state changes before returning to the caller. Specification:

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

#### erc20-transferfrom-never-return-false

Function `transferFrom` Never Returns `false`. The `transferFrom` function must never return `false`. Specification:

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

### Properties related to function `totalSupply`

#### erc20-totalsupply-succeed-always

Function `totalSupply` Always Succeeds. The function `totalSupply` must always succeeds, assuming that its execution does not run out of gas. Specification:

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

#### erc20-totalsupply-correct-value

Function `totalSupply` Returns the Value of the Corresponding State Variable. The `totalSupply` function must return the value that is held in the corresponding state variable of contract contract. Specification:

```
[](willSucceed(contract.totalSupply) ==> <>(finished(contract.totalSupply, return
      == _totalSupply)))
```

#### erc20-totalsupply-change-state

Function `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

Function `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

Function `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

Function `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

Function `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

Function `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

Function `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

Function `approve` Prevents Giving 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

Function `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

Function `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 <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.approve(spender, value), return == true ==>
      _allowances[msg.sender][spender] == value)))
```

#### erc20-approve-change-state

Function `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 Function `approve` Returns `false`, the Contract's State Has Not Been Changed. 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**

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

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

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