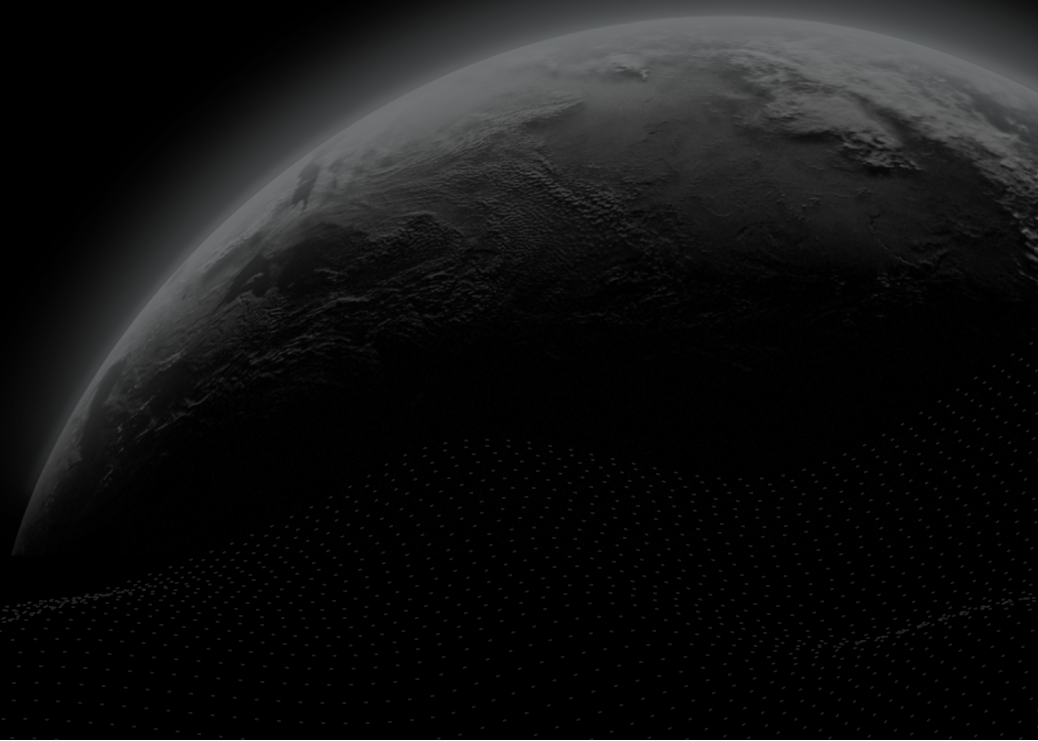
CERTIK

Security Assessment

# Bad Idea AI

CertiK Assessed on Sept 29th, 2023



CertiK Assessed on Sept 29th, 2023

# Bad Idea AI

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

## Executive Summary

| TYPES | ECOSYSTEM | METHODS |
|---|---|---|
| ERC-20 | Ethereum (ETH) | Formal Verification, Manual Review, Static Analysis |

| LANGUAGE | TIMELINE | KEY COMPONENTS |
|---|---|---|
| Solidity | Delivered on 09/29/2023 | N/A |

CODEBASE
https://etherscan.io/address/0x32b86b99441480a7e5bd3a26c124ec2373e3f015
View All in Codebase Page

COMMITS
View All in Codebase Page

## Highlighted Centralization Risks

Initial owner token share is 100%

## Vulnerability Summary

| 2 | 0 | 1 | 0 | 1 | 0 |
|---|---|---|---|---|---|
| Total Findings | Resolved | Mitigated | Partially Resolved | Acknowledged | Declined |

| | | | |
|---|---|---|---|
| 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 Mitigated | | 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. |
| 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. |

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# CODEBASE | BAD IDEA AI

## Repository

https://etherscan.io/address/0x32b86b99441480a7e5bd3a26c124ec2373e3f015

## Commit

# AUDIT SCOPE | BAD IDEA AI

1 file audited ● 1 file with Acknowledged findings

| ID | File | SHA256 Checksum |
| --- | --- | --- |
| ● BAD | contracts/badai.sol | 2c2b61b79f5ad90c311ef6196cb73762bb833<br>52b8afad49c023e5df8033caf15 |

# APPROACH & METHODS | BAD IDEA AI

This report has been prepared for Badidea to discover issues and vulnerabilities in the source code of the Bad Idea AI 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 | BAD IDEA AI

| 2 | 0 | 1 | 0 | 0 | 1 |
|---|---|---|---|---|---|
| Total Findings | Critical | Major | Medium | Minor | Informational |

This report has been prepared to discover issues and vulnerabilities for Bad Idea AI. Through this audit, we have uncovered 2 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 |
|---|---|---|---|---|
| **BAD-01** | **Initial Token Distribution** | **Centralization** | **Major** | **Mitigated** |
| BAD-02 | Big Numbers Could Be Written In A Clearer Way | Coding Style | Informational | Acknowledged |

# BAD-01 | INITIAL TOKEN DISTRIBUTION

| Category | Severity | Location | Status |
| --- | --- | --- | --- |
| **Centralization** | **Major** | **contracts/badai.sol: 9** | **Mitigated** |

## Description

All of the `BAD` tokens are sent to the contract deployer or one or several externally-owned account (EOA) addresses. This is a centralization risk because the deployer or the owner(s) of the EOAs can distribute tokens without obtaining the consensus of the community. Any compromise to these addresses may allow a hacker to steal and sell tokens on the market, resulting in severe damage to the project.

## Recommendation

It is recommended that the team be transparent regarding the initial token distribution process. The token distribution plan should be published in a public location that the community can access. The team should make efforts to restrict access to the private keys of the deployer account or EOAs. A multi-signature (⅔, ⅗) wallet can be used to prevent a single point of failure due to a private key compromise. Additionally, the team can lock up a portion of tokens, release them with a vesting schedule for long-term success, and deanonymize the project team with a third-party KYC provider to create greater accountability.

## Alleviation

`[Certik - 2023/09/29]` : The client shared information about the initial token distribution and the configuration of the multi-sig holding the tokens.

The Initial Token Distribution is assigned to safes (called vaults) with a 3 of 5 signature configuration. Six vaults were created. These vaults are aligned with the whitepaper token distribution of 4.2% Team, 6.9% Marketing Allocation, 6.9% AI Development, 6.9% DAO Development, 6.9% Blockchain Development, and Humanity's Last Hope Fund 10.2%.

Link to the token distribution plan: Page 5 of https://static1.squarespace.com/static/64568e2523471d05956228f1/t/64570517d89163351580ef5c/1683424539459/BAD+IDEA+AI+WHITEPAPER+v1.0.pdf

The multi-sig wallets addresses are:

- 0xe5f6f7181eec4c2a8ae59e5de2afed32e9ea3250
- 0xA41f36D9F8c9eD352Ed80105C921D55559C2F8E9
- 0xBA07DbA88B9d3700c169cE82Ced3C1bF4791b3b6
- 0x7A748CE254bb2E377aaFd24b81Eb4442c1a57734
- 0x33a733B6b613A2178109F2353B6369D2d3a86b0e- 0x22F519e33550A0F521DF80080f8Aabe22e63131d

The signers of those wallets are:

Signer #1: 0x57d75D9eEbbDE7fc7A3fe014cD0aF7b191c66819

Signer #2: 0x7ddCe3602ae7baD35CE19dF718EDD57d1DAC4f97

Signer #3: 0x92f4562060dBF6BF470D2D2b0E94423e3334A2aa

Signer #4: 0x1D410Bc29dD9FB94071b7588310478c9a15af58D

Signer #5: 0xD572fADacCd49a41B12ac3f6662c1661cc994e3E

The threshold of all the multi-sig wallets is 3 out of 5

# BAD-02 | BIG NUMBERS COULD BE WRITTEN IN A CLEARER WAY

| Category | Severity | Location | Status |
| --- | --- | --- | --- |
| Coding Style | Informational | contracts/badai.sol: 9 | Acknowledged |

## Description

The big numbers linked are hard to read, for example `831041059897327311 0117` makes it hard to identify the order of magnitude of the number, decreasing the readability of the code.

## Recommendation

We recommend rewriting all the big numbers in a clearer way, for example the previous number could be rewritten as `8_310_410_598_973_273_110_117` .

## Alleviation

`[Bad Idea AI - 2023/09/29]` : Issue acknowledged. I will fix the issue in the future, which will not be included in this audit engagement.

`[Certik - 2023/09/29]` : The client acknowledged the issue and decided to remain unchanged in the scope of this audit engagement.

# FORMAL VERIFICATION | BAD IDEA AI

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-revert-zero | `transfer` Prevents Transfers to the Zero Address |
| erc20-transfer-succeed-self | `transfer` Succeeds on Admissible Self Transfers |
| erc20-transfer-succeed-normal | `transfer` Succeeds on Admissible Non-self Transfers |
| erc20-transfer-correct-amount-self | `transfer` Transfers the Correct Amount in Self Transfers |
| erc20-transfer-correct-amount | `transfer` Transfers the Correct Amount in Non-self Transfers |
| erc20-transfer-recipient-overflow | `transfer` Prevents Overflows in the Recipient's Balance |
| erc20-transfer-false | If `transfer` Returns `false`, the Contract State Is Not Changed |
| erc20-transfer-exceed-balance | `transfer` Fails if Requested Amount Exceeds Available Balance |
| erc20-transfer-never-return-false | `transfer` Never Returns `false` |
| erc20-transferfrom-revert-from-zero | `transferFrom` Fails for Transfers From the Zero Address |

| Property Name | Title |
| --- | --- |
| erc20-transferfrom-revert-to-zero | `transferFrom` Fails for Transfers To the Zero Address |
| erc20-transferfrom-correct-amount-self | `transferFrom` Performs Self Transfers Correctly |
| erc20-transferfrom-succeed-self | `transferFrom` Succeeds on Admissible Self Transfers |
| erc20-transferfrom-succeed-normal | `transferFrom` Succeeds on Admissible Non-self Transfers |
| erc20-transferfrom-correct-amount | `transferFrom` Transfers the Correct Amount in Non-self Transfers |
| erc20-transferfrom-correct-allowance | `transferFrom` Updated the Allowance Correctly |
| erc20-transferfrom-fail-exceed-allowance | `transferFrom` Fails if the Requested Amount Exceeds the Available Allowance |
| erc20-transferfrom-fail-recipient-overflow | `transferFrom` Prevents Overflows in the Recipient's Balance |
| erc20-transferfrom-fail-exceed-balance | `transferFrom` Fails if the Requested Amount Exceeds the Available Balance |
| erc20-totalsupply-succeed-always | `totalSupply` Always Succeeds |
| erc20-transferfrom-false | If `transferFrom` Returns `false`, the Contract's State Is Unchanged |
| erc20-totalsupply-correct-value | `totalSupply` Returns the Value of the Corresponding State Variable |
| erc20-totalsupply-change-state | `totalSupply` Does Not Change the Contract's State |
| erc20-transferfrom-never-return-false | `transferFrom` Never Returns `false` |
| erc20-balanceof-succeed-always | `balanceOf` Always Succeeds |
| erc20-balanceof-correct-value | `balanceOf` Returns the Correct Value |
| erc20-balanceof-change-state | `balanceOf` Does Not Change the Contract's State |
| erc20-allowance-succeed-always | `allowance` Always Succeeds |
| erc20-allowance-correct-value | `allowance` Returns Correct Value |
| erc20-allowance-change-state | `allowance` Does Not Change the Contract's state |
| erc20-approve-succeed-normal | `approve` Succeeds for Admissible Inputs |
| erc20-approve-revert-zero | `approve` Prevents Approvals For the Zero Address |

| Property Name | Title |
| --- | --- |
| erc20-approve-correct-amount | `approve` Updates the Approval Mapping Correctly |
| erc20-approve-false | If `approve` Returns `false`, the Contract's State Is Unchanged |
| erc20-approve-never-return-false | `approve` Never Returns `false` |
| erc20-transfer-change-state | `transfer` Has No Unexpected State Changes |
| erc20-transferfrom-change-state | `transferFrom` Has No Unexpected State Changes |
| erc20-approve-change-state | `approve` Has No Unexpected State Changes |

## 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 BADIdeaAI (contracts/badai.sol) In Commit 0x32b86b99441480a7e5bd3a26c124ec2373e3f015

#### Verification of ERC-20 Compliance

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-self | True | |
| erc20-transfer-correct-amount | True | |
| erc20-transfer-recipient-overflow | True | |
| erc20-transfer-false | True | |
| erc20-transfer-exceed-balance | True | |
| erc20-transfer-never-return-false | True | |
| erc20-transfer-change-state | 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-correct-amount-self | True | |
| erc20-transferfrom-succeed-self | True | |
| erc20-transferfrom-succeed-normal | True | |
| erc20-transferfrom-correct-amount | True | |
| erc20-transferfrom-correct-allowance | True | |
| erc20-transferfrom-fail-exceed-allowance | True | |
| erc20-transferfrom-fail-recipient-overflow | True | |
| erc20-transferfrom-fail-exceed-balance | True | |
| erc20-transferfrom-false | True | |
| erc20-transferfrom-never-return-false | True | |
| erc20-transferfrom-change-state | 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-succeed-normal | True | |
| erc20-approve-revert-zero | True | |
| erc20-approve-correct-amount | True | |
| erc20-approve-false | True | |
| erc20-approve-never-return-false | True | |
| erc20-approve-change-state | True | |

# APPENDIX | BAD IDEA AI

## Finding Categories

| Categories | Description |
| --- | --- |
| Coding Style | Coding Style findings may not affect code behavior, but indicate areas where coding practices can be improved to make the code more understandable and maintainable. |
| Centralization | Centralization findings detail the design choices of designating privileged roles or other centralized controls over the code. |

## 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

### Technical description

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.

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 of those functions. 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 as operations on the congruence classes arising from the bit-width of the underlying numeric 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 an ERC-20 token 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 definitions

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 steps. 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 to reason about the validity of 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 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 for ERC-20 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)))
```

**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 <= type(uint256).max && _balances[to] >= 0
          && _balances[msg.sender] <= type(uint256).max)
          ==> <>(finished(contract.transfer(to, value), return)))
```

**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] <= type(uint256).max)
          ==> <>(finished(contract.transfer(to, value), return)))
```

**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 <= type(uint256).max
   && _balances[msg.sender] >= 0 && _balances[msg.sender] <= type(uint256).max)
      ==> <>(finished(contract.transfer(to, value), return
            ==> _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] <= type(uint256).max)
     ==> <>(finished(contract.transfer(to, value), return
         ==> _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
      ==> (_totalSupply == old(_totalSupply) && _allowances == old(_allowances)
           && _balances[p1] == old(_balances[p1])  ))))
```

**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 <= type(uint256).max)
   ==> <>(reverted(contract.transfer) || finished(contract.transfer(to, value),
          !return)))
```

#### 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 > type(uint256).max
   && _balances[to] >= 0 && _balances[to] <= type(uint256).max
   && _balances[msg.sender] <= type(uint256).max
   && value > 0 && value <= _balances[msg.sender])
   ==> <>(reverted(contract.transfer) || finished(contract.transfer(to, value),
          !return) || finished(contract.transfer(to, value), _balances[to]
                      > old(_balances[to]) + value - type(uint256).max - 1)))
```

#### 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]
   ==> (_balances == old(_balances) && _totalSupply == old(_totalSupply)
                                    && _allowances == old(_allowances)  ))))
```

#### erc20-transfer-never-return-false

Function `transfe` Never Returns `false` .

The transfer function must never return `false` to signal a failure.

Specification:

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

### Properties for ERC-20 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)))
```

#### 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)))
```

#### 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 <= type(uint256).max
   && value >= 0 && _balances[to] >= 0 && _balances[from] >= 0
   && _balances[from] <= type(uint256).max
   && _allowances[from][msg.sender] >= 0
   && _allowances[from][msg.sender] <= type(uint256).max)
      ==> <>(finished(contract.transferFrom(from, to, value), return)))
```

#### 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] <= type(uint256).max
   && _allowances[from][msg.sender] <= type(uint256).max)
     ==> <>(finished(contract.transferFrom(from, to, value), return)))
```

#### 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] <= type(uint256).max
&& _balances[to] >= 0 && _balances[to] + value <= type(uint256).max)
   ==> <>(finished(contract.transferFrom(from, to, value), return
          ==> _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 <= type(uint256).max && _balances[from] >= 0
   && _balances[from] <= type(uint256).max)
      ==> <>(finished(contract.transferFrom(from, to, value), return
             ==> _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 <= type(uint256).max && _balances[from] >= 0
   && _balances[from] <= type(uint256).max && _balances[to] >= 0
   && _balances[to] <= type(uint256).max && _allowances[from][msg.sender] >= 0
   && _allowances[from][msg.sender] <= type(uint256).max)
      ==> <>(finished(contract.transferFrom(from, to, value), return
          ==> ((_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])
                              == type(uint256).max))))))
```

#### 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
     ==> (_totalSupply == old(_totalSupply) && _balances[p1] == old(_balances[p1])
         && _allowances[p2][p3] == old(_allowances[p2][p3])  ))))
```

#### 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] <= type(uint256).max)
       ==> <>(reverted(contract.transferFrom)
              || finished(contract.transferFrom, !return)))
```

#### 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 <= type(uint256).max)
    ==> <>(reverted(contract.transferFrom)
          || finished(contract.transferFrom(from, to, value), !return)
          || finished(contract.transferFrom(from, to, value), return
             && (msg.sender == from
                 || _allowances[from][msg.sender] == type(uint256).max))))
```

#### 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 > type(uint256).max && value <= type(uint256).max
   && _balances[to] >= 0 && _balances[to] <= type(uint256).max)
      ==> <>(reverted(contract.transferFrom)
          || finished(contract.transferFrom(from, to, value), !return)
          || finished(contract.transferFrom(from, to, value), _balances[to]
              > old(_balances[to]) + value - type(uint256).max - 1)))
```

#### 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.transfer(to, value))
   ==> <>(finished(contract.transfer(to, value), !return
   ==> (_balances == old(_balances) && _totalSupply == old(_totalSupply)
                                    && _allowances == old(_allowances)  ))))
```

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

Function `transferFrom` Never Returns `false`.

The `transferFrom` function must never return `false`.

Specification:

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

### 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)  )))
```

**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)  )))
```

**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)  )))
```

### 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)))
```

#### 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)))
```

#### 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 <= type(uint256).max)
       ==> <>(finished(contract.approve(spender, value), return
              ==> _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
              ==> _totalSupply == old(_totalSupply) && _balances == old(_balances)
                  && _allowances[p1][p2] == old(_allowances[p1][p2])  )))
```

### 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
          ==> (_balances == old(_balances) && _totalSupply == old(_totalSupply)
               && _allowances == old(_allowances)  ))))
```

### erc20-approve-never-return-false

Function `approve` Never Returns `false`.

The function `approve` must never returns `false`.

Specification:

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

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