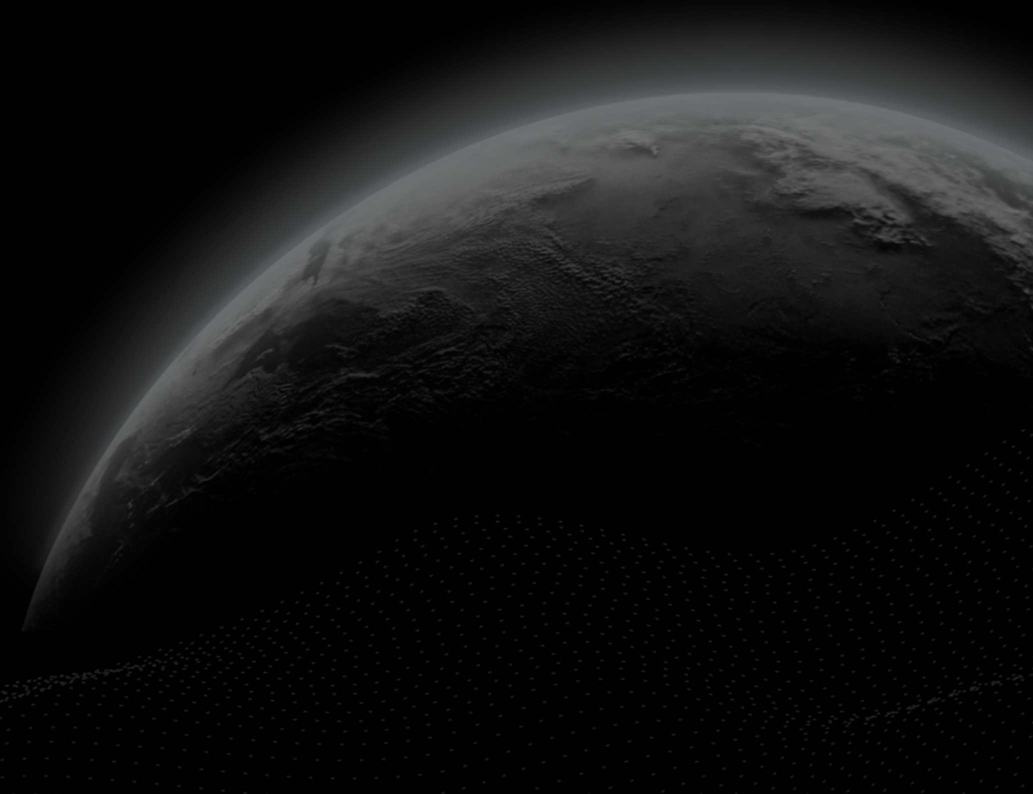
CERTIK

Security Assessment

flamelaunch

CertiK Verified on Mar 27th, 2023



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

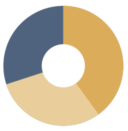
Executive Summary

TYPES	ECOSYSTEM	METHODS
DeFi	FEVM	Formal Verification, Manual Review, Static Analysis
LANGUAGE	**TIMELINE**	**KEY COMPONENTS**
Solidity	Delivered on 03/27/2023	N/A

CODEBASE
https://github.com/FlameLaunch/flame-launch-contracts/tree/127dcaf6e887672ddc64d137f7c792de972c3ec5/contracts
...View All

COMMITS
127dcaf6e887672ddc64d137f7c792de972c3ec5
...View All

Vulnerability Summary



10	4	0	1	5	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.
🟧	0	Major		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.
🟨	4	Medium	2 Resolved, 2 Acknowledged	Medium risks may not pose a direct risk to users' funds, but they can affect the overall functioning of a platform.
🟨	3	Minor	1 Resolved, 1 Partially Resolved, 1 Acknowledged	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.
🟦	3	Informational	1 Resolved, 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.

TABLE OF CONTENTS | FLAMELAUNCH

CODEBASE | FLAMELAUNCH

Repository

https://github.com/FlameLaunch/flame-launch-contracts/tree/127dcaf6e887672ddc64d137f7c792de972c3ec5/contracts

Commit

127dcaf6e887672ddc64d137f7c792de972c3ec5

AUDIT SCOPE | FLAMELAUNCH

4 files audited ● 3 files with Acknowledged findings ● 1 file with Resolved findings

ID	File	SHA256 Checksum
● FCK	Flame.sol	a51db30a4d13b032b15f107a08623f6ed0f2863d83ba1a5a57fa048366d3f52b
● FIC	FlameIdo.sol	e86006734dc2348c531f4faf217e0b0d56081f72d983cf4ac45c7fb87258a616
● FSP	FlameStakePool.sol	8301231fa7e476ada700680daf44c04b32c947c49a11be131f69d74fc2c6905d
● FAC	FlameAirdrop.sol	1d9f56239f39b9f3a83772458c6e13558851d00045c8ce49b57c9781b9e66d21

APPROACH & METHODS | FLAMELAUNCH

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

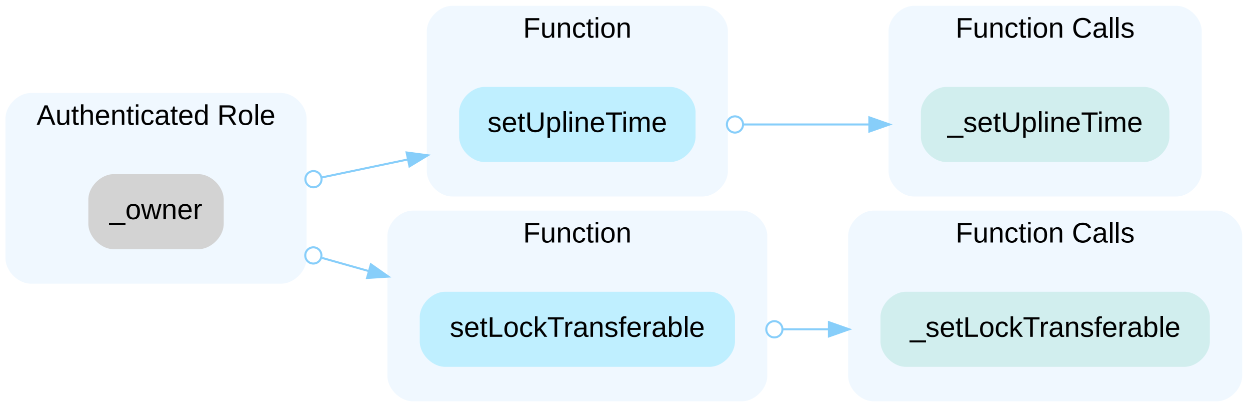
The security assessment resulted in findings that ranged from critical to informational. We recommend addressing these findings to ensure a high level of security standards and industry practices. We suggest recommendations that could better serve the project from the security perspective:

- 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.

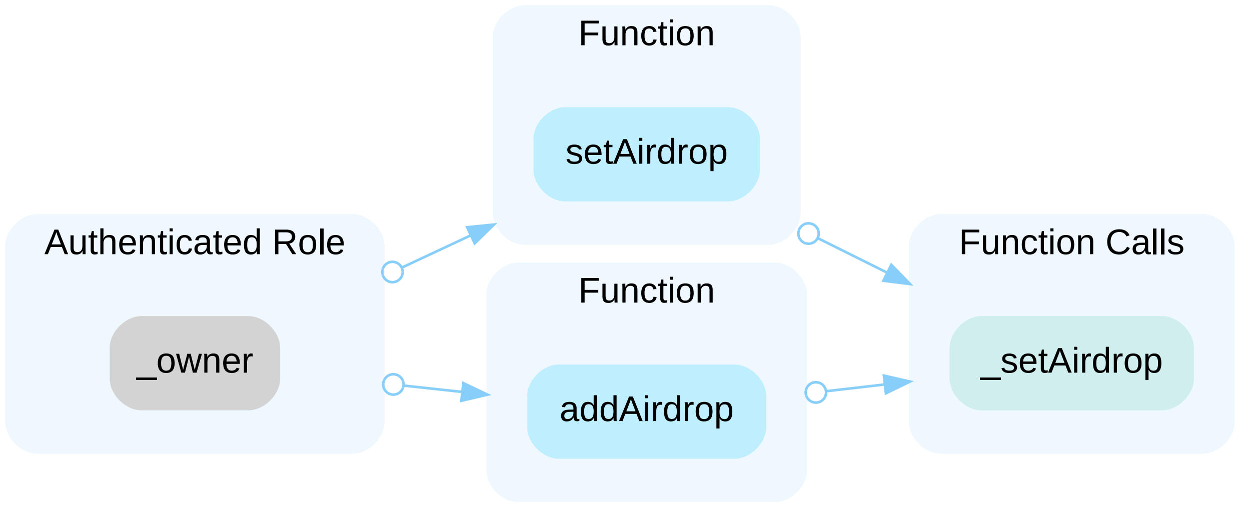
DECENTRALIZATION EFFORTS | FLAMELAUNCH

Description

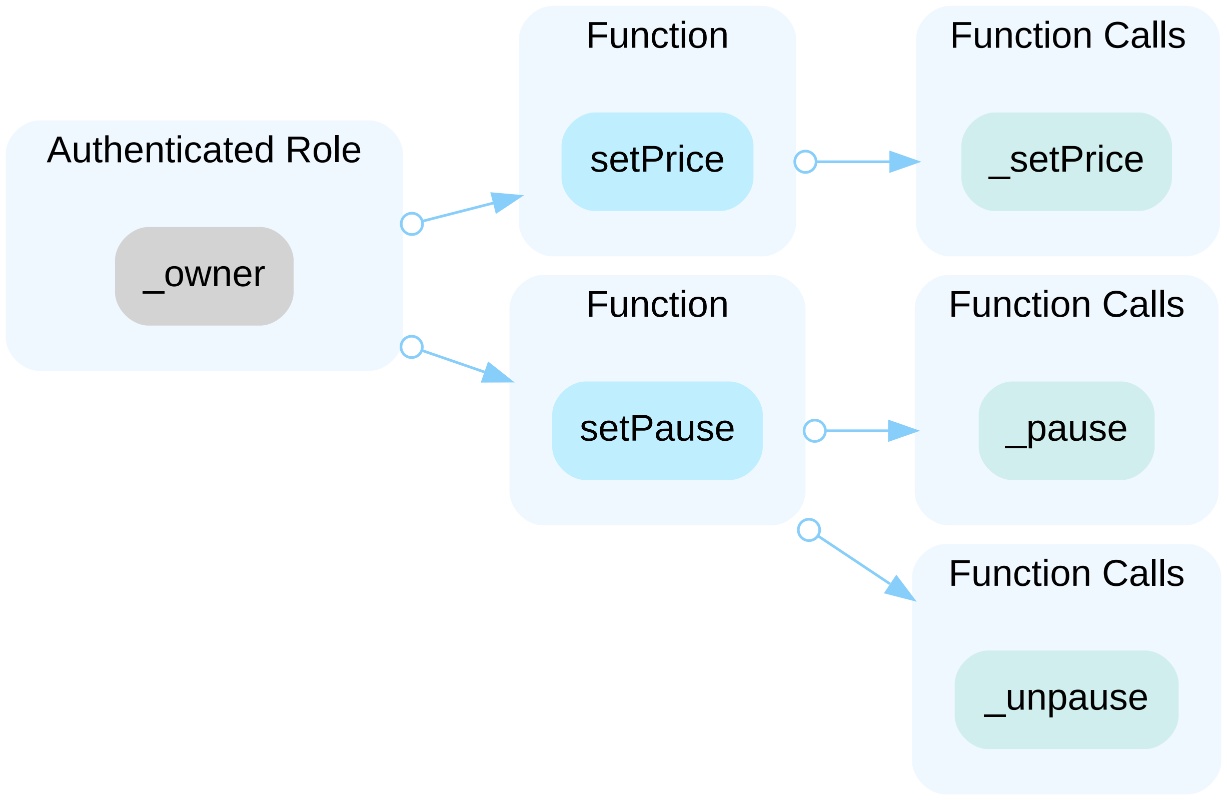
In the contract `FlameToken` the role `_owner` has authority over the functions shown in the diagram below. Any compromise to the `_owner` account may allow the hacker to take advantage of this authority.



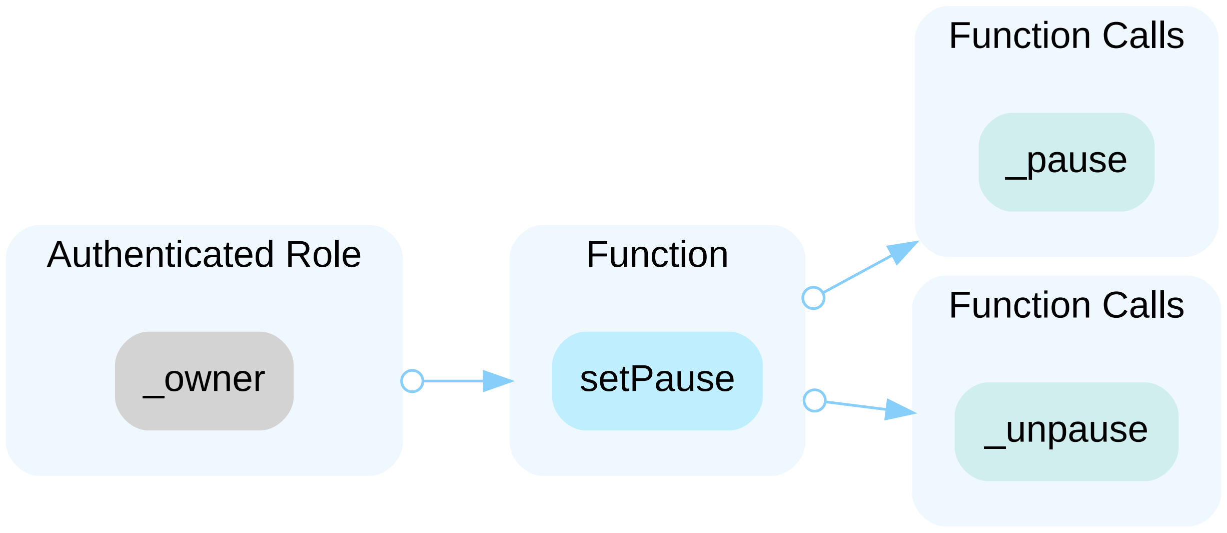
In the contract `FlameAirdrop` the role `_owner` has authority over the functions shown in the diagram below. The owner can also pause/unpause the contract, to pend the call of the function `claim()`. Any compromise to the `_owner` account may allow the hacker to take advantage of this authority.



In the contract `FlameIdo` the role `_owner` has authority over the functions shown in the diagram below. The owner can also pause/unpause the contract, to pend the call of the functions `buy()/mint()`. Any compromise to the `_owner` account may allow the hacker to take advantage of this authority.



In the contract `FlameStake` the role `_owner` has authority over the functions shown in the diagram below. The owner can also pause/unpause the contract, to pend the call of the function `stake()/unstake()`. Any compromise to the `_owner` account may allow the hacker to take advantage of this authority.



Recommendations

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.

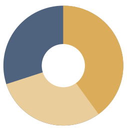
Long Term: Timelock and DAO, the combination, *mitigate* by applying decentralization and transparency.

- 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.

FINDINGS | FLAMELAUNCH



10	0	0	4	3	3
Total Findings	Critical	Major	Medium	Minor	Informational

This report has been prepared to discover issues and vulnerabilities for flamelaunch. Through this audit, we have uncovered 10 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
FCK-03	Missing Variable Change In _setUplineTime	Logical Issue	Medium	● Resolved
FCK-04	Missing Set Up LockTransferable	Logical Issue	Medium	● Acknowledged
FCK-06	Wrong Release Rate	Logical Issue	Medium	● Resolved
FIC-04	The MINT_THRESHOLD Is Impossible To Reach	Logical Issue	Medium	● Acknowledged
FAC-01	Unchecked ERC-20 `transfer()` / `transferFrom()` Call	Volatile Code	Minor	● Resolved
FIC-01	Missing Zero Address Validation	Volatile Code	Minor	● Acknowledged
FIC-02	Unintentional Transferred ETH	Logical Issue	Minor	● Partially Resolved
FCK-05	Logical Issue On _safeTransferLock	Logical Issue	Informational	● Acknowledged
FCK-07	Lack Of Zero Amount Check	Logical Issue	Informational	● Resolved
FSP-01	Logical Issue On Staking Reward	Logical Issue	Informational	● Acknowledged

FCK-03 | MISSING VARIABLE CHANGE IN _SETUPLINETIME

Category	Severity	Location	Status
Logical Issue	● Medium	Flame.sol: 272	● Resolved

Description

The function `_setUplineTime()` does not perform changing of the state variable `UPLINE_AT`.

Recommendation

We recommend to modify the code as below:

```
    function _setUplineTime(uint256 at) internal {
        require(at>block.timestamp&&block.timestamp<UPLINE_AT,"invalid time");
        UPLINE_AT = at;
        emit UplineTimeChanged(at);
    }
```

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FCK-04 | MISSING SET UP LOCKTRANSFERABLE

Category	Severity	Location	Status
Logical Issue	● Medium	Flame.sol: 248, 260	● Acknowledged

Description

In the function `_safeTransferLock()`, the lockTransferable is not set to true for the `to` address. If the `to` address does not own a lock before, the lockTransferable will default to false.

Recommendation

We recommend the client review the code and ensure the logical correctness.

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FCK-06 | WRONG RELEASE RATE

Category	Severity	Location	Status
Logical Issue	● Medium	Flame.sol: 195	● Resolved

Description

When the `ltype` equals Release334For2Month, the tokens will be released in 3 steps: 30%,30%,40%. However, the current code logic cannot release the correct amount of tokens as planed.

Recommendation

We recommend the client review the code and modify as below:

```
    uint8[3] memory map = [3, 6, 10];
```

Alleviation

The team heeded our advice and resolved the issue in commit 2a80b0295f162489d436a2d1dce679922c7802c8.

FIC-04 | THE MINT_THRESHOLD IS IMPOSSIBLE TO REACH

Category	Severity	Location	Status
Logical Issue	● Medium	FlameIdo.sol: 15	● Acknowledged

Description

According to the logic of the `buy()` function, the user pays 1 ETH to get 150 shares. However, the user needs 5000*1e18 shares to mint an NFT which is impossible.

Recommendation

We recommend the team review the logic and fix the code.

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FAC-01 | UNCHECKED ERC-20 `transfer()` / `transferFrom()` CALL

Category	Severity	Location	Status
Volatile Code	● Minor	FlameAirdrop.sol: 49	● Resolved

Description

The return value of the transfer()/transferFrom() call is not checked.

```
49          flameToken.transfer(account, amount);
```

Recommendation

Since some ERC-20 tokens return no values and others return a `bool` value, they should be handled with care. We advise using the OpenZeppelin's `SafeERC20.sol` implementation to interact with the `transfer()` and `transferFrom()` functions of external ERC-20 tokens. The OpenZeppelin implementation checks for the existence of a return value and reverts if `false` is returned, making it compatible with all ERC-20 token implementations.

Alleviation

The team heeded our advice and resolved the issue in commit 2a80b0295f162489d436a2d1dce679922c7802c8.

FIC-01 | MISSING ZERO ADDRESS VALIDATION

Category	Severity	Location	Status
Volatile Code	● Minor	FlameIdo.sol: 34, 35	● Acknowledged

Description

Addresses should be checked before assignment or external call to make sure they are not zero addresses.

```
34          treasury = _trea;
```

- `_trea` is not zero-checked before being used.

```
35          idoTreasury = _idotrea;
```

- `_idotrea` is not zero-checked before being used.

Recommendation

We advise adding a zero-check for the passed-in address value to prevent unexpected errors.

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FIC-02 | UNINTENTIONAL TRANSFERRED ETH

Category	Severity	Location	Status
Logical Issue	● Minor	FlameIdo.sol: 40	● Partially Resolved

Description

It's not fair to dispatch the unintentionally transferred ETH to the treasury address. The user might want to call buy but unintentionally transfers ETH directly to the contract.

Recommendation

We recommend to revert in the receive function.

Alleviation

The team heeded our advice and updated the code in commit 2a80b0295f162489d436a2d1dce679922c7802c8.

FCK-05 | LOGICAL ISSUE ON _SAFETRANSFERLOCK

Category	Severity	Location	Status
Logical Issue	● Informational	Flame.sol: 242	● Acknowledged

Description

In the function `_safeTransferLock()`, when the entire lock is transferred, the `to` address must have no lock before and no matter the `from` lock has been claimed or not. If the transfer amount is not the entire lock, the `from` lock can not be claimed.

Recommendation

We would like to confirm with the client whether the current implementation aligns with the original project design.

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FCK-07 | LACK OF ZERO AMOUNT CHECK

Category	Severity	Location	Status
Logical Issue	● Informational	Flame.sol: 151	● Resolved

Description

The check of zero amount has been commented out in the `_claimAll()` function.

Recommendation

We recommend to have a check for less gas cost.

Alleviation

The team heeded our advice and resolved the issue in commit 2a80b0295f162489d436a2d1dce679922c7802c8.

FSP-01 | LOGICAL ISSUE ON STAKING REWARD

Category	Severity	Location	Status
Logical Issue	● Informational	FlameStakePool.sol: 48	● Acknowledged

Description

There is no staking rewards in this contract. And the `stakeMap` is private, so no child contract can see the info and distribute rewards later.

Recommendation

We would like to confirm with the client whether the current implementation aligns with the original project design.

Alleviation

The team acknowledged this issue and they will leave it as it is for now.

FORMAL VERIFICATION | FLAMELAUNCH

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-succeed-normal	`transfer` Succeeds on Admissible Non-self Transfers
erc20-transfer-correct-amount	`transfer` Transfers the Correct Amount in Non-self Transfers
erc20-transfer-succeed-self	`transfer` Succeeds on Admissible Self Transfers
erc20-transfer-correct-amount-self	`transfer` Transfers the Correct Amount in Self Transfers
erc20-transfer-exceed-balance	`transfer` Fails if Requested Amount Exceeds Available Balance
erc20-transfer-recipient-overflow	`transfer` Prevents Overflows in the Recipient's Balance
erc20-transfer-revert-zero	`transfer` Prevents Transfers to the Zero Address
erc20-transfer-change-state	`transfer` Has No Unexpected State Changes
erc20-transfer-false	If `transfer` Returns `false` , the Contract State Is Not Changed
erc20-transfer-never-return-false	`transfer` Never Returns `false`

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

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

Verification of Compliance with Pausable ERC-721

We verified the properties of the public interface of those token contracts that implement the pausable ERC-721 interface.

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

Property Name	Title
erc721pausable-transferfrom-succeed-normal	`transferFrom` Succeeds on Admissible Inputs
erc721pausable-transferfrom-revert-pause	`transferFrom` Fails when Paused
erc721pausable-supportsinterface-correct-erc721	`supportsInterface` Signals Support for `ERC721`
erc721pausable-balanceof-succeed-normal	`balanceOf` Succeeds on Admissible Inputs
erc721pausable-balanceof-correct-count	`balanceOf` Returns the Correct Value
erc721pausable-balanceof-revert	`balanceOf` Fails on the Zero Address
erc721pausable-balanceof-no-change-state	`balanceOf` Does Not Change the Contract's State
erc721pausable-ownerof-succeed-normal	`ownerOf` Succeeds For Valid Tokens
erc721pausable-ownerof-revert	`ownerOf` Fails On Invalid Tokens
erc721pausable-ownerof-correct-owner	`ownerOf` Returns the Correct Owner
erc721pausable-ownerof-no-change-state	`ownerOf` Does Not Change the Contract's State
erc721pausable-getapproved-succeed-normal	`getApproved` Succeeds For Valid Tokens
erc721pausable-getapproved-correct-value	`getApproved` Returns Correct Approved Address

Property Name	Title
erc721pausable-getapproved-revert-zero	`getApproved` Fails on Invalid Tokens
erc721pausable-getapproved-change-state	`getApproved` Does Not Change the Contract's State
erc721pausable-isapprovedforall-succeed-normal	`isApprovedForAll` Always Succeeds
erc721pausable-isapprovedforall-correct	`isApprovedForAll` Returns Correct Approvals
erc721pausable-isapprovedforall-change-state	`isApprovedForAll` Does Not Change the Contract's State
erc721pausable-approve-set-correct	`approve` Sets Approval
erc721pausable-approve-succeed-normal	`approve` Returns for Admissible Inputs
erc721pausable-approve-revert-not-allowed	`approve` Prevents Unpermitted Approvals
erc721pausable-approve-revert-invalid-token	`approve` Fails For Calls with Invalid Tokens
erc721pausable-setapprovalforall-succeed-normal	`setApprovalForAll` Returns for Admissible Inputs
erc721pausable-approve-change-state	`approve` Has No Unexpected State Changes
erc721pausable-setapprovalforall-multiple	`setApprovalForAll` Can Set Multiple Operators
erc721pausable-setapprovalforall-set-correct	`setApprovalForAll` Approves Operator
erc721pausable-transferfrom-correct-increase	`transferFrom` Transfers the Complete Token in Non-self Transfers
erc721pausable-transferfrom-correct-one-token-self	`transferFrom` Performs Self Transfers Correctly
erc721pausable-transferfrom-correct-approval	`transferFrom` Updates the Approval Correctly
erc721pausable-setapprovalforall-change-state	`setApprovalForAll` Has No Unexpected State Changes
erc721pausable-transferfrom-correct-owner-from	`transferFrom` Removes Token Ownership of From
erc721pausable-transferfrom-correct-owner-to	`transferFrom` Transfers Ownership
erc721pausable-transferfrom-correct-balance	`transferFrom` Sum of Balances is Constant
erc721pausable-transferfrom-correct-state-balance	`transferFrom` Keeps Balances Constant Except for From and To
erc721pausable-transferfrom-correct-state-owner	`transferFrom` Has Expected Ownership Changes

Property Name	Title
erc721pausable-transferfrom-correct-state-approval	`transferFrom` Has Expected Approval Changes
erc721pausable-transferfrom-revert-invalid	`transferFrom` Fails for Invalid Tokens
erc721pausable-transferfrom-revert-to-zero	`transferFrom` Fails for Transfers To the Zero Address
erc721pausable-transferfrom-revert-from-zero	`transferFrom` Fails for Transfers From the Zero Address
erc721pausable-transferfrom-revert-not-owned	`transferFrom` Fails if `From` Is Not Token Owner
erc721pausable-transferfrom-revert-exceed-approval	`transferFrom` Fails for Token Transfers without Approval
erc721pausable-supportsinterface-succeed-always	`supportsInterface` Always Succeeds
erc721pausable-supportsinterface-metadata	`supportsInterface` Signals that ERC721Metadata is Implemented
erc721pausable-supportsinterface-correct-erc165	`supportsInterface` Signals Support for ERC165
erc721pausable-supportsinterface-correct-false	`supportsInterface` Returns `False` for Id 0xffffffff
erc721pausable-supportsinterface-no-change-state	`supportsInterface` Does Not Change the Contract's State

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 FlameToken (contracts20220316v4/Flame.sol)

Verification of ERC-20 Compliance

Detailed results for function `transfer`

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

Detailed results for function `transferFrom`

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

Detailed results for function `totalSupply`

Property Name	Final Result	Remarks
erc20-totalsupply-change-state	● True	
erc20-totalsupply-succeed-always	● Inapplicable	Context not considered
erc20-totalsupply-correct-value	● Inapplicable	Context not considered

Detailed results for function `balanceOf`

Property Name	Final Result	Remarks
erc20-balanceof-correct-value	● Inconclusive	
erc20-balanceof-succeed-always	● Inapplicable	Context not considered
erc20-balanceof-change-state	● True	

Detailed results for function `allowance`

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

Detailed Results For Contract FlameIdo (contracts20220316v4/FlameIdo.sol)

Verification of Compliance with Pausable ERC-721

Detailed results for function `transferFrom`

Property Name	Final Result	Remarks
erc721pausable-transferfrom-succeed-normal	● Inconclusive	
erc721pausable-transferfrom-revert-pause	● Inconclusive	
erc721pausable-transferfrom-correct-increase	● Inconclusive	
erc721pausable-transferfrom-correct-one-token-self	● Inconclusive	
erc721pausable-transferfrom-correct-approval	● Inconclusive	
erc721pausable-transferfrom-correct-owner-from	● Inconclusive	
erc721pausable-transferfrom-correct-owner-to	● Inconclusive	
erc721pausable-transferfrom-correct-balance	● Inconclusive	
erc721pausable-transferfrom-correct-state-balance	● Inconclusive	
erc721pausable-transferfrom-correct-state-owner	● Inconclusive	
erc721pausable-transferfrom-correct-state-approval	● Inconclusive	
erc721pausable-transferfrom-revert-invalid	● Inconclusive	
erc721pausable-transferfrom-revert-to-zero	● Inconclusive	
erc721pausable-transferfrom-revert-from-zero	● Inconclusive	
erc721pausable-transferfrom-revert-not-owned	● Inconclusive	
erc721pausable-transferfrom-revert-exceed-approval	● Inconclusive	

Detailed results for function `supportsInterface`

Property Name	Final Result	Remarks
erc721pausable-supportsinterface-correct-erc721	● True	
erc721pausable-supportsinterface-succeed-always	● True	
erc721pausable-supportsinterface-metadata	● True	
erc721pausable-supportsinterface-correct-erc165	● True	
erc721pausable-supportsinterface-correct-false	● True	
erc721pausable-supportsinterface-no-change-state	● True	

Detailed results for function `balanceOf`

Property Name	Final Result	Remarks
erc721pausable-balanceof-succeed-normal	● True	
erc721pausable-balanceof-correct-count	● True	
erc721pausable-balanceof-revert	● True	
erc721pausable-balanceof-no-change-state	● True	

Detailed results for function `ownerOf`

Property Name	Final Result	Remarks
erc721pausable-ownerof-succeed-normal	● True	
erc721pausable-ownerof-revert	● True	
erc721pausable-ownerof-correct-owner	● True	
erc721pausable-ownerof-no-change-state	● True	

Detailed results for function `getApproved`

Property Name	Final Result	Remarks
erc721pausable-getapproved-succeed-normal	● True	
erc721pausable-getapproved-correct-value	● True	
erc721pausable-getapproved-revert-zero	● True	
erc721pausable-getapproved-change-state	● True	

Detailed results for function `isApprovedForAll`

Property Name	Final Result	Remarks
erc721pausable-isapprovedforall-succeed-normal	● True	
erc721pausable-isapprovedforall-correct	● True	
erc721pausable-isapprovedforall-change-state	● True	

Detailed results for function `approve`

Property Name	Final Result	Remarks
erc721pausable-approve-set-correct	● True	
erc721pausable-approve-succeed-normal	● True	
erc721pausable-approve-revert-not-allowed	● True	
erc721pausable-approve-revert-invalid-token	● True	
erc721pausable-approve-change-state	● True	

Detailed results for function `setApprovalForAll`

Property Name	Final Result	Remarks
erc721pausable-setapprovalforall-succeed-normal	● True	
erc721pausable-setapprovalforall-multiple	● True	
erc721pausable-setapprovalforall-set-correct	● True	
erc721pausable-setapprovalforall-change-state	● True	

APPENDIX | FLAMELAUNCH

Finding Categories

Categories	Description
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.
Volatile Code	Volatile Code findings refer to segments of code that behave unexpectedly on certain edge cases that may result in a vulnerability.

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

`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:

```
[](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

`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

`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

`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

`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 `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

`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

`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

`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 <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[from] >= 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _allowances[from][msg.sender] >= 0 && _allowances[from][msg.sender] <
    0x10000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(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]) ==
        0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF))))))
```

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:

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

erc20-transferfrom-false

If `transferFrom` Returns `false`, the Contract's State Is Unchanged. 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

`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

`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

`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

`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)))
```

Description of ERC-721-Pausable Properties

The specifications are designed such that they capture the desired and admissible behaviors of the ERC-721 functions `transferFrom` , `balanceOf` , `ownerOf` , `getApproved` , `isApprovedForAll` , `approve` , `setApprovalForAll` `supportsInterface` , `tokenURI` , `tokenByIndex` , `tokenByIndex` , `decimals` and `totalSupply` . In the following, we list those property specifications.

Properties related to function `transferFrom`

erc721pausable-transferfrom-succeed-normal

`transferFrom` Succeeds on Admissible Inputs. All invocations of `transferFrom(from, to, tokenId)` must succeed if

- address `from` is the owner of token `tokenId`,
- the sender is approved to transfer token `tokenId`,
- the contract is not paused,
- transferring the token to the address `to` 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, tokenId), !_paused && from != address(0)
    && to != address(0) && _owner[tokenId]==from && ((from == msg.sender) ||
      (_approved[tokenId] == msg.sender) || _approvedAll[from][msg.sender]) &&
  _balances[to] >= 0 && _balances[from] >= 1 && _balances[to] <
  0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
  _balances[from] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==> <>
finished(contract.transferFrom(from, to, tokenId)))
```

erc721pausable-transferfrom-revert-pause

`transferFrom` Fails when Paused. Any call of the form `transferFrom(from, to, tokenId)` to a paused contract must fail. Specification:

```
[](started(contract.transferFrom, _paused) ==> <> reverted(contract.transferFrom))
```

erc721pausable-transferfrom-correct-increase

`transferFrom` Transfers the Complete Token in Non-self Transfers. All invocations of `transferFrom(from, to, tokenId)` that succeed must subtract a token from the balance of address `from` and add the token to the balance of address `to`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != to &&
    _balances[from] > 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
    _balances[to] >= 0) ==> <>(finished(contract.transferFrom(from, to, tokenId),
      _balances[from] == (old(_balances[from]) - 1) && _balances[to] ==
      (old(_balances[to]) + 1))))
```

erc721pausable-transferfrom-correct-one-token-self

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

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

erc721pausable-transferfrom-correct-approval

`transferFrom` Updates the Approval Correctly. All non-reverting invocations of `transferFrom(from, to, tokenId)` that return must remove any approval for token `tokenId`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), p1 != address(0)) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), (_approved[tokenId] !=
        p1))))
```

erc721pausable-transferfrom-correct-owner-from

`transferFrom` Removes Token Ownership of From. All non-reverting and non-self invocations of `transferFrom(from, to, tokenId)` that return, must remove the ownership of token `tokenId` from address `from`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != to && from !=
    address(0) && to != address(0) && (msg.sender==from ||
      _approved[tokenId]==msg.sender || _approvedAll[from][msg.sender])) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), (_owner[tokenId] !=
        from))))
```

erc721pausable-transferfrom-correct-owner-to

`transferFrom` Transfers Ownership. All non-reverting invocations of `transferFrom(from, to, tokenId)` must transfer the ownership of token `tokenId` to the address `to`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != address(0) && to
    != address(0) && _balances[from] >= 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    (msg.sender==from || _approved[tokenId]==msg.sender ||
    _approvedAll[from][msg.sender])) ==> <>(finished(contract.transferFrom(from,
      to, tokenId), (_owner[tokenId] == to))))
```

erc721pausable-transferfrom-correct-balance

`transferFrom` Sum of Balances is Constant. All non-reverting invocations of `transferFrom(from, to, tokenId)` must keep the sum of token balances constant. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from!=address(0) &&
    _balances[from]>0 && to!=address(0) && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
    _balances[to] >= 0) ==> <>(finished(contract.transferFrom(from, to, tokenId),
      (old(_balances[from])-_balances[from]) ==
    (_balances[to]-old(_balances[to])))))
```

erc721pausable-transferfrom-correct-state-balance

`transferFrom` Keeps Balances Constant Except for From and To. All non-reverting invocations of `transferFrom(from, to, tokenId)` must only modify the balance of the addresses `from` and `to`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), p1 != from && p1 != to )
  ==> <>(finished(contract.transferFrom(from, to, tokenId), _balances[p1] ==
      old(_balances[p1]))))
```

erc721pausable-transferfrom-correct-state-owner

`transferFrom` Has Expected Ownership Changes. All non-reverting invocations of `transferFrom(from, to, tokenId)` must only modify the ownership of token `tokenId`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), t1 != tokenId) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), _owner[t1] ==
      old(_owner[t1]) && _owner[t1] == old(_owner[t1]))))
```

erc721pausable-transferfrom-correct-state-approval

`transferFrom` Has Expected Approval Changes. All non-reverting invocations of `transferFrom(from, to, tokenId)` must remove only approvals for token `tokenId` Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), t1 != tokenId) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), _approved[t1] ==
      old(_approved[t1]))))
```

erc721pausable-transferfrom-revert-invalid

`transferFrom` Fails for Invalid Tokens. All calls of the form `transferFrom(from, to, tokenId)` must fail for any invalid token. Specification:

```
[](started(contract.transferFrom(from, to, tokenId), _owner[tokenId] == address(0))
  ==> <>(reverted(contract.transferFrom)))
```

erc721pausable-transferfrom-revert-from-zero

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

```
[](started(contract.transferFrom(from, to, tokenId), from == address(0)) ==>
  <>(reverted(contract.transferFrom(from, to, tokenId))))
```

erc721pausable-transferfrom-revert-to-zero

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

```
[](started(contract.transferFrom(from, to, tokenId), to == address(0)) ==>
  <>(reverted(contract.transferFrom(from, to, tokenId))))
```

erc721pausable-transferfrom-revert-not-owned

`transferFrom` Fails if `From` Is Not Token Owner. Any call of the form `transferFrom(from, to, tokenId)` must fail if address 'from' is not the owner of token `tokenId` . Specification:

```
[](started(contract.transferFrom(from, to, tokenId), _owner[tokenId]!= from) ==>
  <>(reverted(contract.transferFrom)))
```

erc721pausable-transferfrom-revert-exceed-approval

`transferFrom` Fails for Token Transfers without Approval. Any call of the form `transferFrom(from, to, tokenId)` must fail if the sender is neither the token owner nor an operator of the token owner nor approved for token `tokenId` . Specification:

```
[](started(contract.transferFrom(from, to, tokenId), msg.sender!=from &&
    _approved[tokenId]!=msg.sender && !_approvedAll[from][msg.sender]) ==>
  <>(reverted(contract.transferFrom)))
```

Properties related to function `supportsInterface`

erc721pausable-supportsinterface-correct-erc721

`supportsInterface` Signals Support for `ERC721` . Invocations of `supportsInterface(id)` must signal that the interface `ERC721` is implemented. Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0x80ac58cd) ==> <>
  finished(contract.supportsInterface(id), return==true))
```

erc721pausable-supportsinterface-metadata

`supportsInterface` Signals that ERC721Metadata is Implemented. A call of `supportsInterface(interfaceId)` with the interface id of ERC721Metadata must return true. Specification:

```
[](willSucceed(contract.supportsInterface(interfaceId), interfaceId==0x5b5e139f)
  ==> <> finished(contract.supportsInterface(interfaceId), return==true))
```

erc721pausable-supportsinterface-succeed-always

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

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

erc721pausable-supportsinterface-correct-erc165

`supportsInterface` Signals Support for ERC165. Invocations of `supportsInterface(id)` must signal that the interface `ERC165` is implemented. Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0x01ffc9a7) ==> <>
  finished(contract.supportsInterface(id), return==true))
```

erc721pausable-supportsinterface-correct-false

`supportsInterface` Returns `False` for Id 0xffffffff. Invocations of `supportsInterface(id)` with `id` 0xffffffff must return `false` . Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0xffffffff) ==> <>
  finished(contract.supportsInterface(id), return==false))
```

erc721pausable-supportsinterface-no-change-state

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

```
[](willSucceed(contract.supportsInterface(id)) ==>
  <>(finished(contract.supportsInterface(id), other_state_variables ==
    old(other_state_variables))))
```

Properties related to function `balanceOf`

erc721pausable-balanceof-succeed-normal

`balanceOf` Succeeds on Admissible Inputs. All invocations of `balanceOf(owner)` must succeed if the address `owner` is not zero and it does not run out of gas. Specification:

```
[](started(contract.balanceOf(owner), owner!=address(0)) ==>
  <>(finished(contract.balanceOf)))
```

erc721pausable-balanceof-correct-count

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

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

erc721pausable-balanceof-revert

`balanceOf` Fails on the Zero Address. Invocations of `balanceOf(owner)` must fail if the address `owner` is the zero address. Specification:

```
[](started(contract.balanceOf(owner), owner==address(0)) ==>
  <>(reverted(contract.balanceOf(owner))))
```

erc721pausable-balanceof-no-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, _balances ==
      old(_balances) && other_state_variables == old(other_state_variables))))
```

Properties related to function `ownerOf`

erc721pausable-ownerof-succeed-normal

`ownerOf` Succeeds For Valid Tokens. Function `ownerOf(token)` must always succeed for valid tokens if it does not run out of gas. Specification:

```
[](started(contract.ownerOf(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.ownerOf)))
```

erc721pausable-ownerof-correct-owner

`ownerOf` Returns the Correct Owner. Invocations of `ownerOf(token)` must return the owner for a valid token `token` that is held in the contract's owner mapping. Specification:

```
[](willSucceed(contract.ownerOf(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.ownerOf(token), return == _owner[token])))
```

erc721pausable-ownerof-revert

`ownerOf` Fails On Invalid Tokens. Invocations of `ownerOf(token)` must fail for an invalid token. Specification:

```
[](started(contract.ownerOf(token), _owner[token]==address(0)) ==>
  <>(reverted(contract.ownerOf(token))))
```

erc721pausable-ownerof-no-change-state

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

```
[](willSucceed(contract.ownerOf) ==> <>(finished(contract.ownerOf, _owner ==
      old(_owner) && other_state_variables == old(other_state_variables))))
```

Properties related to function `getApproved`

erc721pausable-getapproved-succeed-normal

`getApproved` Succeeds For Valid Tokens. Function `getApproved` must always succeed for valid tokens, assuming that its execution does not run out of gas. Specification:

```
[](started(contract.getApproved(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.getApproved)))
```

erc721pausable-getapproved-correct-value

`getApproved` Returns Correct Approved Address. Invocations of `getApproved(token)` must return the approved address of a valid `token`. Specification:

```
[](willSucceed(contract.getApproved(token)) ==>
  <>(finished(contract.getApproved(token), return == _approved[token] || return ==
    address(0))))
```

erc721pausable-getapproved-revert-zero

`getApproved` Fails on Invalid Tokens. Invocations of `getApproved(token)` with an invalid token must fail. Specification:

```
[](started(contract.getApproved(token), _owner[token]==address(0)) ==>
  <>(reverted(contract.getApproved)))
```

erc721pausable-getapproved-change-state

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

```
[](willSucceed(contract.getApproved) ==> <>(finished(contract.getApproved,
      _approved == old(_approved) && other_state_variables ==
      old(other_state_variables))))
```

Properties related to function `isApprovedForAll`

erc721pausable-isapprovedforall-succeed-normal

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

```
[](started(contract.isApprovedForAll(owner, operator)) ==>
  <>(finished(contract.isApprovedForAll)))
```

erc721pausable-isapprovedforall-correct

`isApprovedForAll` Returns Correct Approvals. Invocations of `isApprovedForAll(owner, operator)` must return whether a non-zero address `operator` is approved for tokens of a non-zero address `owner`, or return false. Specification:

```
[](willSucceed(contract.isApprovedForAll(owner, operator), owner!=address(0) &&
    operator!=address(0)) ==> <>(finished(contract.isApprovedForAll(owner,
        operator), return == _approvedAll[owner][operator])))
```

erc721pausable-isapprovedforall-change-state

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

```
[](willSucceed(contract.isApprovedForAll) ==>
  <>(finished(contract.isApprovedForAll, _approvedAll == old(_approvedAll) &&
    other_state_variables == old(other_state_variables))))
```

Properties related to function `approve`

erc721pausable-approve-succeed-normal

`approve` Returns for Admissible Inputs. All calls of the form `approve(to, tokenId)` must return if

- the sender is the owner or an authorized operator of the owner
- the token `tokenId` is valid and
- the execution does not run out of gas. Specification:

```
[](started(contract.approve(to, tokenId), (_owner[tokenId]!=address(0)) &&
    (_owner[tokenId]==msg.sender || _approvedAll[_owner[tokenId]][msg.sender]) &&
  (_owner[tokenId]!=to)) ==> <>(finished(contract.approve)))
```

erc721pausable-approve-set-correct

`approve` Sets Approval. Any returning call of the form `approve(to, tokenId)` must approve the address `to` for token `tokenId` . Specification:

```
[](willSucceed(contract.approve(to, tokenId), (_owner[tokenId]!=address(0)) &&
    (_owner[tokenId]==msg.sender || _approvedAll[_owner[tokenId]][msg.sender])) ==>
<>(finished(contract.approve(to, tokenId), _approved[tokenId]==to)))
```

erc721pausable-approve-revert-not-allowed

`approve` Prevents Unpermitted Approvals. All calls of the form `approve(to, tokenId)` must fail if the message sender is not permitted to access token `tokenId` . Specification:

```
[](started(contract.approve(to, tokenId), _owner[tokenId]!=msg.sender &&
    !_approvedAll[_owner[tokenId]][msg.sender]) ==> <>(reverted(contract.approve)))
```

erc721pausable-approve-revert-invalid-token

`approve` Fails For Calls with Invalid Tokens. All calls of the form `approve(to, tokenId)` must fail for an invalid token. Specification:

```
[](started(contract.approve(to, tokenId), _owner[tokenId] == address(0)) ==>
  <>(reverted(contract.approve)))
```

erc721pausable-approve-change-state

`approve` Has No Unexpected State Changes. All calls of the form `approve(to, tokenId)` must only update the allowance mapping according to a valid token `tokenId` and the address `to` , and incur no other state changes. Specification:

```
[](willSucceed(contract.approve(approved, tokenId), t1!=tokenId) ==>
  <>(finished(contract.approve(approved, tokenId),
    _approved[t1]==old(_approved[t1]) && other_state_variables ==
    old(other_state_variables))))
```

Properties related to function `setApprovalForAll`

erc721pausable-setapprovalforall-succeed-normal

`setApprovalForAll` Returns for Admissible Inputs. Calls of the form `setApprovalForAll(operator, approved)` must return if

- the message sender is not the `operator` ,
- `operator` is not the zero address and
- the execution does not run out of gas. Specification:

```
[](started(contract.setApprovalForAll(operator, approved), (msg.sender!=operator)
    && (operator!=address(0))) ==> <>(finished(contract.setApprovalForAll)))
```

erc721pausable-setapprovalforall-set-correct

`setApprovalForAll` Approves Operator. All non-reverting calls of the form `setApprovalForAll(operator, approved)` must set the approval of a non-zero address `operator` according to the Boolean value `approved` . Specification:

```
[](willSucceed(contract.setApprovalForAll(operator, approved),
    operator!=address(0)) ==> <>(finished(contract.setApprovalForAll(operator,
        approved), _approvedAll[msg.sender][operator]==approved)))
```

erc721pausable-setapprovalforall-multiple

`setApprovalForAll` Can Set Multiple Operators. Calls of the form `setApprovalForAll(operator, approved)` must be able to set multiple operators for the tokens of the message sender. Specification:

```
[](willSucceed(contract.setApprovalForAll(operator, approved), op1!=address(0) &&
    approved && _approvedAll[msg.sender][op1]   ) ==>
  <>(finished(contract.setApprovalForAll(operator, approved),
    _approvedAll[msg.sender][operator] && _approvedAll[msg.sender][op1])))
```

erc721pausable-setapprovalforall-change-state

`setApprovalForAll` Has No Unexpected State Changes. All calls of the form `setApprovalForAll(operator, approved)` must only update the approval mapping according to the message sender, the address `operator` and the Boolean value `approved` but incur no other state changes. Specification:

```
[](started(contract.setApprovalForAll(op, approved), ow1!=msg.sender || op1!=op)
  ==> <>(finished(contract.setApprovalForAll(op, approved),
      _approvedAll[ow1][op1]==old(_approvedAll[ow1][op1]) &&
      _approvedAll[msg.sender][op]==approved && other_state_variables ==
      old(other_state_variables)) || reverted(contract.setApprovalForAll(op,
        approved))))
```

Description of ERC-721 Properties

The specifications are designed such that they capture the desired and admissible behaviors of the ERC-721 functions `transferFrom` , `balanceOf` , `ownerOf` , `getApproved` , `isApprovedForAll` , `approve` , `setApprovalForAll` `supportsInterface` , `tokenURI` , `tokenByIndex` , `tokenByIndex` , `decimals` and `totalSupply` . In the following, we list those property specifications.

Properties related to function `transferFrom`

erc721-transferfrom-succeed-normal

`transferFrom` Succeeds on Admissible Inputs. All invocations of `transferFrom(from, to, tokenId)` must succeed if

- address `from` is the owner of token `tokenId` ,
- the sender is approved to transfer token `tokenId` ,
- transferring the token to the address `to` 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, tokenId), from != address(0) && to !=
    address(0) && _owner[tokenId]==from && ((from == msg.sender) ||
      (_approved[tokenId] == msg.sender) || _approvedAll[from][msg.sender]) &&
  _balances[to] >= 0 && _balances[from] >= 1 && _balances[to] <
  0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
  _balances[from] <
  0x10000000000000000000000000000000000000000000000000000000000000000) ==> <>
finished(contract.transferFrom(from, to, tokenId)))
```

erc721-transferfrom-correct-increase

`transferFrom` Transfers the Complete Token in Non-self Transfers. All invocations of `transferFrom(from, to, tokenId)` that succeed must subtract a token from the balance of address `from` and add the token to the balance of address `to` . Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != to &&
    _balances[from] > 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
    _balances[to] >= 0) ==> <>(finished(contract.transferFrom(from, to, tokenId),
      _balances[from] == (old(_balances[from]) - 1) && _balances[to] ==
      (old(_balances[to]) + 1))))
```

erc721-transferfrom-correct-one-token-self

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

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

erc721-transferfrom-correct-approval

`transferFrom` Updates the Approval Correctly. All non-reverting invocations of `transferFrom(from, to, tokenId)` that return must remove any approval for token `tokenId`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), p1 != address(0)) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), (_approved[tokenId] !=
        p1))))
```

erc721-transferfrom-correct-owner-from

`transferFrom` Removes Token Ownership of From. All non-reverting and non-self invocations of `transferFrom(from, to, tokenId)` that return, must remove the ownership of token `tokenId` from address `from`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != to && from !=
    address(0) && to != address(0) && (msg.sender==from ||
      _approved[tokenId]==msg.sender || _approvedAll[from][msg.sender])) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), (_owner[tokenId] !=
        from))))
```

erc721-transferfrom-correct-owner-to

`transferFrom` Transfers Ownership. All non-reverting invocations of `transferFrom(from, to, tokenId)` must transfer the ownership of token `tokenId` to the address `to`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from != address(0) && to
    != address(0) && _balances[from] >= 0 && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    (msg.sender==from || _approved[tokenId]==msg.sender ||
    _approvedAll[from][msg.sender])) ==> <>(finished(contract.transferFrom(from,
      to, tokenId), (_owner[tokenId] == to))))
```

erc721-transferfrom-correct-balance

`transferFrom` Sum of Balances is Constant. All non-reverting invocations of `transferFrom(from, to, tokenId)` must keep the sum of token balances constant. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), from!=address(0) &&
    _balances[from]>0 && to!=address(0) && _balances[from] <
    0x10000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] <
    0x10000000000000000000000000000000000000000000000000000000000000000 - 1 &&
    _balances[to] >= 0) ==> <>(finished(contract.transferFrom(from, to, tokenId),
      (old(_balances[from])-_balances[from]) ==
    (_balances[to]-old(_balances[to])))))
```

erc721-transferfrom-correct-state-balance

`transferFrom` Keeps Balances Constant Except for From and To. All non-reverting invocations of `transferFrom(from, to, tokenId)` must only modify the balance of the addresses `from` and `to`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), p1 != from && p1 != to )
  ==> <>(finished(contract.transferFrom(from, to, tokenId), _balances[p1] ==
      old(_balances[p1]))))
```

erc721-transferfrom-correct-state-owner

`transferFrom` Has Expected Ownership Changes. All non-reverting invocations of `transferFrom(from, to, tokenId)` must only modify the ownership of token `tokenId`. Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), t1 != tokenId) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), _owner[t1] ==
      old(_owner[t1]) && _owner[t1] == old(_owner[t1]))))
```

erc721-transferfrom-correct-state-approval

`transferFrom` Has Expected Approval Changes. All non-reverting invocations of `transferFrom(from, to, tokenId)` must remove only approvals for token `tokenId` Specification:

```
[](willSucceed(contract.transferFrom(from, to, tokenId), t1 != tokenId) ==>
  <>(finished(contract.transferFrom(from, to, tokenId), _approved[t1] ==
      old(_approved[t1]))))
```

erc721-transferfrom-revert-invalid

`transferFrom` Fails for Invalid Tokens. All calls of the form `transferFrom(from, to, tokenId)` must fail for any invalid token. Specification:

```
[](started(contract.transferFrom(from, to, tokenId), _owner[tokenId] == address(0))
  ==> <>(reverted(contract.transferFrom)))
```

erc721-transferfrom-revert-from-zero

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

```
[](started(contract.transferFrom(from, to, tokenId), from == address(0)) ==>
  <>(reverted(contract.transferFrom(from, to, tokenId))))
```

erc721-transferfrom-revert-to-zero

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

```
[](started(contract.transferFrom(from, to, tokenId), to == address(0)) ==>
  <>(reverted(contract.transferFrom(from, to, tokenId))))
```

erc721-transferfrom-revert-not-owned

`transferFrom` Fails if `From` Is Not Token Owner. Any call of the form `transferFrom(from, to, tokenId)` must fail if address 'from' is not the owner of token `tokenId` . Specification:

```
[](started(contract.transferFrom(from, to, tokenId), _owner[tokenId]!= from) ==>
  <>(reverted(contract.transferFrom)))
```

erc721-transferfrom-revert-exceed-approval

`transferFrom` Fails for Token Transfers without Approval. Any call of the form `transferFrom(from, to, tokenId)` must fail if the sender is neither the token owner nor an operator of the token owner nor approved for token `tokenId` . Specification:

```
[](started(contract.transferFrom(from, to, tokenId), msg.sender!=from &&
    _approved[tokenId]!=msg.sender && !_approvedAll[from][msg.sender]) ==>
  <>(reverted(contract.transferFrom)))
```

Properties related to function `supportsInterface`

erc721-supportsinterface-correct-erc721

`supportsInterface` Signals Support for `ERC721` . Invocations of `supportsInterface(id)` must signal that the interface `ERC721` is implemented. Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0x80ac58cd) ==> <>
  finished(contract.supportsInterface(id), return==true))
```

erc721-supportsinterface-metadata

`supportsInterface` Signals that ERC721Metadata is Implemented. A call of `supportsInterface(interfaceId)` with the interface id of ERC721Metadata must return true. Specification:

```
[](willSucceed(contract.supportsInterface(interfaceId), interfaceId==0x5b5e139f)
  ==> <> finished(contract.supportsInterface(interfaceId), return==true))
```

erc721-supportsinterface-succeed-always

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

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

erc721-supportsinterface-correct-erc165

`supportsInterface` Signals Support for ERC165. Invocations of `supportsInterface(id)` must signal that the interface `ERC165` is implemented. Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0x01ffc9a7) ==> <>
  finished(contract.supportsInterface(id), return==true))
```

erc721-supportsinterface-correct-false

`supportsInterface` Returns `False` for Id 0xffffffff. Invocations of `supportsInterface(id)` with `id` 0xffffffff must return `false` . Specification:

```
[](willSucceed(contract.supportsInterface(id), id==0xffffffff) ==> <>
  finished(contract.supportsInterface(id), return==false))
```

erc721-supportsinterface-no-change-state

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

```
[](willSucceed(contract.supportsInterface(id)) ==>
  <>(finished(contract.supportsInterface(id), other_state_variables ==
    old(other_state_variables))))
```

Properties related to function `balanceOf`

erc721-balanceof-succeed-normal

`balanceOf` Succeeds on Admissible Inputs. All invocations of `balanceOf(owner)` must succeed if the address `owner` is not zero and it does not run out of gas. Specification:

```
[](started(contract.balanceOf(owner), owner!=address(0)) ==>
  <>(finished(contract.balanceOf)))
```

erc721-balanceof-correct-count

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

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

erc721-balanceof-revert

`balanceOf` Fails on the Zero Address. Invocations of `balanceOf(owner)` must fail if the address `owner` is the zero address. Specification:

```
[](started(contract.balanceOf(owner), owner==address(0)) ==>
  <>(reverted(contract.balanceOf(owner))))
```

erc721-balanceof-no-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, _balances ==
      old(_balances) && other_state_variables == old(other_state_variables))))
```

Properties related to function `ownerOf`

erc721-ownerof-succeed-normal

`ownerOf` Succeeds For Valid Tokens. Function `ownerOf(token)` must always succeed for valid tokens if it does not run out of gas. Specification:

```
[](started(contract.ownerOf(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.ownerOf)))
```

erc721-ownerof-correct-owner

`ownerOf` Returns the Correct Owner. Invocations of `ownerOf(token)` must return the owner for a valid token `token` that is held in the contract's owner mapping. Specification:

```
[](willSucceed(contract.ownerOf(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.ownerOf(token), return == _owner[token])))
```

erc721-ownerof-revert

`ownerOf` Fails On Invalid Tokens. Invocations of `ownerOf(token)` must fail for an invalid token. Specification:

```
[](started(contract.ownerOf(token), _owner[token]==address(0)) ==>
  <>(reverted(contract.ownerOf(token))))
```

erc721-ownerof-no-change-state

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

```
[](willSucceed(contract.ownerOf) ==> <>(finished(contract.ownerOf, _owner ==
      old(_owner) && other_state_variables == old(other_state_variables))))
```

Properties related to function `getApproved`

erc721-getapproved-succeed-normal

`getApproved` Succeeds For Valid Tokens. Function `getApproved` must always succeed for valid tokens, assuming that its execution does not run out of gas. Specification:

```
[](started(contract.getApproved(token), _owner[token]!=address(0)) ==>
  <>(finished(contract.getApproved)))
```

erc721-getapproved-correct-value

`getApproved` Returns Correct Approved Address. Invocations of `getApproved(token)` must return the approved address of a valid `token`. Specification:

```
[](willSucceed(contract.getApproved(token)) ==>
  <>(finished(contract.getApproved(token), return == _approved[token] || return ==
    address(0))))
```

erc721-getapproved-revert-zero

`getApproved` Fails on Invalid Tokens. Invocations of `getApproved(token)` with an invalid token must fail. Specification:

```
[](started(contract.getApproved(token), _owner[token]==address(0)) ==>
  <>(reverted(contract.getApproved)))
```

erc721-getapproved-change-state

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

```
[](willSucceed(contract.getApproved) ==> <>(finished(contract.getApproved,
      _approved == old(_approved) && other_state_variables ==
      old(other_state_variables))))
```

Properties related to function `isApprovedForAll`

erc721-isapprovedforall-succeed-normal

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

```
[](started(contract.isApprovedForAll(owner, operator)) ==>
  <>(finished(contract.isApprovedForAll)))
```

erc721-isapprovedforall-correct

`isApprovedForAll` Returns Correct Approvals. Invocations of `isApprovedForAll(owner, operator)` must return whether a non-zero address `operator` is approved for tokens of a non-zero address `owner`, or return false. Specification:

```
[](willSucceed(contract.isApprovedForAll(owner, operator), owner!=address(0) &&
    operator!=address(0)) ==> <>(finished(contract.isApprovedForAll(owner,
        operator), return == _approvedAll[owner][operator])))
```

erc721-isapprovedforall-change-state

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

```
[](willSucceed(contract.isApprovedForAll) ==>
  <>(finished(contract.isApprovedForAll, _approvedAll == old(_approvedAll) &&
    other_state_variables == old(other_state_variables))))
```

Properties related to function `approve`

erc721-approve-succeed-normal

`approve` Returns for Admissible Inputs. All calls of the form `approve(to, tokenId)` must return if

- the sender is the owner or an authorized operator of the owner
- the token `tokenId` is valid and
- the execution does not run out of gas. Specification:

```
[](started(contract.approve(to, tokenId), (_owner[tokenId]!=address(0)) &&
    (_owner[tokenId]==msg.sender || _approvedAll[_owner[tokenId]][msg.sender]) &&
  (_owner[tokenId]!=to)) ==> <>(finished(contract.approve)))
```

erc721-approve-set-correct

`approve` Sets Approval. Any returning call of the form `approve(to, tokenId)` must approve the address `to` for token `tokenId`. Specification:

```
[](willSucceed(contract.approve(to, tokenId), (_owner[tokenId]!=address(0)) &&
    (_owner[tokenId]==msg.sender || _approvedAll[_owner[tokenId]][msg.sender])) ==>
<>(finished(contract.approve(to, tokenId), _approved[tokenId]==to)))
```

erc721-approve-revert-not-allowed

`approve` Prevents Unpermitted Approvals. All calls of the form `approve(to, tokenId)` must fail if the message sender is not permitted to access token `tokenId`. Specification:

```
[](started(contract.approve(to, tokenId), _owner[tokenId]!=msg.sender &&
    !_approvedAll[_owner[tokenId]][msg.sender]) ==> <>(reverted(contract.approve)))
```

erc721-approve-revert-invalid-token

`approve` Fails For Calls with Invalid Tokens. All calls of the form `approve(to, tokenId)` must fail for an invalid token. Specification:

```
[](started(contract.approve(to, tokenId), _owner[tokenId] == address(0)) ==>
  <>(reverted(contract.approve)))
```

erc721-approve-change-state

`approve` Has No Unexpected State Changes. All calls of the form `approve(to, tokenId)` must only update the allowance mapping according to a valid token `tokenId` and the address `to`, and incur no other state changes. Specification:

```
[](willSucceed(contract.approve(approved, tokenId), t1!=tokenId) ==>
  <>(finished(contract.approve(approved, tokenId),
    _approved[t1]==old(_approved[t1]) && other_state_variables ==
    old(other_state_variables))))
```

Properties related to function `setApprovalForAll`

erc721-setapprovalforall-succeed-normal

`setApprovalForAll` Returns for Admissible Inputs. Calls of the form `setApprovalForAll(operator, approved)` must return if

- the message sender is not the `operator` ,
- `operator` is not the zero address and
- the execution does not run out of gas. Specification:

```
[](started(contract.setApprovalForAll(operator, approved), (msg.sender!=operator)
    && (operator!=address(0))) ==> <>(finished(contract.setApprovalForAll)))
```

erc721-setapprovalforall-set-correct

`setApprovalForAll` Approves Operator. All non-reverting calls of the form `setApprovalForAll(operator, approved)` must set the approval of a non-zero address `operator` according to the Boolean value `approved` . Specification:

```
[](willSucceed(contract.setApprovalForAll(operator, approved),
    operator!=address(0)) ==> <>(finished(contract.setApprovalForAll(operator,
        approved), _approvedAll[msg.sender][operator]==approved)))
```

erc721-setapprovalforall-multiple

`setApprovalForAll` Can Set Multiple Operators. Calls of the form `setApprovalForAll(operator, approved)` must be able to set multiple operators for the tokens of the message sender. Specification:

```
[](willSucceed(contract.setApprovalForAll(operator, approved), op1!=address(0) &&
    approved && _approvedAll[msg.sender][op1]   ) ==>
  <>(finished(contract.setApprovalForAll(operator, approved),
    _approvedAll[msg.sender][operator] && _approvedAll[msg.sender][op1])))
```

erc721-setapprovalforall-change-state

`setApprovalForAll` Has No Unexpected State Changes. All calls of the form `setApprovalForAll(operator, approved)` must only update the approval mapping according to the message sender, the address `operator` and the Boolean value `approved` but incur no other state changes. Specification:

```
[](started(contract.setApprovalForAll(op, approved), ow1!=msg.sender || op1!=op)
  ==> <>(finished(contract.setApprovalForAll(op, approved),
      _approvedAll[ow1][op1]==old(_approvedAll[ow1][op1]) &&
      _approvedAll[msg.sender][op]==approved && other_state_variables ==
      old(other_state_variables)) || reverted(contract.setApprovalForAll(op,
        approved))))
```

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