CERTIK

Cargio

Security Assessment

Cargio - Audit

CertiK Verified on May 7th, 2023

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Cargio - Audit

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

Executive Summary

TYPES
Exchange

ECOSYSTEM
Ethereum | Tron | BSC

METHODS
Formal Verification, Manual Review, Static Analysis

TIMELINE
Delivered on 05/12/2023

LANGUAGE
Solidity

KEY COMPONENTS
N/A

CODEBASE
update 1d7834c03b22b554c3287abec84606135ce3d2bc
base 18790e3ce13bc70af5cda311fb3464e77c24300

Vulnerability Summary

21	20	0	0	1	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.
3	Medium	2 Resolved, 1Acknowledged	Medium risks may not pose a direct risk to users' funds, but they can affect the overall functioning of a platform.
11	Minor	11 Resolved	Minor risks can be any of the above, but on a smaller scale. They generally do not compromise the overall integrity of the project, but they may be less efficient than other solutions.
7	Informational	7 Resolved	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.

AUDIT SCOPE | CARGIO - AUDIT

97 files audited ● 6 files with Acknowledged findings ● 23 files with Resolved findings ● 68 files without findings

ID	File	SHA256 Checksum
● CRG	contracts/CRG.sol	15f920de5c77abc3c0b16a9f24ad24c13ec7f08ccbe0c2c63b7c2a4bc119c50a
● ARF	contracts/facets/RewardFacet.sol	263d5dcca2899fc2d198c0060e23aae3b0ccde6249d61880f9ee6b59cf5ae755
● BMF	contracts/facets/BrokerManagerFacet.sol	97af7eb63449b13b393c05f541a25682d9abaa19fdeedbe97dd033db91078b74
● PFF	contracts/facets/PriceFacadeFacet.sol	f630cf0ce840600275c1119537d90b2236faf6e2b997166e9cd2810c0da73ef4
● LAC	contracts/libraries/LibAccessControlEnumerable.sol	8e5f9b15edbbc30a0a8d2e9b49e102804454de7735cc36f1f0159acccfbb153d
● CRB	contracts/Cargio.sol	d2dbd545e203a55bf491dc662b752f52a8f824a4c721e7d974efffeeb46145d6
● CON	contracts/utils/Constants.sol	bc6118737ceb8d305222a3cf9830ec92843aeed285165764674ce6cef7d3a2f9
● CMF	contracts/facets/CrgManagerFacet.sol	f072f010de6bfc845a6503d63caa0c65df07468736a627a769d00da2bcad2b1e
● LOF	contracts/facets/LimitOrderFacet.sol	eb39a2b13598717f133f587de0b4730f1771b94217b30140917685efc7d33dbd
● OAT	contracts/facets/OrderAndTradeHistoryFacet.sol	bdcb123f06d400ec80ae2d4613d93e1a8c441a41310b85e5a2ba947d513458a6
● PMF	contracts/facets/PairsManagerFacet.sol	467a2f18be5a437fc89733eb3092c37b32534a4736f2v14dd3ed44af3328dc86
● MRF	contracts/facets/MainRewardFacet.sol	df19200edf11c8c4b8c5d129e88a6678c6553d7ff380ec229cf868080fe383b3
● TCF	contracts/facets/TradingCheckerFacet.sol	c5e5e7f1122e981024a8e4116462ee611c7ad26c583295e1d225ccccfb6d9735
● TRA	contracts/facets/TradingCloseFacet.sol	3622806fedcafd0d37098446056ab46def5926d69fae74ae34271f592d440128

ID	File	SHA256 Checksum
TOF	contracts/facets/TradingOpenFacet.sol	2f81bd091357445c2bee8e2414c14fac9b0506df53f75503265b2e8cd53a2710
TPF	contracts/facets/TradingPortalFacet.sol	3b91f6d76cd6cf7a9bh5fe23513da6fcbd4dffa6131c4c2b6d7d173b8d5ecca0
VFB	contracts/facets/VaultFacet.sol	1cde88c8ba31f4b64133e96ac9195571a9d9ac019ecf5530b89eb4f7bc32829b
LCM	contracts/libraries/LibCrgManager.sol	20977aa2edea0c64f928c31efe4306805c1350c7788f065781d63abb0dd7a6b5
LCR	contracts/libraries/LibCrgReward.sol	7850ed7c240928d6e39d121f3870c67644b1c56003dbe03a31b2b53ebc828a5c
LBM	contracts/libraries/LibBrokerManager.sol	777a8424367b2c01922f240952e7c2f5b1aa2a8d4b0206135ab13f468e45a7c1
LCP	contracts/libraries/LibChainlinkPrice.sol	e3c1326b5d547a1817445d735ac802a337f7a470ba1eab8cb4b6860341fd5fb1
LFM	contracts/libraries/LibFeeManager.sol	0042478ec26a78d1e64551d9fb5764faafd9108fcb5469c0875bcb539c73b05d
LLO	contracts/libraries/LibLimitOrder.sol	06d12fc4a64d7315e956eb6871600ea76d4ae7db50966f6559eb27674c2cfad2
LPM	contracts/libraries/LibPairsManager.sol	59153b65e28f17d34ada58c0bc5a5c09c26d062337b06dc9e649b1dbe117da95
LPF	contracts/libraries/LibPriceFacade.sol	ab0eb1cc16ae86abfd030d5528349d5006508fa6f4da5ffe8c12f23487abad43
LSR	contracts/libraries/LibStakeReward.sol	21cb87df5000806324e2ff33fbf5856eddfbb042de3af0144f47ba74aad5aa1a
LTC	contracts/libraries/LibTradingConfig.sol	70d688e39555fc3fd91f1f6c4cf3e0f049bb982fe28e85088c096db6f53140a8
LVB	contracts/libraries/LibVault.sol	77f015c5ffb1bb3fb072a0497713b77610bf911d6ac4d27d63cc5520e649497c
AXI	contracts/upgradeInitializers/CargioInit.sol	f435acceabb51f8a6c780665b5d1425925dbdded4b9243d5030f791b9ab416bd
IWB	contracts/dependencies/IWBNB.sol	977fd2f8dfb43437aa14d624768cbf85e0dc727b304f89c7d03d4f268190ae51
BIT	contracts/utils/Bits.sol	98b01bab7d4fb1e34651578762778241e7ca8d2dc845876e2171e8a832391074

ID	File	SHA256 Checksum
ACE	contracts/facets/AccessControlEnumerable Facet.sol	8ede20f95bae75c5524c757d8b80bb74dccf08707165750d56f42e8e8e416614
CPF	contracts/facets/ChainlinkPriceFacet.sol	d489e32bb961646b9cc9844f66fce4decefb59ddd5ca2041f66d913f98d8965a
DCF	contracts/facets/DiaCutFacet.sol	d340ea66c2fb4762fecb1cd63787141057f8a3463879994d1eac1702a2d43a09
DLF	contracts/facets/DiaLoupeFacet.sol	0e928d5d12fede05d6378208b919d900104c47229590b30892f9130f61ccc605
FMF	contracts/facets/FeeManagerFacet.sol	14d1f231a13a22c0c8db4bb0bd9747c71d282d1e36219939e90d8e3f602a8ce9
PFB	contracts/facets/PausableFacet.sol	65a98f9286068aebff5f61c03ea926964a5c9a635f84dc438a9272ee59939141
TRD	contracts/facets/TradingConfigFacet.sol	05c6f52a8f299c6dce8c3aa89e2cae8c6061b046ffd131aeec698b35c39d3886
TRI	contracts/facets/TradingCoreFacet.sol	2524aac3cc0928bd5f68a6e6d653b0b9504161415bbebc508eb24d451349b818
TRF	contracts/facets/TradingReaderFacet.sol	84045a01e22d5329183049bd75676329559a587c007d22be3ac92679d6953656
TFB	contracts/facets/TransitionFacet.sol	9a898a54302fc8d8e67226dc3451c4a141019095267c6e439cdba51cd4a8bde5f
LDB	contracts/libraries/LibDia.sol	12395822b25ab9c0e53a1a1c0a7ace5b530df407ee41c2d00fee5c615fd2824f
LOA	contracts/libraries/LibraryOrderAndTradingHistory.sol	f07cbb8e827553706cb31fc7d04d6ccfa598e77dd676e5f81ab3fdb203c41f5e
LTB	contracts/libraries/LibTrading.sol	27b9caedc20190c8a10fc473edc27cb03ea8bd9f6eeacf0787632bfe270a48e0
LIT	contracts/libraries/LibTradingCore.sol	d85b105d2fa0227f2b4ffafac29ccb65f3a3bfd02d245267d34448bfc20cc5d3
OSB	contracts/security/OnlySelf.sol	2f62700e27f0f84c6e02f68faf508cfaf8515874d03d1caa02c09e929c92050f
PAU	contracts/security/Pausable.sol	f8d3effea262c040731ef4ba08ca472a49b995c8bdb679e07cc134ded52b6e5e
RGB	contracts/security/ReentrancyGuard.sol	5867ff3562a305eecef3c05085757047f8ca466d6f26b6a7b7c1d2c95f2e3da5

ID	File	SHA256 Checksum
BIS	contracts/utils/Bits.sol	98b01bac7d4fb1e34651578762778241e7ca8d2dc845376e2171e8a832391074
COS	contracts/utils/Constants.sol	3edbabd8143af5e40782952d823ae1381c3f1c5f3f0903812f1acc9fbdc4436b
CRG	contracts/CRG.sol	15f920de5d77abc3c0b16a9f24ad24c13ec7f08ccbe032c63b7c2a4bc119c50a
ACF	contracts/facets/AccessControlEnumerableFacet.sol	70d769fb6dae8bf4c19882752950fa39ad4d7f0b298f794333373cd481f237dd
ALM	contracts/facets/CrgManagerFacet.sol	6fb4fbb7365b463706aba138adafec143af66e25522700389f0ffe3a78bc3cba
APX	contracts/facets/CrgRewardFacet.sol	79d3c03c960f842798d676a11988c782be41b6e4b2ab387c088aa756f719981c
BRO	contracts/facets/BrokerManagerFacet.sol	97af7eb63449e13b393c05f541a25682d9abaa19fdeed3e97dd033db91078b74
CHA	contracts/facets/ChainlinkPriceFacet.sol	d489e34bb961646b9cc9844f66fce4decefb59ddd5ca2031f66d913f98d8965a
DIA	contracts/facets/DiaCutFacet.sol	6754977d5831c0bad40ae4237816914f371eb070e3388393364872bcb8d05c38
DIM	contracts/facets/DiaLoupeFacet.sol	0e928d5d13fede05d6378208b919d900104c47229590330892f9130f61ccc605
FEE	contracts/facets/FeeManagerFacet.sol	14d1f231a13ae2c0c8db4bb0bd9747c71d282d1e36319939e90d8e3f602a8ce9
LIM	contracts/facets/LimitOrderFacet.sol	6045b843562083cfa8ad657a7fd64c8c79877194b602306876d6821d84e6f43d
OAH	contracts/facets/OrderAndTradeHistoryFacet.sol	53e11977530f2755bbb0f1164a156dfa3efde318bc1e063b5503f2e5de684e19
PAI	contracts/facets/PairsManagerFacet.sol	f435f48d9aafa2af803907131209d9d9ddb4c4c1c2a6b93916a8c8fa40f71b2a
PFU	contracts/facets/PausableFacet.sol	65a98f9e86068aebff5f61c03ea926964a5c9a635f84d3438a9272ee59939141
PRI	contracts/facets/PriceFacadeFacet.sol	f630cf0ee840600275c1119537d90b2236faf6e2b997136e9cd2810c0da73ef4
STA	contracts/facets/StakeRewardFacet.sol	df192003df11c8c4b8c5d129e88a6678c6553d7ff380ec219cf868080fe383b3

ID	File	SHA256 Checksum
TIM	contracts/facets/TimeLockFacet.sol	725c0a99e1d7aa26e9a94c8aa8079626b3738157c2187604e8320129a1d75410
TRN	contracts/facets/TradingCheckerFacet.sol	1524450821c8e43648399b46962f3325847ea01a3ba1a6919065b15c24042a3e
TRG	contracts/facets/TradingCloseFacet.sol	cb532608d06f0c103b0671792632cc871df3afbe79c7886134ee741853c154c7
TRC	contracts/facets/TradingConfigFacet.sol	fa263e5c2f5eb55b890d6ce0f8f487a74d9082eeb56be1667d1571c8b7d9ce84
TRO	contracts/facets/TradingCoreFacet.sol	2841a467762d402de7eb24f718e52981dc5645216d61c81a38b2ad86971b2b2d
TRP	contracts/facets/TradingOpenFacet.sol	f6ea980a058a7d877a792578567b39c50ec023d07e91691cece2a42273f0529a
TRR	contracts/facets/TradingPortalFacet.sol	674051ff73929267db4e1c91a28fd1538b1727b856836125b09483f056b5ae04
TRE	contracts/facets/TradingReaderFacet.sol	84045a01e2cd5329183049bd75676329559a587c007d61be3ac92679d6953656
TFU	contracts/facets/TransitionFacet.sol	9a898a54306c8d8e67226dc3451c4a141019095267c61439cdba51cd4a8bde5f
VFU	contracts/facets/VaultFacet.sol	edf7c08d74885825e8e41434a825882b68e07af325fbe261dddfd9777179d8e6
LAE	contracts/libraries/LibAccessControlEnumerable.sol	dc16d922b1df41b69e5475c0626c1310c5505ff7baa9436eaf42cfeb49331771
LIL	contracts/libraries/LibCrgManager.sol	e04970d31c16887301f309f1094b9120c92b246346206dbf194b550284371b5a
LIP	contracts/libraries/LibCrgReward.sol contracts//	1d3bfa71791d7e7db969b18271fa987c47e5472014161ae61f570aac1f0c3a5c
LIO	libraries/LibBrokerManager.sol	065d7d47b7e03a1c5a2fc04ac85052d84c4948c1391cc613778c8e132ee36933
LIC	contracts/libraries/LibChainlinkPrice.sol	ad0a814fe8444d44341ad4514f3027bd31046fc7b2b3fcf68e595567563d49e6
LDU	contracts/libraries/LibDia.sol contracts//	12395822b35ab9c0e53a1a1c0a7ace5b530df407ee47c6d00fee5c615fd2824f
LIF	libraries/LibFeeManager.sol	34c2b5e1cd5989ef12a24eb9eeb8ea2c0f11319f280b786ddcc57d7252d842b3

ID	File	SHA256 Checksum
LII	contracts/libraries/LibLimitOrder.sol contracts//	8f264939847f8bce8bf8c9990562ae1185bb6a9f9112b2c817f86faa89504063
LOT	libraries/LibOrderAndTradeHistory.sol	f07cbb8e837553706cb31fc7d04d6ccfa598e77dd676e5281ab3fdb203c41f5e
LIS	contracts/libraries/LibPairsManager.sol	aaae64907d2673a52babd8b972df2933a3c160f4034b5280cbae2fbae9b71544
LIE	contracts/libraries/LibPriceFacade.sol	0e4600f2bddcc2e0ded3353074d8ab7d399907818f192e37f09411e472ed7425
LID	contracts/libraries/LibStakeReward.sol	b2b2eb46dcdc0c0e2dbc74151af8bff38306b15e0bb3f2e1bf18ac89dcb154f4
LIN	contracts/libraries/LibTimeLock.sol	2078c6cc2fe84cc9948d217ed45663347b0d688c927df24a7c6983965c4ebefd
LTU	contracts/libraries/LibTrading.sol	27b9caedcb0190c8a10fc473edc27cb03ea8bd9f6ee2cf0787632bfe270a48e0
LI8	contracts/libraries/LibTradingConfig.sol	70d688e39555fc3fd91f1f6c4cf3e0f049bb982fe28e85288c096dc6f53140a8
LIU	contracts/libraries/LibTradingCore.sol	d85b105d9fa0227f2b4ffafac29ccb65f3a3bfd02d245227d34448bfc20cc5d3
LVU	contracts/libraries/LibVault.sol	a2256f92e3a33b5f7c10b3bcc3334339e5d77bc48a572162d061c0ca3059d68f
OSU	contracts/security/OnlySelf.sol	2f62700e47f0f84c6e02f68faf508cfaf8515874d03d1c2a02c09e929c92050f
PAS	contracts/security/Pausable.sol	f8d3effea268c040731ef4ba08ca472a49b995c8bdb679207cc134ded52b6e5e
RGU	contracts/security/ReentrancyGuard.sol	5867ff3568a305eecef3c05085757047f8ca466d6f26b2a7b7c1d2c95f2e3da5
AII	contracts/upgradeInitializers/CargioInit.sol	678551bef09f3e0ac65b85c4646830c01e3629aaf41ce2c806d95220fe815dfa
CRG	contracts/Cargio.sol	7e9b7f3e12181e63e12ed87bb2c0af7eb8a64f8f68761c2db10ad5612841b2ef

APPROACH & METHODS | CARGIO - AUDIT 2

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

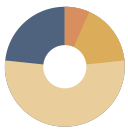
The auditing process pays special attention to the following considerations:

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

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

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

FINDINGS | APOLLOX - AUDIT 2



21	0	0	3	11	7
Total Findings	Critical	Major	Medium	Minor	Informational

This report has been prepared to discover issues and vulnerabilities for Cargio - Audit. Through this audit, we have uncovered 21 issues ranging from different severity levels. Utilizing the techniques of Manual Review & Static Analysis to complement rigorous manual code reviews, we discovered the following findings:

ID	Title	Category	Severity	Status
FAC-01	Potential Reentrancy Attack	Specific	Medium	Resolved
LBM-01	`brokerUpdate*()` Functions Don't Update	Logical Issue	Medium	Resolved
LPF-01	The Storage `LibPriceFacade.requestPriceCallback()`	Volatile	Medium	**Acknowledged**
AXI-01	`supportsInterface()` Is Inconsistent	Inconsistency	Minor	Resolved
LCM-02	Lack Of Sanity Check In `LibCrgManager._calculateCrgAmount`	Volatile Code	Minor	Resolved
LAR-01	`()` Unchecked TRC-20 `transfer()` / `transferFrom()` Call	Volatile Code	Minor	Resolved
LBM-02	`LibBrokerManager.removeBroker()` Allows Removing Of `defaultBroker`	Volatile Code	Minor	Resolved

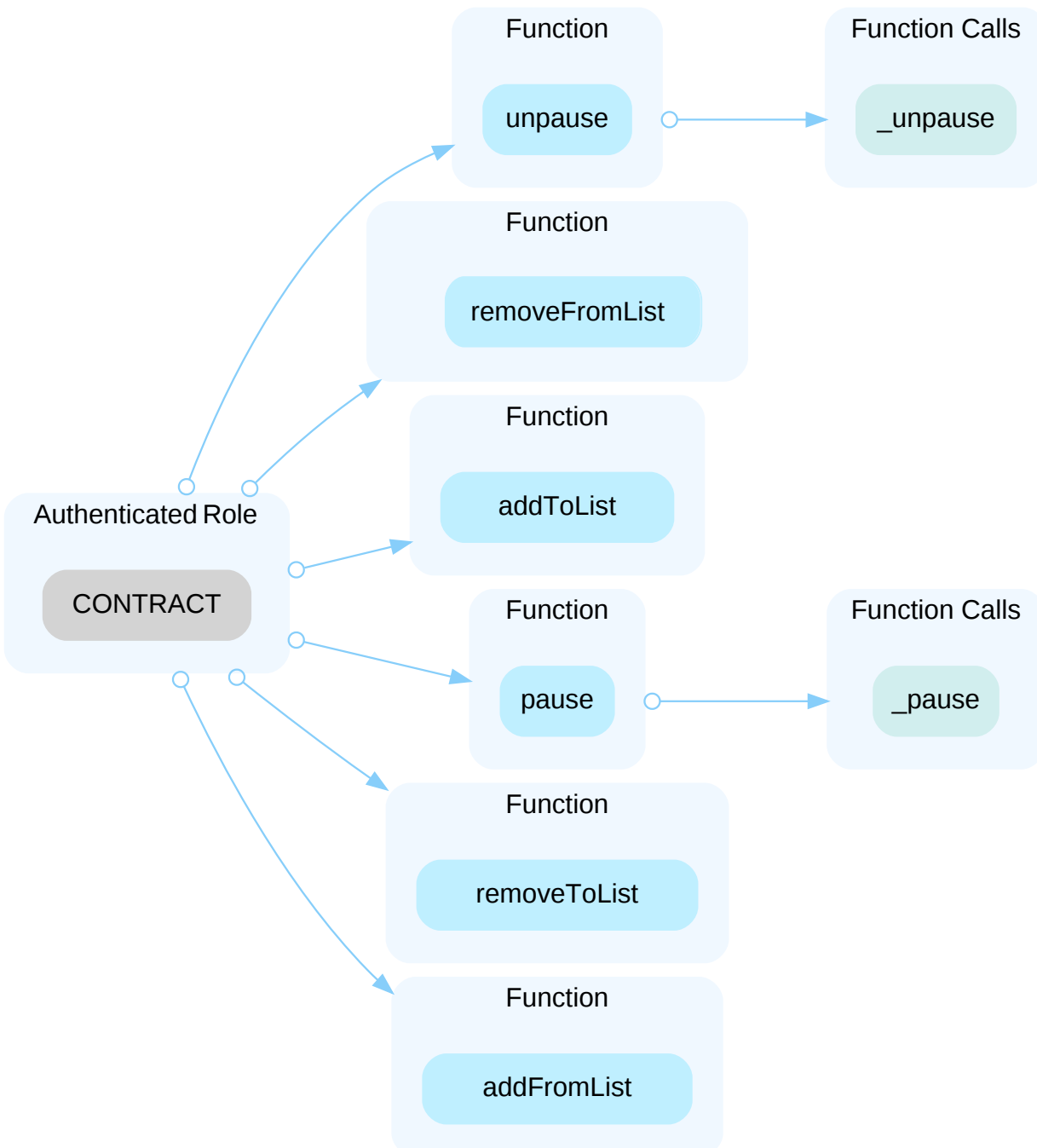
ID	Title	Category	Severity	Status
LCP-01	Missing Validation On `latestRoundData()`	Volatile Code	Minor	Resolved
LFM-01	`LibFeeManager.chargeOpenFee()` Doesn't Update `feeDetails.total` If `daoShareP == 0`	Volatile Code	Minor	Resolved
LPF-02	The Price From Oracle Explicitly Converted To `uint64`	Volatile Code	Minor	Resolved
LPF-03	`maxDelay` Can Be Ignored By `PRICE_FEEDER_ROLE`	Volatile Code	Minor	Resolved
LTC-01	Lack Of Sanity Check In `TradingConfigFacet.initTradingConfigFacet()`	Volatile Code	Minor	Resolved
LVB-01	Strict Comparison In `LibVault.decreaseByCloseTrade()`	Volatile Code	Minor	Resolved
PMF-01	Inconsistent Checks In `_leverageMarginsCheck()`	Inconsistency	Minor	Resolved
CON-02	Redundant Code	Coding Style	Informational	Resolved
DIA-03	Incompatibility With Deflationary Tokens	Logical Issue	Informational	Resolved
LAM-01	Time Units Can Be Used	Magic Numbers	Informational	Resolved
LAM-03	`coolingDuration` Can Be Avoided By Whitelisted CRG Owners	Volatile Code	Informational	Resolved
LIB-01	Basis Point Values Are Referred As Percent	Inconsistency	Informational	Resolved
LVB-02	Redundant Usage Of `LibVault` Namespace	Coding Style	Informational	Resolved

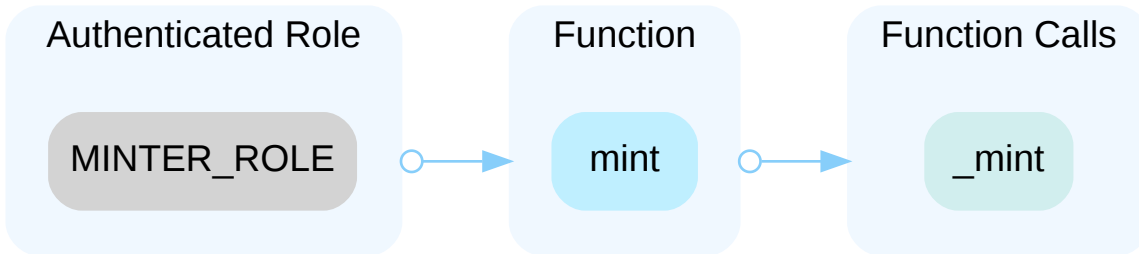
ID	Title	Category	Severity	Status
LVB-01	Redundant Code	Coding Style	Informational	Resolved

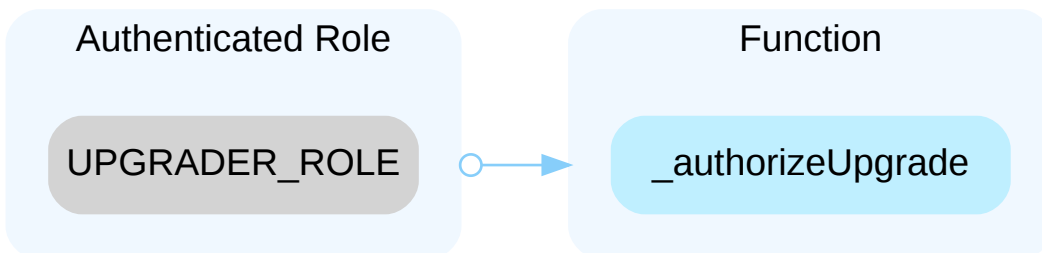
CRG-01 | DECENTRALIZATION IN CRG.SOL

Category	Severity	Location	Status
Decentralization / Privilege	Informational	**contracts/CRG.sol (base): 35, 39, 43, 48, 53, 58, 63, 74**	**Acknowledged**

Description




Authenticated Role
MINTER_ROLE
Function
mint
Function Calls
_mint


Authenticated Role
UPGRADER_ROLE
Function
_authorizeUpgrade

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

Alleviation

[Project Team]: We will not implement the time lock for parameter update because we need to make rapid reactions to adjust parameters based on market situation. Moreover, we have actually added the time lock for upgrade which is managed by a multi-signature address. We plan to distribute more rights (including the management of multi-signature etc) to our DAO governance to achieve even higher decentralization.

LBM-01 `brokerUpdate*()` FUNCTIONS DON'T UPDATE THE STORAGE

Category	Severity	Location	Status
Logical Issue	Medium	contracts/libraries/LibBrokerManager.sol (base): 81~85	Resolved

Description

```
 81     function _checkBrokerExist(BrokerManagerStorage storage bms, uint24 id)
private view returns (Broker memory) {
 82         Broker memory b = bms.brokers[id];
 83         require(b.receiver != address(0), "LibBrokerManager: broker does not
exist");
 84         return b;
 85     }
```

`LibBrokerManager._checkBrokerExist()` returns `Broker memory`.

```
114         Broker memory b = _checkBrokerExist(bms, id);
115         address oldReceiver = b.receiver;
116         b.receiver = receiver;
```

`memory` structure is updated in `updateBrokerReceiver()` and other functions. As a result, the storage is left intact.

Recommendation

We recommend returning `Broker storage` from `_checkBrokerExist()`.

LPF-01 `LibPriceFacade.requestPriceCallback()` CAN BE TOO GAS CONSUMING

Category	Severity	Location	Status
Volatile Code	Medium	contracts/libraries/LibPriceFacade.sol (base): 120	Acknowledged

Description

Users can create very big number of orders and price requests via `TradingPortalFacet.openMarketTrade()` in the same block. Then `PRICE_FEEDER_ROLE` will be unable to execute `PriceFacadeFacet.requestPriceCallback()` due to gas limitation.

In `LibPriceFacade.requestPriceCallback()`

- all the requests are copied into memory from `pfs.pendingPrices[requestId]`
- all the requests are processed and then deleted from storage

Recommendation

We recommend limiting the number of open orders per block or introducing partial price request processing.

AXI-01 | `supportsInterface()` IS INCONSISTENT

Category	Severity	Location	Status
Inconsistency	Minor	contracts/upgradeInitializers/CargioInit.sol (base): 16~25	Resolved

Description

Dia initialization works this way:

1. `CargioInit` contract is deployed with `init()` function
2. `Cargio` contract is deployed with `CargioInit` address specified as `_init` argument
3. `Cargio` constructor calls `CargioInit.init()` function via `delegatecall()`
4. `init()` adds 3 interfaces to `DiaStorage.supportedInterfaces` and 3 more to `LibAccessControlEnumerable.supportedInterfaces`

Both `DiaLoupeFacet` and `AccessControlEnumerableFacet` have `supportsInterface()` functions, each using its own storage.

It is unclear which one will be used by the Dia and unclear why the Dia needs both of them.

Recommendation

We recommend leaving only one `supportsInterface()` function and storing all `supportedInterfaces` at one facet.

LAR-01 | UNCHECKED TRC-20 `transfer()` / `transferFrom()` CALL

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibApxReward.sol (base): 148	Resolved

Description

```
148         ars.rewardToken.transferFrom(msg.sender, address(this), amount);
```

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

Recommendation

Since some TRC-20 tokens return no values and others return a `bool` value, they should be handled with care. We advise using the OpenZeppelin's `SafeTRC20.sol` implementation to interact with the `transfer()` and `transferFrom()` functions of external TRC-20 tokens. The OpenZeppelin implementation checks for the existence of a return value and reverts if `false` is returned, making it compatible with all TRC-20 token implementations.

LBM-02 `LibBrokerManager.removeBroker()` ALLOWS REMOVING OF `defaultBroker`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibBrokerManager.sol (base): 100	Resolved

Description

`LibBrokerManager.removeBroker()` doesn't check that the removed broker is `defaultBroker`. `defaultBroker` is used by `updateBrokerCommission()` in case the requested broker is absent. In case it was removed, the commissions will be accumulated for the same `id` and can be withdrawn if a new broker with the same `id` will be added in the future.

Recommendation

We recommend preventing of `defaultBroker` removal.

LCP-01 | MISSING VALIDATION ON `latestRoundData()`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibChainlinkPrice.sol (base): 65~66	Resolved

Description

```
65          (, int256 price_, uint256 startedAt_,,) = oracle.latestRoundData();
66          price = uint256(price_);
```

The `price` provided by `oracle.latestRoundData()` can theoretically be negative. In this case, it is silently converted to `uint256`.

Recommendation

We recommend checking the return values of third-party services and reverting in case of unexpected.

LFM-01 `LibFeeManager.chargeOpenFee()` DOESN'T UPDATE `feeDetails.total` IF `daoShareP == 0`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibFeeManager.sol (base): 120~124, 141	Resolved

Description

```
120         if (daoShare > 0) {
121             ITRC20(token).safeTransfer(fms.daoRepurchase, daoShare);
122             detail.total += feeAmount;
123             detail.daoAmount += daoShare;
124         }
```

`LibFeeManager` allows `daoShareP` to be zero. However, in this case, the `LibFeeManager.chargeOpenFee()` doesn't update `feeDetails[token].total`. `FeeManagerFacet.getFeeDetails()` will return incorrect results.

`chargeCloseFee()` is also affected.

Recommendation

We recommend updating the `detail.total` in any case.

LPF-02 THE PRICE FROM ORACLE EXPLICITLY CONVERTED TO `uint64`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibPriceFacade.sol (base): 170	Resolved

Description

`LibPriceFacade.getPriceFromCacheOrOracle()` gets the `uint256` price by `LibChainlinkPrice.getPriceFromChainlink()` and than explicitly converts it to `uint64`. This can lead to a accidental hidden overflow that will get unnoticed.

Recommendation

We recommend explicitly checking that the provided by the third-party values fit into `uint64`.

LPF-03 | `maxDelay` CAN BE IGNORED BY `PRICE_FEEDER_ROLE`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibPriceFacade.sol (base): 135~138	Resolved

Description

```
135         // The time interval is too long.
136         // receive the current price but not use it
137         // and wait for the next price to be feed.
138         if (block.timestamp > updatedAt + pfs.maxDelay) {
```

In `LibPriceFacede.requestPriceCallback()` the `PRICE_FEEDER_ROLE` provides the `price`. If the `beforePrice` extracted by `getPriceFromCacheOrOracle()` was stored there more than `pfs.maxDelay` time ago, then the provided `price` is "rejected".

However, since that `price` is saved to `pfs.callbackPrices[pendingPrice.token]` with the current `block.timestamp`, the next call to `requestPriceCallback()` by `PRICE_FEEDER_ROLE` with the same arguments will be successful: the price will be used, callbacks called, `pendingPrices` deleted.

Recommendation

We recommend clarifying the intended logic of `pfs.maxDelay`.

LTC-01 LACK OF SANITY CHECK IN `TradingConfigFacet.initTradingConfigFacet()`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibTradingConfig.sol (base): 35	Resolved

Description

```
35          require(tcs.executionFeeUsd == 0 && tcs.minNotionalUsd == 0 &&
tcs.maxTakeProfitP == 0, "LibTradingConfig: Already initialized");
```

`TradingConfigFacet.initTradingConfigFacet()` is supposed to be called once by `DEPLOYER_ROLE`. The check above is supposed to ensure that. However, all three argument values can and probably will be 0, `initTradingConfigFacet()` doesn't enforce the arguments to be non-zero.

Recommendation

We recommend adding `require(minNotionalUsd > 0 && maxTakeProfitP > 0)` to make the function consistent with other library setters.

LVB-01 STRICT COMPARISON IN `LibVault.decreaseByCloseTrade()`

Category	Severity	Location	Status
Volatile Code	Minor	contracts/libraries/LibVault.sol (base): 214	Resolved

Description

```
214             require(index.into() > 0 && otherTokenAmountUsd < totalBalanceUsd,
"LibVault: Insufficient funds in the treasury");
```

The code requires `otherTokenAmountUsd` to be strictly less than `totalBalanceUsd`, however, equal balances are also enough to finish the operation.

Recommendation

We recommend using `otherTokenAmountUsd <= totalBalanceUsd` instead.

PMF-01 | INCONSISTENT CHECKS IN `_leverageMarginsCheck()`

Category	Severity	Location	Status
Inconsistency	Minor	contracts/facets/PairsManagerFacet.sol (base): 141	Resolved

Description

`PairsManagerFacet._leverageMarginsCheck()` performs checks of `leverageMargins`.

The check `lm.tier >= leverageMargins[(i + ONE).into()].tier` is redundant since `lm.tier != (i + ONE).into()` check is performed.

It is not ensured that `lm.initialLostP > nextLm.initialLostP`.

Recommendation

We recommend rewriting the conditions in `require()` form (ensuring the conditions are satisfied instead of looking for unsatisfied). We recommend adding the missing condition and removing redundant one.

CON-02 | REDUNDANT CODE

Category	Severity	Location	Status
Coding Style	Informational	contracts/Cargio.sol (base): 41~46; contracts/utils/Constants.sol (base): 4~6	Resolved

Description

```
41          LibDia.DiamStorage storage ds;
42          bytes32 position = LibDia.DIA_STORAGE_POSITION;
43          // get dia storage
44          assembly {
45              ds.slot := position
46          }
```

The code in `Cargio.fallback()` reimplements the `LibDia.diaStorage()` . Can be rewritten as `LibDia .DiaStorage storage ds = LibDia .diaStorage();` .

```
4  type Price8 is uint64;
5  type Qty10 is uint80;
6  type Usd18 is uint96;
```

The types and constants `PRICE_DECIMALS` - `FUNDING_FEE_RATE_DIVISOR` from `Constants` library are never used.

Recommendation

We recommend following the recommendations.

DIA-03 | INCOMPATIBILITY WITH DEFLATIONARY TOKENS

Category	Severity	Location	Status
Logical Issue	Informational	contracts /facets /CrgRewardFacet .sol (base): 28; contract s/dia/facets/StakeRewardFacet .sol (base): 32, 37; contracts/dia/libraries/LibCrgReward.sol (base): 105, 124, 148, 149; contracts/dia/libraries/LibStakeReward.sol (base): 63, 66, 78, 79	Resolved

Description

When transferring deflationary TRC20 tokens, the input amount may not be equal to the received amount due to the charged transaction fee.

LAM-01 | TIME UNITS CAN BE USED

Category	Severity	Location	Status
Magic Numbers	Informational	contracts/dia/libraries/LibCrgManager.sol (base): 35	Resolved

Description

```
34          // default 30 minutes
35          ams.coolingDuration = 1800;
```

Time unit `minutes` can be used.

Recommendation

We recommend using `30 minutes` instead of `1800` and removing the comment.

LAM-03 `coolingDuration` CAN BE AVOIDED BY LISTED CRG OWNERS

Category	Severity	Location	Status
Volatile Code	Informational	contracts/dia/libraries/LibAlpManager.sol (base): 15~16	Resolved

Description

`LibCrgManager` manages `lastMintedAt` parameter of each user and doesn't allow to `burnCrg()` / `burnCrgBNB()` if `coolingDuration` has not yet expired since last mint.

However, members of `CRG.fromList` and `CRG.toList` can avoid that limitation and burn immediately by transferring of minted CRG to another address.

LIB-01 | BASIS POINT VALUES ARE REFERRED AS PERCENT

Category	Severity	Location	Status
Inconsistency	Informational	contracts /dia/libraries /LibBrokerManager .sol (base): 20; contracts /dia/libraries /LibFeeManager .sol (base): 20~21, 33; contracts/dia/libraries/LibPriceFacade .sol (base): 34~35, 1 26; contracts/dia/libraries/LibVault.sol (base): 42	Resolved

Description

```
42          uint16 securityMarginP;   // %
```

Many values hold basis points (1.0 is represented as 10000), however, they commented as `%` and have the `P` suffix in their names.

```
126           uint gapPercentage = priceGap * 1e4 / beforePrice;
```

Using the word "percentage" for the value in basis points is incorrect. The "percentage" refers to a value out of 100, while basis points refer to a value out of 10000

Recommendation

We recommend updating the comments to "// basis points" to avoid ambiguity and replacing `P` suffix with `BPS`. We recommend renaming `LibVault.AvailableToken.weight` to `weightBPS`, etc.

Alleviation

Comments were updated.

LVB-02 | REDUNDANT USAGE OF `LibVault` NAMESPACE

Category	Severity	Location	Status
Coding Style	Informational	contracts/dia/libraries/LibVault.sol (base): 249	Resolved

Description

```
249         LibVault.VaultStorage storage vs = LibVault.vaultStorage();
```

In `LibVault` library it is not required to mention `LibVault` namespace to access own structures and methods.

Recommendation

We recommend omitting of `LibVault` namespace wherever possible. Like this:

```
249         VaultStorage storage vs = vaultStorage();
```

OPTIMIZATIONS | APOLLOX - AUDIT 2

ID	Title	Category	Severity	Status
DIA-01	Tautology	Gas Optimization	Optimization	Resolved
DIA-02	Arguments Should Be `calldata`	Gas Optimization	Optimization	Resolved
FAC-03	`_check()` Argument Can Be Declared `storage`	Gas Optimization	Optimization	Resolved
LAC-01	Redundant Data In `LibAccessControlEnumerable`	Gas Optimization	Optimization	Acknowledged
LIB-02	Unnecessary Use Of SafeMath	Gas Optimization	Optimization	Resolved
LIB-03	`memory` Variable Can Be Used Instead Of `storage`	Gas Optimization	Optimization	Resolved
OAT-01	`OrderAndTradeHistoryFacet.getOrderAndTradeHistory()` Is Gas Consuming	Gas Optimization	Optimization	Resolved
TRA-02	`TradingCloseFacet._transferToUserForClose()` Can Be Optimized	Coding Style	Optimization	Resolved

DIA-01 | TAUTOLOGY

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/facets/CrgRewardFacet.sol (base): 14, 15; contracts/dia/libraries/LibCrgReward.sol (base): 155	Resolved

Description

Comparisons that are always `true` are unnecessary.

```
14          require(_crgPerBlock >= 0, "Invalid _crgPerBlock");
15          require(_startBlock >= 0, "Invalid _startBlock");
```

```
155          require(_crgPerBlock >= 0, "crgPerBlock greater than 0");
```

Recommendation

We recommend clarifying the intended behavior (if zero values are expected or not) and either removing `require()` or using strict comparisons (`>`). We recommend updating the error messages to reflect the expected conditions.

DIA-02 | ARGUMENTS SHOULD BE `calldata`

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/facets/OrderAndTradeHistoryFacet.sol (bas e): 19; contracts/dia/facets/PairsManagerFacet.sol (base): 61~63, 119; contracts/dia/facets/TradingCheckerFacet.sol (base): 226, 424; contracts/dia/facets/VaultFacet.sol (bas e): 28, 35, 53; contracts/dia/libraries/LibVault.sol (base): 79	Resolved

Description

Non changed arguments of external functions are declared as `memory` .

Recommendation

We recommend declaring the non changed arguments of external functions as `calldata` to save gas.

FAC-03 | `_check()` ARGUMENT CAN BE DECLARED `storage`

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/facets/TradingCloseFacet.sol (base): 384; c ontracts/dia/facets/TradingPortalFacet.sol (base): 20	Resolved

Description

`TradingPortalFacet._check()` accepts `memory ot` argument. All the function callers provide `storage` data structure.

`TradingCloseFacet._removeOpenTrade()` is also affected.

Recommendation

We recommend declaring `ot` argument as `storage` to avoid redundant copying.

LAC-01 | REDUNDANT DATA IN `LibAccessControlEnumerable`

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/libraries/LibAccessControlEnumerabl e.sol (base): 60~64	Acknowledged

Description

```
60          if (!hasRole(role, account)) {
61              acs.roles[role].members[account] = true;
62              emit RoleGranted(role, account, msg.sender);
63          }
64          acs.roleMembers[role].add(account);
```

`acs.roleMembers` can be updated only if `!hasRole(role, account)` (account doesn't have the role already).

`RoleData.members` and `RoleData` structure in general are redundant. `roleMembers` uses `EnumerableSet.AddressSet` to store members of role in an enumerable way. As a result, holding members as part of `roles` structure is not required.

Recommendation

We recommend replacing `mapping(bytes32 => RoleData) roles` structure with `mapping(bytes32 => bytes32) role` . We recommend using `acs.roleMembers[role].contains(account)` in `hasRole()` .

LIB-02 | UNNECESSARY USE OF SAFEMATH

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/libraries/LibCrgReward.sol (base): 173, 174, 175; contracts/dia/libraries/LibStakeReward.sol (base): 64, 65, 76, 77	Resolved

Description

With Solidity compiler versions 0.8.0 or newer, arithmetic operations will automatically revert in case of integer overflow or underflow. `SafeMath` library is used for `uint256` type in `LibCrgReward` and `LibStakeReward` contracts.

Recommendation

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

LIB-03 | `memory` VARIABLE CAN BE USED INSTEAD OF `storage`

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/libraries/LibChainlinkPrice.sol (base): 45~4 6; contracts/dia/libraries/LibVault.sol (base): 263~264	Resolved

Description

```
261             address tokenAddress = vs.tokenAddresses[i.into()];
262             LibVault.AvailableToken storage at = vs.tokens[tokenAddress];
263             uint256 price = LibPriceFacade.getPrice(at.tokenAddress);
264             uint256 balance = vs.treasury[at.tokenAddress];
```

In `getTotalValueUsd()` `tokenAddress` variable can be used instead of `at.tokenAddress` storage field to save gas.

```
45          address priceFeed = pf.feedAddress;
46          require(pf.feedAddress != address(0), "LibChainlinkPrice: Price feed
does not exist");
```

In `removeChainlinkPriceFeed()` `priceFeed` variable can be used instead of `pf.feedAddress` storage field to save gas.

Recommendation

We recommend using `memory` variables instead of `storage` fields.

OAT-01 `OrderAndTradeHistoryFacet.getOrderAndTradeHistory()` IS GAS CONSUMING

Category	Severity	Location	Status
Gas Optimization	Optimization	contracts/dia/facets/OrderAndTradeHistoryFacet.sol (ba se): 64	Resolved

Description

`OrderAndTradeHistoryFacet.getOrderAndTradeHistory()` is an `external` `view` function. `view` functions can be limited by the amount of computational resources available on a particular node. If a `view` function is particularly resource-intensive, it may cause nodes to become overwhelmed and unable to execute it.

```
64          ActionInfo[] memory infos = hs.actionInfos[user];
```

The function copies all the `hs.actionInfos[user]` array from `storage` into `memory`. The array can be extremely big and copying can be expensive in terms of gas.

Recommendation

We recommend omitting the copying of the whole array and accessing the `hs.actionInfos[user]` elements directly:

```
71                  UC oldest = uc(hs.actionInfos[user].length - start - 1);
72                  ...
73                  ActionInfo memory ai = hs.actionInfos[user][(oldest -
i).into()];
```

TRA-02 `TradingCloseFacet._transferToUserForClose()` CAN BE OPTIMIZED

Category	Severity	Location	Status
Coding Style	Optimization	contracts/dia/facets/TradingCloseFacet.sol (base): 221~224	Resolved

Description

```
 221             if (userReceive > 0) {
 222                 _closeTradeReceived(tradeHash, to, settleTokens[0].token,
userReceive);
 223             }
 224             settleTokens[0].amount -= userReceive;
```

`settleTokens[0].amount` can be updated only if `userReceive > 0`.

The function contains code repetitions and can be refactored.

It is recommended to check at line 267 that

```
 267     require(userReceiveUsd == 0, "TradingCloseFacet: Insufficient funds in the
openTrade");
```

Recommendation

We recommend performing function refactoring.

FORMAL VERIFICATION | CARGIO - AUDIT

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 TRC-20 Compliance

We verified properties of the public interface of those token contracts that implement the TRC-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
trc20-transfer-revert-zero	`transfer` Prevents Transfers to the Zero Address
trc20-transfer-correct-amount	`transfer` Transfers the Correct Amount in Non-self Transfers
trc20-transfer-correct-amount-self	`transfer` Transfers the Correct Amount in Self Transfers
trc20-transfer-change-state	`transfer` Has No Unexpected State Changes
trc20-transfer-false	If `transfer` Returns `false`, the Contract State Is Not Changed
trc20-transfer-exceed-balance	`transfer` Fails if Requested Amount Exceeds Available Balance
trc20-transfer-never-return-false	`transfer` Never Returns `false`
trc20-transferfrom-revert-from-zero	`transferFrom` Fails for Transfers From the Zero Address
trc20-transferfrom-revert-to-zero	`transferFrom` Fails for Transfers To the Zero Address
trc20-transferfrom-correct-amount	`transferFrom` Transfers the Correct Amount in Non-self Transfers

Property Name	Title
trc20-transferfrom-correct-amount-self	`transferFrom` Performs Self Transfers Correctly
trc20-transferfrom-correct-allowance	`transferFrom` Updated the Allowance Correctly
trc20-transferfrom-fail-exceed-allowance	`transferFrom` Fails if the Requested Amount Exceeds the Available Allowance
trc20-transferfrom-fail-exceed-balance	`transferFrom` Fails if the Requested Amount Exceeds the Available Balance
trc20-transferfrom-change-state	`transferFrom` Has No Unexpected State Changes
trc20-totalsupply-succeed-always Succeeds	`totalSupply` Always
trc20-transferfrom-false	If `transferFrom` Returns `false`, the Contract's State Is Unchanged
trc20-transferfrom-never-return-false	`transferFrom` Never Returns `false`
trc20-totalsupply-correct-value	`totalSupply` Returns the Value of the Corresponding State Variable
trc20-totalsupply-change-state	`totalSupply` Does Not Change the Contract's State
trc20-balanceof-succeed-always	`balanceOf` Always Succeeds
trc20-balanceof-correct-value	`balanceOf` Returns the Correct Value
trc20-balanceof-change-state	`balanceOf` Does Not Change the Contract's State
trc20-allowance-succeed-always	`allowance` Always Succeeds
trc20-allowance-correct-value	`allowance` Returns Correct Value
trc20-allowance-change-state	`allowance` Does Not Change the Contract's State
trc20-approve-revert-zero	`approve` Prevents Approvals For the Zero Address
trc20-approve-succeed-normal	`approve` Succeeds for Admissible Inputs
trc20-approve-correct-amount	`approve` Updates the Approval Mapping Correctly
trc20-approve-change-state	`approve` Has No Unexpected State Changes
trc20-approve-false	If `approve` Returns `false`, the Contract's State Is Unchanged
trc20-approve-never-return-false	`approve` Never Returns `false`

Property Name	Title
trc20-transfer-succeed-normal	`transfer` Succeeds on Admissible Non-self Transfers
trc20-transfer-succeed-self	`transfer` Succeeds on Admissible Self Transfers
trc20-transfer-recipient-overflow	`transfer` Prevents Overflows in the Recipient's Balance
trc20-transferfrom-succeed-normal	`transferFrom` Succeeds on Admissible Non-self Transfers
trc20-transferfrom-succeed-self	`transferFrom` Succeeds on Admissible Self Transfers
trc20-transferfrom-fail-recipient-overflow	`transferFrom` Prevents Overflows in the Recipient's Balance

Verification Results

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

Verification of TRC-20 Compliance

Detailed results for function `transfer`

Property Name	Final Result	Remarks
trc20-transfer-revert-zero	True	
trc20-transfer-correct-amount	True	
trc20-transfer-correct-amount-self	True	
trc20-transfer-change-state	True	
trc20-transfer-false	True	
trc20-transfer-exceed-balance	True	
trc20-transfer-never-return-false	True	

Detailed results for function `transferFrom`

Property Name	Final Result	Remarks
trc20-transferfrom-revert-from-zero	True	
trc20-transferfrom-revert-to-zero	True	
trc20-transferfrom-correct-amount	True	
trc20-transferfrom-correct-amount-self	True	
trc20-transferfrom-correct-allowance	True	
trc20-transferfrom-fail-exceed-allowance	True	
trc20-transferfrom-fail-exceed-balance	True	
trc20-transferfrom-change-state	True	
trc20-transferfrom-false	True	
trc20-transferfrom-never-return-false	True	

Detailed results for function `totalSupply`

Property Name	Final Result	Remarks
trc20-totalsupply-succeed-always	True	
trc20-totalsupply-correct-value	True	
trc20-totalsupply-change-state	True	

Detailed results for function `balanceOf`

Property Name	Final Result	Remarks
trc20-balanceof-succeed-always	True	
trc20-balanceof-correct-value	True	
trc20-balanceof-change-state	True	

Detailed results for function `allowance`

Property Name	Final Result	Remarks
trc20-allowance-succeed-always	True	
trc20-allowance-correct-value	True	
trc20-allowance-change-state	True	

Detailed results for function `approve`

Property Name	Final Result	Remarks
trc20-approve-revert-zero	True	
trc20-approve-succeed-normal	True	
trc20-approve-correct-amount	True	
trc20-approve-change-state	True	
trc20-approve-false	True	
trc20-approve-never-return-false	True	

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.

Verification of TRC-20 Compliance

Detailed results for function `transfer`

Property Name	Final Result	Remarks
trc20-transfer-revert-zero	True	
trc20-transfer-correct-amount	True	
trc20-transfer-succeed-normal	True	
trc20-transfer-succeed-self	True	
trc20-transfer-correct-amount-self	True	
trc20-transfer-change-state	True	
trc20-transfer-exceed-balance	True	
trc20-transfer-false	True	
trc20-transfer-never-return-false	True	
trc20-transfer-recipient-overflow	True	

Detailed results for function `transferFrom`

Property Name	Final Result	Remarks
trc20-transferfrom-revert-from-zero	True	
trc20-transferfrom-revert-to-zero	True	
trc20-transferfrom-correct-amount	True	
trc20-transferfrom-correct-amount-self	True	
trc20-transferfrom-succeed-normal	True	
trc20-transferfrom-succeed-self	True	
trc20-transferfrom-correct-allowance	True	
trc20-transferfrom-fail-exceed-balance	True	
trc20-transferfrom-fail-exceed-allowance	True	
trc20-transferfrom-change-state	True	
trc20-transferfrom-false	True	
trc20-transferfrom-never-return-false	True	
trc20-transferfrom-fail-recipient-overflow	True	

Detailed results for function `totalSupply`

Property Name	Final Result	Remarks
trc20-totalsupply-succeed-always	True	
trc20-totalsupply-correct-value	True	
trc20-totalsupply-change-state	True	

Detailed results for function `balanceOf`

Property Name	Final Result	Remarks
trc20-balanceof-succeed-always	True	
trc20-balanceof-correct-value	True	
trc20-balanceof-change-state	True	

Detailed results for function `allowance`

Property Name	Final Result	Remarks
trc20-allowance-succeed-always	True	
trc20-allowance-correct-value	True	
trc20-allowance-change-state	True	

Detailed results for function `approve`

Property Name	Final Result	Remarks
trc20-approve-succeed-normal	True	
trc20-approve-revert-zero	True	
trc20-approve-correct-amount	True	
trc20-approve-false	True	
trc20-approve-change-state	True	
trc20-approve-never-return-false	True	

APPENDIX | CARGIO - AUDIT

Finding Categories

Categories	Description
Centralization / Privilege	Centralization / Privilege findings refer to either feature logic or implementation of components that act against the nature of decentralization, such as explicit ownership or specialized access roles in combination with a mechanism to relocate funds.
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.
Language Specific	Language Specific findings are issues that would only arise within Solidity, i.e. incorrect usage of private or delete.
Coding Style	Coding Style findings usually do not affect the generated byte-code but rather comment on how to make the codebase more legible and, as a result, easily maintainable.
Inconsistency	Inconsistency findings refer to functions that should seemingly behave similarly yet contain different code, such as a constructor assignment imposing different require statements on the input variables than a setter function.
Magic Numbers	Magic Number findings refer to numeric literals that are expressed in the codebase in their raw format and should otherwise be specified as constant contract variables aiding in their legibility and maintainability.

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 Tron 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:

- Consumption is not taken into account, i.e. we assume that executions do not terminate prematurely.
- 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 TRC-20 Properties

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

Properties related to function `transfer`

trc20-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)))
```

trc20-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:

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]))))
```

trc20-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 <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(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
    >= 0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[msg.sender] <
    0x1000000000000000000000000000000000000000000000000000000000000000 && 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 -
      0x1000000000000000000000000000000000000000000000000000000000000000)))
```

trc20-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)))))
```

trc20-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`

trc20-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)))
```

trc20-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 <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[from] >= 0 && _balances[from] <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _allowances[from][msg.sender] >= 0 && _allowances[from][msg.sender] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(finished(contract.transferFrom(from, to, value), return == true ==>
      ((_allowances[from][msg.sender] == old(_allowances[from][msg.sender]) -
      value) || (_allowances[from][msg.sender] ==
      old(_allowances[from][msg.sender]) && (from == msg.sender ||
        old(_allowances[from][msg.sender]) ==
        0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF))))))
```

trc20-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] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(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 <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(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 >= 0x1000000000000000000000000000000000000000000000000000000000000000 &&
    value < 0x1000000000000000000000000000000000000000000000000000000000000000 &&
    _balances[to] >= 0 && _balances[to] <
    0x1000000000000000000000000000000000000000000000000000000000000000) ==>
  <>(reverted(contract.transferFrom) || finished(contract.transferFrom(from, to,
       value), return == false) || finished(contract.transferFrom(from, to,
       value), _balances[to] > old(_balances[to]) + value -
     0x1000000000000000000000000000000000000000000000000000000000000000)))
```

trc20-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)))))
```

trc20-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)))
```

trc20-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)))
```

trc20-totalsupply-change-state

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

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

Properties related to function `balanceOf`

erc20-balanceof-succeed-always

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

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

erc20-balanceof-correct-value

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

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

erc20-balanceof-change-state

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

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

Properties related to function `allowance`

erc20-allowance-succeed-always

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

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

erc20-allowance-correct-value

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

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

erc20-allowance-change-state

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

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

Properties related to function `approve`

erc20-approve-revert-zero

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

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

erc20-approve-succeed-normal

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

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

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

erc20-approve-correct-amount

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

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

erc20-approve-change-state

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

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

erc20-approve-false

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

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

erc20-approve-never-return-false

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

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

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