



# SMART CONTRACT SECURITY AUDIT OF



# GMX

# Summary

**Audit Firm** Guardian

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**Client Firm** GMX

**Final Report Date** September 1, 2023

## Audit Summary

GMX engaged Guardian to review the security of its real-time feed integration. From the 21st of August to the 1st of September, a team of 2 auditors reviewed the source code in scope. All findings have been recorded in the following report.

Notice that the examined smart contracts are not resistant to internal exploit. For a detailed understanding of risk severity, source code vulnerability, and potential attack vectors, refer to the complete audit report below.

 Blockchain network: **Arbitrum, Avalanche**

 Verify the authenticity of this report on Guardian's GitHub: <https://github.com/guardianaudits>

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# Project Overview

## Project Summary

Project Name	GMX
Language	Solidity
Codebase	<a href="https://github.com/gmx-io/gmx-synthetics">https://github.com/gmx-io/gmx-synthetics</a>
Commit(s)	c7af4b0c877bc4cb4f82ab040852111e9153605c

## Audit Summary

Delivery Date	September 1, 2023
Audit Methodology	Static Analysis, Manual Review, Written Tests, Contract Fuzzing

## Vulnerability Summary

Vulnerability Level	Total	Pending	Declined	Acknowledged	Partially Resolved	Resolved
● Critical	0	0	0	0	0	0
● High	0	0	0	0	0	0
● Medium	3	0	0	1	0	2
● Low	11	0	0	5	0	6

# Audit Scope & Methodology

ID	File	SHA-1 Checksum(s)
CON	Config.sol	c8ecffd6defb76e89cd43a250d4697528926a871
TIME	Timelock.sol	5ef65a907382bd4a97670afbffd31b917673f41
KEY	Keys.sol	ec5e13a8e8a84915b97ec1688c902bb4c80d417e
EDPU	ExecuteDepositUtils.sol	863ccc9b96cf533e257198088e3349e9df0fb1c0
ERR	Errors.sol	f6998a7e61b8843dbc9c9d0e9817aed2c4d90b16
ADL	AdlHandler.sol	997a862d7bb0a7aff77f8370f53e7cb1f20a069b
BOH	BaseOrderHandler.sol	1c29e866c18a7a6be3b27adb3f9cbaa1a86433ef
DEPH	DepositHandler.sol	b27d88814cc1d9c8bfc46eb6eb7c6213eeb581cf
WTDH	WithdrawalHandler.sol	e19c98f0036aa26e66d5e3197d36cdfd11b7f195
GSU	GasUtils.sol	55f63f3c8bcfdb5f20e156febd47cf3614a31ee2
MKTU	MarketUtils.sol	47deb4beb9a9a8d12b39dd62af6eabc00871c8d4
OCLU	OracleUtils.sol	3e25aaaa6865fe50a834ce875e371fdb5db97667
OCL	Oracle.sol	8c3bd8839197ea77e53a14929e3410c7cac0d9d6
ORDU	OrderUtils.sol	6a3021b06d65c790d23c7fda46db634888dcf045
DPCU	DecreasePositionCollateralUtils.sol	d8956a4b540e3459f75e4d16b1d8fe4b10d2960c
DPU	DecreasePositionUtils.sol	7f4fa2ff2bc69cf3c44dfec25a8891a513482064
SPU	SwapPricingUtils.sol	fd4d7efe4829aaf38878959756c7efcfdcf796d2
SWPU	SwapUtils.sol	c3bbd2100a3eac50bac5a1f0a0508c8489cc7601
EWDU	ExecuteWithdrawalUtils.sol	279df4e265a9da6238f7836e1349e520bc8c3794
WTDU	WithdrawalUtils.sol	e3c738577befac0f8f3bc1d62ee50efdad62285b

# Audit Scope & Methodology

## Vulnerability Classifications

Vulnerability Level	Classification
● Critical	Easily exploitable by anyone, causing loss/manipulation of assets or data.
● High	Arduously exploitable by a subset of addresses, causing loss/manipulation of assets or data.
● Medium	Inherent risk of future exploits that may or may not impact the smart contract execution.
● Low	Minor deviation from best practices.

## Methodology

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.
- Comprehensive written tests as a part of a code coverage testing suite.
- Contract fuzzing for increased attack resilience.

# Findings & Resolutions

ID	Title	Category	Severity	Status
OCL-1	DoS Due To Crossed Markets	DoS	<div><div></div></div> Medium	Acknowledged
OCL-2	Verifier Configuration Risk-Free Trade	Protocol Manipulation	<div><div></div></div> Medium	Resolved
EDPU-1	Positive Impact Deposit Not Validated	Validation	<div><div></div></div> Medium	Resolved
OCLU-1	Unsorted Block Numbers	Logical Error	<div><div></div></div> Low	Acknowledged
OCLU-2	Typo	Typo	<div><div></div></div> Low	Resolved
OCL-3	Inaccurate Revert Data	Typo	<div><div></div></div> Low	Resolved
TIME-1	Inconsistent Realtime Feed Action Key	Typo	<div><div></div></div> Low	Resolved
OCL-4	Outdated Comment	Documentation	<div><div></div></div> Low	Resolved
OCL-5	Prices May Be Older Than The Allowed Age	Validation	<div><div></div></div> Low	Acknowledged
OCLU-3	Outdated NatSpec	Documentation	<div><div></div></div> Low	Resolved
OCL-6	Hardcoded VerifierProxy	Configuration	<div><div></div></div> Low	Acknowledged
OCL-7	Lack Of Realtime Feed Tokens Optimization	Optimization	<div><div></div></div> Low	Acknowledged
EDWU-1	Inconsistent Pool Value For Withdrawals	Events	<div><div></div></div> Low	Resolved
OCL-8	Bid/Ask Manipulation	Protocol Manipulation	<div><div></div></div> Low	Acknowledged

# OCL-1 | DoS Due To Crossed Markets

Category	Severity	Location	Status
DoS	● Medium	Oracle.sol: 561-563	Acknowledged

## Description

GMX reverts when the bid price is greater than the ask price, otherwise known as a crossed market. Crossed markets can typically happen in times of volatility, or when pricing is based on multiple venues/data providers. For example, if the highest bid is from Coinbase but the lowest ask is from Binance, the chance of a reported bid larger than the ask increases.

```
if (report.bid > report.ask) {  
    revert Errors.InvalidRealtimeBidAsk(token, report.bid, report.ask);  
}
```

Internal feeds cannot be used to regain protocol functionality because internal feeds cannot be enabled when a realtime feed is enabled for a particular token.

## Recommendation

Verify whether the realtime feeds report crossed markets, if so consider an alternative to the strict validation or document and prepare for the risk of DoS.

## Resolution

GMX Team: With the realtime feeds bid should always be less than or equal to ask, will check with Chainlink about including this info in the docs.



# OCL-2 | Verifier Configuration Risk-Free Trade

Category	Severity	Location	Status
Protocol Manipulation	<div> <div></div> <div>Medium</div> </div>	Oracle.sol: 549	Resolved

## Description

The configuration of the Chainlink VerifierProxy and Verifier contracts pose a non-trivial threat to the GMX V2 system.

A malicious user may observe any of the following scenarios and leverage them to execute a risk free trade on the platform:

- A certain feed used by GMX V2 is deactivated with isDeactivated == true
- A verifier has been unset with the unsetVerifier function for a particular configDigest used by GMX V2
- A particular config that corresponds to the configDigest used by GMX is not active with isActive == false

In any of the above scenarios a malicious actor is able to submit a market order which is un-executable during the period where the feedId or configDigest is deactivated/misconfigured. If market prices move against the trader during this time, the trader can simply cancel their order.

GMX V2 offers no alternative means of execution for these orders until the feedId or configDigest is reactivated as they cannot be executed with the regular oracle system and changing the oracle configuration for the tokens used would take days using the Timelock contract.

## Recommendation

Consider implementing an alternative pathway to provide prices for orders in the event that a feedId or configDigest is deactivated or misconfigured. Otherwise consider disallowing the creation of orders that rely on certain feedId's or configDigest's that are currently deactivated.

## Resolution

GMX Team: Added an option for the multisig to allow internal price feeds, will also check with Chainlink about this.

# EDPU-1 | Positive Impact Deposit Not Validated

Category	Severity	Location	Status
Validation	● Medium	ExecuteDepositUtils.sol: 409	Resolved

## Description

In the `_executeDeposit` function the pool amount is incremented by the positive price impact amount in the `_params.tokenOut`.

However only the `_params.tokenIn` is validated against the `validatePoolAmountForDeposit` validation. This could lead to the `tokenOut` balance exceeding the desired cap during deposits.

## Recommendation

Validate that the increased `tokenOut` amount is also within the deposit cap with `validatePoolAmountForDeposit`.

## Resolution

GMX Team: The recommendation was implemented.

# OCU-1 | Unsorted Block Numbers

Category	Severity	Location	Status
Logical Error	● Low	OracleUtils.sol: 210	Acknowledged

## Description

The `getUncompactedOracleBlockNumbers` function appends the min and max block numbers from realtime feeds to the end of the arrays. As a result, it is possible for the `minBlockNumbers` and `maxBlockNumbers` to be unsorted. This may cause ADL execution to be less predictable since the first `minBlockNumber` is selected to be the `updatedAtBlock` for the order:

```
cache.key = AdlUtils.createAdlOrder(  
    AdlUtils.CreateAdlOrderParams(  
        dataStore,  
        . . .  
        cache.minOracleBlockNumbers[0] <---  
    )  
);
```

For example:

ADL does not execute when the `cache.minOracleBlockNumbers` are `[x, x+1]` since `OracleUtils.validateBlockNumberWithinRange` prevent executions for the `updatedAtBlock` of `x`.

Now with the realtime feed block numbers appended, the `cache.minOracleBlockNumbers` can be unsorted as `[x+1, x]` with stale pricing used at block `x` and the ADL order will execute.

## Recommendation

Consider having the block numbers sorted and/or document this potential behavior with the realtime reports.

## Resolution

GMX Team: As long as the ADL order's block number is within every block range of each oracle report, the oracle reports are considered valid and not stale.

# OCU-2 | Typo

Category	Severity	Location	Status
Typo	● Low	OracleUtils.sol: 85	Resolved

## Description

The comment “the highest price the a buyer will pay” should read “the highest price that a buyer will pay”.

## Recommendation

Implement the above recommended changes.

## Resolution

GMX Team: The recommendation was implemented.

# OCL-3 | Inaccurate Revert Data

Category	Severity	Location	Status
Typo	● Low	Oracle.sol: 396	Resolved

## Description

The Errors.InvalidBlockNumber revert supplies the minOracleBlockNumber however it is the maxOracleBlockNumber which failed the block number validation.

## Recommendation

Revert with the maxOracleBlockNumber as the invalid block number.

## Resolution

GMX Team: The recommendation was implemented.

# TIME-1 | Inconsistent Realtime Feed Action Key

Category	Severity	Location	Status
Typo	● Low	Timelock.sol: 479	Resolved

## Description

In the `_setRealtimeFeedActionKey` function the “setPriceFeed” string is used to create the realtime feed action key. However following from the patterns of the other action keys, the realtime feed action key ought to use the string “setRealtimeFeed” to match the `actionLabel`.

## Recommendation

Use the “setRealtimeFeed” string to construct the realtime feed action key in the `_setRealtimeFeedActionKey` function.

## Resolution

GMX Team: The recommendation was implemented.

# OCL-4 | Outdated Comment

Category	Severity	Location	Status
Documentation	● Low	Oracle.sol: 334	Resolved

## Description

The comment above the `_setPrices` function is outdated, it references initializing a `SetPricesCache` which does not happen immediately in the `_setPrices` function. Additionally there is no referenced `signers` param.

## Recommendation

Update the documentation for the `_setPrices` function.

## Resolution

GMX Team: The documentation was updated for the `_setPrices` function.

# OCL-5 | Prices May Be Older Than The Allowed Age

Category	Severity	Location	Status
Validation	● Low	Oracle.sol: 572	Acknowledged

## Description

The `maxPriceAge` validation is performed on the `currentBlockTimestamp` which is based on the upper bound block number. Therefore bid and ask values can technically come from before the `maxPriceAge` window, though perhaps a trivial amount of time.

## Recommendation

Be aware that the `maxPriceAge` can be slightly exceeded and configure the `maxPriceAge` as such.

## Resolution

GMX Team: Acknowledged.



# OCU-3 | Outdated NatSpec

Category	Severity	Location	Status
Documentation	● Low	OracleUtils.sol: 206	Resolved

## Description

The NatSpec for the `getUncompactedOracleBlockNumbers` function is outdated, it includes the wrong name for the `compactedOracleBlockNumbersLength` parameter and lacks reference to the reports and `oracleBlockNumberType` parameters.

## Recommendation

Update the NatSpec for the `getUncompactedOracleBlockNumbers` function.

## Resolution

GMX Team: The NatSpec for the `getUncompactedOracleBlockNumbers` was updated.

# OCL-6 | Hardcoded VerifierProxy

Category	Severity	Location	Status
Configuration	● Low	Oracle.sol: 86	Acknowledged

## Description

In the event that a new VerifierProxy is deployed by Chainlink the Oracle contract would have to be redeployed as the realtimeFeedVerifier variable is immutable.

However it may be more wieldy to allow the realtimeFeedVerifier implementation to be configurable in the event that a new proxy should be used.

## Recommendation

Consider allowing the realtimeFeedVerifier implementation to be configurable in the datastore rather than immutable.

## Resolution

GMX Team: Have checked with Chainlink that the VerifierProxy should not be changed.

# OCL-7 | Lack Of Realtime Feed Tokens Optimization

Category	Severity	Location	Status
Optimization	● Low	Oracle.sol: 525	Acknowledged

## Description

In the event that there are no `realtimeFeedTokens`, the `_validateRealtimeFeeds` function logic can be shortcut to avoid expending gas on extra opcodes.

## Recommendation

Consider implementing a `realtimeFeedTokens.length == 0` early return statement at the beginning of the `_validateRealtimeFeeds` function.

## Resolution

GMX Team: Acknowledged.

# EWDU-1 | Inconsistent Pool Value For Withdrawals

Category	Severity	Location	Status
Events	● Low	ExecuteWithdrawalUtils.sol: 321-329	Resolved

## Description

In the `_getOutputAmounts` function the pool value information emitted with the `MarketPoolValueUpdated` event is obtained with the following call:

```
MarketPoolValueInfo.Props memory poolValueInfo = MarketUtils.getPoolValueInfo(
    params.dataStore,
    . . .
    Keys.MAX_PNL_FACTOR_FOR_WITHDRAWALS,
    false
);
```

This differs from the call to `MarketUtils.getPoolValueInfo` in `_executeWithdrawal` since the `pnlFactorType` is set to `Keys.MAX_PNL_FACTOR_FOR_DEPOSITS` and the value is maximized:

```
MarketPoolValueInfo.Props memory poolValueInfo = MarketUtils.getPoolValueInfo(
    params.dataStore,
    . . .
    Keys.MAX_PNL_FACTOR_FOR_DEPOSITS, <---
    true <---
);
```

## Recommendation

Consider whether these parameters are desired for the data emitted in the `MarketPoolValueUpdated` event. If they are not, modify the `pnlFactorType` to `Keys.MAX_PNL_FACTOR_FOR_WITHDRAWALS` and set `maximize` to `false`.

## Resolution

GMX Team: The recommendation was implemented.

# OCL-8 | Bid/Ask Manipulation

Category	Severity	Location	Status
Protocol Manipulation	● Low	Oracle.sol	Acknowledged

## Description

Execution prices with realtime feeds are based on bid/ask spreads from a collection of reference exchanges, however, they do not consider the liquidity at any given bid or ask price. Therefore, a malicious actor may manipulate the lowest ask or increase the highest bid with a relatively small liquidity on a reference exchange and trade based on that synthesized lowest ask or highest bid with a significant size on GMX V2.

Any potential manipulation is however limited in magnitude to the spread between the bids and asks.

## Recommendation

Ensure that there is a sufficiently high minimum liquidity barrier to consider a bid or ask and that fees and price impact on the GMX V2 platform can effectively counteract the profitability of any such manipulation.

## Resolution

GMX Team: Have checked with Chainlink that liquidity will be taken into account for determining the bid and ask price.

# Disclaimer

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