HIMA

SMART SAFETY.

Manual

HIQuad®X

Safety Manual

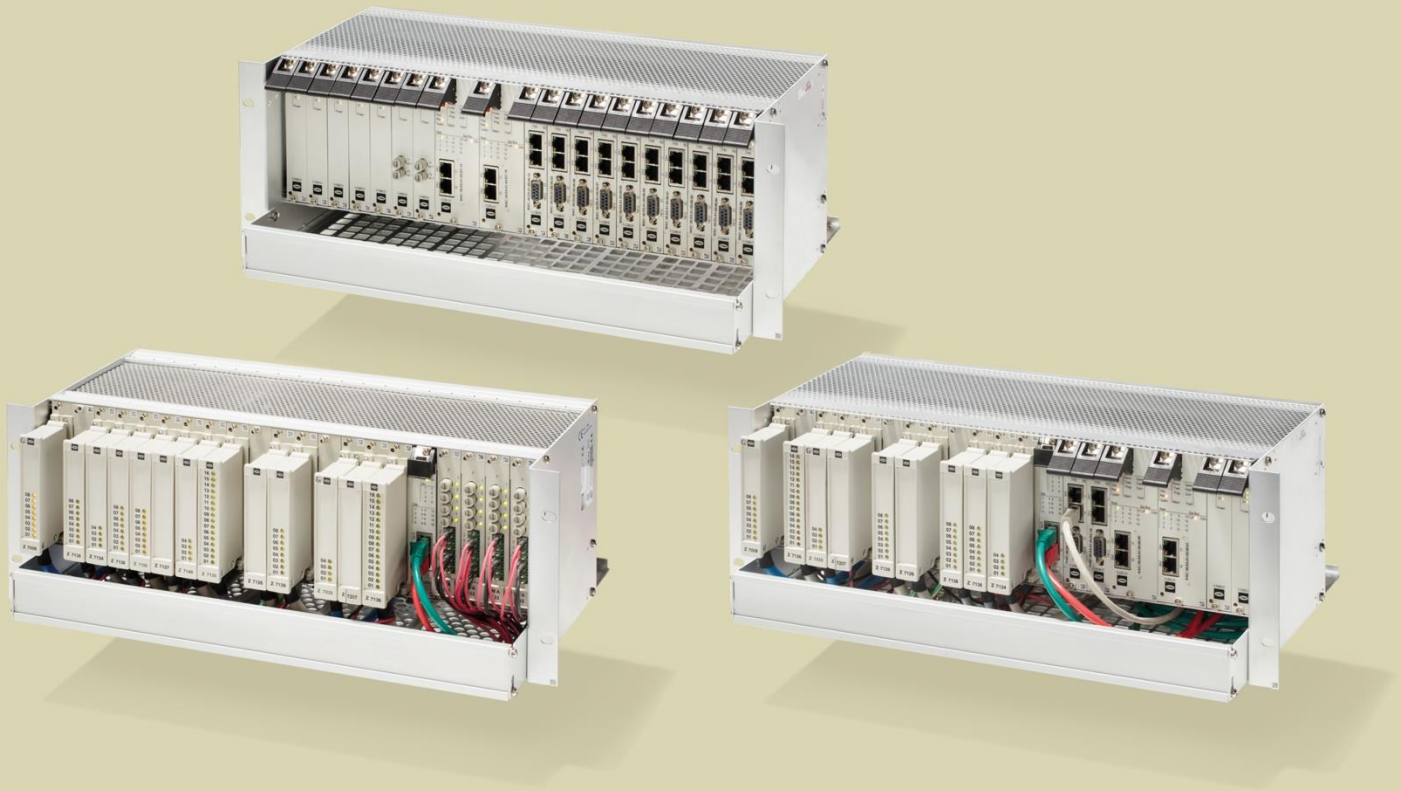

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Table of Contents

1 Introduction

This manual contains information on how to operate the safety-related programmable electronic system HIQuad X in the intended manner.

The following conditions must be met to safely install and start up the system and to ensure safety during their operation and maintenance:

- Knowledge of regulations.
- Proper technical implementation of the safety instructions detailed in this manual performed by qualified personnel.

HIMA will not be held liable for severe personal injuries, damage to property or the environment caused by any of the following:

- Unqualified personnel working on or with the systems.
- De-activation or bypassing of safety functions.
- Failure to comply with the instructions detailed in this manual.

HIMA develops, manufactures and tests the HIQuad X system in compliance with the pertinent safety standards and regulations. The use of the systems is only allowed if the following requirements are met:

- They are only used for the intended applications.
- They are operated under the specified environmental conditions.
- They are only connected to the approved external devices.

To provide a clearer exposition, this manual does not specify all details of all system versions.

This safety manual represents the "Original instructions" as of Machinery Directive (Directive 2006/42/EC).

The "Original documentation" for the HIMA system is written in German language. The statements made in the German documentation shall apply.

1.1 Validity and Current Version

This safety manual was created for the following versions:

- HIQuad X Operating systems in accordance with revision list.
- SILworX as of V12.

For details on how to use previous HIQuad X and SILworX versions, refer to the corresponding previous versions of this manual.

1.2 Target Audience

This document is aimed at the planners, design engineers, programmers and the persons authorized to start up, operate and maintain the automation systems. Specialized knowledge of safety-related automation systems is required.

1.3 Writing Conventions

To ensure improved readability and comprehensibility, the following writing conventions are used in this document:

Bold	To highlight important parts. Names of buttons, menu functions and tabs that can be clicked and used in the programming tool.
Italics	Parameters and system variables, references.
`Courier`	Literal user inputs.
RUN	Operating states are designated by capitals.
Chapter 1.2.3	Cross-references are hyperlinks even if they are not specially marked. In the electronic document (PDF): When the mouse pointer hovers over a hyperlink, it changes its shape. Click the hyperlink to jump to the corresponding position.

Safety notices and operating tips are specially marked.

1.3.1 Safety Notices

Safety notices must be strictly observed to ensure the lowest possible risk.

The safety notices are represented as described below.

- Signal word: warning, caution, notice.
- Type and source of risk.
- Consequences arising from non-observance.
- Risk prevention.

The signal words have the following meanings:

- Warning indicates hazardous situations which, if not avoided, could result in death or serious injury.
- Caution indicates hazardous situation which, if not avoided, could result in minor or moderate injury.
- Notice indicates a hazardous situation which, if not avoided, could result in property damage.

⚠ SIGNAL WORD

Type and source of risk!

Consequences arising from non-observance.

Risk prevention.

NOTICE

Type and source of damage!

Damage prevention.

1.3.2 Operating Tips

Additional information is structured as presented in the following example:

i	The text giving additional information is located here.

Useful tips and tricks appear as follows:

TIP	The tip text is located here.

1.4 Safety Lifecycle Services

HIMA provides support throughout all the phases of a plant's safety lifecycle, from planning and engineering through commissioning to maintenance of safety and security.

HIMA's technical support experts are available for providing information and answering questions about our products, functional safety and automation security.

To achieve the qualification required by the safety standards, HIMA offers product or customer-specific seminars at HIMA's training center or on site at the customer's premises. The current seminar program for functional safety, automation security and HIMA products can be found on HIMA's website.

Safety Lifecycle Services:	
Onsite+ / On-Site Engineering	In close cooperation with the customer, HIMA performs changes or extensions on site.
Startup+ / Preventive Maintenance	HIMA is responsible for planning and executing preventive maintenance measures. Maintenance actions are carried out in accordance with the manufacturer's specifications and are documented for the customer.
Lifecycle+ / Lifecycle Management	As part of its lifecycle management processes, HIMA analyzes the current status of all installed systems and develops specific recommendations for maintenance, upgrading and migration.
Hotline+ / 24 h Hotline	HIMA's safety engineers are available by telephone around the clock to help solve problems.
Standby+ / 24 h Call-Out Service	Faults that cannot be resolved over the phone are processed by HIMA's specialists within the time frame specified in the contract.
Logistics+/ 24 h Spare Parts Service	HIMA maintains an inventory of necessary spare parts and guarantees quick, long-term availability.

Contact details:	
Safety Lifecycle Services	https://www.hima.com/en/about-hima/contacts-worldwide/
Technical Support	https://www.hima.com/en/products-services/support/
Seminar Program	https://www.hima.com/en/products-services/seminars//

2 Use of the HIQuad X System

All safety information, notes and instructions specified in this manual must be strictly observed. The product may only be used if all guidelines and safety instructions are adhered to.

The product is operated with SELV or PELV. No imminent risk results from the product itself. Use in the Ex zone is only permitted if additional measures are taken.

2.1 Intended Use

This chapter describes the intended use of the safety-related automation system HIQuad X.

The automation system is designed for controlling and regulating industrial process plants. SILworX, HIMA's programming tool, is used for programming, configuring, monitoring, operating and documenting the HIQuad X system.

2.1.1 Application in Accordance with the De-Energize to Trip Principle

The HIQuad X system is designed in accordance with the de-energize to trip principle.

A system operating in accordance with the de-energize to trip principle switches off, for instance, an actuator to perform its safety function.

2.1.2 Application in Accordance with the Energize to Trip Principle

The HIQuad X system can also be used in applications that operate in accordance with the energize to trip principle.

A system operating in accordance with the energize to trip principle switches on, for instance, an actuator to perform its safety function.

When designing the automation system, the requirements specified in the application standards must be taken into account. For instance, line monitoring (SC/OC) for inputs and outputs or message reporting a triggered safety function may be required.

2.1.3 Use in Fire Alarm Systems

The HIQuad X systems with analog inputs are tested and certified for use in fire alarm systems in accordance with DIN EN 54-2 and NFPA 72.

The conditions of use provided in this manual must be observed, see Chapter 12.

2.1.4 Explosion Protection

The HIQuad X automation system is suitable for mounting in zone 2.

The conditions provided in Chapter 13 must be observed.

2.2 Tasks of Operators and Machine and System Manufacturers

Operators as well as machine and system manufacturers are responsible for ensuring that HIQuad X systems are safely operated in automated systems and plants.

Machine and system manufacturers must sufficiently validate that the HIQuad X systems were properly programmed.

2.2.1 Connecting to Communication Partners

Only devices with electrically protective separation may be connected to the communication interfaces.

2.2.2 Implementing Safety-Related Communications

When implementing safety-related communications between various devices, ensure that the overall response time does not exceed the process safety time.

All calculations must be performed in accordance with the rules given in Chapter 11.3and in the manuals for the communication protocols.

2.3 ESD Protective Measures

Only personnel with knowledge of ESD protective measures may work on the HIQuad X system.

NOTICE

Damage to the HIQuad X system due to electrostatic discharge!

- **When performing the work, make sure that the workspace is free of static, and wear a grounding strap.**
- **If not used, ensure that the modules are protected from electrostatic discharge, e.g., by storing them in their packaging.**

2.4 Additional System Documentation

In addition to this manual, the following documents for configuring the HIQuad X systems are also available:

Name	Content	Document no.
HIQuad X system manual	Hardware description of the modular system	HI 803 211 E
Certificates	Test results	---
Revision list	Operating system versions certified by the TÜV	---
Component-specific manuals	Description of the individual components	---
Maintenance manual	Description of significant operational and maintenance actions.	HI 803 213 E
Communication manual	Description of safeethernet communication and of the available protocols.	HI 801 101 E
Automation security manual	Description of automation security aspects related to the HIMA systems.	HI 801 373 E
SILworX first steps manual	Introduction to the use of SILworX for engineering, start-up, testing and operation.	HI 801 103 E
SILworX online help (OLH)	Instructions on how to use SILworX	---

Table 1: Overview of the System Documentation

All the current manuals can be obtained upon request by sending an e-mail to: documentation@hima.com. Registered customers can download the product documentation from the HIMA Extranet.

3 Safety Concept

This chapter contains important general information on the functional safety of HIQuad X systems.

- Safety and availability.
- Safety-relevant time parameters.
- Proof test.
- Safety requirements.
- Automation security.
- Certification.
  - CE declaration of conformity.
  - EC type test certificate.

3.1 Safety and Availability

Thanks to the 1oo2 microprocessor structure of the processor modules, the HIQuad X system is already approved for use as an automation safety-system up to safety integrity level 3 (SIL 3) in accordance with IEC 61508 as a mono system.

No imminent risk results from the HIQuad X automation systems.

⚠ WARNING

Possible physical injury caused by safety-related automation systems improperly connected or programmed.

Check all connections and test the entire system for compliance with the specified safety requirements before start-up!

Depending on the required availability, the HIQuad X system can be equipped with redundant processor modules (F-CPU 01), redundant communication modules (F-COM 01) and redundant I/O modules.

Redundant modules increase availability. If a module fault occurs, the faulty module automatically enters the safe state and the redundant module maintains operation with no interruption.

HIMA strongly recommends replacing failed modules as soon as possible to restore redundancy.

A failed module may be replaced during operation. The new module starts operation and automatically adopts the functionality of the failed module. This requires that the new module is of the same type or an approved replacement type.

If specific faults are present for longer than 24 h, additional system components are shut down for safety reasons.

3.1.1 Calculating the PFD and the PFH Values

The PFD (probability of failure on demand) and PFH (probability of failure per hour) values for the HIQuad X system have been calculated in accordance with IEC 61508.

For SIL 3, the IEC 61508-1 standard defines the following values:

PFD = 10^{-4}…10^{-3}.

PFH = 10^{-8}…10^{-7} per hour.

The values for PFD, PFH and SFF can be obtained upon request by sending an e-mail to: documentation@hima.com.

3.1.2 Self-Test and Fault Diagnostics

Comprehensive self-tests are performed in the HIQuad X system at start-up and during operation.

The operating system of the controllers executes comprehensive self-tests at start-up and during operation.

The scope of the testing includes:

- Processors.
- Memory areas (RAM, NVRAM).
- The watchdog.
- Connections between modules.
- Individual I/O channels of the I/O modules.
- The power supply.

If the HIQuad X system detects module faults during the self-test, the affected module will enter the safe state. If a module fault is already detected during start-up, the module will not start operation at all. If a channel fault occurs and the I/O module supports channel switch-off, only the failed channel is switched off. If an internal channel fault is detected during initialization, the channel or module will not be activated or start up.

If a fault occurs in mono systems, either the sub-functions or the entire system is shut down. If the application has a redundant configuration instead of a mono structure, the function is performed by the redundant modules or redundant channels.

Processor modules, I/O processing modules, communication modules and power supply modules are equipped with LEDs indicating detected faults. This allows the user to quickly diagnose module faults or faults detected in the external wiring.

Additionally, the SILworX programming tool provides system variables that allow the user program to evaluate the module states.

HIQuad X carries out an extensive diagnosis of the system behavior. The diagnostic messages and detected faults are stored to the diagnostic memory of the processor module and I/O processing module. Modules with a safety-related processor system perform their own diagnosis. The diagnostic messages can also be read out after a system fault using the programming tool.

For further details on how to evaluate diagnostic messages, refer to the HIQuad X system manual (HI 803 211 E).

For a very small number of component failures that do not affect safety, the HIQuad X system does not provide any diagnostic information.

3.1.3 PADT

The PADT is used to configure the controller and create the user program. The safety concept of the PADT supports the user in the proper implementation of the control task. The PADT implements numerous actions to verify the information entered.

The PADT is a personal computer installed with the SILworX programming tool.

3.1.4 Redundancy

To improve availability, all parts of the system including active components can be set up redundantly and, if necessary, replaced while the system is operating.

The component redundancy does not impair the system safety. Safety integrity level 3 (SIL 3) is guaranteed.

Redundancy affects the PFD and PFH values of the HIQuad X system, see Chapter 3.1.1.

3.1.5 Structuring Safety Systems in Accordance with the Energize to Trip Principle

Safety systems operating in accordance with the energize to trip principle have the following function:

1. The safe state of a module is the de-energized state. This state is adopted, for instance, if a fault has occurred in the module.
2. The controller can trigger the safety function on demand by switching on an actuator.

3.1.5.1 Detection of Failed System Components

Thanks to the automatic diagnostic function, the safety system is able to detect that modules have failed.

3.1.5.2 Safety Function in Accordance with the Energize to Trip Principle

The safety function is performed when the safety system energizes one or several actuators.

The users must plan the following actions:

- Include and configure a redundant module for every I/O module.
- Every I/O module must be provided with short-circuit and open-circuit monitoring. Short-circuit and open-circuit monitoring must be configured for each channel.
- The operation of the actuators can be monitored through a position feedback.

3.1.5.3 Redundancy of Components

It may be necessary to redundantly structure the following components:

- Power supply of the controller.
- HIQuad X modules.
- Sensors and actuators.

If redundancy is lost, the controller must be repaired as soon as possible.

For details on component redundancy, refer to the system manual (HI 803 211 E).

It is not required to design the safety system modules redundantly if, in the event of a safety system failure, the required safety level can otherwise be achieved, e.g., by implementing organizational measures.

3.2 Safety-Relevant Time Parameters

The following time parameters must be taken into account for the controller's safety considerations:

- Process safety time.
- Safety time (of the resource).
- Watchdog time (of the resource).
- Response time

i Resource refers to the image of the controller (PES) in the SILworX programming tool.

3.2.1 Process Safety Time

According to IEC 61508-4, the process safety time is the time interval between a failure of the EUC or the EUC control system with the potential to cause a hazardous event and the point in time when the EUC response must be completed to prevent the hazardous event from occurring.

During the process safety time, the process may allow faulty signals to exist without a hazardous state occurring.

A safety-related response of the controller including all delays due to sensors, actuators, I/O modules and process (response of the plant to a tripping) must occur within the process safety time.

3.2.2 The Safety Time [ms] Parameter (of the Resource)

The *Safety Time [ms]* parameter in the resource properties $\mathbf{t}_{SR}$ affects the response time of the resource $\mathbf{t}_{RR}$ as follows:

$$\mathbf{t}_{RR} \leq \mathbf{t}_{SR} + \mathbf{t}_{DO\ max.}$$

$\mathbf{t}_{SR}$ The *Safety Time [ms]* parameter

$\mathbf{t}_{DO\ max.}$ Maximum shutdown time of the output modules and the F 3430 relay module itself, see Table 2.

Module	$\mathbf{t}_{DO\ max.}$
F 3330	13 ms, in accordance with IEC 61131-2, Type 2
F 3331	18 ms, in accordance with IEC 61131-2, Type 2
F 3333	22 ms, in accordance with IEC 61131-2, Type 2
F 3334	21 ms, in accordance with IEC 61131-2, Type 2
F 3335	89 ms, in accordance with IEC 61131-2, Type 2
F 3349	7 ms, in accordance with IEC 61131-2, Type 2
F 3430	11 ms
F 6705	68 ms, current drop from 20 mA to 0/4 mA at a load of 550 Ohm

Table 2: Shutdown Times of the Output Modules

The following factors prolong the response time of the resource and must be taken into account during set-up:

- Physical delays, e.g., due to the switching times of external relays.
- Delays configured in the user program, e.g., the timer function blocks TON and TOF.
- Delays due to µP modules.

If one of the µP modules F 5220, F 6217, F 6220 or F 6221 with its own processor system is used, the delay of this modules must be taken into account:

$$t_{RR} \leq t_{SR} + t_{DO\ max.} + t_{D\ \mu P}$$

If several µP modules are used, then the module with the largest delay is the one to be considered, see Table 3.

µP module	$t_{D\ \mu P}$
F 5220	t_{SR} + 200 ms
F 6217	201 ms
F 6220	t_{SR} + 200 ms
F 6221	t_{SR} + 200 ms

Table 3: Delay of the µP Modules

Example: F 6220, t_{SR} = 1000 ms, $t_{DO\ max.}$ = 0

$$t_{RR} \leq t_{SR} + t_{DO\ max.} + t_{D\ \mu P}$$

$$t_{RR} \leq t_{SR} + 0 + t_{SR} + 200\ ms$$

$$t_{RR} \leq 2 \times t_{SR} + 200\ ms$$

$$t_{RR} \leq 2 \times 1000\ ms + 200\ ms$$

$$t_{RR} \leq \underline{2200\ ms}$$

The *Safety Time [ms]* parameter t_{SR} in the resource properties can be set in SILworX within 20…22 500 ms.

To ensure that the fault response is triggered within the configured resource safety time, the following requirements must be met:

- The user program must respond within a RUN cycle.
- No delays configured through the user program.
- The *Safety Time [ms]* parameter t_{SR} must be adjusted if the µP modules F 5220, F 6220 or F 6221 are used.

If the µP modules F 5220, F 6220 or F 6221 are used, the following conditions apply to the *Safety Time [ms]* parameter:

$$t_{SR} \geq 4 \times t_{WD}$$

$$t_{SR} \geq 1000\ ms$$

$$t_{WD} \geq 50\ ms$$

t_{WD} Watchdog time (of the resource)

3.2.3 Estimating the Watchdog Time

HIMA recommends meeting the following conditions to ensure sufficient availability of the controller:

$$3 \times t_{WD} \leq t_{SR}$$ **(***Safety Time [ms]* **parameter*)***

3.2.4 Determining the Watchdog Time through Testing

The watchdog time t_{WD} can be determined through testing during commissioning or start-up. To this end, the system must be in RUN and operated under full load. All engineered modules must be inserted and all the configured communication connections (e.g., safe**ethernet** and other standard protocols) must be operating.

The maximum system load results from synchronization, when the process modules are removed and reinserted. The watchdog time must be set so that synchronization at full load is always possible.

To perform the test

1. In the resource properties, set the *Safety Time [ms]* to the maximum value (22 500 ms).
2. In the resource properties, set the *Watchdog Time [ms]* to the maximum value (7 500 ms).
3. In the resource properties, set the *Maximum System Bus Latency [µs]* to the default value `System Defaults`.
4. Compile the configuration and load it into the controller by performing a download.
5. Start the resource (cold start).
6. Open the Control Panel for the resource and reset the cycle time statistics.

For the following steps, the system must be operated under full load.

7. Read out the maximum cycle time in the Control Panel, wait several minutes and note down the variations and load peaks.
8. In succession, remove all I/O processing modules (F-IOP 01) from the racks. Once the last I/O processing module has been removed, read the maximum system cycle time in the Control Panel and note it down.
9. Insert the removed I/O processing modules into the racks in any order and wait for the system to properly operate again.
10. Remove the processor module with the highest slot number from the base rack and reset the cycle statistics in the Control Panel.
11. Reinsert the processor module that has been removed in the previous step into the base rack and wait for it to be completely synchronized with the existing processor module. Afterwards, read the maximum cycle time in the Control Panel and note it down.

i When a redundant processor module is added, it automatically synchronizes with the configuration of the existing processor modules. The time required for synchronization extends the controller cycle.

12. Perform steps 10 and 11 using the processor module with the lowest slot number.

13. Use the noted times in the following equation:

t_{WD} $t_{Sync} + t_{Reserve} + t_{Com} + t_{Config} + t_{Peak}$

t_{Sync} Maximum synchronization time of the processor modules. Use the highest value resulting from steps 11 and 12.

$t_{Reserve}$ Safety margin 12 ms.

t_{Com} System parameter *Max. Com.Time Slice ASYNC [ms]*, which is configured in the resource properties

t_{Config} System parameter *Max. Duration of Configuration Connections [ms]*, which is configured in the resource properties.

t_{Peak} Maximum load peak of the cycle time (t_{Peak}). Use the highest value resulting from steps 7 and 8.

3.2.5 Typical Response Time

Assuming that no delay results from the configuration or the user program logic, the response time of HIQuad X controllers running in cycles is twice the cycle time of these systems are properly operating. The additional delays of the I/O modules used for a safety function must also be taken into account, see Table 2 and Table 3.

TIP For a conservative calculation of the response time during proper operation, HIMA recommends using the configured watchdog time instead of the cycle time.

3.3 Proof Test (in Accordance with IEC 61508)

The objective of the proof test is to detect dangerous hidden failures in a safety-related system so that, if necessary, it can be restored to its designed functionality. After a successful proof test, safe operation including the safety functions are ensured again.

The proof test execution depends on:

- The system characteristics (EUC = equipment under control).
- The system's risk potential.
- The standards used for operating the system.
- The standards applied by the test authority for the system's approval.

According to IEC 61508 1-7, IEC 61511 1-3, IEC 62061 and VDI/VDE 2180, Sheets 1 to 4, the operator of the safety-related systems is responsible for proof testing. The complete safety functions within the HIMA safety-related system must be checked during the proof test.

HIMA safety systems must be subject to a proof test in regular intervals. The proof test interval for HIMA controllers must be in accordance with the interval required by the application-specific safety integrity level (SIL).

The proof test execution is described in the maintenance manual (HI 803 213 E).

3.4 Safety Requirements

For using the safety-related HIQuad X automation system, the following safety requirements must be met:

3.4.1 Product-Independent Hardware Requirements

Personnel configuring the HIQuad X hardware must observe the following product-independent safety requirements.

- To ensure safety-related operation, approved fail-safe hardware and software components must be used. Approved HIMA components are listed in the HIQuad X version list.
  The latest versions can be found in the version list, which is maintained together with the test authority.
- The conditions of use specified in this safety manual about EMC, mechanical, chemical and climatic influences must be observed.
- Non-fail-safe, interference-free hardware components and software components can be used for processing non-safety-relevant signals, but not for handling safety-related tasks. Non-fail-safe components must not be used for processing safety-related tasks.
- The de-energize to trip principle must be applied to all safety circuits externally connected to the system.

3.4.2 Product-Dependent Hardware Requirements

Personnel configuring the HIQuad X hardware must observe the following product-dependent safety requirements.

- Only devices with electrically protective separation from the power supply may be connected to the system
- Only safety-related modules may be used to process safety-related tasks.
- The conditions of use detailed in the system manual, particularly those concerning supply voltage and climate, must be observed.
- Power must be supplied by power supply units complying with SELV and PELV. For the power supply units, the following applies:
  - **24 VDC** power supply: The voltage of the power supply units may not exceed 31 V.
  - **48 VDC** power supply: The voltage of the power supply units may not exceed 62 V.
- The requirements for power supply provided through the mains supply are the same as those applying to power supply units.

3.4.3 Product-Independent Programming Requirements

Personnel developing user programs must observe the following product-independent safety requirements:

- In safety-relevant applications, ensure that the safety-relevant system parameters are properly configured.
- In particular, this applies to the system configuration, maximum cycle time and safety time.

3.4.4 Product-Dependent Programming Requirements

The SILworX programming tool must be used for programming the HIQuad X system. The following requirements for using SILworX must be met.

- The application described in the specification must be validated, verified and its proper implementation must be documented. Functional tests must be performed to completely test the logic.
- If the user program is changed, all the logic parts affected by the changes must be tested.
- A system response to faults must be defined for faults in safety-related input and output modules in accordance with the application-specific safety-related requirements. These are for instance fault responses in the user program and the configuration of safe initial values for variables.

3.4.5 Communication

The following requirements for communication of data and to systems must be met.

- When implementing safety-related communications between various HIMA systems, ensure that the overall response time of the system does not exceed the worst case response time permitted for safe**ethernet** or HIPRO-S V2. All calculations must be performed in accordance with the rules given in Chapter *Worst Case Response Time for safe**ethernet***.
- During the transfer of (safety-relevant) data, IT security rules must be observed.
- The transfer of safety-relevant data through public or publicly accessible networks (e.g., the Internet, WLAN) is only permitted if additional security measures have been implemented, e.g., a VPN tunnel and firewall.
- If data is transferred through company/plant internal networks, administrative and technical measures must be implemented to ensure sufficient protection against manipulation (e.g., a firewall to separate the safety-relevant components of the network from other networks).
- Never use the standard protocols to transfer safety-related data.
- The communication interfaces must be connected to devices with electrically protective separation.

3.4.6 Maintenance

Operators are responsible for ensuring proper maintenance. They must take the required measures to ensure safe operation during maintenance.

Whenever necessary, the operator must consult with the test authority responsible for the application and determine the access to the system by implementing administrative and technical measures.

3.4.7 Temperature Monitoring

The temperature of the following modules is measured by embedded sensors and can be displayed and used in the programming tool.

- F-CPU 01
- F-IOP 01
- F-PWR 01
-

i The temperature can be used in the user program, e.g., as additional shutdown condition; however, the temperature is not recorded in a safety-related manner.

Temperature State may be used as an additional shutdown condition.

The user must implement suitable measures to ensure that the ambient temperature limits specified for the system are met.

3.4.8 Environmental Requirements

For using the safety-related HIQuad X automation system, the following general environmental requirements must be met:

General information	
Protection class	Protection class II in accordance with IEC/EN 61131-2
Ambient temperature	0…+60 °C
Transport and storage temperature	-40…+70 °C
Pollution	Pollution degree II in accordance with IEC/EN 60664-1
Installation height	< 2000 m
Enclosure	Standard: IP20 If required by the relevant application standards (e.g., EN 60204), the system must be installed in an enclosure with the specified degree of protection (e.g., IP54).
Power Supply Input Voltage	24 VDC

Table 4: Environmental Requirements

Refer to the relevant data sheets for potential deviations.

3.5 Automation Security

HIMA distinguishes between the terms *safety*, which refers to functional safety, and *security*, which refers to the system protection against manipulation.

Industrial controllers (PES) must be protected against IT-specific problem sources, for instance:

- Inadequate protection of IT equipment (e.g., open WLAN, obsolete operating systems).
- Lack of awareness of proper use of the equipment (e.g., USB sticks).
- Direct access to protected areas.
- Attackers inside the company premises.
- Attackers via communication networks inside and outside the company premises.

HIMA safety systems are composed of the following parts to be protected:

- Safety-related automation system.
- PADT.
- Optional X-OPC Server (on a host PC)
- Optional communication connections to external systems.

3.5.1 Product Properties

The HIQuad X controller with basic settings already fulfils the requirements for automation security.

Protective mechanisms for preventing unintentional or unapproved modifications to the safety system are integrated into the controllers and the programming tool:

- Each change to the user program or controller configuration results in a new configuration CRC.
- Online changes of the safety parameters can be deactivated in the controller. Therefore, changes to the safety parameters are only possible by performing a download or reload.
- The user can set up a user management scheme to increase security. This scheme is used to specify the user groups, user accounts, access permissions for PADT and controllers (PES) for each project. In the user management scheme, the user can define if an authorization is required to open the project and log in to a controller.
- The data of a controller can only be accessed if the user projects loaded in the PADT and controller are the same. The CRCs must be identical (archive maintenance!).
- A physical connection between PADT and controller (PES) is not required during operation and must be interrupted for security reasons. The PADT can be reconnected to the controller for diagnostic and maintenance purposes.

The requirements of the safety and security standards must be complied with. The operator is responsible for authorizing personnel and implementing the required protective actions.

⚠ WARNING

Physical injury possible due to unauthorized manipulation of the controllers!

Protect the controllers against unauthorized access!!

- **Change the default settings for login and password.**
- **Supervise access to controllers and PADTs!**
- **For further protection measures, refer to the automation security manual (HI 801 373 E).**

3.5.2 Risk Analysis and Planning

Security is a process, not a product. Maintained network maps, for instance, help to ensure that secure networks are permanently separated from public networks. It is recommended to only have one well-defined connection, e.g., via a firewall or a DMZ (demilitarized zone).

Careful planning should identify the necessary measures. The required measures are to be implemented after the risk analysis is completed, and may include:

- Assignment of access permissions for user groups and user accounts according to the intended tasks.
- Use of passwords in accordance with the security requirements.

A periodical review of the security measures is necessary, e.g., every year.

i **The operator is responsible for implementing the necessary measures in a way suitable for the plant!**

Refer to the HIMA automation security manual (HI 801 373 E) for more details.

3.6 Certification

The HIQuad X programmable electronic system complies with the standards listed in this chapter.

3.6.1 CE Declaration of Conformity

With respect to performance and design, the HIQuad X automation system complies with international and European Directives, and also meets complementary national requirements. Conformity was declared through the CE marking.

The declaration of conformity for the automation system can be found on the website www.hima.com/en or obtained by sending an e-mail request to: documentation@hima.com.

3.6.2 EC Type Test Certificate

The test institute TÜV Rheinland has tested and certified the safety-related HIQuad X automation system for applications in accordance with the functional safety standards. The safety-related HIQuad X automation system is provided with the following mark of conformity:

TÜV Rheinland Industrie Service GmbH
Automation, Software and Information Technology
Am Grauen Stein
51105 Köln

EC type test certificate
Safety-Related Programmable System
HIQuad X

3.6.3 Current Standards

The HIQuad X safety-related automation system is tested in accordance with the following functional safety standards and is certified by the TÜV:

International standards:	Safety level
IEC 61508, Parts 1-7:2010	SIL 3
IEC 61511-1:2016 + Corr.1:2016 + AMD1:2017	SIL 3
EN ISO 13849-1:2015 [1)]	PL e
EN 62061:2005 + AC:2010 + A1:2013 + A2:2015	SIL CL 3
EN 50156-1:2015	SIL 3
EN 12067-2:2004	---
EN 298:2012	---
EN 60079-0:2012 + A11:2013	---
EN 60079-11:2012	---
EN 60079-15:2010	---
NFPA 72:2016	---
NFPA 85:2015	---
NFPA 86:2015	---
EN 61131-2:2007	Zone B
EN 61131-6:2012	---
EN 61326-3-1:2017	---
EN IEC 61326-3-2:2018	---
EN 54-2:1997 + AC:1999 + A1:2006 [2)]	---
EN 50130-4:2011 + A1:2014 [2)]	---
EN 61000-6-7:2015	---

1) Exception: The F 3430 module is not certified in accordance with EN ISO 13849-1.

2) Exception: The F 3330 module may not be used for applications in accordance with these standards.

Table 5: International Standards and Safety Levels

The following chapter contains a detailed list of all environmental and EMC tests performed.

3.6.4 Test Requirements

The HIQuad X system has been tested for compliance with the following standards related to EMC, climatic, mechanical and voltage testing:

Standard	Content
IEC/EN 61131-2 Zone B	Programmable controllers Part 2: Equipment requirements and tests
IEC/EN 61000-6-2	Electromagnetic compatibility (EMC) Part 6-2: Generic standards – Immunity for industrial environments
IEC/EN 61000-6-4	Electromagnetic compatibility (EMC) Part 6-4: Generic standard – Emission standard for industrial environments
EN 298	Automatic burner control systems for burners and appliances burning gaseous or liquid fuels
EN 61326-1	Electrical equipment for measurement, control and laboratory use - EMC requirements Part 1: General requirements
EN 61326-3-1	Electrical equipment for measurement, control and laboratory use - EMC requirements Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - General industrial applications
EN 61326-3-2	Electrical equipment for measurement, control and laboratory use - EMC requirements Part 3-2: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - Industrial applications with specified electromagnetic environment
EN 50130-4	Alarm systems Part 4: Electromagnetic compatibility - Product family standard: Immunity requirements for components of fire, intruder, hold up, CCTV, access control and social alarm systems
EN 54-2	Fire alarm systems

Table 6: Standards for EMC, Climatic and Environmental Requirements

Higher interference levels are required for safety-related systems. HIQuad X systems meet these requirements in accordance with IEC 62061 and IEC 61326-3-1.

IEC/EN 61000-6-4	Noise emission tests
EN 55011 Class A	Emission test: radiated, conducted

Table 7: Noise Emission Tests

3.6.4.1 Climatic Tests

The following table lists the most important tests and limits for climatic requirements:

Standard	Climatic tests
IEC/EN 61131-2	Dry heat and cold; withstand tests: +70 °C / -40 °C, 16 h, +85 °C, 1 h Power supply not connected.
	Temperature changes, withstand test: Fast temperature changes: -40 °C / +70 °C, power supply not connected.
	Immunity test Slow temperature changes: -10 °C / +70 °C power supply connected.
	Cyclic damp-heat; withstand tests: +25 °C / +55 °C, 95 % relative humidity, Power supply not connected.
EN 54-2	Damp-heat 93 % relative humidity, 40 °C, 4 days in operation 93 % relative humidity, 40 °C, 21 days, power supply not connected.

Table 8: Climatic Tests

3.6.4.2 Mechanical Tests

The following table lists the most important tests and limits for mechanical requirements:

Standard	Mechanical tests
IEC/EN 61131-2	Vibration immunity test: 5…8.4 Hz / 3.5 mm. 8.4…150 Hz / 1 g, controller in operation, 10 cycles per axis
	Shock immunity test: 15 g, 11 ms, HIQuad X in operation, 3 shocks per axis and direction (18 shocks)

Table 9: Mechanical Tests

3.6.4.3 EMC Tests

The controller meets the requirements of the EMC Directive of the European Union, see the system's EU Declaration of Conformity.

All controller modules meet the requirements of the EMC Directive of the European Union (2014/30/EU) and bear the CE marking.

The controller responds safely to interferences exceeding the specified limits.

3.6.4.4 Supply Voltage

The following table lists the most important tests and limits for the supply voltage:

Standard	Verification of the DC supply characteristics
IEC/EN 61131-2	The power supply must at least comply with one of the following standards or meet one of the following requirements: ▪ IEC 61131-2 ▪ SELV (Safety Extra Low Voltage) ▪ PELV (Protective Extra Low Voltage)
	The HIQuad X system must be fuse-protected as specified in the data sheets.
	Voltage range test: 24 VDC, -20…+25 % (19.2…30.0 VDC).
	Momentary external current interruption immunity test: DC, PS 2: 10 ms.
	Reversal of DC power supply polarity test.
	Backup duration, withstand test: Test A, 300 h at 60 C, Goldcap for date/time.

Table 10: Verification of the DC Supply Characteristics

4 Processor Module (F-CPU 01)

The safety-related processor module is composed of two microprocessors, each with its own RAM, that simultaneously process the same programs, operating systems and the user program. A hardware comparator continuously aligns the data from the two microprocessors and those from the memories. The processor module reports detected differences and automatically enters the ERROR STOP state.

The processor module carries out many additional self-tests such as the program sequence monitoring (watchdog).

4.1 Self-Tests

The operating system of the processor module executes comprehensive self-tests at start-up and during operation. If the operating system detects single faults that could cause a hazardous operating state to occur, the faulty components are switched off. This is the safe state and is performed within the safety time.

The scope of the testing includes:

- The microprocessors.
- Memory areas (RAM, NVRAM).
- The watchdog.
- The I/O buses inside the controller.
- The power supply.

4.2 Responses to Faults in the Processor System

If the processor module detects an internal module fault, an entry is written to the diagnostic history. Subsequently, a reboot is performed.

After the first reboot due to faults, the processor module restarts and, once all self-tests are complete, attempts to start system operation. If the internal module fault is still present, the processor module performs a second reboot.

If a further internal fault occurs within the first minute after restart, the processor module no longer participates in the system's operation.

If the last processor module fails, the entire system stops system operation, i.e., the protocol connections are closed, the outputs are de-energized.

4.3 Replacing Processor Modules

Prior to replacing a processor module, ensure that the replacement will not cause a running HIQuad X system to stop.

In particular, this applies for systems running in accordance with the energize to trip principle. The failure of such systems causes the loss of the safety function.

Redundant processor modules can be replaced during operation, provided that the redundant processor module is still available, which maintains safety-related operation while the other module is being replaced.

NOTICE

Interruption of safety-related operation possible!

Replacing a processor module with a lit or blinking Ess **LED can result in the interruption of a controller's operation.**

Do not remove processor modules if the Ess **LED is lit or blinking.**

A lit or blinking **Ess** LED indicates that the processor module is essential for the system to function.

Even if the LED is not lit or blinking, the system redundancies, which this processor module is part of, must be checked using SILworX. The communication connections processed by the processor module must also be taken into account.

For further details on how to replace processor modules, refer to the processor module manual (HI 803 214 E) and to the system manual (HI 803 211 E).

5 Communication Module (F-COM 01)

Communication modules are used for both exchanging safety-related data with other HIMA controllers and for exchanging standard data via fieldbuses and Ethernet.

- The processor module controls the safety-related data exchange with the SIL 3-certified transmission protocols safe**ethernet** and HIPRO-S V2. The communication module forwards the data to the connected HIMA controllers. The safety-related safe**ethernet** protocol ensures that corrupted messages are detected (black-channel principle).

  This allows safety-related communication via non safety-related transmission paths, i.e., standard network components.
- The supported standard protocols are specified in the communication manual (HI 801 101 E).

Refer to the following documents for further details on communication and communication modules:

- This manual, Chapter 11.1.
- Communication module manual (HI 803 223 E)
- Communication manual (HI 801 101 E).
- System manual (HI 803 211 E).

6 I/O Processing Module (F-IOP 01)

I/O processing modules within the HIQuad X system communicate with the processor modules in the base rack via the two safety-related system buses. Additionally, the I/O processing module manages the internal I/O bus of the rack in which it is located.

The system buses are used to transmit data via a safety-related protocol. A HIQuad X system that **only** contains **one processor module** can be operated at a reduced availability level using one system bus only.

I/O processing modules cannot be wired redundantly. If redundancy is required at the I/O level, a redundant extension rack must be used. For an overview of the different HIQuad X system concepts, refer to the system manual (HI 803 211 E).

The safety-related I/O processing module is equipped with a 1oo2 processor system (HICore 2). A hardware comparator continuously aligns the data from the internal microprocessors and those from the memories. The I/O processing module reports detected differences and automatically enters the ERROR STOP state.

The I/O processing modules monitor the 5 V power supply of the racks on which they are installed. If the minimum voltage is underrun, I/O processing modules switch off the I/O level of their rack.

The I/O processing modules test and monitor the I/O modules in one rack and report their states. Additionally, the I/O processing modules provide the watchdog signal for the output modules.

I/O processing modules provide the input values of the I/O modules in a rack to the user program. The user program's output values are sent to the I/O processing module, which writes them to the output modules. The output modules thus control the field level, e.g., the actuators.

6.1 Self-Tests

The operating system of the I/O processing module executes comprehensive self-tests at start-up and during operation. If the operating system detects single faults that could cause a hazardous operating state to occur, the faulty components are switched off. This is the safe state and is performed within the safety time.

The scope of the testing includes:

- The microprocessors.
- Memory areas (RAM, NVRAM).
- The watchdog.
- The I/O buses.
- The 5 V supply voltage.
- The internal voltages.

6.2 Responses in the Event of Faults

If a failure occurs on a system bus, communication is ensured via the redundant system bus, provided that both system buses have been previously configured.

If the system runs in mono operation with only one processor module, the redundant system bus is not available.

If a disturbance affects the I/O bus, no process data are transmitted. The I/O level is no longer available to the system.

The module reports faults through the LEDs on the front plate.

If faults occur, all the output modules inserted in the extension rack use the second shutdown option to enter the safe state. The input module data are no longer sent.

6.3 Responses to Faults in the Processor System

The I/O processing module reports differences detected by the hardware comparators and automatically enters the ERROR STOP state. The I/O processing module also enters the ERROR STOP state if the hardware comparator fails.

A hardware comparator within the I/O processing module constantly checks if the data from the internal microprocessor 1 is identical to the data from microprocessor 2. If this is not the case or the test routines detect a fault in the I/O processing module, the I/O processing module automatically enters the ERROR STOP state.

6.4 Rack ID

The rack ID is used for unambiguously identifying the individual racks within the system. A 10-pole DIP switch on the I/O processing module is used to set the rack ID. A unique rack ID that matches the configuration in SILworX must be allocated to each rack. The rack ID of the H51X base rack is 0 since no I/O processing module is used in this rack. For a description of the rack IDs and DIP switches, refer to the I/O processing module manual (HI 803 219 E).

The rack ID is the **safety parameter** for addressing the racks and the modules inserted in them!

6.5 Service Mode

The I/O processing module is equipped with a service mode function. This allows the users to replace the I/O modules within a rack during operation without having to switch off the entire I/O level of a rack. To replace the I/O modules during operation, the service mode must be activated for the I/O processing module.

When the service mode is active, I/O module faults requiring that the affected rack is shut down, are suppressed. The system issues a warning for the affected rack. This warning is signaled via the rack connection indicators.

i If the service mode is active, the second shutdown option (via the I/O watchdog) is blocked! This option cannot be used to put the output modules in the safe state.

The service mode is either activated or deactivated using the service push-button (SERV) on the front side of the I/O processing module or via a PADT command.

The service mode stops automatically 24 h after activation, unless it was manually deactivated beforehand.

If the user deactivates the service mode, the system remains in service mode until the faulty or replaced I/O modules have been initialized and no modules report a fault after initialization is complete. After 24 h, the system deactivates the service mode.

If 24 h after activation the service mode is automatically deactivated, no I/O modules are re-initialized. If faults requiring the rack to shut down are still present in the rack (e.g., a missing output module), the I/O watchdog (second shutdown option) , is switched off and all output modules within the rack enter the safe state.

The SERV push-button can be locked using the *Deactivate service mode push-button*. If the SERV push-button is locked through the user program, then the service mode can only be controlled through a PADT command.

To replace I/O modules

1. Press the service mode push-button (SERV) on the I/O processing module (F-IOP 01) located in the rack of the I/O modules to be replaced, for 2 s to 7 s. Alternatively, select the I/O processing module with the *Start Service Mode* PADT command to switch to the module's service mode.
   ☑ The *Service Mode Active* system parameter is TRUE.
   ☑ Step result (optional). When the I/O processing module operates in service mode, the red LEDs *Slot* and *Chn* are blinking.
2. Completely release the fastening screws from the I/O module to be replaced.
3. Unscrew the cable plug or remove the I/O module with inserted cable plug.
4. Insert the new I/O module without cable plug and screw it in place. Observe the description provided in the system manual!
5. Plug in the cable plug and screw it in place.
6. Repeat steps 2 through 5 for each module to be replaced.
7. Press the service mode push-button (SERV) on the I/O processing module (F-IOP 01) for 2 to 7 seconds or deactivate the service mode using the *Initiate termination of service mode PADT* command.
   ☑ The *Service Mode Active* system parameter is FALSE.
   ☑ The LEDs of the I/O processing module report the regular module and channel diagnosis.

► The I/O modules have been replaced and are operating again without faults.

For further details on the service mode, refer to the F-IOP 01 manual (HI 803 219 E).

7 Input Modules

The following table provides an overview of the input modules of the HIQuad X system:

Digital input modules [1)]	Channels	Safety-related	(Ex)i
F 3221	16	---	---
F 3224A	4	---	X
F 3236	16	X	---
F 3237	8	X	---
F 3238	8	X	X
F 3240	16	X	---
F 3248	16	X	---
Analog input modules [1)]	Channels	Safety-related	(Ex)i
F 6215	8	---	---
F 6217	8	X	---
F 6220	8	X	X
F 6221	8	X	X
Counter module [1)]	Channels	Safety-related	(Ex)i
F 5220	2	X	

[1)] Interference-free: When a module performing part of a safety function is not affected by other operating modules. This applies irrespective of whether the modules are safety-related or not.

Table 11: Overview of the Input Modules

7.1 General Information

Safety-related inputs may be used for safety-related as well as for non-safety-related signals. Non-safety-related signals, however, may not be used for safety functions!

The safety-related input modules F 5220, F 6217, F 6220 and F 6221 are equipped with their own 1oo2 processor system that allows for increased module complexity. The 1oo2 processor system of these modules automatically carries out safety-related tests during operation and transmits safe data to the I/O processing system.

The safety-related input modules without processor system are automatically subjected to a high-quality, cyclic self-test during operation. The input modules include wiring elements ensuring that the module function is tested with special test routines integrated in the operating system (I/O processing module). These test routines ensure the safe functioning of the corresponding input module.

Detection of faults during the self-tests automatically triggers a safety-related response of the I/O processing system and generates the corresponding error messages. The detailed error messages can be evaluated in the user program by reading out the error codes.

The input modules in HIQuad X may restart automatically (automatic restart). As soon as a detected error is no longer present, the input modules automatically resume processing incoming values. In HIQuad, by contrast, the ACK key needs to be pressed first. The automatic restart can be deactivated in SILworX.

To ensure the module's proper operation, HIMA cable plugs must be used.

For further details on the input modules, refer to the module-specific manuals.

7.2 Response in the Event of a Fault

If a fault is detected at the signal inputs, the user program processes the input's initial value. A module fault in the input module causes the user program to process the initial value for all the inputs. The initial value of the global value must be configured in SILworX accordingly (default value = 0).

In addition to the *Slot* and *Chn* LEDs on the I/O processing modules, error and status messages are generated and saved in the processor module. These can be read out from the diagnostic memory using the PADT.

To increase availability, the safety-related input modules can also be used redundantly. Redundant input modules do not impair the system safety, see Chapter 3.1.1.

The status and error messages as well as the system variables can be used to program application-specific fault responses. For further details, refer to the module-specific manual.

7.3 Safety of Sensors, Encoders and Transmitters

In safety-related applications, the controller (PES) and connected sensors, encoders and transmitters must all meet the safety requirements and achieve the specified SIL. For details on how to achieve the required SIL for sensors, refer to the IEC 61511-1 standard, Section 11.4.

7.4 I/O Noise Blanking

If noise blanking is active, the system does not respond to transient interference. In such cases, the interference does not immediately de-energize the outputs and has no effects on the data sources.

For further details on noise blanking, refer to the HIQuad X system manual (HI 803 211 E).

Noise blanking only operates within the resource safety time and only if the resource safety time is ≥ 3 × resource watchdog time.

i Noise blanking is permanently active on the F 5220, F 6220 and F 6221 input modules and cannot be deactivated. The activation field in SILworX is grayed out and has no functionality.

7.5 Safety-Related Digital Input Modules F 3236, F 3237, F 3238, F 3240 and F 3248

The input modules read the digital signals at the inputs and provide failsafe values to the user program in every processor module cycle.

7.5.1 Test Routines

The test routines check whether the input channels are able to forward both signal levels (low and high), irrespective of the signals actually present on the input. This functional test is performed while the input signals are being read. If an error occurs, the initial value is processed for each input.

Additionally, the modules for proximity switches and mechanical contacts with line monitoring test the wire up to the sensor. Safety-related proximity switches can be connected to these modules. Self-tests ensure that all requirements for detecting thresholds in safety-related proximity switches are met.

Wiring with two resistors in accordance with the manual is required for the sensor current monitoring of a mechanical contact.

7.5.2 Redundancy of Digital Inputs

Digital inputs may be wired redundantly. The redundant connection is used to increase the availability of the inputs.

7.5.3 Surges on Digital Inputs

Due to the short cycle time of the HIQuad X systems, a surge pulse as described in EN 61000-4-5 can be read in to the digital inputs as a short-term high level.

If shielded cables are used for digital inputs, no additional precautionary measures are required to protect against surges.

The following measures ensure proper operation in environments where surges may occur:

- Install shielded input wires.
- Program noise blanking in the user program. A signal must be present for at least two cycles before it is evaluated. The fault response is triggered with a corresponding delay.

i The measures specified above are not necessary if the plant design precludes surges within the system.

In particular, the design must include protective measures with respect to overvoltage, lightning, ground grounding and plant wiring in accordance with the relevant standards and the instructions specified in the system manual (HI 803 211 EE).

7.6 Safety-Related F 5220 Counter Module

This 2-channel counter module has its own 1oo2 processor system with one safety-related output for each channel. Depending on its configuration, the module can be used to gather the following process values:

- Pulse count.
- For measuring the frequency or the rotational speed via an adjustable gate time.
- For limit value monitoring through cycle-independent output operation with comparison functions.
- Detection of rotation direction.

The counter module processes pulses to the following frequency in a safety-related manner:

$$\mathbf{f_{max} = 2^{22} / (t_{SR} + 100\ ms)}$$

The safety time of the resource $\mathbf{t_{SR}}$ operating in *Pulse Count* mode depends on the maximum frequency $\mathbf{f_{max}}$ up to which the counter inputs may be operated in a safety-related manner:

$$\mathbf{t_{SR} = (2^{22} / f_{max}) - 100\ ms}$$

If the gate time is modified, the correct measured value is only available at the output after three gate times.

The counter module does not need the I/O watchdog signal for operation. The absence of the I/O watchdog signal has no effects on the counter module function nor on their switching outputs.

For further details, refer to the module-specific manual (HI 803 191 E).

7.6.1 Test Routines

The module has a 1oo2 processor system that automatically carries out the safety-related self-tests and provides the data to the user program.

If the test routines detect a module fault, both safety-related outputs are switched off. If a channel fault occurs, the safety-related output allocated to the affected channel is switched off.

7.6.2 Behavior in the Event of Short-Circuits and Open-Circuits

If a short-circuit or open-circuit is detected at a counter input, the module switches off the corresponding safety-related output. The *-> Process Value OK [BOOL]* parameter is set to FALSE.

7.6.3 Redundancy of Counter Inputs

Counter inputs may be wired redundantly. The redundant connection increases the availability of the inputs.

The redundant connection of two counter modules must be implemented with the user program since SILworX does not support the creation of redundancy groups for counter modules.

7.6.4 Configuration Notes

Observe the following points when engineering the module:

- Noise blanking is always active. Pulses occurring during noise blanking are not counted. For safety-related operation, the *Lock Restart [BOOL] ->* parameter must be set to TRUE!
- Test mode is configured in the Hardware Editor and is only permitted during start-up or for test purposes!
  The following parameters are intended for test mode and must not be used in the user program during normal operation:
  - *Test Mode [BOOL] ->*
  - *Maximum Test Mode Time [ms]* > 0
  - *-> Remaining Time Test Mode [s] [UDINT]*
  - *Force Value Active [BOOL] ->*
- Line monitoring is only active in *Proximity Switch Pulse* mode. If a short-circuit or an open-circuit is detected on the counter inputs, the corresponding parameter *-> SC [BOOL]* or *-> OC [BOOL]* is set to TRUE.

7.7 Safety-Related Analog F 6217 Input Module

The module has a 1oo2 processor system that automatically carries out the safety-related self-tests and provides the data to the user program. The analog value is available for each channel as a raw value (data type DINT) and as a scaled process value (data type REAL).

7.7.1 Test Routines

The module uses the test D/A converter to apply test values and tests these values with the A/D converter with which the input signal is digitized.

7.7.2 Redundancy of Analog Inputs

Analog inputs may be wired redundantly. The redundant connection is used to increase the availability of the inputs.

If 2 inputs are redundantly configured, the larger of the two scaled values is written to the redundant system parameter *-> Process Value [REAL].* This applies provided that both modules are in proper working order. If faults occur, only the value of the functional module is processed. This requires an identical signal source for both inputs, e.g., a measured value. Deviation between the two measured values is only permitted within the safety-related accuracy.

7.7.3 Configuration Notes

To ensure safety-related use, the limit values for short-circuits and open-circuits must be configured in SILworX for each channel. HIMA recommends retaining the preset NAMUR values for open-circuits (3.6 mA) and short-circuits (21 mA).

A safety-related evaluation is only permissible within 0…21 mA. A metrological accuracy exceeding this range cannot be ensured.

The -> *Process Value [REAL]* parameter automatically adopts the configured initial value if the limit values are violated or if an internal channel fault occurs. The users must adopt measures in the user program to ensure that this initial value causes the respective safety function to enter the safe state.

The -> *Raw Value [1 mA = 10 000] [DINT]* parameter may only be used under the following conditions:

1. Measuring range 0…21 mA
2. Additional evaluation of the -> *Process Value OK [BOOL]* parameter within the user program. FALSE must cause the respective safety function to enter the safe state.
3. Evaluation of the limit values for open-circuits and short circuits as -> *Process Value OK [BOOL]* automatically changes to FALSE when the set limit values are exceeded. Alternatively, the thresholds can also be evaluated in the user program.
4. Programming of a substitute value (initial value) in the user program, which causes the respective safety function to enter the safe state.

7.8 Safety-Related Analog F 6220 Input Module

The analog input and temperature module has 8 channels for connecting thermocouples of various types and one reference temperature input for connecting to a Pt 100 resistance thermometer. The channels are implemented with the type of protection Intrinsic Safety and are safely separated from the output and power supply circuit. The module is equipped with its own 1oo2 processor system.

The inputs can also be used to measure low voltages, see module.

7.8.1 Test Routines

The module has a 1oo2 processor system that automatically carries out the safety-related self-tests and provides the data to the user program. Each of the 9 channels (8 + 1) provides safe input values and a safe fault status.

7.8.2 Redundancy of Analog F 6220 Input Modules

Analog inputs may not be wired redundantly to connect to thermocouples. If two input modules are redundant to one another, each input channel must be connected to its own thermocouple.

The redundant connection is used to increase the availability of the inputs.

If 2 inputs are redundantly configured, the larger of the two scaled values is written to the redundant system parameter -> *Process Value [REAL].* This applies provided that both modules are in proper working order. If faults occur, only the value of the functional module is processed. This requires an identical signal source for both inputs, e.g., a measured value. Deviation between the two measured values is only permitted within the safety-related accuracy.

7.8.3 Configuration Notes

To ensure safety-related use, the limit values preset in SILworX for short-circuits and open-circuits must be set in accordance with their use. The limit values must be configured individually for each channel.

A safety-related evaluation of the setting *Voltage Input* is only permissible within -100…+100 mV. A metrological accuracy exceeding this range cannot be ensured.

A safety-related evaluation of the setting *Thermocouple Type X* is only permissible within the monitored operating range specific to each thermocouple type. Refer to the F 6220 data sheet (HI 803 194 E) for details. A metrological accuracy exceeding the monitored operating ranges cannot be ensured. Additionally, the cold junction temperature range for Pt100 (-40 … +80 °C) must be maintained.

The -> *Process Value [REAL]* parameter automatically adopts the configured initial value if the limit values are violated or if an internal channel fault occurs. The users must adopt measures in the user program to ensure that this initial value causes the respective safety function to enter the safe state.

The -> *Raw Value [1 °C/1 mV = 10 000] [DINT]* parameter may only be used under the following conditions:

1. The measuring range for the voltage input or for the thermocouples is maintained. The cold junction temperature range for Pt100 (-40 … +80 °C) is maintained.
2. Additional evaluation of the -> *Process Value OK [BOOL]* parameter within the user program. FALSE must cause the respective safety function to enter the safe state.
3. Evaluation of the limit values for open-circuits and short circuits as -> *Process Value OK [BOOL]* automatically changes to FALSE when the set limit values are exceeded. Alternatively, the thresholds can also be evaluated in the user program.
4. Programming of a substitute value (initial value) in the user program, which causes the respective safety function to enter the safe state.

Additionally, observe the following points:

- Unused inputs must be short-circuited.
- The cold junction temperature for operation in accordance with SIL 3 must be taken directly from the user program or must be determined by comparing the cold junction temperatures of two modules within the user program.
- For SIL 3, the thermocouple temperature must be determined by comparing the temperatures of two different thermocouples.
- All possible deviations must be considered and taken into account when evaluating the measured values.

7.9 Safety-Related Analog F 6221 Input Module

The analog input module has 8 channels to directly connect analog transmitters from the (Ex) zone. The channels are implemented with the type of protection Intrinsic Safety and are safely separated from the output and power supply circuit. The transmitter supply voltage can be ensured through the F 3325 supply module or another power supply in accordance with the data sheet specifications. This transmitter voltage supply must be connected to the F 6221 module for monitoring purposes.

7.9.1 Test Routines

The module has a 1oo2 processor system that automatically carries out the safety-related self-tests and provides the data to the user program. Each of the 8 channels provides safe input values and a safe fault status.

7.9.2 Redundancy of Analog Inputs

Analog inputs may be wired redundantly. The redundant connection is used to increase the availability of the inputs.

If 2 inputs are redundantly configured, the larger of the two scaled values is written to the redundant system parameter -> *Process Value [REAL].* This applies provided that both modules are in proper working order. If faults occur, only the value of the functional module is processed. This requires an identical signal source for both inputs, e.g., a measured value. Deviation between the two measured values is only permitted within the safety-related accuracy.

7.9.3 Configuration Notes

To ensure safety-related use, the limit values for short-circuits and open-circuits must be configured in SILworX for each channel. HIMA recommends retaining the preset NAMUR values for open-circuits (3.6 mA) and short-circuits (21 mA).

A safety-related evaluation is only permissible within -2…+22 mA. A metrological accuracy exceeding this range cannot be ensured.

The -> *Process Value [REAL]* parameter automatically adopts the configured initial value if the limit values are violated or if an internal channel fault occurs. The users must adopt measures in the user program to ensure that this initial value causes the respective safety function to enter the safe state.

The -> *Raw Value [1 mA = 10 000] [DINT]* parameter may only be used under the following conditions:

1. Measuring range -2…22 mA
2. Additional evaluation of the -> *Process Value OK [BOOL]* parameter within the user program. FALSE must cause the respective safety function to enter the safe state.
3. Evaluation of the limit values for open-circuits and short circuits as -> *Process Value OK [BOOL]* automatically changes to FALSE when the set limit values are exceeded. Alternatively, the thresholds can also be evaluated in the user program.
4. Programming of a substitute value (initial value) in the user program, which causes the respective safety function to enter the safe state.

Additionally, observe the following points:

- Unused voltage inputs 0...1 V must be short-circuited on the terminal block.
- Unused current inputs are terminated with a shunt in the cable plug.
- Only the applications described in the F 6221 data sheet are allowed.
- The Ex protection regulations and Ex connection requirements must be observed.

7.10 Checklist for Safety-Related Inputs

HIMA recommends using the available checklists for engineering, programming and starting up safety-related inputs. The checklist can be used as a planning document and also serve as proof of careful planning.

When engineering and starting up the system, a checklist must be filled out for each of the safety-related input channels used in the system to verify the requirements to be met. This is the only way to ensure that all requirements were considered and clearly recorded. The checklist also provides documentation about the relationship between the external wiring and the user program.

The current checklists can be obtained upon request by sending an e-mail to: documentation@hima.com. The checklists are available for registered HIMA customers in the download area https://www.hima.com/en/downloads/.

8 Output Modules

The following table provides an overview of the HIQuad X output modules:

Digital output modules[1)]	Channels	Safety-related	Load capacity
F 3322	16	---	≤ 0.5 A
F 3330	8	X	≤ 0.5 A
F 3331	8	X	≤ 0.5 A
F 3333	4	X	≤ 2 A
F 3334	4	X	≤ 2 A
F 3335	4 (Ex)i	X	22 V ≤ 0.053 A
F 3349	8	X	≤ 48 V ≤ 0.5 A
Relay output modules[1)]	Channels	Safety-related	Load capacity
F 3422	8	---	≤ 60 V ≤ 2 A
F 3430	4	X	≤ 250 V ≤ 4 A
Analog output modules[1)]	Channels	Safety-related	Load capacity
F 6705	2	X	0…20 mA
F 6706	2	---	0…20 mA

[1)] Interference-free: When a module performing part of a safety function is not affected by other operating modules. This applies irrespective of whether the modules are safety-related or not.

Table 12: Overview of the Output Modules

8.1 General Information

The safety-related output modules write the values created by the user program to the outputs once per cycle. The output signals are read back and compared with the specified output data.

Additionally, all outputs for which the switched-on channels are briefly switched off and switched-off channels are briefly switched on are subject to background tests. The test pulses are present in the F 3330, F 3333, F 3335 and F3430 for 250 µs. For F 3331, F 3334 and F 3349, the duration of pulse tests and the test interval can be configured, see the module-specific manuals.

These tests ensure that the switchability of the outputs is checked without affecting the function of the connected actuators, if these tolerate the test duration of 250 µs. As a result, the freezing (switch welding) of each output is detected, even if the output signal is static.

The output modules in HIQuad X may restart automatically (automatic restart). As soon as a detected error is no longer present, the output modules automatically return the values created in the user program to the outputs. In HIQuad, by contrast, the ACK key needs to be pressed first. The automatic restart can be deactivated in SILworX.

If inductors or lamp loads are connected, the test pulse duration configured for output modules with line monitoring must be checked and, if necessary, extended. The safe state of the outputs is 0 or an open relay contact.

To ensure the module's proper operation, HIMA cable plugs must be used.

8.2 Response in the Event of a Fault

The foreground and background tests of the output modules provide the following responses if a fault occurs:

- A module fault always causes the module and its outputs to enter the safe de-energized state.
- An output module that can no longer be addressed by the F-IOP module causes all the output modules within a rack to switch off since the safe state of the output module can no longer be checked. To replace an output module during operation, the service mode must first be activated on the I/O processing module (F-IOP)
- If a high level is present on an output of digital output module switched off by the user program instead a low level as expected, the I/O processing module reports a module fault and the output module enters the safe de-energized state.
- If a low level is present on an output of digital output modules switched on by the user program instead of a high level as expected, the I/O processing module reports a channel fault.
- If a background test detects that an output of digital output modules with a high level cannot be switched off the I/O processing module returns a module warning. HIMA recommends removing the cause of the module warning within 24 h since all output modules within the affected racks will enter the safe state after this time. On the other hand, if an output cannot be switched off when changing from high-level to low-level, the output module immediately enters the de-energized state.
- If a background test detects that an output of digital output modules with a low level cannot be switched on, the I/O processing module returns a module warning. If the module warning is still present once the background test has been completed, the output module enters the safe, de-energized state.
- If a short-circuit to L- or an overload is detected on a channel activated by a user program (within a F 3331 or F 3334 module), the I/O processing module reports a module fault and the output module enters the de-energized state. Additionally, if the system parameter *SC/OC Active* is active and *SC/OC Mode [UINT] ->* is set to 1 or 2, the system variable *SC* in the channel affected by the short-circuit is set to TRUE. Observe the hardware revision status of the F 3334 output module, see Chapter 8.5.3.
- A short-circuit detected on L- or an overload at an output of the F 3349 module causes the channel to switch off. The switched off channel is switched on again after approximately 4.5 seconds if the fault is no longer present.
- The digital output modules F 3330 through F 3335 do not support switching off individual channels.
- In current source mode, all faults detected in any of the modules cause the analog F 6705 output module to enter the safe, de-energized state. In current sink mode, the module can only enter the safe, de-energized state by switching off the external voltage source. The user program must shut down the voltage supply for the current loop safely.
- If an F 3330, F 3333, F 3335 or F 3430 module is shut down due to a fault and the automatic restart is activated for the module, 1 ms test pulses can be actuated in the field in intervals of 1 s!
- If an F 3331 or F 3334 module is shut down due to a fault and the automatic restart is activated for the module, test pulses can be actuated in the field in intervals of 1 s! Depending on the value configured for the Max. Test Pulse Duration [ms] system parameter, the following values result:
  - If the value is 0, the resulting maximum test pulse duration is 1 ms.
  - If the configured value is 50, the resulting maximum test pulse duration is 50 ms.
- If an F 3349 module is shut down due to a fault and the automatic restart is activated for the module, 100 µs test pulses can be actuated in the field in intervals of 100 ms!
- If an F 6705 module is shut down due to a fault and the automatic restart is activated for the module, 16 ms test pulses can be actuated in the field in intervals of 16 s!

8.3 Safety of Actuators

In safety-related applications, the controller (PES) and connected actuators must all meet the safety requirements and achieve the specified SIL. For details on how to achieve the required SIL for actuators, refer to the IEC 61511-1 standard, Section 11.4.

8.4 I/O Noise Blanking

If noise blanking is active, the system does not respond to transient interference. In such cases, the interference does not immediately de-energize the outputs and has no effects on the data sources.

For further details on noise blanking, refer to the HIQuad X system manual (HI 803 211 E).

Noise blanking only operates within the resource safety time and only if the resource safety time is ≥ 3 × resource watchdog time.

8.5 Safety-Related Digital Output Modules F 3330, F 3331, F 3333, F 3334, F 3335, F 3349

The output modules ensure the safety function using 3 safety switches connected in series for each channel where 2 are implemented as safety switches. If a fault is detected in the output voltage or safety switch, the safety switches causes all the outputs to enter the de-energized state.

Each safety switch can be individually switched off via the I/O bus. If a fault occurs and an output module cannot be switched off via the I/O bus, the second, independent shutdown option (I/O watchdog) is used to place the output module in the de-energized state.

If a module fault occurs, this integrated safety function safely de-energizes all the channels (de-energized state).

8.5.1 Test Routines

The modules are tested automatically during operation. The main test functions are:

- Reading back the output signals. The switching threshold for a read-back low level is ≤ 6.5V, this does not apply to the F 3349.
- Checking the integrated redundant safety shutdown.
- Testing of read-back units; this only applies to the F 3349.
- Applying the test patterns during the background test with configurable test intervals and maximum test pulse duration.
- Reading the line monitoring (SC/OC) for the switched-on channel, if existing.
- Reading the line monitoring (SC/OC) for all the channels during the test pattern test, if existing.

8.5.2 Redundancy of Digital Outputs

Digital outputs may be wired redundantly. The redundant connection is used to increase the availability of the outputs.

8.5.3 Engineering Notes

Open-circuit monitoring requires a minimum load of 10 mA.

The minimum load required for redundant channels is twice as high (20 mA).

As of hardware revision status AS03, the F 3334 output module no longer detects short-circuits. The *-> LS [BOOL]* system variable may not be evaluated as of hardware revision AS03.

Prior to deleting an F 3330, F 3331, F 3333 or F 3334 module from the project configuration, the outputs must be set to the safe (switched-off)state, e.g., the forcing process must be stopped for outputs that are being forced to high level.

8.6 Safety-Related F 3430 Relay Module

Relay modules are connected to the actuator under any of the following circumstances:

- Electric and galvanic separation is required.
- Higher amperages are to be connected.
- Alternating currents are to be connected.

8.6.1 Test Routines

The modules are tested automatically during operation. The main test functions are:

- Reading the output signals back from the diverse, 3-channel relay switch.
- Checking the integrated redundant safety shutdown.
- Applying the test patterns and testing for crosstalk (walking bit test) during the background test.

8.6.2 Behavior in the Event of External Short-Circuit

External short-circuits cause the fuse for the relevant channel to trigger. No error message is issued.

8.6.3 Redundancy of Relay Outputs

Relay inputs may be wired redundantly. The redundant connection is used to increase the availability of the outputs.

8.6.4 Engineering Notes

Relays are electromechanical components with limited lifetime due to their construction. The lifetime of relays depends on the switching capacity of the contacts (voltage/current) and the number of switching cycles.

At nominal operating conditions, the lifetime is approx. 300 000 switching operations at 30 VDC and 4 A.

To meet the IEC 61508 requirements (PFD/PFH, see Chapter 3.1.1), the proof-test interval is 5 years for SIL 3 applications and 20 years for SIL 2 applications.

The required tests are performed by HIMA.

8.7 Safety-Related Analog F 6705 Output Module

The analog outputs forward the values determined in the user program to the actuators.

The analog F 6705 module can be operated in current source or current sink mode. In current source mode, the de-energized state (output current = 0 ma) is the safe state.

The initial values must be set to 0 to ensure that the input variables transmit the value 0 to the user program if a fault occurs.

In current sink mode, the module can only enter the safe state if additional measures are implemented. The user program must safely shut down the supply voltage for the current loop.

8.7.1 Test Routines for Analog Outputs

The modules are tested automatically during operation. The main test functions are:

- Reading back of the output signals.
- Linearity testing of the D/A converter.
- Crosstalk testing between the outputs.
- Checking the integrated redundant safety shutdown.

8.7.2 Behavior in the Event of External Short-Circuit or Overload

An external open-circuit cannot be distinguished from internal faults and shuts down the module.

8.7.3 Redundancy of Analog Outputs

Analog outputs may be wired redundantly. The analog connection is used to increase the availability of the outputs. For details on the redundant output wiring, refer to the F 6705 module manual (HI 803 196 E).

8.8 Replacing Output Modules

If a fault occurs or maintenance work is necessary and the output modules need be replaced, the service mode option on the I/O processing module (F-IOP) must be activated beforehand, see Chapter 6.5. Additionally, the *Deactivate service mode push-button* system parameter must be deactivated.

8.9 Checklist for Safety-Related Outputs

HIMA recommends using the checklists for engineering, programming and starting up safety-related outputs. The checklist can be used as a planning document and also serve as proof of careful planning. The checklists are available in Microsoft® Word® format on the HIMA website.

When engineering and starting up the system, a checklist must be filled out for each of the safety-related output channels used in the system to verify the requirements to be met. This is the only way to ensure that all requirements were considered and clearly recorded. The checklist also provides documentation about the relationship between the external wiring and the user program..

The current checklists can be obtained upon request by sending an e-mail to: documentation@hima.com. The checklists are available for registered HIMA customers in the download area https://www.hima.com/en/downloads/.

9 Software

The software for the safety-related HIQuad X automation system includes the following parts:

- SILworX programming tool in accordance with IEC 61131-3.
- Operating system.
- User program.

The user program, which contains the application-specific functions to be performed by the automation system, is used to create the user program. The programming tool is used to configure and operate the operating system functions of the hardware components.

The code generator integrated in the programming tool translates the user program into a machine code. The programming tool uses the Ethernet interface to transfer this machine code to the flash EPROM of the automation system.

9.1 Safety-Related Aspects of Operating Systems

Each approved operating system is clearly identified by the revision number and the CRC signature. The valid versions of the operating system and corresponding signatures (CRCs) - approved by the TÜV for use in safety-related automation devices - are subject to a revision control and are documented in a version list.

The Revision List of HIQuad X Systems of HIMA Paul Hildebrandt GmbH is created and maintained by HIMA Paul Hildebrandt GmbH in co-operation with the TÜV Rheinland GmbH.

The current version of the operating system can only be read using the SILworX programming tool. Users must ensure that the operating system versions loaded in the modules are valid.

9.2 Operation and Functions of Operating Systems

The operating system executes the user program cyclically. In a simplified form, it performs the following functions:

- Reading of the input data.
- Processing of the logic functions, programmed in accordance with IEC 61131-3.
- Writing of the output data.

The following basic functions are also executed:

- Comprehensive self-tests.
- Test of inputs and outputs during operation.
- Data transmission.
- Diagnostics.

9.3 Safety-Related Aspects of Programming

When creating or changing a user program, the requirements detailed in this chapter must be observed.

9.3.1 Safety Concept of SILworX

The safety concept for the SILworX programming tool includes the following points:

- When SILworX is installed, a CRC checksum ensures the programming tool's integrity on the way from the manufacturer to the user.
- SILworX performs validity checks to reduce the likelihood of faults while entering data.
- SILworx compiles the program twice and compares the resulting configuration CRCs (checksums) to one another. This ensures that data corruption in the application due to temporary faults in the PC in use is detected.
- SILworX and the measures defined in this safety manual make it sufficiently improbable that a code generated properly from a semantic and syntactic view point can still contain undetected systematic faults resulting from the code generation process.

When starting up a safety-related controller for the first time, a comprehensive functional test must be performed by the user to verify the safety of the entire system.

- Verify whether the control tasks were properly implemented based on the data and signal flows.
- Verify the logic of all functions by trial.

If a user program is changed, at least the program components affected by the change must be tested. The safety-related SILworX version comparison can be used to determine and prove changes compared to a previous version.

Whenever the safety-related controller is started up, the verification and validation requirements specified in the application standards must be observed!

9.3.2 Verifying the Configuration and the User Programs

To check the user programs for compliance with the safety functions, the user must create suitable test cases that validate the specified safety functions.

An independent test of each individual loop (consisting of input, processing including user connections, output) is usually sufficient.

Suitable test cases must be created for the numerical evaluation of formulas. The evaluation can be performed, for instance, using equivalence class tests. The test cases must be selected such that the calculations can be proven to be correct. The required number of test cases depends on the formula used and must include critical value pairs.

HIMA recommend performing an active simulation with data sources. This will prove that the sensors and actuators in the system are properly wired. The same also applies to sensors and actuators that are connected to the system via remote I/Os.

SILworX can be used as test equipment for:

- Checking inputs.
- Forcing outputs.

This procedure must be followed both when initially creating the user program and when modifying it.

9.3.3 Archiving a Project

HIMA recommends archiving the project after each download or reload.

SILworX stores all a project's data to a single file. For reasons of data security, HIMA recommends additionally storing the project on an external medium.

9.3.4 Identifying Configuration and Programs

Changes to a program cause the CRC to change and therefore affect the configuration CRC.

To determine the changes to the current configuration, the project is compared to a saved or loaded configuration. The individual changes can be proved using the safe SILworX version comparison.

9.4 Resource Parameters

Some parameters are defined in SILworX for actions permitted during the resource's safety-related operation and are referred to as safety parameters.

⚠ WARNING

Physical injury possible due to invalid configuration!

Neither the programming tool nor the controller can verify the configured project-specific parameters. For this reason, enter the safety parameters correctly in the programming tool and verify the whole entry upon completion of the PES load from within the controller.

These parameters are:

- **For the rack ID, refer to the system manual (HI 803 211 E).**
- **The parameters marked as safety-related in Table 13.**

Settings that may be defined for safety-related operation are not firmly bound to any specific requirement classes. Instead, each of these must be agreed upon together with the competent test authority for each separate implementation of the controller.

9.4.1 Resource System Parameters

The system parameters of the resource determine how the controller will behave during operation. The system parameters can be set in SILworX, in the *Properties* dialog box of the resource.

Parameter	S [1)]	Description	Setting for safe operation
Name	N	Name of the resource.	Any
System ID [SRS]	Y	System ID of the resource. Range of values: 1…65 535 Default value: 60 000 The value assigned to the system ID must differ from the default value, otherwise the project is not able to run!	Unique value within the controller network. This network includes all controllers that can potentially be interconnected.
Safety Time [ms]	Y	For details on the safety time of the resource (in milliseconds), refer to the safety manual (HI 801 003 E). Range of values: 20…22 500 ms Default value: 600 ms (can be changed online)	Application-specific
Watchdog Time [ms]	Y	For details on the watchdog time of the resource (in milliseconds), refer to the safety manual (HI 801 003 E). Range of values: 6…7500 ms Default value: 200 ms (can be changed online)	Application-specific
Target Cycle Time [ms]	N	Target or maximum cycle time, see *Target Cycle Time Mode*. Range of values: 0…7500 ms Default value: 0 ms (can be changed online) The maximum target cycle time value may not exceed the configured *Watchdog Time [ms]* minus the minimum value that can be set for *Watchdog Time [ms]* (6 ms, see above); otherwise the entry is rejected. If the default value is set to 0 ms, the target cycle time is not taken into account. For further details, refer to the following chapters.	Application-specific
Target Cycle Time Mode	N	For details on the use of the *Target Cycle Time [ms],* see the following chapters. Default value: *Fixed-tolerant* (can only be changed online).	Application-specific
Multitasking Mode	N	Mode 1 The duration of a CPU cycle is based on the required execution time for all user programs. Mode 2 The processor provides the execution time portion not needed by lower priority user programs to higher priority user programs. Mode of operation for high availability. Mode 3 The processor waits until the execution time not needed by the user programs has expired, thus increasing the cycle. Default value: Mode 1	Application-specific
Max. Com.Time Slice [ms]	N	Highest value in ms for the time slice used for communication during a resource cycle, see the communication manual (HI 801 101 E). Range of values: 2…5000 ms Default value: 60 ms	Application-specific

Parameter	S [1)]	Description	Setting for safe operation
Optimized Use of Com. Time Slice	N	The system parameter reduces the response times for communications via processor module(s). i This can affect the temporal utilization of *Max.Com. Time Slice ASYNC [ms]* and the system parameter *Max. Duration of Configuration Connections [ms]* such that these two times can be subject to more demands (e.g., during reload).	---
Max. Duration of Configuration Connections [ms]	N	This defines how much time within a CPU cycle is available for configuration connections. Range of values: 2...3500 ms Default value: 20 ms For further details, refer to the following chapters.	Application-specific
Maximum System Bus Latency [µs]	N	Maximum delay of a message between an I/O processing module and a processor module. Settings: System defaults or 100…50,000 µs Default value: System Defaults i A license is required for setting the maximum system bus latency to a value ≠ *System Defaults*.	---
Allow Online Settings	Y	TRUE: **All** the switches/parameters listed under FALSE can be changed online using the PADT. This is only valid if the system variable *Read-only in RUN* has the value FALSE. Default value: TRUE. FALSE: The following parameters **cannot** be changed online: ▪ *System ID* ▪ *Autostart* ▪ *Global Forcing Allowed* ▪ *Global MultiForcing Allowed* ▪ *Global Force Timeout Reaction* ▪ *Load Allowed* ▪ *Reload Allowed* ▪ *Start Allowed* The following parameters can be changed online if *Reload Allowed* is TRUE. ▪ *Watchdog Time (for the resource)* ▪ *Safety Time* ▪ *Target Cycle Time* ▪ *Target Cycle Time Mode* *Allow Online Settings* can only be TRUE when the controller is stopped or by performing a reload.	HIMA recommends using the FALSE setting.

Parameter	S [1)]	Description		Setting for safe operation
Autostart	Y	TRUE:	If the processor module is connected to the supply voltage, the user programs start automatically. Default value: TRUE.	Application-specific
		FALSE:	The user program does not start automatically after connecting the supply voltage.	
		Observe the settings in the resource program properties!		
Start Allowed	Y	TRUE:	Cold start or warm start permitted with the PADT in RUN or STOP. Default value: TRUE.	Application-specific
		FALSE:	Start not allowed.	
Load Allowed	Y	TRUE:	Configuration download is allowed. Default value: TRUE.	Application-specific
		FALSE:	Start not allowed.	
Reload Allowed	Y	TRUE:	Configuration reload is allowed. Default value: TRUE.	Application-specific
		FALSE:	Configuration reload is not allowed. A running reload process is not aborted when switching to FALSE.	
Global Forcing Allowed	Y	TRUE:	Global forcing is permitted for this resource. Default value: TRUE.	Application-specific
		FALSE:	Global forcing is not permitted for this resource.	
Global Force Timeout Reaction	N	Specifies how the resource should behave when the global force timeout has expired: ▪ *Stop Forcing Only*. ▪ *Stop Forcing* and *Stop Resource*. Default value: *Stop Forcing Only*.		Application-specific
Global MultiForcing Allowed	Y	TRUE:	Users with MultiForcing access can write force data (force values and individual force switches) for global variables in a resource if the required higher-order conditions have been met and the force permissions have been granted.	Application-specific
		FALSE:	Users with MultiForcing access cannot force global variables. Default value: FALSE (can be changed online).	

Parameter	S [1)]	Description	Setting for safe operation
Minimum Configuration Version	N	With this setting, it is possible to generate code that is compatible with previous or newer HIQuad X operating system versions in accordance with the project requirements. The installed SILworX version is the default setting. HIQuad X is only supported as of SILworX V10. Any setting to a SILworX version prior to V10 is rejected for HIQuad X. An error message is displayed in the logbook! For further details, refer to the chapter on the *Minimum Configuration Version p*arameter.	Application-specific
Fast Start-Up	Y	Not applicable to HIQuad X.	---
[1)] The operating system handles the system parameter in a safety-related manner, yes (Y) or no (N).			

Table 13: Resource System Parameters

9.4.1.1 Use of the Parameters *Target Cycle Time* and *Target Cycle Time Mode*

Using the settings for the *Target Cycle Time Mode* system parameter, the cycle time can be maintained as constant as possible at the value of *Target Cycle Time [ms]*. To do this, the system parameter must be set to a value > 0.

In doing so, HIQuad X limits reload and synchronization on the redundant modules to ensure that the target cycle time is maintained.

The following table describes the settings for the *Target Cycle Time Mode* system parameter.

Setting	Description
Fixed	If a CPU cycle is shorter than the defined Target Cycle Time, the CPU cycle is extended to the target cycle time. If the CPU cycle takes longer than the target cycle time, the CPU resumes the cycle without delay. i A reload or synchronization process is rejected if the reserve time is not sufficient (target cycle time minus actual cycle time).
Fixed-tolerant	Similar to *Fixed*, but with the following differences: 1. To ensure that the synchronization process can be performed successfully, the target cycle time may be violated for a CPU cycle. 2. To ensure that the reload can be performed successfully, the target cycle time may be violated for 1 to n CPU cycles (where n is the number of changed user programs). The default setting is *Fixed-tolerant*! i After the first reload activation cycle, the values of watchdog time, target cycle time and target cycle time mode apply in accordance with the new configuration. A maximum of every fifth cycle can be extended during the reload. One single cycle may be extended during synchronization.
Dynamic	The CPU processes each CPU cycle as fast as possible. This corresponds to a target cycle time of 0 ms. i A reload or synchronization process is rejected if the reserve time is not sufficient (target cycle time minus actual cycle time). A maximum of every fifth cycle can be extended during the reload. One single cycle may be extended during synchronization.
Dynamic-tolerant	Similar to *Dynamic*, but with the following differences: 1. If necessary, the target cycle time is automatically increased for one CPU cycle to ensure that the synchronization process can be performed successfully. 2. To ensure that the reload can be performed successfully, the target cycle time may be automatically increased for 1 to n CPU cycles (where n is the number of changed user programs). i After the first reload activation cycle, the values of watchdog time, target cycle time and target cycle time mode apply in accordance with the new configuration. A reload or synchronization process is rejected if the reserve time is not sufficient (target cycle time minus actual cycle time).

Table 14: Settings for Target Cycle Time Mode

9.4.1.2 Maximum Communication Time Slice

The maximum communication time slice is the time period in milliseconds (ms) per CPU cycle assigned to the processor module for processing the communication tasks.

If not all upcoming communication tasks can be processed within one CPU cycle, the whole communication data is transferred over multiple CPU cycles (number of communication time slices > 1). However, safety-relevant monitoring is always performed in each CPU cycle for all the protocols.

For calculating the maximum response time, the number of communication time slices must be equal to 1.

If the CPU cycle uses the communication time slice, the duration of the communication time slice must be set so that the CPU cycle cannot exceed the watchdog time specified by the process.

9.4.1.3 Determining the Maximum Duration of the Communication Time Slice

For a first estimate of the maximum duration of the communication time slice, the sum of the following times must be entered in the *Max. Com. Time Slice [ms]* system parameter located in the properties of the resource.

- For each communication module (F-COM): 3 ms.
- For each redundant safe**ethernet** connection: 1 ms.
- For non-redundant safe**ethernet** connection: 0.5 ms.
- For each kilobyte user data of non-safety-related protocols, e.g., Modbus: 1 ms.

HIMA recommends comparing the value estimated for *Max. Com. Time Slice [ms]* with the value displayed in the Control Panel and, if necessary, correcting it in the properties of the resource. This can be done during an FAT (factory acceptance test) or SAT (site acceptance test).

To determine the actual duration of the maximum communication time slice

1. Operate the HIQuad X system under full load (FAT, SAT):
   All communication protocols are in operation (safe**ethernet** and standard protocols).
2. Open the **Control Panel** and select the **Com. Time Slice** structure tree folder.
3. Read the vale displayed for *Maximum Com. Time Slice Duration per Cycle [ms].*
4. Read the value displayed for *Maximum Number of Required Com. Time Slice Cycles*.

9.4.1.4 Calculating the *Maximum Duration of Configuration Connections [ms]* T_{Config}

The *Max. Duration of Configuration Connections [ms]* system parameter corresponds to the time budget ($\mathbf{t}_{Config}$) required for the system-internal communication connections (tasks):

- PADT online connections (e.g., download/reload, OS update, online test, diagnostics).
- Remote I/O status connections (start, stop and diagnostics).
- Configuration of modules (e.g., loading of replaced modules).

If these tasks cannot be completed within one CPU cycle, the remaining tasks are processed in the next CPU cycle. This can cause unexpected delays for these tasks.

i HIMA recommends dimensioning $\mathbf{t}_{Config}$ in such a way that all tasks can be processed in a single CPU cycle.

$\mathbf{t}_{Config}$ for F-CPU 01 processor modules is calculated as follows:

F-CPU 01: $\mathbf{t}_{Config} = (\mathbf{n}_{Com} + \mathbf{n}_{PADT}) * 1\ ms + \mathbf{n}_{RIO} * 0.25\ ms + 4\ ms + 4 * (\mathbf{t}_{Latency} * 2 + 0.8\ ms)$

$t_{Config:}$	System parameter *Max. Duration of Configuration Connections [ms]*
$n_{COM:}$	Number of modules with Ethernet interfaces (F-CPU, F-COM)
$n_{PADT:}$	5, maximum number of PADT connections
$n_{RIO:}$	Number of configured remote I/Os
$t_{Latency:}$	Use the active maximum system bus latency, see the following descriptions. If the value of the maximum system bus latency is expressed in µs, it must be divided by 1000 before the calculation to obtain the value in ms.

If *System Defaults* is selected for the *Maximum System Bus Latency [µs]* parameter, the value 2.2 ms must be used in the upper formula. If a value of 100…50 µs was manually entered for $t_{Latency}$, then this value must be used in the upper formula as $t_{Latency}$.

TIP The current system bus latency is displayed in the Control Panel.

When generating the code or converting the project, a warning message is displayed in the PADT logbook if the value defined for $\mathbf{t}_{Config}$ is less than the value resulting from the previous equation.

i Setting the value for $\mathbf{t}_{Config}$ too low can significantly impair the performance of PADT online connections (tasks) and cause the connection to remote I/Os to be aborted.

HIMA recommends comparing the value calculated for $\mathbf{t}_{Config}$ with the value displayed in the Control Panel and, if necessary, correcting it in the properties of the resource. This can be done during a SAT (site acceptance test).

For test purposes, $\mathbf{t}_{Config}$ can also be set online in the Control Panel.

The value set for $\mathbf{t}_{Config}$ must be taken into account for dimensioning the required watchdog time. For details, refer to the section on safety-relevant time parameters.

9.4.1.5 The Minimum Configuration Version Parameter

- The highest *Minimum Configuration Version* is always selected for new projects. Verify that this setting is in accordance with the operating system version in use.
- In a previous project converted to the current SILworX version, the value for *Minimum Configuration Version* remains the value set in the previous version. This ensures that the configuration CRC resulting from the code generation is the same as in the previous version and the configuration is still compatible with the operating systems of the modules.

  The value of *Minimum Code Generation* only needs to be increased for converted projects if additional functions of a controller should be used.
- If features requiring a higher configuration version are used in the project, SILworX automatically generates a configuration version higher than the preset *Minimum Configuration Version*. This is indicated by SILworX in the code generation logbook. The modules reject loading configurations if their version and operating system do not match.

  The safety-related SILworX version comparison can be used to determine and prove changes performed to the current project version compared to a previous one.
- For HIQuad X, *Minimum Configuration Version* must be set to *SILworX V10* or higher.

9.4.1.6 Rack System Variables

These system variables are used to change the behavior of the controller while it is operating in specific states. These variables can be set in the *System* tab located in the rack detail view of the SILworX Hardware Editor.

System variables	S [1)]	Function	Setting for safe operation
Forcing Deactivation	Y	Prevents the forcing process from starting and terminates a running forcing process. Default setting: FALSE.	Application-specific
MultiForcing Denied	Y	MultiForcing can be enabled and disabled using the *MultiForcing Denied* system variable so that the associated functions can be controlled by the user program. For MultiForcing, the system variable must be set to FALSE. Default setting: FALSE.	Application-specific
Emergency Stop 1... Emergency Stop 4	Y	Shuts down the controller if faults are detected by the user program. Default setting: FALSE.	Application-specific
Read-only in RUN	Y	After the controller is started, the access permissions are downgraded to *Read-Only*. Exceptions are forcing and reload. Default setting: FALSE.	Application-specific
Reload Deactivation	Y	Locks the execution of reload. Default setting: FALSE.	Application-specific
1) Safety-related system parameter yes/no (Y/N)			

Table 15: Rack System Variables

Global variables can be connected to these system variables; the value of the global variables is modified using a physical input or the user program logic.

9.4.2 Locking and Unlocking the Controller

Locking the controller locks all functions and prevents users from accessing them during operation. This also protects against unauthorized manipulations to the user program.

Unlocking the controller deactivates any locks previously set, e.g., to perform work on the controller.

The three system variables *Read-only in Run*, *Reload Deactivation* and *Forcing Deactivation* are used to lock the PES, see Table 15.

If all three system variables are TRUE, no access to the controller is possible. In this case, the controller can only enter the STOP state by restarting all processor modules. Only then can a new user program be loaded. The example describes a simple case, in which a key-operated switch is used to lock or unlock all interventions to the resource.

Example: To make a controller lockable

1. Define a global variable of type BOOL and set its initial value to FALSE.
2. Assign the global variable as output variable to the three system variables *Read-only in Run*, *Reload Deactivation* and *Forcing Deactivation*.
3. Assign the global variable to the channel value of a digital input.
4. Connect a key switch to the digital input.
5. Compile the program, load it into the controller, and start it.

► The owner of a corresponding key-operated switch is able to lock and unlock the controller. If the corresponding digital input module fails, the controller is automatically unlocked.

This simple example can be modified using multiple global variables, digital inputs and key switches. The permissions for forcing, reload and other operating functions can be distributed on different keys and persons.

9.5 Forcing

Forcing is the procedure of manually writing to variables with values that do not result from the process, but are defined by the user, while the controller is processing the user program.

There are different types of globally forcible data sources in a system:

- All input and status information from modules (e.g., I/O modules) and communication protocols.
- All global variables that have not been written, but have been read (VAR_EXTERNAL).
- All global variables that have been written to by a user program (VAR_EXTERNAL).

In addition to the globally forcible data sources in a system, there are also different types of locally (in the user program) forcible data sources:

- All user program variables that have not been written, but have been read (VAR).
- All variables from a user program that have been written (VAR).

i When a variable is forced, forcing always applies to its data source! A forced variable does not depend on the process since its value is defined by the users.

9.5.1 Use of Forcing

Forcing supports users during the following tasks:

- Testing of the user program for cases that do not, or only infrequently occur during normal operation and are therefore only testable up to a certain extent.
- Simulation of sensor values, e.g., of unconnected sensors.
- Service and repair work.
- General troubleshooting.

⚠ WARNING

Physical injury due to forced values is possible!

- **Only force values after consent of the person responsible for the plant and the test authority during commissioning.**
- **Only remove existing forcing restrictions with the consent of the person responsible for the plant and the test authority during commissioning.**

When forcing values, the person in charge must take further technical and organizational measures to ensure that the process is sufficiently monitored in terms of safety. HIMA recommends setting a time limit for the forcing procedure, refer to Chapter 9.5.3 for details.

⚠ WARNING

Failure of safety-related operation possible due to forced values!

- **Forced value may lead to unexpected output values.**
- **Forcing prolongs the cycle time. This can cause the watchdog time to be exceeded.**

Forcing can operate at two levels:

- Global forcing: Global variables are forced for all applications.
- Local forcing: Local variables are forced within a user program.

9.5.2 Assigning a Data Source Changed through Reload

Assigning variables to a new data source by performing a reload may have unexpected results in conjunction with the following inputs:

- Hardware.
- Communication protocols.
- System variables.

The following changes resulting from a reload lead to changed force states:

1. A global variable A is assigned to a forced data source and is thus forced itself.
2. The assignment of global variable A is removed by performing a reload. The data source maintains the property *Forced*. Global variable A is no longer forced.
3. The forced data source is assigned another global variable (global variable B).
4. During the next reload, global variable B will be forced, even if unintentionally.

Consequence

To prevent this effect, stop forcing a variable before changing the data source. To this end, deactivate the individual force switch.

The *Inputs* tab in the Force Editor displays which channels are being forced.

i Global variables having the user program as data source retain the *forced* setting even when the assignment is changed.

9.5.3 Time Limits

Different time limits can be set for global or local forcing. Once the defined time has expired, the controller stops forcing values.

The behavior of the HIQuad X system upon expiration of the time limit can be configured:

- For global forcing, the following settings can be selected:
  - *Stop Resource.*
  - *Stop Forcing Only,* i.e., the resource continues to operate.
- For local forcing, the following settings can be selected:
  - *Stop Program.*
  - *Stop Forcing Only,* i.e., the user program continues to run.

Forcing can also be used without time limit. In this case, the forcing procedure must be stopped manually.

The person responsible for forcing must clarify what effects stopping forcing have on the entire system!

9.5.4 Restricting the Use of Forcing

The user can limit the use of forcing; disturbed operation which may be caused by forcing, is to be avoided. The following measures can be implemented in the configuration:

- Configuration of different user profiles with or without forcing permissions.
- Explicit enabling of forcing for a resource (PES).
- Set-up of MultiForcing user accounts in the PES User Management.
- Explicit enabling of local forcing for a user program.
- Immediate stop of forcing via the *Force Deactivation* system variable using the key switch.
- Disabling of MultiForcing through the *MultiForcing Denied* system variable.

9.5.5 MultiForcing

Users with MultiForcing access can write force data (force values and individual force switches) for global variables in a resource if the required higher-order conditions have been met and the force permissions have been granted. To all other functions of a resource, users have Read-Only access. Starting, stopping or resetting a force process is not possible.

The use of MultiForcing is limited to a maximum of 5 users at a time. The users can be working from separate locations and also independently of each other in terms of time. The separation of the tasks performed by the individual users must be ensured by the operator through organizational measures.

⚠ WARNING

Behavior that cannot be controlled by the user, is possible!

The operator must ensure that different Force Users do not force the same variables simultaneously and that there can be no overlaps in timing. If several Force Users write to the same variables, those force values and force switches will prevail which were written last by the firmware. Because force data are transferred in several blocks , it would otherwise be possible for the settings of different Force Users to take effect on one single controller. This behavior cannot be controlled by the user.

⚠ WARNING

Existing force data is not deactivated, if *MultiForcing Denied* = TRUE!

If *MultiForcing Denied* is TRUE, users with MultiForcing access cannot modify force values or the force switches. Existing force data is not deactivated, if *MultiForcing Denied* = TRUE! Global Forcing, if allowed, is then only possible for a single user with at least Operator permissions.

Refer to the system manual (HI 803 211 E) and the SILworX online help for further details on forcing.

9.5.5.1 Objectives of MultiForcing

For commissioning, normative and functional loop tests are prescribed as part of the site acceptance test, whereby a loop represents the path from the sensor to the actuator. MultiForcing makes it possible to distribute the resulting tasks to up to 5 PADTs thus processing them efficiently.

Based on loop tests, the nominal operating range is checked as well as the responses in the event of open-circuits and short-circuits. Because numerous loops must be tested frequently, the duration of site acceptance testing is a significant cost factor. MultiForcing can help to optimize these tasks.

- The behavior of actuators and linked information (e.g., end position feedback) is tested through forcing. The output signals are forced directly. This tests the wiring and the external circuit.
- In a system which is only partially functional, sensors are tested through forcing in such a way that the tests have no effect on the actuators. This approach can also be used for troubleshooting in connection with sensors.

9.5.5.2 Global MultiForcing

Global MultiForcing is the simultaneous writing of force data (force values and force switches) for global variables by more than one user (Force Users).

A Force User is a person who is logged into a controller with either MultiForcing, Operator, Write or Administrator permissions. Every Force User is able to read and also at least write force data. A maximum of 5 Force Users can be logged into each controller. The number of current Force Users is displayed in the SILworX status bar.

Force values and force switches set by a Force User with MultiForcing access may only take effect if the user is logged into the controller with at least Operator permissions. Only this user can start or stop forcing.

i To perform Global MultiForcing, Global Forcing must be allowed as well! The settings are displayed online.

9.6 Safe Version Comparison

During the code generation, SILworX creates various files. This data set is referred to as the resource configuration. The complete resource configuration is loaded to the resource whenever a download or reload is performed.

During a safe version comparison, different resource configurations are compared to one another and the differences between the individual files are detected.

Essentially, there are three types of resource configurations:

1. The created resource configuration which is the result of the last code generation.
2. The loaded resource configuration which is the configuration that was loaded into the controller by performing a reload or download.
3. An unknown resource configuration which was exported and saved. This represents any state of the resource configuration.

To verify the program changes, the safe version comparison must be started **before** the program is loaded to the controller.

The version comparison exactly determines the changed parts of the resource configuration. This facilitates testing and identifying the changes. The result has SIL 3 quality and may be submitted to the inspection authority as a piece of evidence.

Structured programming, and the use of significant names from the first resource configuration on, facilitate understanding of the comparison result.

For further details, refer to the version comparison manual (HI 801 286 E).

9.7 Security Measures for the Application Programming Interface (API)

SILworX API supports the following security measures:

- The use of SILworX API requires a license.
- SILworX API must be explicitly activated in the *settings.ini* file.
- Access to the SILworX API is only possible via SSL (TLS 1.2). This requires the installation of OpenSSL and a valid certificate.
- Access to projects via the SILworX API requires the same user permissions as during human interaction.
- Configurable timeouts when accessing the SILworX API ensure that projects are automatically closed if no further API queries are sent within the timeout.
- Any API activity is displayed in the SILworX status bar.
- Any actions are tracked in the SILworX logbook. This applies to both human interaction and API accesses.

i **Important:**

Users must perform a tool classification and qualification for their SILworX API application.

The API documentation in HTLM format and a C# application example is available in the subfolder …\c3\openapi within the SILworX installation directory.

10 Safety-Related Aspects of User Programs

This chapter describes the safety-related aspects that are important for the user programs.

Programming goals for a user program:

- Understandable.
- Traceable.
- Testable.
- Easy to modify.

10.1 Safety-Related Usage

The user programs must be created with the programming tool SILworX.

SILworX can only be installed on a PC with Microsoft Windows operating system. The minimum requirements for the computer used to run SILworX are specified on the corresponding installation DVD.

The SILworX programming tool includes the following functions:

- Global Variable Editor (for creating global variables with symbolic names and data types).
- Hardware Editor (for assigning the controllers of the HIQuad X system).
- FBD Editor (for creating the user program).
- Code generator (for translating the user program into a machine code).
- Configuration of communication.
- Monitoring and documentation.

The safety requirements specified in this manual must be observed, see Chapter 3.4.

10.1.1 Programming Basics

The tasks to be performed by the controller must be defined in a specification or a requirements specification. This documentation serves as the basis for checking its proper implementation in the user program.

The documentation depends on the control task and can be represented in two ways.

Combinational logic:

- Cause/effect diagram.
- Logic of the connection with functions and function blocks.
- Function blocks with specified characteristics.

Sequential controllers (sequence control system):

- Written description of the steps and their enabling conditions and of the actuators to be controlled.
- Flow charts.
- Matrix or table form of the step enabling conditions and the actuators to be controlled.
- Definition of constraints, e.g., operating modes, emergency stop.

10.1.1.1 I/O Concept

The I/O concept of the system must include the analysis of the field circuits, i.e., the type of sensors and actuators:

Digital and analog sensors:

- Signals during normal operation (de-energize to trip principle with digital sensors, 'life-zero' with analog sensors).
- Signals if a fault occurs.
- Definition of safety-related redundancies required for safety (1oo2, 2oo3).
- Discrepancy monitoring and response.

Actuators:

- Positioning and activation during normal operation.
- Safe response/positioning at shutdown or after power loss.

10.1.2 Programming Steps

To program HIQuad X systems for safety-related applications, perform the following steps:

1. Specify the control functions.
2. Write the user programs.
3. Compile the user programs using the C code generator.
   - The user programs are free from errors and able to run.
4. Verify and validate the user programs (FAT, SAT).
5. Tests the user programs.

After these steps, the user programs are ready to start safety-related operation!

10.1.3 User Program Functions

The user program functions can be freely programmed.

- Only elements complying with IEC 61131-3 together with their functional requirements are used within the logic.
- The physical inputs and outputs usually operate in accordance with the de-energize to trip principle, i.e., their safe state is 0.
- The user programs are built of logic and/or arithmetic functions irrespective of the de-energize to trip principle of the physical inputs and outputs.
- The program logic should be clear and easy to understand and well documented to assist in debugging. This includes the use of functional diagrams.
- To simplify the logic, the inputs and outputs of all function blocks and variables can be inverted in any given order.
- The programmer must evaluate the fault signals from the inputs/outputs or from logic blocks.

HIMA recommends encapsulating functions to user-specific function blocks and functions based on standard functions. This ensures that user programs can be clearly structured in modules (functions, function blocks). Each module can be viewed and tested on an individual basis. By grouping modules into larger ones and combining them into a single user program, users are effectively creating a comprehensive, complex function.

10.1.4 User Program System Parameters

The following user parameters can be set in the *Properties* dialog box of the user programs:

System parameter	S [1)]	Description		Setting for safe operation
Name	N	Name of the user program. The name must be unique within the resource.		Any
Program ID	Y	ID for identifying the program when displayed in SILworX. Range of values: 0…4 294 967 295 Default value: 0 If *Code Generation Compatibility* is set to *SILworX V2*, only the value 1 is permitted.		Application-specific
Priority	Y	Priority of the user program. Range of values: 0…31 Default value: 0 (highest priority) This setting is only required if several user programs are used!		Application-specific
Program's Maximum Number of CPU Cycles	Y	Maximum number of CPU cycles that a user program cycle may take. Range of values: 1…4 294 967 295 Default value: 1 This setting is only required if several user programs are used!		Application-specific
Max. Duration for Each Cycle [µs]	N	Maximum time in each processor module cycle for executing the user program. Range of values: 0…4 294 967 295 Default value: 0 (no limitation) The safety-related response is ensured through the watchdog. This setting is only required if several user programs are used!		Application-specific
Watchdog Time [ms] (calculated)	---	Monitoring time of the user program, calculated from the product of the watchdog time of the resource and the configured maximum number of CPU cycles. Not changeable!		
Classification	N	Classification of the user program in *Safety-related* or *Standard*; the setting is for documentation only and has no effects on the program's performance. Default value: *Safety-related*.		Application-specific
Allow Online Settings	Y	If *Allow Online Settings* is deactivated, the settings of the reamaining program switches cannot be changed online (from within the Control Panel). Only applies if the *Allow Online Settings* switch for the resource is set to TRUE! Default value: TRUE.		
Autostart	Y	Enabled type of Autostart: *Cold Start*, *Warm Start*, *Off*. Default value: *Warm Start*.		Application-specific
Start Allowed	Y	TRUE:	The PADT may be used to start the user program. Default value: TRUE.	Application-specific
		FALSE:	The PADT may not be used to start the user program.	

System parameter	S [1]	Description		Setting for safe operation
Test Mode Allowed	Y	TRUE:	The test mode is permitted for the user program.	Application-specific [2]
		FALSE:	The test mode is not permitted for the user program. Default value: FALSE.	
Reload Allowed	Y	TRUE:	The user program reload is permitted. Default value: TRUE.	Application-specific
		FALSE:	The user program reload is not permitted.	
		Observe the settings in the resource properties!		
Local Forcing Allowed	Y	TRUE:	Forcing is permitted at program level.	FALSE is recommended
		FALSE:	Forcing is not permitted at program level. Default value: FALSE.	
Local Force Timeout Reaction	Y	Behavior of the user program after the forcing time has expired: ▪ *Stop Forcing Only.* ▪ *Stop Program.* Default value: *Stop Forcing Only*.		
Code Generation Compatibility	-	Code generation is compatible with previous versions of SILworX.		Application-specific
		SILworX V2	Code generation is compatible with SILworX V2.	
		SILworX V3	Code generation is compatible with SILworX V3.	
		SILworX V4 – V6b	Code generation is compatible with SILworX V4 up to SILworX V6b.	
		SILworX V7 and higher	Code generation is compatible with SILworX V7.	
		Default value for all new projects: *SILworX V7 and higher*.		

[1] The operating system handles the system parameter in a safety-related manner, yes (Y) or no (N)

[2] Once the test mode has stopped, a cold start must be performed prior to starting a safety-related operation!

Table 16: System Parameters of the User Program

10.1.5 Notes on the *Code Generation Compatibility* Parameter

Observe the following points in conjunction with the *Code Generation Compatibility* parameter:

- In a new project, SILworX selects the current setting for the *Code Generation Compatibility* parameter. This ensures that the current, enhanced features are activated and the current module and operating system versions are supported. Verify that this setting is in accordance with the hardware in use.
- In a previous project converted to the current SILworX version, the value for *Code Generation Compatibility* remains the value set in the previous version. This ensures that the configuration CRC resulting from the code generation is the same as in the previous version and the configuration is still compatible with the operating systems of the modules.
  The value of *Code Generation Compatibility must only be changed for converted projects if additional functions of a controller should be used.*
- If a *Minimum Configuration Version* of *SILworX V4* and higher is set in the resource properties, the *Code Generation Compatibility* parameter must be set to *SILworX V7 and Higher* in every user program.

10.1.6 Code Generation

After completing the user programs and the resource configuration, the code generator creates a code with a typical configuration CRC.

The configuration CRC is a signature for all of the configured elements and is issued as a 32-bit, hexadecimal code.

For safety-related operation, the user program must be compiled twice. The two checksums generated during compilation must be identical!

By compiling the user program twice and comparing the checksums of the generated code, the user can detect potential corruptions of the user programs resulting from random faults in the hardware or operating system of the PC in use.

The result of the CRC comparison is displayed in the logbook.

10.1.7 Loading and Starting the User Program

A resource configuration can only be loaded into a controller through download if the controller is in the STOP state.

The user program can be started after successful resource configuration download.

i The PADT is only able to operate the controller, e.g., by performing a reload and forcing, if the project matching the resource configuration is opened in SILworX.

HIMA recommends archiving the project after each download or reload.

SILworX stores all a project's data to a single file. For reasons of data security, HIMA recommends additionally storing the project on an external medium.

The backup ensures that the project data matching the resource configuration remains available even if the PADT fails.

10.1.8 Reload

If changes were performed to a project, they can be transferred to the controller by performing a reload. After being tested by the operating system, the modified project is activated and assumes the control task.

The reload can only be performed if the *Reload Allowed* system parameter is set to TRUE and the *Reload Deactivation* system variable is set to FALSE.

i A reload is only permitted after receiving consent from the test authority responsible for the acceptance test. During the entire reload process, the person in charge must take further technical and organizational measures to ensure that the process is sufficiently monitored in terms of safety.

i **Observe the following points when reloading sequence chains:**

The reload information for sequence chains does not take the current sequence status into account. A reload can therefore cause the sequence to change setting it to an undefined state. The user is responsible for properly performing the reload.

Examples:

- Deletion of the active step causes all the steps within the step sequence to lose the *active* state!
- Renaming an initial step while another step is active leads to a step sequence with two active steps!

Observe the following points when reloading actions:

During the reload, actions are loaded with their complete data. All potential consequences must be carefully analyzed prior to performing a reload.

Examples:

- If a timer action qualifier is deleted due to the reload, the timer expires immediately. Depending on the remaining settings, the *Q* output can therefore be set to TRUE.
- If the status action qualifier (e.g., the *S* action qualifier) is deleted for a set element, the element remains set.
- Removing a *P0* action qualifier set to TRUE actuates the trigger function.

Prior to performing a reload, the operating system checks if the required additional tasks would increase the cycle time of the current user programs to such an extent that the defined watchdog time is exceeded. In this case, the reload process is aborted with an error message and the controller continues operation with the previous resource configuration.

The controller can abort a reload.

Reload can be performed successfully by planning a sufficient reserve for the reload when determining the watchdog time or temporarily increasing the controller watchdog time by a reserve.

Any temporary increases in the watchdog time must be agreed upon with the competent test authority.

Exceeding the target cycle time can also lead to an abort of the reload.

The user is responsible for ensuring that the watchdog time includes a sufficient reserve time. This should allow the user to manage the following situations:

- Variations in the user program's cycle time.
- Sudden, strong cycle loads, e.g., due to communication.
- Expiration of time limits during communication.

10.1.9 Online Test

Online test fields (OLT fields) can be used in the user program logic to display variables while the controller is operating.

For further details on how to use OLT fields, use OLT field as keyword in the SILworX online help and refer to the SILworX first steps manual (HI 801 103 E).

10.1.10 Test Mode

SILworX offers a test mode for punctual troubleshooting. In test mode, the user program can be run in single steps, i.e., cycle by cycle. Each cycle is triggered by a command from the PADT. In the period between 2 cycles, the global variables written to by the user program remain **frozen**. The assigned physical outputs and communication data then no longer respond to changes in the process!

The test mode can be configured individually for each user program by activating or deactivating the *Test Mode Allowed* parameter.

Test Mode Allowed	Description
Deactivated	Test mode deactivated (default setting).
Activated	Test mode activated.

Table 17: User Program Parameter *Test Mode Allowed*

NOTICE

Failure of safety-related operation possible!

If a user program operating in test mode is stopped, it cannot provide a safety-related response to changes on the inputs and cannot control the outputs!

Test mode is therefore not permitted in safety-related operation!

For safety-related operation, the *Test Mode Allowed* parameter must be deactivated!

10.1.11 Changing the System Parameters during Operation

The system parameters specified in Table 18 may be changed during operation (online).

A typical application case is the temporary increase of the watchdog time to be able to perform a reload.

Prior to using an online command to set parameters, make sure that this change will not result in a dangerous state of the plant. If required, organizational and/or technical measures must be implemented to preclude any damage. The application standards must be observed!

The safety time and the watchdog time must be checked and compared to the actual cycle time and to the safety time required by the application. The controller cannot verify these values!

The controller ensures that the watchdog time is not set to a value less than the watchdog time value of the configuration loaded in the controller.

Parameter	Can be changed in the following controller state
System ID	STOP
Watchdog Time (for the resource)	RUN, STOP/VALID CONFIGURATION
Safety Time	RUN, STOP/VALID CONFIGURATION
Target Cycle Time	RUN, STOP/VALID CONFIGURATION
Target Cycle Time Mode	RUN, STOP/VALID CONFIGURATION
Allow Online Settings	TRUE -> FALSE: All FALSE -> TRUE: STOP
Autostart	All
Start Allowed	All
Load Allowed	All
Reload Allowed	All
Global Forcing Allowed	All
Global Force Timeout Reaction	All
Global MultiForcing Allowed	All

Table 18: Online Changeable Parameters

10.1.12 Project Documentation for Safety-Related Applications

The SILworX programming tool allows the user to automatically print the documentation for a project. The most important document types include:

- Interface declaration.
- Signal list.
- Logic.
- Description of data types.
- Configurations for system, modules and system parameters.
- Network configuration.
- List of signal cross-references.

This documentation is required for the factory acceptance test (FAT) of a system subject to approval by a test authority, e.g., TÜV.

10.1.13 Multitasking

Multitasking refers to the capability of the HIQuad X system to process up to 32 user programs within the processor module.

The individual user programs can be started and stopped independently from one another.

A user program cycle can take multiple processor module cycles. This can be controlled with the resource and user program parameters. SILworX uses these parameters to calculate the user program watchdog time:

Watchdog Time$_{\text{User program}}$ = **Watchdog Time**$_{\text{Processor module}}$ * **Maximum Number of Cycles**

The individual user programs operate in an interference-free manner and independently from one another. However, reciprocal influence can be caused by:

- Use of the same global variables in several user programs.
- Unpredictably long runtimes can occur in individual user programs if no limit is configured with *Max. Duration for Each Cycle*.
- The distribution of user program cycles over processor module cycles strongly affects the user program response time and the response time of the variables written to by the user program!
- A user program evaluates global variables written to by another user program at the earliest one CPU module cycle later. Depending on the value set for *Program's Maximum Number of CPU Cycles* in the program properties, the evaluation process may be prolonged by many CPU cycles, which also causes a delayed response.

Refer to the system manual (HI 803 211 E) for further details on multitasking.

10.1.14 Factory Acceptance Test and Test Authority

HIMA recommends involving the test authority as soon as possible when designing a system that is subject to approval.

The factory acceptance test (FAT) only applies to the user functionality, but not to the safety-related modules and automation devices of the HIQuad X system that have already been approved.

10.2 Checklist for Creating a User Program

To comply with all safety-related aspects during the programming phase, HIMA recommends using the checklist prior to and after loading a new or modified program. The checklist can be used as a planning document and also serve as proof of careful planning.

The current checklists can be obtained upon request by sending an e-mail to: documentation@hima.com. The checklists are available for registered HIMA customers in the download area https://www.hima.com/en/downloads/.

11 Configuring Communication

In addition to using the physical input and output variables, variable values can also be exchanged with other systems through a data connection. In this case, the variables are declared with SILworX, in the Protocols area of the corresponding resource.

11.1 Standard Protocols

Many communication protocols only ensure a non-safety-related data transmission. These protocols can be used for the non-safety-related aspects of an automation task.

⚠ WARNING

Physical injury possible due to usage of non-safe import data!

Do not use data imported from non-safe sources for the user program's safety functions.

The standard protocols listed in the communication manual are available for HIQuad X.

11.2 Safety-Related safe**ethernet** Protocol

Safety-related communication via safe**ethernet** is certified up to SIL 3.

Use the safe**ethernet** Editor to configure how safety-related communication is monitored.

For further details on safe**ethernet**, refer to the communication manual (HI 801 101 E).

i **The safe state may be entered inadvertently!**

***Receive Timeout* and *Production Rate* are safety-related parameters!**

Receive Timeout is the monitoring time within which a valid response from the other controller must be received.

If a correct response is not received from the communication partner within *Receive Timeout*, HIQuad X terminates the safety-related communication. The input variables of this safe**ethernet** connection respond in accordance with the preset parameter *Freeze Data on Lost Connection [ms]*. For safety-related functions, which are implemented via safe**ethernet**, the setting **Use Initial Value** must be used.

In the following equations for determining the worst case response time, the target cycle time can be used instead of the watchdog time, if it is guaranteed that the process module maintains the target cycle time, even in case of reload and synchronization.

In this case, the following requirements apply to the *Fixed-tolerant* or *Dynamic-tolerant* settings of *Target Cycle Time Mode*:

1. **Watchdog time ≥ 1.5 x target cycle time**
2. **Receive timeout ≥ 5 x target cycle time + 4 x latency**

   Latency refers to the delay on the transport path.
3. For reload, there is either just one user program or several user programs, the cycle of which is limited to a single processor module cycle.

11.3 Worst Case Response Time for safeethernet

In the following examples, the formulas for calculating the worst case response time only apply for a connection with HIMatrix controllers if their programming does not include noise blanking. These formulas always apply to HIMax and HIQuad X controllers.

i The allowed worst case response time depends on the process and must be agreed upon together with the competent test authority.

The following table describes the parameters and conditions that must be taken into account in SILworX to calculate the worst case response time:

Terms	Description
Receive Timeout	Monitoring time of controller 1 (PES 1) within which a valid response from controller 2 (PES 2) must be received. Otherwise, safety-related communication is terminated after the time has expired.
Production Rate	Minimum interval between two data transmissions.
Watchdog Time	Maximum duration permitted for a controller's RUN cycle. The duration of the RUN cycle depends on the complexity of the user program and the number of safe**ethernet** connections. The watchdog time (WDT) must be entered in the resource properties.
Worst Case Response Time	The worst case response time is the time between a change in a physical input signal (in) of PES 1 and a change in the physical output signal (out) of PES 2.
Response Time of the HIQuad X controller	For further details on the response time of the HIQuad X controller (resource) t_{RR}, see Chapter *Safety-Relevant Time Parameters*.
Delay	Delay of a transport path, e.g., when a modem or satellite connection is used. For direct connections, an initial delay of 2 ms can be assumed. The responsible network administrator can measure the actual delay on a transport path.

Table 19: safe**ethernet** Parameter Description and Conditions

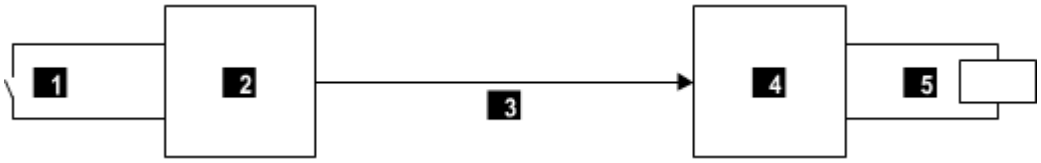
The following conditions apply to the calculations of the maximum response times specified below:

- The signals transmitted over safe**ethernet** must be processed in the corresponding controllers within one CPU cycle.
- The response times of the sensors and the actuators must also be added up.

The calculations also apply to signals in the opposite direction.

11.3.1 Calculating the Worst Case Response Time of 2 HIQuad X Controllers

The worst case response time T_R is the time between a change on the sensor input signal (in) of controller 1 and a response on the corresponding output (out) of controller 2. It is calculated as follows:



1 Input
2 HIQuad X controller 1
3 Safety-related protocol
4 HIQuad X controller 2
5 Output

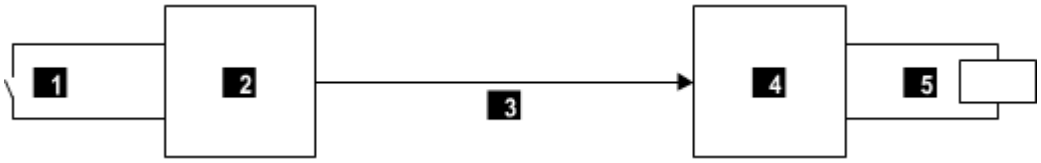
Figure 1: Response Time when 2 HIQuad X Controllers are Interconnected

$$T_R = t_1 + t_2 + t_3$$

T_R Worst case response time
t_1 Response time of HIQuad X controller 1
t_2 *Receive Timeout*
t_3 Response time of HIQuad X controller 2

11.3.2 Calculating the Worst Case Response Time with 1 HIMatrix Controller

The worst case response time T_R is the time between a change on the sensor input signal (in) of the HIQuad X controller and a response on the corresponding output (out) of the HIMatrix controller. It is calculated as follows:



1 Input
2 HIQuad X controller
3 Safety-related protocol
4 HIMatrix controller
5 Output

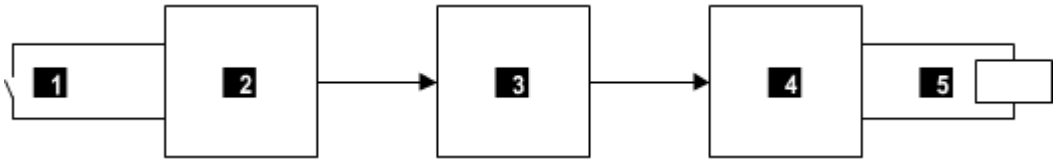
Figure 2: Response Time when 1 HIQuad X and 1 HIMatrix Controllers are Interconnected

$$T_R = t_1 + t_2 + t_3$$

T_R Worst case response time
t_1 Response time of the HIQuad X controller
t_2 *Receive Timeout*
t_3 2 * Watchdog time of the HIMatrix controller

11.3.3 Calculating the Worst Case Response Time with 2 HIMatrix Controllers or Remote I/Os

The worst case response time T_R is the time between a change on the sensor input signal (in) of the first HIMatrix controller or remote I/O (e.g., F3 DIO 20/8 01) and a response on the corresponding output (out) of the second HIMatrix controller or remote I/O (out). It is calculated as follows:



1 Input
2 Remote I/O 1
3 HIQuad X controller
4 Remote I/O 2
5 Output

Figure 3: Response Time with 2 HIMatrix Controllers or Remote I/Os and 1 HIQuad X Controller

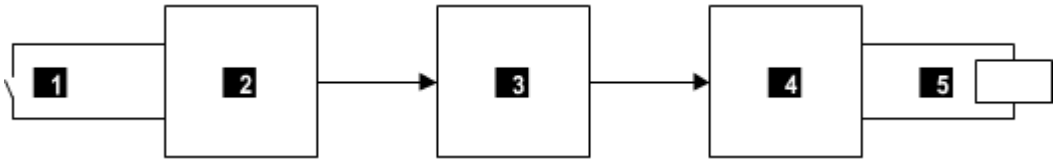
$$T_R = t_1 + t_2 + t_3 + t_4 + t_5$$

T_R	Worst case response time
t_1	2 * watchdog time of the HIMatrix controller or the remote I/O 1
t_2	*Receive Timeout1*
t_3	Response time of the HIQuad X controller
t_4	*Receive Timeout2*
t_5	2 * watchdog time of the HIMatrix controller or the remote I/O 2

i Remote I/O 1 and remote I/O 2 can also be identical. The time values still apply if a HIMatrix controller is used instead of a remote I/O.

11.3.4 Calculating the Worst Case Response Time with 2 HIQuad X and 1 HIMatrix Controllers

The worst case response time T_R is the time between a change on the sensor input signal (in) of the first HIQuad X controller and a response on the corresponding output (out) of the second HIQuad X controller. It is calculated as follows:



1 Input
2 HIQuad X controller 1
3 HIMatrix controller
4 HIQuad X controller 2
5 Output

Figure 4: Response Time with 2 HIQuad X Controllers and 1 HIMatrix Controller

$$T_R = t_{RR1} + t_1 + t_2 + t_3 + t_{RR2}$$

T_R Worst case response time
t_{RR1} Response time of HIQuad X controller 1
t_1 *Receive Timeout1*
t_2 2 * watchdog time of the HIMatrix controller
t_3 *Receive Timeout2*
t_{RR2} Response time of HIQuad X controller 2

i Both HIQuad X controllers, 1 and 2, can also be identical.
The HIMatrix controller can also be a HIQuad X controller.

11.4 Safety-Related HIPRO-S V2 Protocol

The HIPRO-S V2 protocol is used for safety-related SIL 3 communication between HIQuad controllers and HIQuad X, HIMax or HIMatrix controllers.

For further information, refer to the HIPRO-S V2 manual (HI 800 723 E).

- For HIQuad X controllers.
- For HIQuad controllers with an operating system release as of BS41q/51q V7.0-8 (08.xx).
- For HIMatrix 03 controllers with an operating system release as of V12 (CPU) / V16.10 (COM).

The HIPRO-S V2 protocol may only be used for connecting HIQuad controllers to one another or to HIQuad X controllers. Connections between HIQuad X controllers with one another and with other HIMA controllers (HIMax, HIMatrix) must be established with safe**ethernet**.

For further information, refer to the HIPRO-S V2 manual (HI 800 723 E).

12 Use in Fire Alarm Systems

The HIQuad X systems may be used in fire alarm systems in accordance with DIN EN 54-2 and NFPA 72, if line monitoring is configured for the inputs and outputs.

In this case, the user program must fulfill the requirements specified for fire alarm systems in accordance with the standards previously mentioned.

DIN EN 54-2 requires 10 s as the maximum cycle time allowed for fire alarm systems. This value can be easily met with the HIMA systems since the cycle time for these systems is in the milliseconds range. This also applies to the safety time of 1 s (fault response time) required in certain cases.

According to DIN EN 54-2, the fire alarm system must enter the fault report state within 100 s after the HIQuad X system has received the fault message.

The connection to fire detectors is implemented based on the energized to trip principle with line monitoring (short-circuit and open-circuit monitoring). To this end, the following inputs and outputs may be used:

- The digital inputs supporting line monitoring and used in the F 3237 and F 3238 input modules.
- The analog inputs supporting line monitoring and used in the F 6217 and F 6221 input modules.

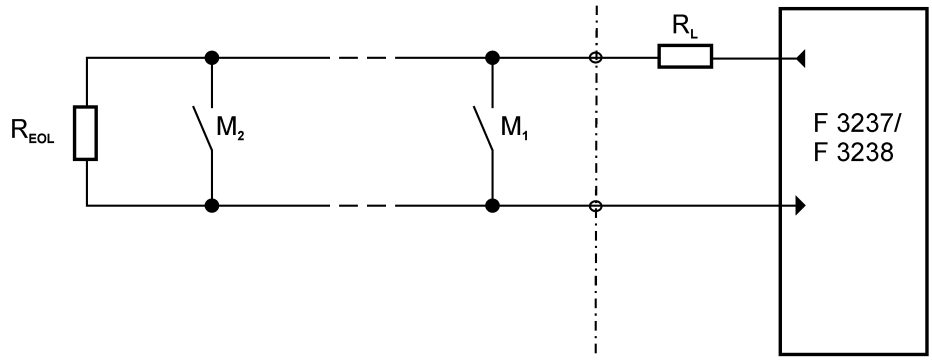
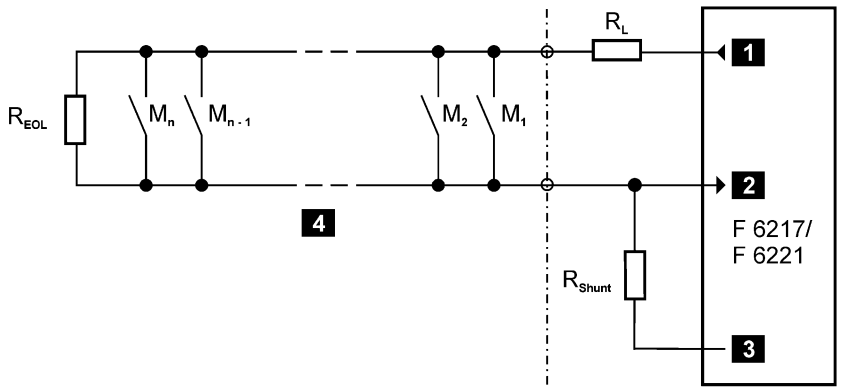


Figure 5: Wiring of Fire Detectors with Digital Inputs



1 Sensor supply
2 Analog input
3 Reference potential
4 Detection loop

M: Fire detectors
R_{EOL}: Terminating resistor on the last loop sensor
R_{Shunt} Shunt
R_L: Limitation of the maximum permissible loop current

Figure 6: Wiring of Fire Detectors with Analog Inputs

For the application, the R_{EOL}, R_L and R_{Shunt} resistors must be calculated as dictated by the sensors in use and the number of sensors per detection loop. Refer to the data sheet from the sensor manufacturer for the necessary data.

Additionally, the values specified for the F 3237 and F 3238 modules must be observed (see the corresponding data sheet). This is particularly important if the fire detectors are equipped with electronic outputs instead of mechanical contacts.

The alarm outputs for activating lamps, sirens, horns etc. are operated in accordance with the energize to trip principle. These outputs must be monitored for short-circuits and open-circuits.

A user program can be adjusted to tailor the activation of the visual display systems, indicator light panels, LED indicators, alphanumeric displays and audible alarms, etc.

The routing of fault signal messages via output modules or to transmission equipment for fault signaling must occur in accordance with the de-energize to trip principle.

The transmission of fire alarms among HIMA systems can be implemented using the available communication standards such as Ethernet (OPC). Communication monitoring is an essential part of the user program. HIMA recommends configuring communication redundantly to ensure communication even if a transmission component fails, e.g., due to a line or hardware fault. The component failure must be reported and the replacement or repair of the faulty component during operation should be ensured.

HIQuad X systems that are used as fire alarm systems must have a redundant power supply. Additionally, precautionary measures must be implemented against power supply drops, e.g., the use of a battery-powered horn. Continuous operation must be ensured while switching from the main power supply to the backup power supply. Voltage drops for up to a duration of 10 ms are permitted.

If a system failure occurs, the operating system writes to the system variables defined in the user program. This allows the user to program fault signaling for faults detected by the system. If a fault occurs, the HIQuad X system switches off the safety-related inputs and outputs with the following effects:

- The low level is processed in all channels of the faulty inputs.
- All channels of the faulty outputs are switched off.

Ground fault monitoring is required if fire detection and fire alarm systems in accordance with EN 54-2 and NFPA 72 are used.

13 Use of HIQuad X in Zone 2

HIQuad X components are suitable for mounting in the explosive atmospheres of zone 2. In addition to the specific conditions, the mounting and installation instructions provided in the system manual (HI 803 211 E) and in the module-specific manuals must be observed.

HIQuad X components meet the requirements of the following standards:

Standard	Description
IEC 60079-0	Explosive atmospheres - Part 0: Equipment - General requirements
EN 60079-0	
IEC 60079-15	Explosive atmospheres - Part 15: Equipment protection by degree of protection "n"
EN 60079-15	

Table 20: Standards for HIQuad X Components in Zone 2

The current declaration of conformity for HIQuad X components is available on the HIMA website, at www.hima.com/en.

HIQuad X components are approved for the temperature range 0 °C ≤ Ta ≤ +60 °C and are provided with Ex marking:

 II 3G Ex nA IIC T4 Gc

 II 3G Ex nA nC IIC T4 Gc

0 °C ≤ Ta ≤ +60 °C

Marking	Description
	Explosion protection marking complying with Directive 2014/34/EU.
II	Equipment group, for all areas with explosive atmosphere, other than underground mines.
3G	Equipment category, for use in areas where explosive gas atmosphere is unlikely to occur or, if it does occur, will persist for a short period only.
Ex	Explosion protection marking complying with the relevant standard.
nA	Type of protection for non-sparking equipment.
nC	Type of protection for sparking, sealed equipment.
IIC	Gas group for explosive gas atmospheres, typical gas is hydrogen.
T4	Temperature class T4, with a maximum surface temperature of 135 °C.
Gc	Equipment protection level, corresponds to ATEX equipment category 3G.

Table 21: Ex Marking Description for HIQuad X Components

Special conditions

1. The HIQuad X components must be installed in an enclosure that fulfils the requirements of the IEC 60079-0/EN 60079-0 or IEC 60079-15/EN 60079-15 with degree of protection IP54 or better.
2. The device must be provided with a warning:

   WARNING: Work is only permitted in the de-energized state

   Exception:

   If a potentially explosive atmosphere has been precluded, work can also be performed when the device is under voltage.
3. HIQuad X components are designed for operation not exceeding pollution degree 2.
4. The enclosure in use must be able to safely dissipate the generated heat.
5. The supply voltages must be taken from power supply units with protective separation. Use power supply units of type PELV or SELV only.
6. The requirements specified in the module manuals must be observed.
7. The racks must be provided with forced cooling.

Applicable standards:

IEC 60079-14	Explosive atmospheres - Part 14: Electrical installations design, selection and erection
EN 60079-14	

The requirements for type of protection "n" must be observed.

Appendix

Glossary

Term	Description
AI	Analog input
AO	Analog output
ARP	Address resolution protocol, network protocol for assigning the network addresses to hardware addresses
COM	Communication module
CRC	Cyclic redundancy check
DI	Digital input
DO	Digital output
EMC	Electromagnetic compatibility
EN	European standard
ESD	Electrostatic discharge
EUC	Equipment under control, monitored controller
FAT	Factory acceptance test, testing conducted at the site at which the product is developed to prove that a system operates in accordance with its specifications.
FB	Fieldbus
FBD	Function block diagrams
HW	Hardware
ICMP	Internet control message protocol, network protocol for status or error messages
IEC	International electrotechnical commission
SC/OC	Short-circuit/open-circuit
MAC	Media access control address, hardware address of one network connection
PADT	Programming and debugging tool (in accordance with IEC 61131-3), PC with SILworX
PELV	Protective extra low voltage
PES	Programmable electronic system
R	Read, the variable is read out
Rack ID	Rack identification (number)
Interference-free	In this context, interference-free refers to safety-related and non-safety-related modules, which may be operated within a rack, if they are marked as interference-free. In terms of functional safety, the non-safety-related-module has no influence on the safety-related modules.
R/W	Read/Write, column title for system variable type
SAT	Site acceptance test, testing conducted at the customer's site to prove the product's compliance with its specifications.
SELV	Safety extra low voltage
SFF	Safe failure fraction, portion of faults that can be safely controlled
SIL	Safety integrity level (in accordance with IEC 61508)
SILworX	Programming Tool
SNTP	Simple network time protocol (RFC 1769)
SRS	System.Rack.Slot, addressing of a module
SSL	Secure sockets layer, see TLS
SW	Software
TLS	Transport layer security, hybrid cryptographic protocol
TMO	Timeout
W	Write, the variable receives a value, e.g., from the user program
WD	Watchdog, device for monitoring the system's correct operation Signal for fault-free process
WDT	Watchdog time
r_P	Peak value of a total AC component

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HIQuad X Sicherheitshandbuch

HI 803 209 E

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https://www.hima.com/en/products-services/hiquad-x

www.hima.com