

# SmartGuard 600 Controllers



**Safety Reference Manual**

**Catalog Numbers 1752-L24BBB,  
1752-L24BBBE**

## Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication [SGL-1.1](#) available from your local Rockwell Automation sales office or online at <http://literature.rockwellautomation.com>) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.





In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

<b>WARNING</b> 	Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
<b>IMPORTANT</b>	Identifies information that is critical for successful application and understanding of the product.
<b>ATTENTION</b> 	Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence
<b>SHOCK HAZARD</b> 	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
<b>BURN HAZARD</b> 	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.

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The information below summarizes the changes to this manual since the last printing.

To help you find new and updated information in this release of the manual, we have included change bars as shown to the right of this paragraph.

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Updated certification information	7 and 9
Added reference to EtherNet/IP network	14
Updated SmartGuard 600 controller features	19
Added EtherNet/IP to communication capabilities	20
Added reference to EtherNet/IP standard target	21
Updated status indication for 1752-L24BBBE controller	21
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## About This Publication

This manual explains how SmartGuard 600 controllers can be used in Safety Integrity Level (SIL) 3, according to IEC 61508, Performance Level PL(e) according to ISO 13849-1, and Category (CAT) 4, according to EN 954-1. It describes the SmartGuard 600-specific safety requirements and controller features, including PFD and PFH values, the safety network number (SNN), configuration signature, safety-locking, and project verification.

### IMPORTANT

You must read and understand the safety concepts and requirements presented in this manual prior to operating a SmartGuard 600 controller in a safety system.

## Who Should Use This Publication

Use this manual if you are responsible for designing, installing, programming, or troubleshooting control systems that use SmartGuard 600 controllers.

You must have a basic understanding of electrical circuitry and familiarity with relay logic. You must also be trained and experienced in the creation, operation, and maintenance of safety systems.

## Understanding Terminology

The following table defines abbreviations used in this manual.

Abbreviation	Full Term	Definition
1oo2	One Out of Two	Refers to the behavioral design of a multi-processor system.
CIP	Common Industrial Protocol	A communication protocol designed for industrial automation applications.
PC	Personal Computer	Computer used to interface with a control system via programming software.
PFD	Probability of Failure on Demand	The average probability of an operational system to fail to perform its design function on demand.
PFH	Probability of Failure per Hour	The probability of an operational system to have a dangerous failure occur per hour.
RPI	Requested Packet Interval	When communicating over a network, this is the expected rate in time for production of data.
SNN	Safety Network Number	A unique number that identifies a section of a safety network.
—	Standard	Any object, task, tag, program, or component in your project that is not a safety-related item (that is, a standard controller refers generically to a ControlLogix controller).

## Conventions

The following conventions are used throughout this manual:

- Bulleted lists, such as this one, provide information, not procedural steps.
- Numbered lists provide sequential steps or hierarchical information.
- **Bold** type is used for emphasis.

## Additional Resources

The table provides a listing of publications that contain important information about SmartGuard 600 controller systems.

Resource	Description
SmartGuard 600 Controller Installation Instructions, publication <a href="#">1752-IN001</a>	Information on installing the SmartGuard 600 controller
SmartGuard 600 Controllers User Manual, publication <a href="#">1752-UM001</a>	Information on using SmartGuard 600 controllers
DeviceNet Safety I/O Installation Instructions, publication <a href="#">1791DS-IN001</a>	Information on installing Guard I/O DeviceNet Safety modules
Guard I/O DeviceNet Safety Modules User Manual, publication <a href="#">1791DS-UM001</a>	Information on using Guard I/O DeviceNet Safety modules

You can view or download publications at <http://literature.rockwellautomation.com>. To order paper copies of technical documents, contact your local Rockwell Automation distributor or sales representative.



# Safety Concept of the SmartGuard 600 Controller

## Introduction

This chapter introduces you to the safety requirements and features of the SmartGuard 600 controller.

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## Certification

Certificate No. 968/EZ238.00/06  
 TÜV Rheinland Group  
 TÜV Industrie Service GmbH  
 Automation, Software, and Informationstechnologie

Safety restrictions can be found in this manual.

For a listing of TÜV-certified product and software versions, refer to:  
<http://www.rockwellautomation.com/products/certification/safety/index.html>

## Introduction to Safety

The SmartGuard 600 controller is type-approved and certified for use in safety applications up to and including Safety Integrity Level (SIL) 3, according to IEC 61508, Performance Level PL(e) according to ISO 13849-1, and Category (CAT) 4, according to EN954-1. SIL requirements are based on the standards current at the time of certification.

The TÜV Rheinland Group has approved the SmartGuard 600 controller for use in safety applications in which the de-energized state is considered to be the safety state.

Hardware modules and software components that are not fail-safe, but do not cause any adverse reactions, can be used to process standard signals. However, they cannot be used to carry out safety tasks.

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**ATTENTION**



Limit the use of standard devices in your application to standard critical components. If you choose to use standard devices in a safety critical fashion, you must be sure that the system design meets SIL 3 requirements.

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**IMPORTANT**

You are responsible for:

- the set-up, SIL rating, and validation of any sensors or actuators connected to the system.
  - project management and functional testing.
  - access control to the safety system, including password handling. When applying Functional Safety, restrict access to qualified, authorized personnel who are trained and experienced.
  - programming the application software and the device configurations in accordance with the information in this safety reference manual and the SmartGuard 600 Controllers User Manual, publication [1752-UM001](#).
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## **PFD and PFH Calculated Values**

IEC 61508 requires you to perform various functional verification (proof) tests of the equipment used in the system. The controller should be included in the functional-verification testing of the other components in the safety system.

The average probability of a system to fail to satisfactorily perform its safety function on demand is called probability of failure on demand (PFD). The probability of a system to have a dangerous failure occur per hour is called probability of failure per hour (PFH).

PFD and PFH calculations have been carried out for the SmartGuard 600 controller in accordance with IEC 61508. These values must be calculated for the overall devices within the system to comply with the SIL required for the specific application.

#### **PFD and PFH Calculations for SmartGuard 600 Controllers**

<b>Functional Verification Test Interval (Years)</b>	<b>PFD</b>	<b>PFH</b>
0.25	4.30E-07	3.93E-10
0.5	8.56E-07	3.91E-10
1	1.71E-06	3.90E-10
2	3.41E-06	3.89E-10
5	8.53E-06	3.89E-10
10	1.71E-05	3.89E-10

## **Additional Safety Data**

These additional pieces of data are used in SIL calculations for the SmartGuard 600 controllers:

- Safe failure fraction - 99.94%
- Diagnostic coverage - greater than 90%

## **Safety Network Number**

The safety network number (SNN) is a unique number that identifies the safety network sub-net. The SNN, in conjunction with the target's node address, enables a target to determine with high integrity whether or not safety connection requests it receives have reached the correct destination.

Each end node in a DeviceNet Safety control system must have a unique node identifier. This unique node reference for a DeviceNet Safety node is a combination of the SNN and the node address of the network device. It is used to precisely identify the intended target device during configuration and I/O connection establishment.

Any device that originates a safety connection to another safety device must be configured with the SNN of the target device.

The configuration software automatically assigns an SNN, based on the date and time, when a new network configuration file is created.

For typical users, the automatic assignment of an SNN is sufficient. However, you can assign an SNN manually.

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**IMPORTANT**

If you assign an SNN manually, take care to ensure that system expansion does not result in duplication of SNN and node address combinations.

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**IMPORTANT**

If you are using a device that has been used in another location, reset the device to the out-of-box configuration by right-clicking the device and choosing Reset Safety Device. Check the Safety Network Number checkbox and click OK.

Refer to the SmartGuard 600 Controllers User Manual, publication [1752-UM001](#), for more information on safety reset.

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**ATTENTION**



If a safety project is copied to another project intended for a different hardware installation and that installation may reside within the same routable safety system, the SNN must be changed to be sure that the SNN is not repeated.

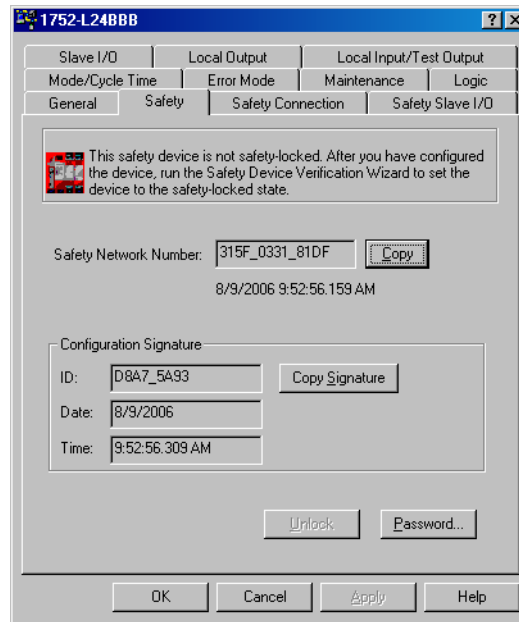
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## Configuration Signature

The configuration signature defines the controller's configuration. It can be read and monitored and is used to uniquely identify the controller's configuration in several operations.

- During download from the configuration software, the configuration signature provides you with a means to check that the device and the configuration tool agree on the information downloaded.
- During device replacement, the configuration signature lets you verify that the configuration in the software is the correct configuration. If the originator is used to automatically configure a device, the configuration signature indicates whether reconfiguration is necessary and ensures the integrity of the operation.
- During connection establishment, the originator and the target devices use the configuration signature to ensure that both devices agree on the device configuration.
- The configuration signature is auto-generated by the configuration software when a SmartGuard 600 controller is added to the project.

## Configuration Signature



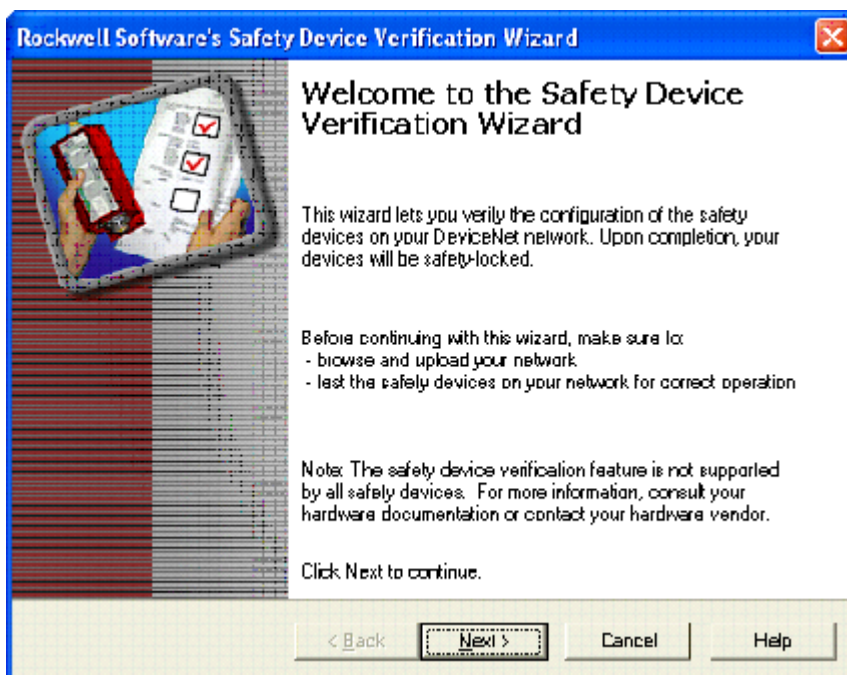
## Safety-lock with Password Protection

The configuration of the controller can be protected by the use of an optional password. Download, safety-reset, and safety-lock and -unlock are password protected. When a device is safety-locked, you also cannot change the password or change the status of the device, without first entering the existing password.

After configuration data has been downloaded and verified, the configuration data within the controller can be protected using RSNetWorx for DeviceNet software. Run the Safety Device Verification Wizard to lock the controller.

When applying Functional Safety, restrict access to qualified, authorized personnel who are trained and experienced. The safety-lock function with passwords is provided by the Safety Device Verification Wizard in RSNetWorx for DeviceNet software. You are responsible for controlling access to the safety system, including password use and handling.

## Verification Wizard



If you forget a password, you can reset passwords using the vendor password. Contact Rockwell Automation Technical Support and provide the device's serial number and security code to obtain the vendor password.

## Configuration and Programming

Use RSNetWorx for DeviceNet software, version 8.0 (minimum) or later (version 9.1 is recommended), to configure, program, and monitor the status of the 1752-L24BBB controller. Use RSNetWorx for DeviceNet software, version 9.1 or later, to configure, program, and monitor the status of the 1752-L24BBBE controller. With RSNetWorx for DeviceNet software, you can configure the controller by using the SmartGuard controller's USB port or via the DeviceNet network or EtherNet/IP network. The logic editor is launched from within RSNetWorx for DeviceNet software.

You also need RSLinx software, version 2.55 or later, which lets you configure a 1752-L24BBBE controller on EtherNet/IP.

A variety of SIL 3-compliant applications can be programmed using the logic functions and function blocks supported by the controller. A maximum of 254 logic functions and function blocks can be used in a maximum of 32 programming pages. You can password-protect both configuration data and project files.

The controller supports these logic functions:

- NOT
- AND
- OR
- Exclusive OR
- Exclusive NOR
- Routing
- RS flip-flop
- Multi-connector
- Comparator

The controller supports these function blocks:

- Reset
- Restart
- Emergency stop push button monitoring
- Light curtain monitoring
- Safety gate monitoring
- Two-hand controller
- OFF-delay timer
- ON-delay timer
- User mode switch
- External device monitoring
- Muting
- Enable switch
- Pulse generator
- Counter

Programs are created from logic functions and function blocks that indicate commands, from input tags that indicate data input sources, and from output tags that indicate data output destinations.

Input tags reflect the status of inputs from these I/O areas:

- Input area of the controller's local terminals
- Input area of safety slaves registered as communication partners
- I/O area reflected from safety master data
- I/O area reflected from standard master data
- Local input status
- Local output status
- General unit status
- Test output status
- Muting lamp status

Output tags reflect the status of outputs from these I/O areas:

- Output area of the controller's local terminals
- Output area of safety slaves registered as communication partners
- I/O area reflected from safety master data
- I/O area reflected from standard master data

#### ATTENTION



Always verify that safety-related signals used in safety-related logic meet applicable standards and regulations. Use only safety input signals to function blocks. It is your responsibility to verify that the proper sources for signals used in conjunction with these function blocks and the overall safety logic implementation adhere to relevant safety standards and regulations.

Only safety data transmitted over safety connections may be used as safety data in safety application logic.

#### Permitted Use of Safety and Standard Data

End-device Signal Definition	Connection Type	Permitted Use in Application
Safety	Safety	Safety
	Standard	Standard
Standard	Safety	Standard
	Standard	Standard



## System Reaction Time

The system reaction time is the amount of time from a safety-related event as input to the system until the system is in the safe state. The system reaction time is the sum of the reaction times of each element in the safety chain, considering the occurrence of faults or errors in that safety chain. The system reaction time must meet the required safety system specifications.

See [Chapter 4](#) for examples of typical safety chains and system reaction time calculations.

## Error Diagnostics

Status indicators and an alphanumeric display provide status and error information about the SmartGuard 600 controller. You can also view status and error messages in the error log using RSNetWorx for DeviceNet software.

Controller errors fall into three categories: nonfatal errors, abort errors, and critical errors.

### Controller Error Categories

Error Type	Controller Response
Nonfatal	When a nonfatal error occurs, the controller places the local I/O terminal or safety I/O connection where the error occurred into the safety state. The controller continues to operate in Run mode.
Abort	When an abort error occurs, the controller completely stops safety functions and places them in the safety state. To enable you to check the error state, explicit message communication is supported.
Critical	When a critical error occurs, all controller functions stop. The error log is saved in nonvolatile memory.

## Additional Resources

Refer to the SmartGuard 600 Controllers User Manual, publication [1752-UM001](#), for more information on the following:

- Programming and details on logic functions and function block operation
- Controller error handling and error log descriptions
- Safety reset

[Chapter 2](#) of this manual also contains information on I/O error handling.

## **Notes:**

## Controller Overview

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### About the Controller

The SmartGuard 600 controller (catalog numbers 1752-L24BBB and 1752-L24BBBE) are programmable electronic systems featuring 16 digital inputs, 8 digital outputs, 4 test pulse sources, and connections for USB and DeviceNet safety communication. In addition, the 1752-L24BBBE controller offers EtherNet/IP connectivity.

**IMPORTANT**

The SmartGuard controllers must not be directly connected to any network that is not protected from outside intrusion. For example, do not connect the SmartGuard 600 controller to an Ethernet network that is not protected with a firewall or other security measures.

### Power Supply Requirements

Power for the controller is provided via an external 24V dc power source. The output hold time must be 20 ms or longer.

To comply with the CE Low Voltage Directive (LVD), DeviceNet connections and I/O must be powered by a dc source compliant with Safety Extra Low Voltage (SELV) or Protected Extra Low Voltage (PELV).

To comply with UL restrictions, DeviceNet connections and I/O must be powered by dc sources whose secondary circuits are isolated from the primary circuit by double insulation or reinforced insulation. The dc power supply must satisfy the requirements for Class 2 circuits or limited voltage/current circuits defined in UL 508.

## Communication Capabilities

The controller can act as a DeviceNet safety master or slave, as a DeviceNet standard slave, EtherNet/IP standard target, or as a standalone controller when DeviceNet communication is disabled.

Explicit messages can be used to read controller status information. Explicit messages configured from the RSNetWorx for DeviceNet software can be sent from the user program. The messages can be routed between DeviceNet and EtherNet/IP networks.

The USB port can be used to program the SmartGuard controller and to configure devices on the DeviceNet network. The SmartGuard provides some limited pass-through capability from USB to DeviceNet, for programming and configuration purposes. When used in Standalone mode, the controller communicates with the configuration software via USB communication.

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**IMPORTANT**

The data attributes handled by standard I/O communication and explicit message communication are non-safety data. The necessary measures for safety data are not taken during generation of standard or explicit message data. Do not use this data to operate a safety control system.

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A single controller can function simultaneously as a DeviceNet safety master, DeviceNet safety slave, DeviceNet standard slave, and an EtherNet/IP standard target.

### *DeviceNet Safety Master*

As a safety master, the controller can perform safety I/O communication with up to 32 connections, using up to 16 bytes per connection. A master-slave relationship is established for each connection on the DeviceNet Safety network, separate from the master-slave communication on the DeviceNet standard network. This enables the controller to be the safety master to control the connections.

### *DeviceNet Safety Slave*

As a safety slave, the controller can perform safety I/O communication with a maximum of four connections, using up to 16 bytes per connection. The controller's internal status information and a specified area of I/O can be allocated in the safety master.

### *DeviceNet Standard Slave or EtherNet/IP Standard Target*

As a standard slave, the controller can perform standard I/O communication on DeviceNet or EtherNet/IP networks with one standard master for up to two connections, using up to 16 bytes per connection (128 bytes for input data for EtherNet/IP communication). The controller's internal status information and a specified area of I/O can be allocated in the standard master.

## Status Indication

The controller's internal status information and I/O data can be monitored online using RSNetWorx for DeviceNet software with either a USB or DeviceNet network connection or EtherNet/IP connection.

The status indicators and alphanumeric display on the controller provide status and error information.

### **IMPORTANT**

Status indicators are not reliable indicators for safety functions. They should be used only for general diagnostics during commissioning or troubleshooting. Do not attempt to use status indicators as operational indicators.

When the service switch on the front of the controller is pressed, the alphanumeric display shows the controller's safety configuration signature two digits at a time for a total of ten pairs of numbers.

Errors detected by the controller are recorded in an error history log, along with the total operating time (starting when the controller entered the Execute mode) at the time the error was detected.

## Behavior for Power Supply Interruptions

The controller reacts when voltage drops to 85% of the rated voltage or lower, but can recover if the power supply voltage returns to 85% or more of the rated voltage.

### *Voltage Drops*

If the power supply voltage for the internal circuit (V0, G0) drops to 85% of the rated voltage or lower, the controller turns off the outputs.

If the power supply voltage for inputs (V1, G1) drops to 85% of the rated voltage or lower when the power supply for the internal circuit

is normal, the controller continues operating, but will not refresh inputs. Similarly, if the power supply, voltage for outputs (V2, G2) drops to 85% of the rated voltage or lower, the controller will continue operation but will stop refreshing outputs.

### *Automatic Recovery*

If the power supply returns to 85% of the rated voltage or more because of a fluctuation in the power supply voltage:

- operation might automatically restart. This occurs if the power supply to the controller is completely stopped because of a voltage drop to 85% of the rated voltage or lower.
- a critical error could occur, which will require you to cycle the power supply to restore operation. This occurs if the power supply fluctuates around the lower operational limit of the internal power/voltage detection circuit.

I/O refresh is automatically restarted when the power supply is recovered to 85% or more of the rated voltage. The I/O power monitor error is also automatically cancelled.

## Operating Mode Summary

The controller supports these operating modes.

### SmartGuard 600 Controller Operating Modes

Operating Mode	Description	Module Status (MS) Indicator
Self-diagnostic mode	The controller performs internal self-diagnosis to ensure the integrity of safety functions.	Flashing red/green
Configuration mode	While waiting for the completion of configuration from RSNetWorx for DeviceNet software, the controller is in Configuration mode. The controller switches to Configuration mode when it is not yet configured after initialization is complete or when there is an error in the configuration data.	Flashing red/green
Idle mode	The controller enters Idle mode while waiting for Run mode after initialization has been completed. Non-safety-related control, such as standard I/O and message communication, is supported.	Flashing Green

**SmartGuard 600 Controller Operating Modes**

<b>Operating Mode</b>	<b>Description</b>	<b>Module Status (MS) Indicator</b>
Run mode	Safety and non-safety control are supported.	Solid green
Abort mode	The controller changes to Abort mode if the controller node address switch setting is changed after the configuration is complete. The controller stops all functions except for message communication and enters the safety state.	Flashing red
Critical Error mode	The controller enters this mode and sends all safety functions to the safety state when a critical error occurs.	Solid red

**About the Safety Inputs**

The controller has 16 local safety inputs that support:

- input circuit diagnosis. Test pulse sources can be used to monitor internal circuits, external devices, and external wiring.
- input on- and off-delays. You can set input time constraints of 0...126 ms in multiples of the controller cycle time. Setting input on- and off-delays helps reduce the influence of chattering and external noise.

**IMPORTANT**

Input on- and off-delays must be added to the I/O response time. This will affect the system reaction time calculations.

See [Chapter 4](#) for information on calculating reaction times.

- Dual Channel mode. You can set Dual Channel mode for pairs of related local inputs. When Dual Channel mode is set, time discrepancies in data changes or input signals between two paired local inputs can be evaluated.

## Input Channel Mode Settings

The Input Channel mode of local safety inputs is set based on the type of external device to which you want to connect.

### Channel Mode Descriptions

Channel Mode	Description
Not used	The input channel is not connected to an external device.
Test pulse from test output	Use this mode when connecting a contact-type safety input device (such as E-stop or Gate Interlock) to the input that will perform pulse testing on the circuit. Select the test output terminal to use as the test source and set the test output mode to Pulse Test Output. This enables detection of short circuits with the power supply line (positive side), earth faults, and short circuits with other input signal lines.
Used as a safety input	Use this mode to connect to a safety device with a semiconductor output, such as a light curtain.
Used as a standard input	Use this mode to connect to a standard (non-safety) device.



## Dual Channel Mode Settings

Local safety input channels can be set to Dual Channel mode. Setting Dual Channel mode enables the status of two inputs to be evaluated and reflected in I/O tags. The discrepancy time between changes in the status of two inputs can also be evaluated.

### Dual Channel Mode Input Settings

Channel Mode	Description
Single Channel	The safety input terminal is used independently.
Dual Channel Equivalent	The safety input terminal is used as a Dual Channel Equivalent with a pair safety input terminal.
Dual Channel Complementary	The safety input terminal is used as a Dual Channel Complement with a paired safety input terminal.

The controller supports function blocks with diagnostic functionality equivalent to Dual Channel mode. In many case, annunciation and troubleshooting of system faults is easier when the function blocks are used to detect faults rather than the SmartGuard hardware. If you wish to use the function blocks to detect system faults, the safety inputs must be configured for single channel

## Error Handling

When an error is detected, the reaction of the controller depends upon the channel mode setting: Single or Dual Channel.

In Single Channel mode, if an error is detected during self-diagnosis:

- I/O tags that correspond to the safety input terminals with errors are made inactive.
- the status indicator for the safety input terminals with errors illuminates red.
- the error is written in the error history.
- the controller continues to operate.

If a discrepancy error is detected in Dual Channel mode:

- I/O tags that correspond to the safety input pairs with errors are made inactive.
- status indicators for both input pairs illuminate red.
- the errors are written in the error history.
- the controller continues to operate.

If an error is detected in one of the two inputs in Dual Channel mode:

- I/O tags that correspond to the safety input pairs with errors are made inactive.
- the status indicator of the safety input with the error illuminates red. The status indicator of the paired input flashes red.
- the error appears in the error history.
- the controller continues to operate.

To recover from an error in a safety input:

- the cause of the error must be removed.
- the error latch time must have passed.
- the input signal must return to inactive status with no error condition detected, for example, by pressing an emergency stop button or opening a door.

## About the Safety Outputs

The controller has eight local safety outputs that support:

- output circuit diagnosis. Test pulses can be used to diagnose the controller's internal circuits, external devices, and external wiring.
- overcurrent detection and protection. To protect the circuit, an output is blocked when an overcurrent is detected.
- Dual Channel mode. Both of two paired outputs can be set into a safety state when an error occurs in either of the two paired local outputs without depending on the user program.

## Output Channel Mode Settings

You set the Output Channel mode based on the type of external device to which you want to connect.

### Output Channel Mode Descriptions

Channel Mode	Description
Not used	The output terminal is not connected to an output device.
Safety	A test pulse is not output when the output is on. When the output is off, short circuits with the power supply line can be detected. Ground faults can also be detected.
Safety Pulse Output	A test pulse is output when the output is on. This enables detection of short circuits with the power supply line (positive side) whether the output is on or off. Ground faults and short circuits between output signals can also be detected.

#### IMPORTANT

If a safety pulse output is set, an off pulse signal (pulse width 580  $\mu$ s) is output to diagnose the output circuit when the safety output turns on. Check the input response time of the control device to make sure this output pulse will not cause malfunctions.

## Dual Channel Mode Settings

Local safety output terminals can also be set to Dual Channel mode. Setting Dual Channel mode enables an error to be detected if the two outputs from a user program are not equivalent. If an error is detected in one of two outputs circuits, both outputs to the device will become inactive.

### Dual Channel Mode Output Settings

Channel Mode	Description
Single Channel	The safety output terminal is used independently.
Dual Channel	The safety output terminal is paired with another output terminal. The output can be turned on when both the output and the paired safety output are set to the same state.

## Error Handling

When an error is detected, the reaction of the controller depends upon the channel mode setting: Single or Dual Channel.

If an error is detected in Single Channel mode during self-diagnosis:

- the safety output with the error becomes inactive without depending on the user program.
- the status indicator of the safety output with the error illuminates red.
- the error is written in the error history.
- the controller continues to operate.

If an error is detected in one of the two paired outputs in Dual Channel mode:

- both outputs become inactive without depending on the user program.
- the status indicator of the output with the error illuminates red. The status indicator of the paired output flashes red.
- the error is written in the error history.
- the controller continues to operate.

If the two outputs from the user program to the output I/O tags are not equivalent:

- both outputs to the external device become inactive without depending on the user program.
- the status indicators for the paired outputs illuminate red.
- the error is written in the error history.
- the controller continues to operate.

To recover from an error in a safety output:

- the cause of the error must be removed.
- the error latch time must have passed.
- the output signals to the output I/O tags from the application that correspond to the safety output terminals must go inactive.

---

**IMPORTANT**

If Dual Channel mode is set for two outputs to implement redundant circuits and an error is detected for one of the two outputs, the other output can be forced to go inactive without relying on the user program. If the redundant circuits are implemented using two outputs in Single Channel mode, user program logic must be written to detect the error, using the External Device Monitoring function block.

---

## About the Pulse Test Sources

These four independent test outputs are normally used in combination with safety inputs. They can also be set for use as signal (standard) output terminals. The test pulse outputs feature:

- current monitoring for muting lamp. A disconnect can be detected for the T3 terminal only.
- overcurrent detection and protection. To protect the circuit, an output is blocked when an overcurrent is detected.

---

**ATTENTION**

Pulse test outputs must not be used as safety-related outputs (for example, for the control of safety-related actuators).

---

## Error Handling

The controller performs the following operations if an error is detected during self-diagnosis:

- The output terminals for which errors have been detected are made inactive without intervention from the user program.
- The error is written in the error history.
- The controller continues to operate.

## Error Latch Time

You can set the time to latch the error state when an error occurs in a safety input terminal, safety output terminal, or test output terminal. The error state continues until the error latch time passes even if the cause of the error is momentarily removed. When monitoring errors from a monitoring system, take the monitoring interval into account when setting the error latch time.

The error latch time can be set from 0...65,530 ms in increments of 10 ms. The default setting is 1000 ms.

---

**IMPORTANT**

Errors detected at test output terminals are automatically reset after the error latch time. Leaving the short-circuit state as is may result in failure due to increased temperatures. If an external load short-circuit occurs, remove the cause immediately.

---

## About Remote I/O

The remote I/O areas used in safety masters or slaves and standard masters or slaves are automatically allocated in the controller's I/O memory, according to settings made in RSNetWorx for DeviceNet software.

### Remote I/O Area Attributes

The controller's remote I/O area has mode change, communication error, and power on attributes. All values in the safety remote I/O area are cleared if the operating mode is changed. If a communication error occurs, all data for the connection with the error is cleared.

#### Remote I/O Area Attributes

Remote I/O Area Type	Mode Change		Communication Error	Power On
	Run to Idle	Run or Idle to Configuration		
DeviceNet safety remote I/O area	Cleared (safety state)	Cleared (safety state)	Cleared for the connection (safety state)	Cleared (safety state)
DeviceNet standard remote I/O area	Depends upon slave I/O area hold setting	Cleared	Depends upon slave I/O area hold setting	Cleared

The standard slave I/O area hold setting specifies whether to clear or hold the data in the standard slave I/O area when the operating mode is changed or when a communication error occurs. The default setting is clear. Both settings are valid when power is cycled.

#### Slave I/O Area Hold Settings

Setting	Description
Clear	<p>The standard slave output area (inputs to the SmartGuard application program) is cleared when a communication (connection) error occurs.</p> <p>The standard slave input area (outputs to a standard master) is cleared when the operating mode is changed to Idle.</p>
Hold	<p>The last data in the standard slave output area (inputs to the SmartGuard application program) is held when a communication (connection) error occurs.</p> <p>The last data in the standard slave input area (outputs to a standard master) is held when the operating mode is changed to Idle.</p> <p>Values are cleared when a critical error or abort occurs or when the power supply is turned on again.</p>

## Status Area

When the controller operates as an input safety slave or a standard slave, status information can be added to the first line of the transmit data. This information can be stored in a programmable controller and used to establish a monitoring system.

### Status Information

Tag Name	Data Size	Attribute Type
General Status	Byte	Non-safety
Local Input Status	Word	Safety
Local Output Status	Byte	Safety
Test Output/Muting Lamp Status	Byte	Non-safety

#### ATTENTION



For data with a non-safety attribute, the necessary measures for safety data are not taken during data generation. Do not use this data to operate a safety control system.

In addition, even if the attribute for an item is safety, it becomes non-safety if data is input using standard communication or I/O tags connected with standard devices. Therefore, those items must not be used to operate a safety control system.

**Notes:**



# Safety Application Development

## Introduction

Topic	Page
Safety Concept Assumptions	33
Basics of Application Development and Testing	33
Establish a New Safety Network	34
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## Safety Concept Assumptions

The safety concept assumes that:

- those responsible for creating, operating, and maintaining the application are fully qualified, specially trained personnel, experienced in safety systems.
- you apply the logic correctly, meaning that programming errors can be detected. Programming errors can be detected by strict adherence to specifications, programming, and naming rules.
- you perform a critical analysis of your application and use all possible measures to detect a failure.
- you confirm all application downloads via a manual check of the configuration signatures.
- you perform a complete functional test of the entire system before the initial start-up of a safety-related system.

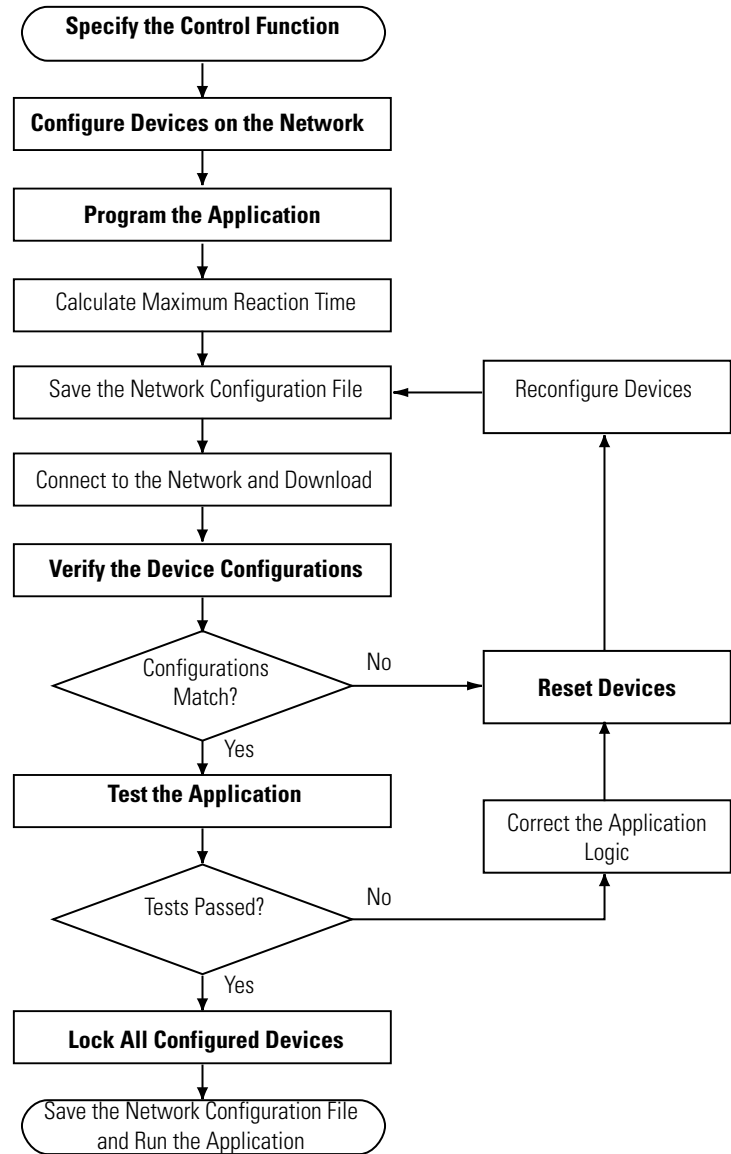
## Basics of Application Development and Testing

The application program for the intended SIL 3 system should be developed by the system integrator and/or user trained and experienced in safety applications. The developer must follow good design practices.

- Use functional specifications, including:
  - flow charts.
  - timing diagrams.
  - sequence charts.
- Perform a program review.
- Perform program validation.

## Establish a New Safety Network

The flowchart below shows the steps required for commissioning a new SmartGuard 600 controller system. Items in bold are explained in the following sections.



For information on calculating response time, see [Chapter 4](#).

## Specification of the Control Function

You must create a specification for your control function. Use this specification to verify that program logic correctly and fully address your application's functional and safety control requirements. The specification may be presented in a variety of formats, depending on your application. However, the specification must be a detailed description that includes the following (if applicable):

- Sequence of operations
- Flow and timing diagrams
- Sequence charts
- Program description
- Program print out
- Verbal descriptions of the steps with step conditions and actuators to be controlled, including:
  - input definitions.
  - output definitions.
  - I/O wiring diagrams and references.
  - theory of operation.
- Matrix or table of stepped conditions and the actuators to be controlled, including the sequence and timing diagrams
- Definition of marginal conditions, for example, operating modes or emergency stop.

The I/O portion of the specification must contain the analysis of field circuits, that is, the type of sensors and actuators.

- Sensors (Digital or Analog)
  - Signal in standard operation (dormant current principle for digital sensors, sensors OFF means no signal)
  - Determination of redundancies required for SIL levels
  - Discrepancy monitoring and visualization, including your diagnostic logic
- Actuators
  - Position and activation in standard operation (normally OFF)
  - Safe reaction/positioning when switching OFF or power failure.
  - Discrepancy monitoring and visualization, including your diagnostic logic

## Configuring Devices on the Safety Network

You must commission all devices with the node address, safety network number (SNN), and communication rate, if necessary, before their installation on the safety network. Devices are assigned an SNN and configured using RSNetWorx for DeviceNet software, version 8 or later.

---

**IMPORTANT**

Perform user testing to make sure the system bandwidth does not cause problems.

---

## Programming the Application

The logic and instructions used in programming the application must be:

- easy to understand.
- easy to trace.
- easy to change.
- easy to test.

All logic should be reviewed and tested. Keep safety-related logic and non-safety-related logic separate.

### *Labeling the Program*

The application program is clearly identified by one of the following:

- Name
- Date
- Revision
- Any other user identification

## Verify the Device Configurations

Since RSNetWorx for DeviceNet software is not a SIL 3-certified application, the configuration values resulting from user operations and software computation are not considered to be of high integrity until download, read-back, and user testing is complete.

After the configuration is downloaded to the devices, perform these steps to verify the device configurations.

1. Read the configuration back from the device and print it out.
2. Compare this printed configuration to the configuration from RSNetWorx for DeviceNet software.
3. Check that the printed configuration meets the application specification requirements.
4. Reset and reconfigure the affected devices if the configurations do not match, or the application requirements are not met.

---

**IMPORTANT**

You must review all safety device configurations and record the configuration signatures prior to operating a safety application.

---

## Reset Devices

When changing a configuration because of verification or user testing results, you must clear the previous configuration before downloading the new parameters. Reset the device by setting the reset type to Return to out-of-box configuration and emulate cycling power.

Refer to the SmartGuard 600 Controller User Manual, publication [1752-UM001](#), for details.

## Test the Application

To check the application program for adherence to the specification, you must generate a suitable set of test cases covering the application. The set of test cases must be filed and retained as the test specification.

You must include a set of tests to prove the validity of the calculations (formulas) used in your application logic. Equivalent range tests are acceptable. These are tests within the defined value ranges, at the limits, or in invalid value ranges. The necessary number of test cases depends on the formulas used and must comprise critical value pairs.

Active simulation with sources (field devices) must also be included, since it is the only way to verify that the sensors and actuators in the system are wired correctly. Verify the operation of programmed functions by manually manipulating sensors and actuators.

You must also include tests to verify the reaction to wiring faults and network communication faults.

This includes required functional verification tests of fault routines, input and output channels to make sure that the safety system operates properly.

To perform a functional verification test on the controller, you must perform a full test of the application. You must toggle each sensor and actuator involved in every safety function. From a controller perspective, this means toggling the I/O point going into the controller, not necessarily the actual actuators. Be sure to test all shutdown functions, since these functions are typically not exercised during normal operation.

Also, be aware that a functional verification test is only valid for the specific application tested. If the controller is moved to another application, you must also perform start-up and functional verification testing on the controller in the context of the new application.

An independent, third-party review of the safety system may be required before the system is approved for operation.

## Lock All Configured Devices

---

**IMPORTANT**

Before you lock your safety device configurations, you must perform all of the verification steps required for your application.

---

Lock the configuration of all devices to indicate they have been verified, as well as to prevent parameters from being unintentionally modified.

Run the Safety Device Verification Wizard in RSNetWorx for DeviceNet software to safety-lock your devices.

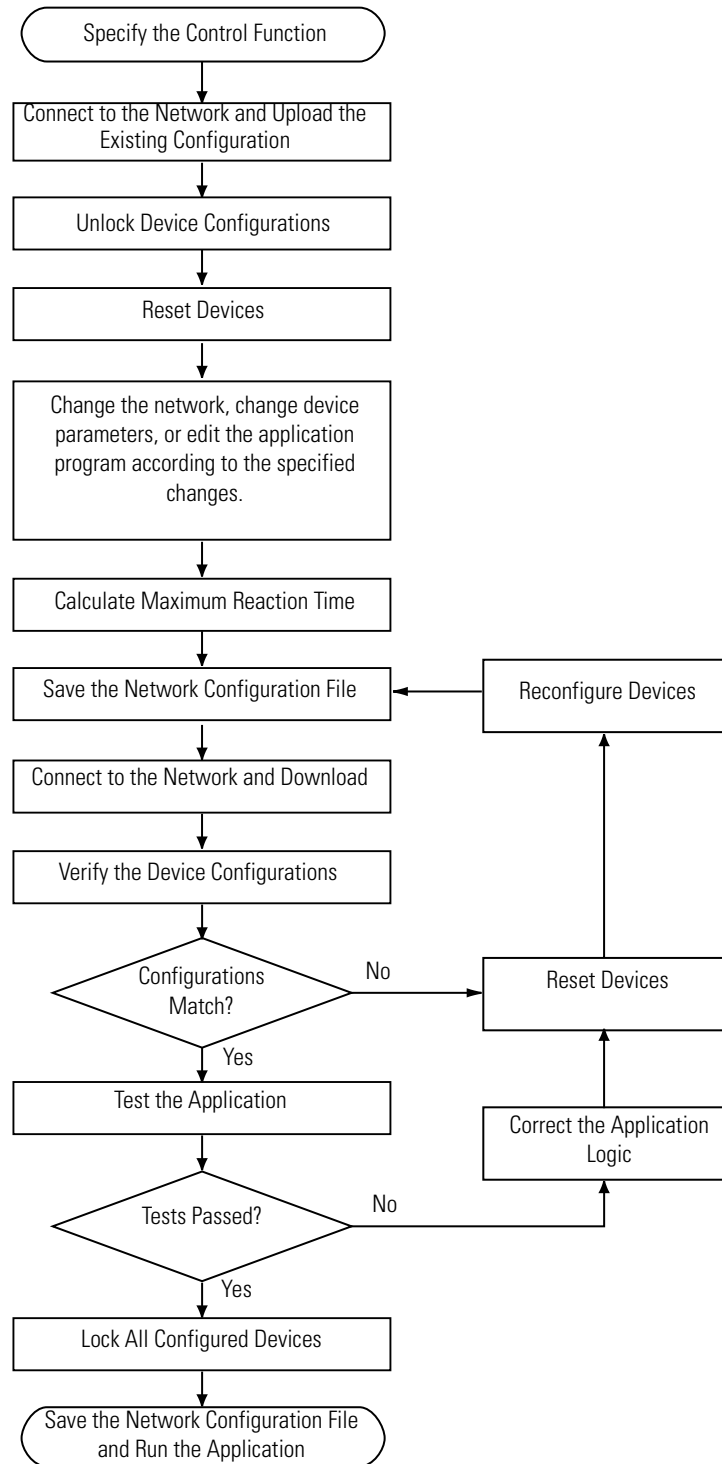
## Changing Your Application Program

The following rules apply to changing your application program:

- Only authorized, specially-trained personnel can make program edits. These personnel should use all supervisory methods available, for example, using the software password protections.
- When authorized, specially-trained personnel make program edits, they assume the central safety responsibility while the changes are in progress. These personnel must also maintain safe application operation.
- You must sufficiently document all program edits, including:
  - authorization.
  - impact analysis.
  - execution.
  - test information.
  - revision information.
- Before you connect a device to the network, you must clear the previous configuration.
- You must commission all devices with the node address, safety network number (SNN), and communication rate, if necessary, before their installation on the safety network.

## Edit Your Project

This flowchart explains the steps required to modify an existing network and user program.





## System Performance and Reaction Time

### Introduction

Topic	Page
Assumptions	41
Operational Flow and Cycle Time	41
I/O Refresh Cycle Time and Network Reaction Time	43
System Reaction Time	45

### Assumptions

The calculations shown here assume that:

- the configuration is correct.
- the power has been turned on, the self-diagnostic function has completed, and the controller is in Run mode.
- the necessary safety slaves have been added to the system.

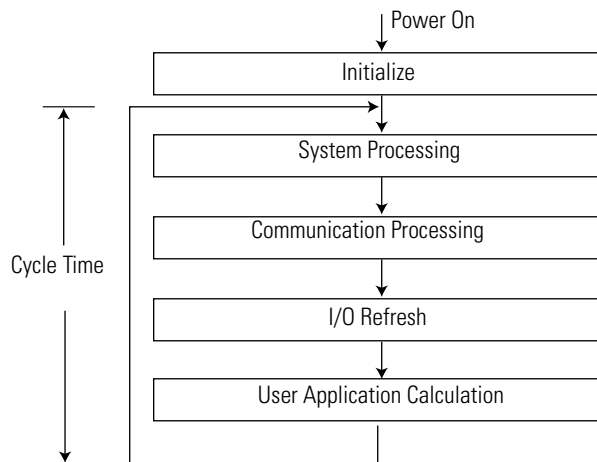
### Operational Flow and Cycle Time

The operation of the controller is outlined in the flow diagram. The controller initializes itself internally when the power is turned on. Unless there are errors, the controller cyclically executes system processing, such as DeviceNet, EtherNet/IP, and USB communication, I/O refresh, and user program logic. In Standalone Controller mode, the controller executes all but the DeviceNet and EtherNet/IP communication processes. The cycle time depends on the scale of the user program and the configuration of DeviceNet remote I/O communication.

**IMPORTANT**

Approximately six seconds are required to complete initialization after the power is turned on. Initialization processing includes the self-diagnosis required for the controller to perform safety functions.

### Operational Flow

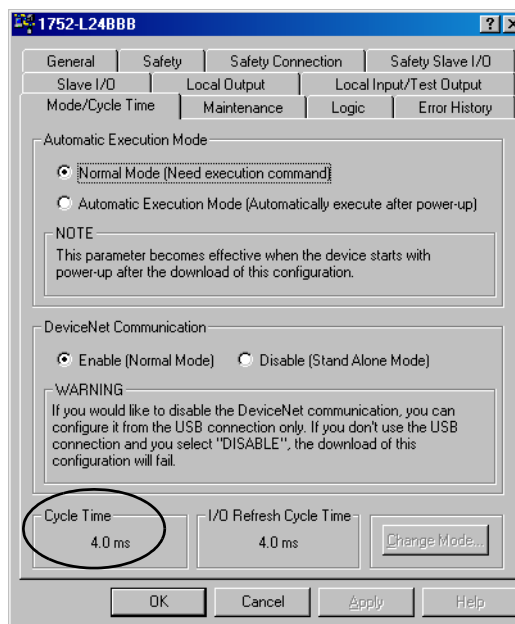


Cycle time is expressed by the following formula:

Controller cycle time =  
 System processing time + DeviceNet and/or USB communication time  
 + I/O refresh time + User application execution time

The cycle time of the controller is set in 1 ms increments, depending upon the configuration. You can view the cycle time in RSNetWorx for DeviceNet software.

### Mode/Cycle Tab in RSNetWorx for DeviceNet Software



After the controller has started operating, DeviceNet connections are established and devices are verified to start DeviceNet safety I/O communication. This process can take up to two seconds to be completed depending on the controller's configuration.

The processing time after the connection is established until the safety I/O data is sent and received using that connection = requested packet interval (RPI) setting x 3 + controller cycle time x 6.

After the controller is initialized and has verified that no duplicate node addresses exist on the DeviceNet network, the controller is added to the DeviceNet network. This process takes approximately two seconds. This process is not completed before controller operation is started if the controller is configured for automatic execution at start-up. You must take this time into account when evaluating the time until DeviceNet I/O communication data becomes valid.

## **I/O Refresh Cycle Time and Network Reaction Time**

The I/O refresh cycle time and network reaction time parameters are required to evaluate local I/O response and I/O communication performance for the controller.

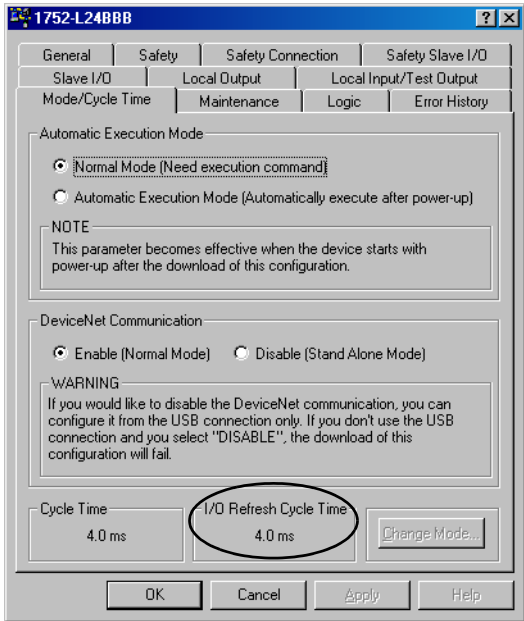
### **I/O Refresh Cycle Time**

The I/O reaction time of the controller is used when calculating the local I/O reaction time. The I/O refresh cycle time is set to the optimum value for the configuration from among these settings:

- 3.5 ms
- 4.0 ms
- 4.5 ms
- 5.0 ms
- 5.5 ms
- 6.0 ms
- 6.5 ms

You can view the I/O refresh cycle time in RSNetWorx for DeviceNet software.

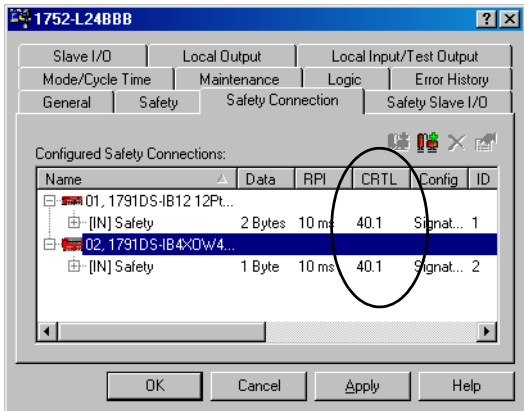
Mode/Cycle Tab in RSNetWorx for DeviceNet Software



Network Reaction Time

The network reaction time of the controller is used to calculate remote I/O reaction time. You can view the connection reaction time in RSNetWorx for DeviceNet software.

Safety Connection Tab in RSNetWorx for DeviceNet Software



## System Reaction Time

System reaction time is the amount of time from a safety-related event as input to the system until the system is in the safety state. Reaction time is variably dependent on factors such as the type of DeviceNet Safety I/O modules and instructions used in the application program. Faults within the system can also have an effect upon the reaction time of the system.

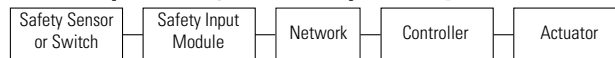
The reaction time is calculated for each safety chain. You must verify that the reaction time of all safety chains meets the application requirements specification.

The following illustrations show some typical safety chains.

### Local Input Through Local Output Safety Chain



### Remote Input Through Local Output Safety Chain



### Local Input Through Remote Output Safety Chain



### Remote Input Through Remote Output Safety Chain

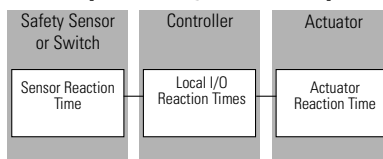


I/O response time is not required in the reaction time calculation when operation is normal. With the reaction time, the output shutoff time will be maintained even if faults or failures occur in devices or in the network.

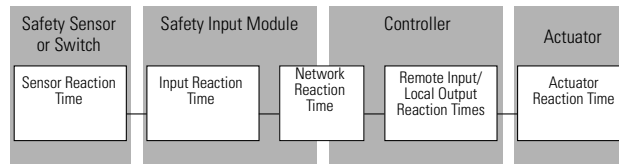
## Calculating Reaction Time

The elements of the reaction time equation are listed below for each safety chain.

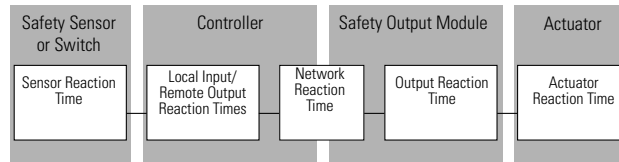
### Local Input Through Local Output Safety Chain Reaction Time



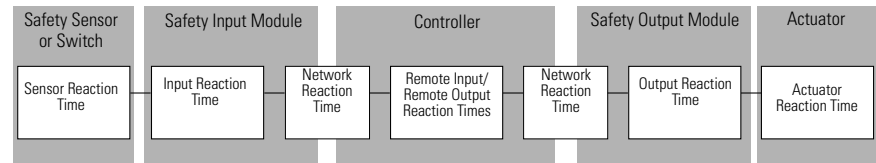
### Remote Input Through Local Output Safety Chain Reaction Time



### Local Input Through Remote Output Safety Chain Reaction Time



### Remote Input Through Remote Output Safety Chain Reaction Time



### Reaction Time Formulas

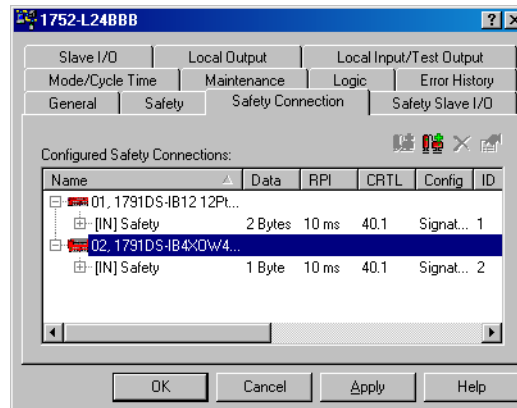
Safety Chain Element	Formula
Local I/O reaction times (ms) at the controller	= On/Off delay time + I/O refresh cycle + controller cycle time x 2 + 2.5
Remote input/local output reaction time (ms) at the controller	= Controller cycle time + 2.5
Local input/remote output reaction time (ms) at the controller	= On/Off delay time + I/O refresh cycle + controller cycle time x 2
Remote input/remote output reaction time (ms) at the controller	= Controller cycle time
Input reaction time (ms) at the input module	= On/Off delay time + input reaction time
Output reaction time (ms) at the output module	= Output reaction time
Network reaction time (ms)	= Read from RSNetWorx for DeviceNet software

#### IMPORTANT

If an output from a function block is fed back to the input side of the same function block, the cycle time of the controller must be added to the reaction time for the safety chain.

The controller cycle time and I/O refresh cycle time are displayed on the Mode/Cycle Time tab of the Properties dialog in RSNetWorx for DeviceNet software. The Connection Reaction Time Limit is displayed on the Safety Connection tab of the same dialog.

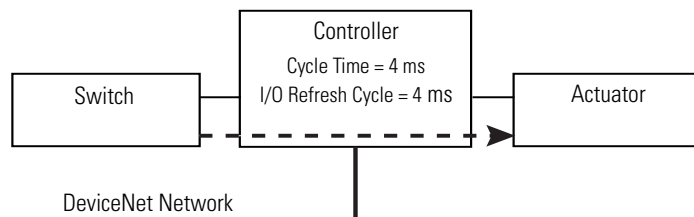
### Safety Connection Tab in RSNetWorx for DeviceNet Software



### Reaction Time Examples

These examples illustrate how to calculate system reaction time of different types of safety chains.

#### *Example One: Local Input to Local Output Reaction Time*



Reaction time (ms) =  
switch reaction time + controller local input/local output reaction time  
+ actuator reaction time.

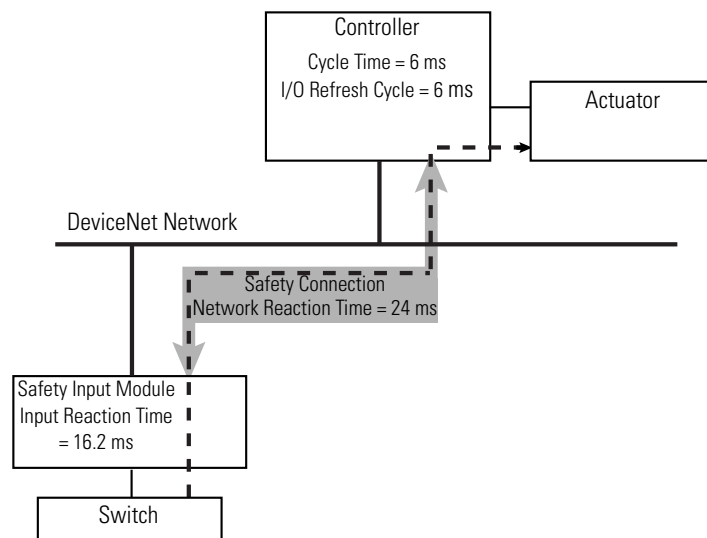
Therefore, system reaction time =  
switch reaction time  
+ [on/off delay time + I/O refresh cycle + (controller cycle time x 2)  
+ 2.5] + actuator reaction time.

Using the values from example one, system reaction time =  
 switch reaction time  
 + [on/off delay time + 4 + (4 x 2) + 2.5] + actuator reaction time.

**IMPORTANT**

Example one shows the configuration for minimizing reaction time in the SmartGuard controller. The guideline for minimum reaction time is 15 ms. The controller cannot be used when a reaction time of 15 ms must be assigned to the controller itself because you must also account for the switch and actuator reaction times.

*Example Two: Remote Input to Local Output Reaction Time*



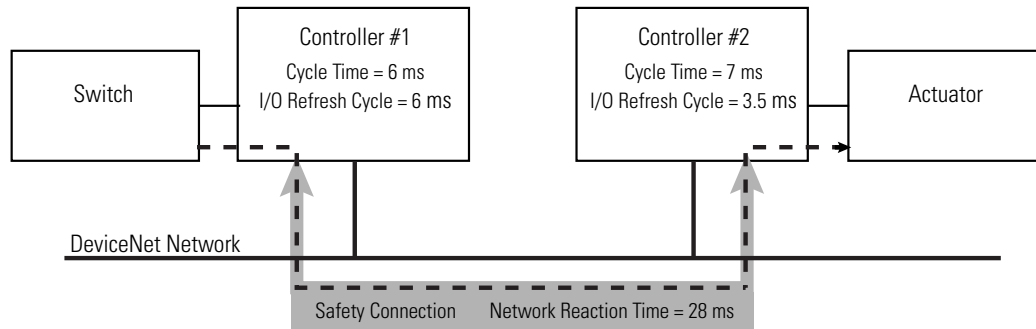
Reaction time (ms) =  
 switch reaction time  
 + input reaction time of the safety input module  
 + network reaction time  
 + controller remote input to local output reaction time  
 + actuator reaction time.

Therefore, system reaction time =  
 switch reaction time  
 + input module on/off delay time + input module reaction time  
 + network reaction time  
 + [controller cycle time + 2.5]  
 + actuator reaction time.

Using the values from example two, system reaction time =  
 switch reaction time  
 + [input module on/off delay time + 16.2]  
 + 24  
 + [6 + 2.5]  
 + actuator reaction time.



*Example Three: Local Input to Remote Output Reaction Time  
Controller-to-controller Interlocking*

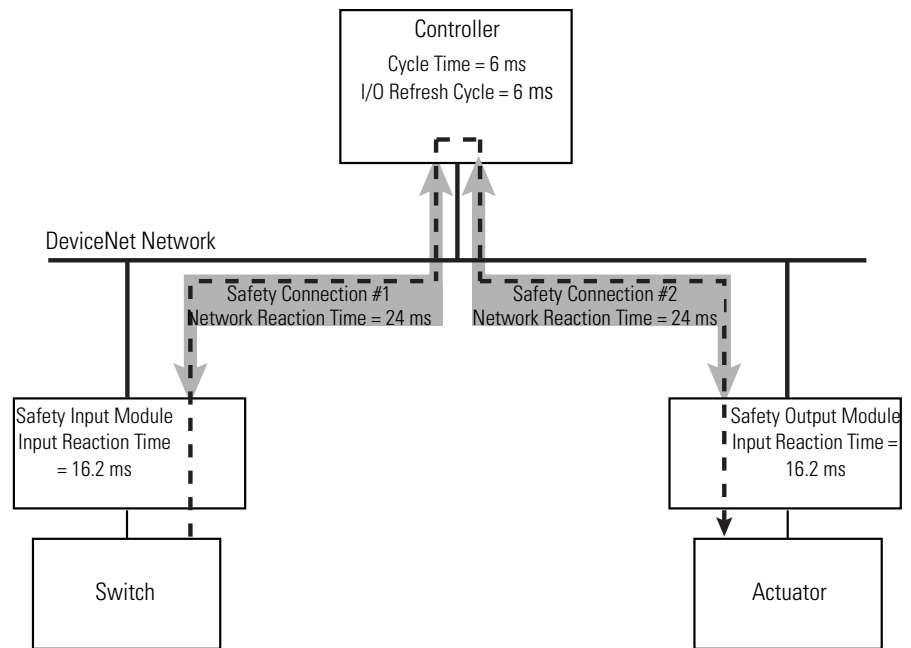


Reaction time (ms) =  
 switch reaction time  
 + controller one local input/remote output reaction time  
 + network reaction time  
 + controller two remote input to local output reaction time  
 + actuator reaction time.

Using the reaction time formulas, system reaction time =  
 switch reaction time  
 + [controller one on/off delay time + I/O refresh cycle  
   + (controller one cycle time x 2)]  
 + network reaction time  
 + [controller cycle time + 2.5]  
 + actuator reaction time.

Using the values from example three, system reaction time =  
 switch reaction time  
 + [controller one on/off delay time + 6 + (6 x 2)]  
 + 28  
 + [7 + 2.5]  
 + actuator reaction time.

*Example Four: Remote Input to Remote Output Reaction Time*



Reaction time (ms) =  
 switch reaction time  
 + safety input module reaction time  
 + network reaction time one  
 + remote input/remote output reaction time  
 + network reaction time two  
 + safety output module reaction time  
 + actuator reaction time.

Using the reaction time formulas, system reaction time =  
 switch reaction time  
 + [on/off delay time + input reaction time]  
 + network reaction time one  
 + controller cycle time  
 + network reaction time two  
 + output reaction time  
 + actuator reaction time.

Using the values from example four, system reaction time =  
 switch reaction time  
 + [on/off delay time + 16.2]  
 + 24  
 + 6  
 + 24  
 + 6.2  
 + actuator reaction time.

## Verifying the Reaction Time

Always confirm that the reaction time calculated for each safety chain satisfies the required specifications. If the reaction time exceeds the application requirements, consider these factors that affect system reaction time:

- Network reaction time can be reduced by shortening the requested packet interval (RPI). However, shortening the RPI reduces network bandwidth that could be used for other connections.
- The cycle time of the controller is automatically calculated based on the size of the application program, the number of connections, and other factors. Cycle time can be reduced by using separate controllers for safety chains that require high-speed reaction times.

## Notes:

## Checklist for SmartGuard 600 Controllers

### Overview

Use this checklist for system configuration, programming, and start-up of SmartGuard 600 controller systems. To be sure that requirements are fully and clearly satisfied during system configuration or start-up, an individual checklist for controlling the requirements can be filled in for every single safety channel in the system. This checklist can also be used as documentation on the connection of external wiring to the application program.

This checklist provides a sample of safety considerations and is not intended to be a complete list of items to verify. Your particular safety application may have additional requirements, for which we have left space in the checklists.

### Checklist for Configuring, Programming, and Start-up of SmartGuard 600 Controller System

Company:				
Site:				
Safety Function Definition:				
<b>SmartGuard 600 Controller</b>				
Number	Requirement	Fulfilled		Comments
		Yes	No	
1	Have you calculated the system's safety response time for each safety chain?			
2	Is the system response time in proper relation to the process tolerance time?			
3	Have PFD/PFH values been evaluated against the system's configuration requirements?			
4	Have you performed all appropriate functional verification tests?			
5	Have you determined how the system will handle faults?			
6	Does each network in the safety system have a unique safety network number (SNN)?			
7	Is each DeviceNet Safety node commissioned with a unique node reference (combination of SNN and MAC ID) that is unique within your entire network?			
8	Is each DeviceNet Safety target correctly configured?			
9	Are the safety connection timing parameters suitable for the capacity of all CIP Safety links traversed?			

**Checklist for Configuring, Programming, and Start-up of SmartGuard 600 Controller System**


**Safety Input Channels**

Number	Requirement	Fulfilled		Comments
		Yes	No	
1	Is this a safety input?			
2	Is this a digital input?			
3	Have you followed installation instructions and precautions to conform to applicable safety standards?			
4	Are inputs wired in compliance with CAT 4, according to EN954-1?			
5	Have you verified that the electrical specifications of the sensor and input are compatible?			
6	Are the error code system signals for the used input channels evaluated in the application program logic?			

**Safety Output Channels**

Number	Requirement	Fulfilled		Comments
		Yes	No	
1	Is this a safety output?			
2	Is this a digital output?			
3	Is this a pulse test source?			
4	Have you followed installation instructions and precautions to conform to applicable safety standards?			
5	Have you verified that test outputs are not used as safety outputs?			

**Checklist for Configuring, Programming, and Start-up of SmartGuard 600 Controller System**

6	Are outputs wired in compliance with CAT 4, according to EN954-1?			
7	Have you verified that the electrical specifications of the output and the actuator are compatible?			
8	Are the error code system signals for the used output channels evaluated in the application program logic?			

**Application Program Development**

Number	Requirement	Fulfilled		Comments
		Yes	No	
1	Are you using version 8 or later of RSNetWorx for DeviceNet software?			
2	Were the programming guidelines in <a href="#">Chapter 3</a> followed during creation of the safety application program?			
3	Does the safety application program clearly differentiate between standard and safety components?			
4	Have you made sure that explicit message data is not used as safety data?			
5	Has the program been reviewed by an independent safety reviewer (if required)?			
6	Have you executed the Safety Device Verification Wizard in RSNetWorx for DeviceNet software to safety-lock the safety system configurations?			
7	Did you review and print the verification report for your records?			

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#### Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444

Europe/Middle East/Africa: Rockwell Automation, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640

Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

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