ROBOTICS

Application manual

SafeMove1

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Application manual

SafeMove1

RobotWare 6.09

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Table of contents

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Overview of this manual

About this manual

This manual describes SafeMove. It contains a description of the functionality and how to connect signals for that functionality. It also describes the SafeMove configuration functionality in RobotStudio.

Usage

This manual should be used during installation and configuration of SafeMove.

Who should read this manual?

This manual is mainly intended for:

- personnel that are responsible for installations and configurations of hardware/software
- personnel that make configurations of the I/O system
- system integrators

Prerequisites

The reader should have the required knowledge of:

- mechanical installation work
- electrical installation work
- working with industrial robots
- using RobotStudio
- personal safety, see the safety chapter in *Product manual - IRC5*.

References

Reference	Document ID
Operating manual - RobotStudio	*3HAC032104-001*
Product manual - IRC5 IRC5 of design M2004	*3HAC021313-001*
Product manual - IRC5 IRC5 of design 14	*3HAC047136-001*
Technical reference manual - RAPID Instructions, Functions and Data types	*3HAC050917-001*
Technical reference manual - System parameters	*3HAC050948-001*
Operating manual - Getting started, IRC5 and RobotStudio	*3HAC027097-001*
Application manual - Additional axes and stand alone controller	*3HAC051016-001*

Revisions

Revision	Description
-	Released with RobotWare 6.0.

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Revision	Description
A	Released with RobotWare 6.01. Updated to current standards in section *Safety aspects for SafeMove on page 203*. Minor corrections throughout the manual.
B	Released with RobotWare 6.02. Added clarifications of the views in section *Changing the graphical display view on page 176*.
C	Released with RobotWare 6.03. Added IRB 760, IRB 1400, IRB 1410, and IRB 8700 to list of supported robots.
D	Released with RobotWare 6.04. • Updated the list of supported robots in section *Supported robots on page 17*. • Changed configuration chapter to only use Visual SafeMove. The old SafeMove configurator is removed.
E	Released with RobotWare 6.06. • Updated section *Brake check guidelines on page 136*. • Minor corrections.
F	Released with RobotWare 6.07. • Changed manual name to SafeMove1, to differentiate from the newer function SafeMove2. • Added **Read access to controller disks** to required user grants.
G	Released with RobotWare 6.08. • Added information and code example to section *Cyclic Brake Check for MultiMove systems on page 137*. • Added IRB 6790 to list of supported robots.
H	Released with RobotWare 6.09. • Added clarification on limitation with SafeMove1 and independent axis, see *Limitations on page 17*.

Product documentation

Categories for user documentation from ABB Robotics

The user documentation from ABB Robotics is divided into a number of categories. This listing is based on the type of information in the documents, regardless of whether the products are standard or optional.

All documents can be found via myABB Business Portal, *www.myportal.abb.com*.

Product manuals

Manipulators, controllers, DressPack/SpotPack, and most other hardware is delivered with a **Product manual** that generally contains:

- Safety information.
- Installation and commissioning (descriptions of mechanical installation or electrical connections).
- Maintenance (descriptions of all required preventive maintenance procedures including intervals and expected life time of parts).
- Repair (descriptions of all recommended repair procedures including spare parts).
- Calibration.
- Decommissioning.
- Reference information (safety standards, unit conversions, screw joints, lists of tools).
- Spare parts list with corresponding figures (or references to separate spare parts lists).
- References to circuit diagrams.

Technical reference manuals

The technical reference manuals describe reference information for robotics products, for example lubrication, the RAPID language, and system parameters.

Application manuals

Specific applications (for example software or hardware options) are described in **Application manuals**. An application manual can describe one or several applications.

An application manual generally contains information about:

- The purpose of the application (what it does and when it is useful).
- What is included (for example cables, I/O boards, RAPID instructions, system parameters, software).
- How to install included or required hardware.
- How to use the application.
- Examples of how to use the application.

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Operating manuals

The operating manuals describe hands-on handling of the products. The manuals are aimed at those having first-hand operational contact with the product, that is production cell operators, programmers, and troubleshooters.

Safety

Safety of personnel

When working inside the robot controller it is necessary to be aware of voltage-related risks.

A danger of high voltage is associated with the following parts:

- Devices inside the controller, for example I/O devices, can be supplied with power from an external source.
- The mains supply/mains switch.
- The power unit.
- The power supply unit for the computer system (230 VAC).
- The rectifier unit (400-480 VAC and 700 VDC). Capacitors!
- The drive unit (700 VDC).
- The service outlets (115/230 VAC).
- The power supply unit for tools, or special power supply units for the machining process.
- The external voltage connected to the controller remains live even when the robot is disconnected from the mains.
- Additional connections.

Therefore, it is important that all safety regulations are followed when doing mechanical and electrical installation work.

Safety regulations

Before beginning mechanical and/or electrical installations, ensure you are familiar with the safety regulations described in *Operating manual - General safety information*[1] .

1 This manual contains all safety instructions from the product manuals for the manipulators and the controllers.

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1 Introduction

1.1 Overview of SafeMove

Purpose

SafeMove is a safety controller in the robot system. The purpose of the safety controller is to ensure a high safety level in the robot system using supervision functions that can stop the robot and monitoring functions that can set safe digital output signals.

The supervision functions can be activated by safe digital input signals. Both input and output signals can be connected to, for instance, a safety PLC that can control which behavior is allowed for the robot at different times.

The safety controller also sends status signals to the main computer, that is the standard IRC5 robot controller.

Note that SafeMove is one component in a cell safety system, normally complemented by other equipment, e.g. light barriers, for detecting the whereabouts of the operator.

Some examples of applications:

- Manual loading of gripper
- Manual inspection in robot cell during operation
- Optimization of cell size
- Protection of sensitive equipment
- Ensuring safe orientation of emitting processes

What is included

The following is included with the option SafeMove [810-2]:

- Safety controller, DSQC 647 (3HAC026272-001)
- Two 12 pole plug contacts and two 10 pole plug contacts for I/O connections.

The option SafeMove gives you access to SafeMove Configurator functionality in RobotStudio.

With SafeMove Configurator you can:

- configure supervision functions (active supervision that can stop the robot)
- configure activation signals for the supervision functions
- configure monitoring functions (passive monitoring, only sets output signals)
- configure output signals for the monitoring functions
- easily modify the configuration

Prerequisites

RobotWare 5.10.02 or later version is necessary to run the IRC5 robot controller. The *SafeMove* option is the required RobotWare option to utilize SafeMove on the IRC5 controller.

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Basic approach

This is the general approach for setting up *SafeMove*. For more detailed instructions of how this is done, see chapters *Installation* and *Configuration*.

1. Connect I/O connections to sync switch and safety PLC, or similar.
2. Create a safety user in the User Authorization System, UAS (using RobotStudio).
3. Configure the settings for the SafeMove functions via the SafeMove Configurator and restart the controller.
4. Log on as safety user and set the PIN code on the FlexPendant. Restart the controller.
5. Synchronize the safety controller, using a sync switch or software synchronization.
6. Make sure the activation input signals are activating the desired supervision functions.

   Now the SafeMove functions are activated.
7. Validate the configuration.

Requirements

Robust monitoring function in SafeMove requires correct settings of payload and additional axes, since this will affect the calculated accepted servo lag. Please also note that external forces applied on the manipulator can cause a negative influence on the supervision functions, since the servo lag might differ from the calculated values, due to such external forces.

DANGER

A SafeMove configuration must always be validated to verify that the desired safety is achieved. If no validation is performed, or the validation is inadequate, the configuration cannot be relied on for personal safety.

The validation must also consider that the braking starts after a zone is violated, so additional stopping distances may be required, which depend on many factors, for example mass and speed.

Tip

The function Collision Detection has to be used with tuned parameters to prevent a too large servo lag. If a too large servo lag is detected, SafeMove gets unsynchronized.

1.2 Limitations

Supported robots

The following robot families are supported by SafeMove1:

- IRB 140
- IRB 260
- IRB 460
- IRB 660
- IRB 760
- IRB 1400
- IRB 1410
- IRB 1600/1660
- IRB 2400
- IRB 2600
- IRB 4400
- IRB 4600
- IRB 6620
- IRB 6640
- IRB 6660
- IRB 6650S
- IRB 6700
- IRB 6790
- IRB 7600
- IRB 8700

Other robot models are not supported.

SafeMove cannot be used for parallel arm robots, such as IRB 360.

SafeMove can only be used together with floor mounted robots.

Supported cabinets

SafeMove does not support IRC5 Compact controller.

Supported additional axes

Basically the SafeMove option only supports ABB track motion units.

Non ABB track motion units, non ABB positioners, and other additional axis may be supported by the SafeMove option but this needs to be verified case by case.

To verify if a non ABB additional axis can be used with SafeMove, tune the additional axis before configuring the SafeMove parameters. If a properly tuned and configured non ABB additional axis still generates error messages regarding servo lag, then it cannot be used with SafeMove. For more information about tuning an additional axis see *Application manual - Additional axes and stand alone controller*. For more information about servo lag see *Servo Delay Factor and Servo Lag on page 215*.

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The SafeMove option only supports additional axes that are single axis mechanical units. For example, two axes positioners cannot be supported.

Further, there are always the following upper and lower work area limitations:

- Track unit length (arm side) max ± 100 m
- Rotating axis (arm side) max ± 25 700 degrees or ± 448 radians

On the motor side there is also a limitation of ± 32 000 revolutions.

Stand alone controller

Stand alone controller or drive module without TCP-robot, are not supported by SafeMove.

Servo welding gun

SafeMove does not support supervision of servo welding guns. That is, the robot axes can be supervised, but not the axis of the servo welding gun.

Tool changer

SafeMove supports up to 4 different tools. All included tools must have their appropriate settings in the configuration file. Selection of tool to be supervised is done by 2 binary coded safe inputs on SafeMove.

Robot mounted on rotational axis

SafeMove does not support supervision or monitoring of a robot mounted on a rotational axis.

No deactivation

All supervised and monitored axes must be active all the time. SafeMove does not support activation/deactivation of additional axis.

The ABB positioners normally use the activation/deactivation feature and therefore they are not supported by SafeMove.

Independent joint

Independent joint cannot be monitored by SafeMove.

Shared drive modules

Drive units of supervised and monitored axes cannot be shared, for instance between positioner axes.

Track motion coordinates

When a robot is mounted on a track motion, the following limitations apply:

- It is only possible to define a rotation (no translation) of the robot base frame relative the track motion base frame.
- It is only possible to define a translation (no rotation) of the track motion base frame relative the world frame.

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Limit switch override cannot be used

If the option SafeMove is used, it is not allowed to connect any signal to the limit switch override (X23 on the contactor board).

RAPID non motion execution

This test feature cannot fully be used together with the SafeMove option.

Borderline positions

In very rare cases an error message, elog 20473, might be presented if the robot is stopped for a time longer than 40 min in a position exactly on the border of the defined range. This is because of the internal safe design of the SafeMove controller, using a safe two channel microprocessor solution.

Tip

To avoid this, never leave the robot for a longer period in a position near the borders of Monitor Axis Range.

Alternative calibration position

The alternative calibration position, which can be used for robots and additional axes, is not supported by SafeMove. The calibration position shall be defined to zero position.

Note

Calibration position is set in the system parameter *Calibration Position*, which is found under topic *Motion* and type *Arm*.

MultiMove

Note

The option *MultiMove* is not available in RobotWare 5.60.

It is not supported to use a mixture of EPS (Electronic Position Switches) and SafeMove in a MultiMove installation. However, robots can be used with or without SafeMove in a mixed setup.

1.3 Terminology

About these terms

Some words have a specific meaning when used in this manual. It is important to understand what is meant by these words. This manual's definitions of these words are listed below.

Term list

Term	Definition
Category 0 stop	Stop by immediate removal of power to the actuators. Mechanical brakes are applied. A robot that is stopped with a category 0 stop does not follow its programmed path while decelerating.
Category 1 stop	Controlled stop with power available to the actuators to achieve the stop. Power is removed from the actuators when the stop is achieved. A robot that is stopped with a category 1 stop follows its programmed path while decelerating.
Monitoring	Passive monitoring with signaling function only.
Occupationally safe	Safe for a person to be in an area.
Operationally safe	Safe for the machinery but not safe for persons to enter the area.
Safe input	Dual monitored digital input.
Safe output	Dual monitored digital output.
Safety controller	A safety board used with IRC5. Can be an Electronic Position Switch safety controller or a SafeMove safety controller.
Supervision	Active supervision with deactivation of robot if limit is exceeded.
Antivalent signal	Same as complementary signal. The logical value of one channel is the complement of the other in a dual channel signal.
Equivalent signal	The logical value of one channel is equivalent to the other in a dual channel.

1.4 Abbreviations and acronyms

Overview

This section specifies typical abbreviations and acronyms used in this manual.

Abbreviatons/acronyms list

Abbreviation/acronym	Description
CES	Control Error Supervision
CSC	Cyclic Sync Check
MAR	Monitor Axis Range
MST	Monitor Stand Still
MTZ	Monitor Tool Zone
OSR	Operational Safety Range
SAR	Safe Axis Range
SAS	Safe Axis Speed
SST	Safe Stand Still
STS	Safe Tool Speed
STZ	Safe Tool Zone

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2 SafeMove functions

2.1 Overview of SafeMove functions

Overview

The SafeMove functions can be divided into the following categories:

- general functions (e.g. manual operation)
- sync check functions (hardware switch or software synchronization)
- supporting functions (e.g. verification of brakes)
- supervision functions (active, can stop the robot)
- monitoring functions (passive, only sets output signals)

Supervision functions

Supervision functions can stop the robot (and additional axes) if a violation occurs.

Supervision functions can be activated and deactivated with safe digital input signals or be configured to be permanently active.

Monitoring functions

Monitoring functions are permanently active and use digital output signals for signaling status to an external device, like a safety PLC, that can stop the robot.

Combining functions

The supervision and monitoring functions can be used separately, or in a variety of combinations.

2.2 General functions

2.2.1 Manual Operation

Manual Operation

Manual Operation is a function that overrides all safety functions in SafeMove and allows movements at a maximum speed of 250 mm/s. This is necessary when a supervision function is triggered and the robot must be jogged back to a position that does not cause any safety violation.

Functionality

Manual Operation overrides safety functions by forcing the relays to close and outputs to be high.

While Manual Operation is active, a supervision makes sure that the TCP, tool0 and elbow speed does not exceed 250mm/s.

If Manual Operation is active and the robot is jogged out of the violation and then into a supervision violation position again, the robot will stop again. The new violation must be confirmed by releasing the three-position enabling device on the FlexPendant before the jogging can be resumed. The Run chain becomes electrically opened when the enabling device is opened.

DANGER

Using the function Manual Operation compromises the safety. It is intended for commissioning and when an axis or TCP must be jogged out of its forbidden position.

Tip

If the robot stops frequently during jogging when the Manual Operation is active, change the MOC parameter *Teach mode max value* from 0.25 to 0.1 (100mm/s).

Settings

There are no parameters that need to be configured for Manual Operation.

Function activation

Manual Operation is activated with the Manual Operation safe digital input signal (X10.9 and X10.10).

A warning message (elog 20481) is shown when the function is being activated.

Dependencies to other supervision functions

Manual Operation can be used in combination with all other SafeMove functions, but all other supervision functions, except for speed supervision, will be temporarily inactive while Manual Operation is active.

2.2.2 Operational Safety Range

Operational Safety Range

Operational Safety Range relaxes the supervision of the servo lag if ALL configured axes are within a defined axis range.

Functionality

Operational Safety Range is a special definition of an axis range that relaxes the Control Error Supervision (servo lag) to a higher value if ALL configured axes are within (inclusive) the defined axis range. It can be used, for instance, in machine tending, when the servo loop gain is reduced (soft servo) or during Force Control. It is also useful when external forces are applied to the robot.

If the robot is within the defined range, then the safety level is considered to be operationally safe rather than occupationally safe. That means it is not safe for personnel to be in the range defined for Operational Safety Range.

To activate the relaxed control error, all of the following conditions must be true:

- The reference values for ALL configured axes must be within the range defined by the Operational Safety Range function.
- The measured values for ALL configured axes must be within the range defined by the Operational Safety Range function.

The function is automatically activated after the safety controller has been synchronized with the robot position. No dynamic activation is possible.

Up to 9 axes can be monitored simultaneously.

Settings

The following settings need to be configured for Operational Safety Range:

- Axis range definition for each axis, physical position in degrees or mm on arm side.
- Permissible control error for each axis, in degrees or mm on arm side.

The definition of axis range consists of:

- Minimum axis limit (degrees or mm).
- Maximum axis limit (degrees or mm).

How to define these settings is described in *Operational Safety Range configuration on page 91*.

Dependencies to other supervision functions

If Operational Safety Range is active, it overrides the Control Error Supervision function. That means that all other active safety controller functions work with relaxed Control Error Supervision.

Operational Safety Range can be used in combination with all other SafeMove functions, but the other function may be restricted due to relaxed Control Error Supervision. For example, Safe Stand Still must not be used within an active range of Operational Safety Range.

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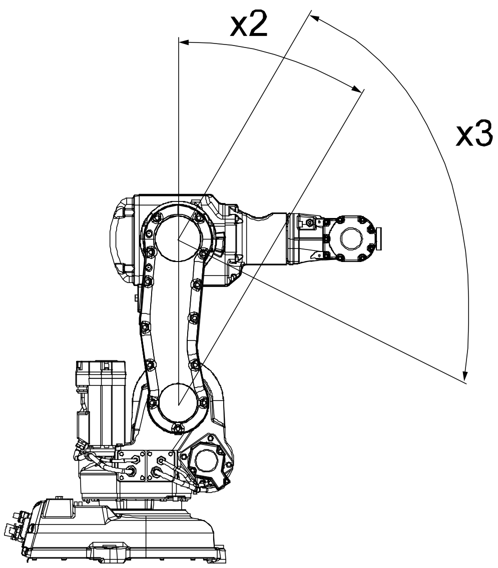
Related information

Control Error Supervision on page 43.

Examples

This example shows a robot with defined axis ranges for axes 2 and 3. The function Operational Safety Range monitors if axis 2 is within the range x2 and if axis 3 is within the range x3. As long as the measured values and the reference values for both axes are within these ranges, the Control Error Supervision is relaxed.



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2.3 Sync check functions

2.3.1 Cyclic Sync Check

Cyclic Sync Check

Cyclic Sync Check is a function that makes sure that the robot calibration is correct by using a physical switch.

Unsynchronized state can, for example, occur:

- When Cyclic Sync Check has timed out.
- When Control Error Supervision has triggered (for example a too large servo lag due to a collision).

Functionality

The robot must move to a safe sync position to ensure that the safety controller and the robot controller are synchronized. The safe sync position is defined during configuration and stored in the safety controller.

With a defined interval (sync cycle time), the robot must move to the safe sync position and activate a switch. If the sync check is not performed within the sync cycle time, the robot will stop and SafeMove goes to unsynchronized state. A warning is shown on the FlexPendant a pre-defined time (pre-warning time) before the sync cycle time has passed.

When the switch is activated, the safety controller assumes that the robot revolution counters are correct. It also calculates the arm position from the motor positions, the gear ratio, and its internal revolution counter. If the position matches the stored sync position within half a motor revolution, then the synchronization is assumed to be correct.

If the synchronization is correct, the safety controller then sends elog 20452 to the robot controller, telling that the safety controller is synchronized to its mechanical units, and continues with its regular operation.

WARNING

The supervision and monitoring functions can only be active while SafeMove is synchronized. When unsynchronized, only speed and time limited movement is possible. For more information, see *Recovery from unsynchronized state on page 143*.

Tip

If a safe information is needed to see if SafeMove is in unsynchronized state or not, it is recommended to use a monitoring output signal for this purpose. For example, to configure a Monitor Axis Range where the axis range covers the whole working area. In this case the Monitor Axis Range output will be low only when SafeMove is unsynchronized.

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Settings

The following settings need to be configured for Cyclic Sync Check:

- Sync cycle time, 12-720 hours.
- Pre-warning time, 1-11 hours.
- Angles and positions of robot (and additional axes) at sync position.

Dependencies to other supervision functions

Only one synchronization procedure can be present in one setup, i.e. synchronization by switch or by software, not both of them at the same time. Selection is done in the configuration program in RobotStudio.

Cyclic Sync Check has no dependencies to any supervision functions.

Virtual output signals from main computer

A virtual output signal is set when the prewarning time has expired. Another virtual signal will correspond to the sync status. See also *Virtual output signals from main computer on page 146*.

Limitations

- The safe sync position must be within reach for the robot. It must not be a singularity, that is all six axis must have unique positions.

Related information

Synchronization guidelines for Cyclic Sync Check on page 133.

Recovery after safety violation on page 143

2.3.2 Software Sync Check

Software Sync Check

Software Sync Check is a function that makes sure that the robot calibration is correct. If wrong robot calibration easily can be detected by the application, then it is generally possible to execute the synchronization check by software. In that case it is done when required, not cyclically.

Unsynchronized state can, for example, occur:

- When Control Error Supervision has triggered (for example a too large servo lag due to a collision).

Functionality

Software synchronization is performed by running the service routine `SoftwareSync`. How to run the service routine is described in section *Use service routine to perform synchronization on page 135*.

If the safety controller has not been synchronized before, and the synchronization attempt was unsuccessful, the user has to check and confirm on the FlexPendant that both the robot controller and the safety controller have the same opinion about robot axes positions.

WARNING

The supervision and monitoring functions can only be active while SafeMove is synchronized. When unsynchronized, only speed and time limited movement is possible. For more information, see *Recovery from unsynchronized state on page 143*.

Tip

If a safe information is needed to see if SafeMove is in unsynchronized state or not, it is recommended to use a monitoring output signal for this purpose. For example, to configure a Monitor Axis Range where the axis range covers the whole working area. In this case the Monitor Axis Range output will be low only when SafeMove is unsynchronized.

Settings

The following settings need to be configured for Software Sync Check:

- Angles and positions of robot (and additional axes) at sync position.

Dependencies to other supervision functions

Only one synchronization procedure can be present in one setup, i.e. synchronization by switch or by software, not both of them at the same time. Selection is done in the configuration program in RobotStudio.

Software Sync Check has no dependencies to any supervision functions.

Continues on next page

Virtual output signals from main computer

A virtual output signal corresponds to the sync status. See *Virtual output signals from main computer on page 146*.

Related information

Synchronization guidelines for Software Sync Check on page 135.

Recovery after safety violation on page 143

2.4 Supporting functions

2.4.1 Cyclic Brake Check

Cyclic Brake Check

Cyclic Brake Check is a function that verifies that the brakes work correctly.

Note

After download of a new configuration it is recommended to run the Cyclic Brake Check function.

Note

Before running the Cyclic Brake Check function the Safe Stand Still function shall be deactivated.

Functionality

The brake check is initiated by the robot controller or an external PLC. The robot moves to a safe position where the brakes are locked with servos engaged. The motors of the robot are then used to generate torque. If any axes moves, the system is set in reduced speed mode. A new successful brake check must be performed before the robot can be used again with normal speeds.

With a defined interval (brake cycle time), the robot must move to the safe position and perform a brake test. If the brake check is not performed within the brake cycle time an error message is generated, and depending on configuration the robot will be set to reduced speed or keep its normal supervision levels. A warning appears on the FlexPendant a predefined time (prewarning time) before the brake cycle time has passed.

Settings

The following parameters need to be configured for Cyclic Brake Check:

- Activation of Cyclic Brake Check.
- Brake check interval (between 12 and 720 hours).
- Prewarning time before brake check interval expires.
- It is possible to select Reduced max speed when the interval timer expires.
- It is possible to exclude individual axes from the brake checks.

How to define these settings is described in *Cyclic Brake Check configuration on page 89*.

Function activation

Cyclic Brake Check cannot be dynamically activated/deactivated. If it is configured to be active, it is always active, i.e. a constant supervision that a brake check has been performed within the configured time interval.

Continues on next page

The actual brake check can be activated by the robot controller or an external PLC. See *Brake check guidelines on page 136*.

Dependencies to other supervision functions

The Safe Stand Still function is not dependent on the Cyclic Brake Check.

Virtual output signal from main computer

A virtual output signal is set when the prewarning time has expired. See also *Virtual output signals from main computer on page 146*.

Interrupted brake check

It is not recommended, but it is possible to stop the execution while running a brake check.

If the brake check is interrupted, it will be resumed when the program execution starts again. The brake check can be resumed up to 3 times.

If the brake check is interrupted more than 3 times, a new brake check is required. Only reduced speed can be used until a new brake check is performed.

2.4.2 Safe Brake Ramp

Safe Brake Ramp

Safe Brake Ramp is an active supervision function that supervises category 1 stops initiated by the safety controller.

Supervision functionality

When a category 1 stop is triggered by SafeMove, the motors are used for a controlled deceleration. Safe Brake Ramp supervises this deceleration. If the deceleration is too slow, a category 0 stop is triggered.

Note

Depending on the application, Safe Brake Ramp may trigger more often, for example for tilted robot or heavy load. This results in a category 0 stop.

Settings

For track motions and other additional axes, the parameters **Brake Ramp Limit** and **Ramp Delay** have to be set in the SafeMove Configurator. The parameter **Start Speed Offset** is used for both manipulator and all additional axes.

Function activation

Safe Brake Ramp cannot be dynamically activated/deactivated. If it is configured to be active, it is always active.

Dependencies to other supervision functions

Safe Brake Ramp will be used in combination with all other SafeMove functions.

Limitations

- Safe Brake Ramp only supervises category 1 stops initiated by the safety controller. Stops initiated elsewhere, e.g. by the robot controller, are not supervised.
- A category 1 stop usually stops faster than the margins for Safe Brake Ramp, so under normal circumstances Safe Brake Ramp does not trigger.

Related information

Category 1 stop (see *Terminology on page 20*)

Category 0 stop (see *Terminology on page 20*)

2.5 Supervision functions

2.5.1 Safe Stand Still

Safe Stand Still

Safe Stand Still is an active supervision function ensuring that all supervised axes are standing still.

Supervision functionality

Safe Stand Still can supervise that a robot is standing still even if the servo and drive system are in regulation. If any supervised axis starts to move, Safe Stand Still will cause a category 0 stop.

When Safe Stand Still is active for all axes (including all additional axes), it is safe for a person to enter the robot cell.

4 different sets of up to 9 axes can be defined. When Safe Stand Still is activated for a set, all axes in that set are supervised.

DANGER

Working under an axis affected by gravity which has no balancing may require a safety level of category 4, which is not provided by SafeMove. If this kind of work is intended, the risk must be added to the risk analysis of the installation and eliminated by other means (for example additional mechanical stops).

DANGER

It is not recommended to activate the Safe Stand Still function within a range for Operational Safety Range because Control Error Supervision is relaxed in this range and is not reliable enough for personal safety.

DANGER

For additional axes, a standstill reference tolerance must be configured.

Note

If the robot tries to move due to an error during active Safe Stand Still supervision, SafeMove will detect this and initiate a stop. Since there is a certain reaction time involved a slight jerk may occur.

Note

The Manual Operation function will override the Safe Stand Still function. Therefore, Safe Stand Still may not guarantee that the robot is standing still in manual mode.

Continues on next page

Settings

The following parameters need to be configured for Safe Stand Still:

- Assignment of safe digital inputs for activation of Safe Stand Still.
- Which axes to supervise, with specified stand still measurement tolerance, for each stand still set. See *Safe Stand Still configuration on page 92*.
- For additional axes, a stand still tolerance must be configured. See *Additional axis configuration on page 81*.

Function activation

Safe Stand Still is activated by safe digital input signals.

If no safe digital input signal is assigned to Safe Stand Still during configuration, the function is inactive.

> **Note**
>
> If SafeMove becomes unsynchronized the robot will stop and the Safe Stand Still function will be deactivated. A time limited movement with reduced speed is possible.

Dependencies to other supervision functions

Safe Stand Still can be used in combination with:.

- Safe Axis Speed
- Safe Axis Range
- Safe Tool Speed
- Safe Tool Zone
- all monitoring functions

2.5.2 Safe Axis Speed

Safe Axis Speed

Safe Axis Speed is an active supervision function that supervises the speed of robot axes and additional axes.

Supervision functionality

Supervision of the speed for up to 9 axes (robot axes and additional axes).

If any of the supervised axes exceeds its maximum speed, the safety controller will stop the robot. The speed violation will cause a category 0 stop or a category 1 stop, depending on the configuration.

Settings

The following parameters need to be configured for Safe Axis Speed:

- Which axes to supervise.
- Maximum speed, defined per axis.
- Category 0 stop or category 1 stop if an axis exceeds its maximum speed.
- Assignment of safe digital inputs for activation of Safe Axis Speed.

How to define these settings is described in *Safe Axis Speed configuration on page 93*.

Function activation

Safe Axis Speed is activated by a safe digital input signal.

If no safe digital input signal is assigned during configuration, the function is inactive.

Dependencies to other supervision functions

Safe Axis Speed can be used in combination with:

- Safe Stand Still
- Safe Axis Range
- Safe Tool Speed
- Safe Tool Zone
- all monitoring functions

Limitations

The highest maximum speed that can be configured is 3600 degrees/s for rotational axes and 10000 mm/s for linear axes.

2.5.3 Safe Tool Speed

Safe Tool Speed

Safe Tool Speed is an active supervision function that supervises the speed of the tool, robot flange and arm check point.

> **Note**
>
> The resultant robot TCP speed could in some situations be higher than the programmed TCP speed. This could happen for some robot types if the move instructions are of type `MoveJ` or `MoveAbsJ`. If this occurs, either increase the STS **Max Speed**, or try to add intermediate robot targets in the RAPID program.

> **Note**
>
> When the robot is running in manual mode, neither the elbow point nor the TCP point will exceed 250mm/s. When the robot is running in auto mode, IRC5 will not consider the elbow speed when generating the path, only the defined TCP speed and reorient speed. (If additional axis exists in the system, the speed data for this will also be considered.) The result from this is that the elbow speed is sometimes higher than the programmed TCP speed. Since STS supervises TCP, tool0 and the elbow, the speed of these points must be taken into account when configuring STS or creating the RAPID program.

Supervision functionality

Safe Tool Speed supervises the linear speed (in mm/s) for:

- TCP for the tool held by the robot
- Tool 0 (the robot flange)
- Arm check point (position depending on robot but located around axis 3)

If any of these points exceed the maximum speed, the safety controller triggers a stop. The speed violation will cause a category 0 stop or a category 1 stop, depending on the configuration.

Settings

The following parameters need to be configured for Safe Tool Speed:

- Maximum allowed speed (in mm/s) for TCP, tool0 and arm check point.
- Category 0 stop or category 1 stop if a point exceeds its maximum speed.
- Assignment of safe digital inputs for activation of Safe Tool Speed.

How to define these settings is described in *Safe Tool Speed configuration on page 94*.

Function activation

Safe Tool Speed is activated by a safe digital input signal.

If no safe digital input signal is assigned during configuration, the function is inactive.

Continues on next page

Dependencies to other supervision functions

Safe Tool Speed can be used in combination with:

- Safe Stand Still
- Safe Axis Speed
- Safe Axis Range
- Safe Tool Zone
- all monitoring functions

2.5.4 Safe Axis Range

Safe Axis Range

Safe Axis Range is an active supervision function that ensures that all axes are within the defined ranges.

When configuring the Safe Axis Range function there is a possibility to invert the function by unchecking the **Allow inside** check box.

Supervision functionality

Supervision of up to 9 axes (robot axes and additional axes) in each set. Up to 8 sets can be configured.

If an axis in an active set exceeds its allowed range, the safety controller triggers a stop. This violation will cause a category 0 stop or a category 1 stop, depending on the configuration.

Settings

The following parameters need to be configured for Safe Axis Range:

- Which axes to supervise.
- Axis ranges (degrees or mm) for each axis.
- Inclusive or exclusive range for each axis.
- Allow inside, i.e. to invert or not invert the result of the function.
- Category 0 stop or category 1 stop if an axis exceeds its maximum range.
- Assignment of safe digital inputs for activation of each set of axis ranges, or set as permanently activated.

How to define these settings is described in *Safe Axis Range configuration on page 95*.

Function activation

Each set of axis ranges can be activated by a safe digital input signal or be permanently activated.

If the set is not configured to be permanently active and no safe digital input signal is assigned, the set is inactive.

Dependencies to other supervision functions

Safe Axis Range can be used in combination with:

- Safe Stand Still
- Safe Axis Ranges
- Safe Tool Speed
- Safe Tool Zone
- all monitoring functions

The ranges are defined independently of the ranges defined in the function Monitor Axis Range.

Continues on next page

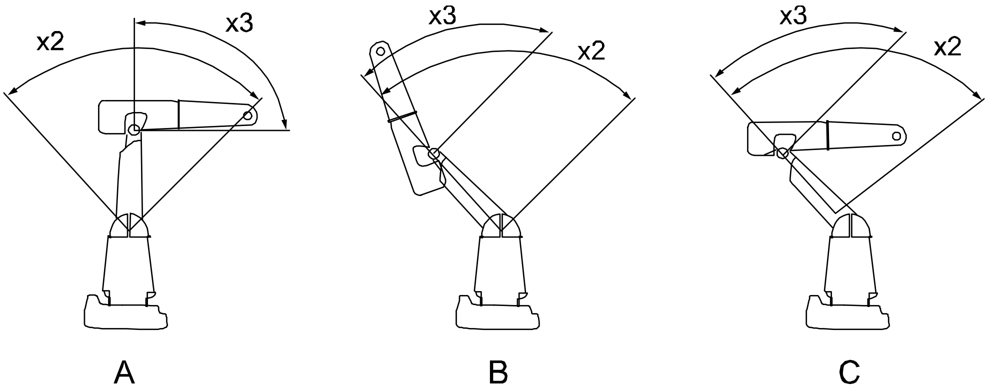
Related information

Monitor Axis Range on page 46

Examples

This example shows a robot with defined axis ranges for axes 2 and 3 in three different positions. The function Safe Axis Range supervises that axis 2 is within range x2 and that axis 3 is within range x3.

In positions A and B, all supervised axes are within the allowed ranges. In position C, axis 3 is not within the defined range.



xx0600003331

x2	Allowed axis position range for axis 2.
x3	Allowed axis position range for axis 3.
A	Robot position A. Both axis 2 and axis 3 are within the allowed ranges.
B	Robot position B. Both axis 2 and axis 3 are within the allowed ranges.
C	Robot position C. Axis 2 is within the allowed range but axis 3 is not within its allowed range.

Note

The ranges define axis angles, not the position of the TCP. In robot position C, the TCP is still within what seems to be a safe range, but axis 3 is outside its defined range.

WARNING

Be aware of that the braking starts when the axis exceeds the configured limit value. The braking distance depends on robot type, load, position and speed.

2.5.5 Safe Tool Zone

Safe Tool Zone

Safe Tool Zone is an active supervision function that supervises that the robot TCP, elbow, tool points and tool orientation are within their allowed zone, while moving at allowed speed.

Supervision functionality

Up to 8 zones can be configured. Each zone consists of:

- a geometrical shape in space, that the TCP, elbow and tool points should be inside or outside
- a tool orientation with an allowed tolerance
- a maximum speed for the TCP and elbow.

If the TCP, elbow, tool points, tool orientation, TCP speed or elbow speed is outside its allowed value, the safety controller triggers a stop. This violation will cause a category 0 stop or a category 1 stop, depending on the configuration.

Settings

The following parameters need to be configured for Safe Tool Zone:

- Tool zones (shape, height, position).
- Tool orientation and tolerance for each zone.
- Tool speed limit.
- Assignment of a safe digital input for activation of each zone, or set as permanently activated.
- Category 0 stop or category 1 stop if the tool violates its zone limits.
- Elbow position supervision activation.
- Elbow offset parameters.

How to define these settings is described in *Safe Tool Zone configuration on page 100*.

If more tool points than TCP should be supervised, also configure:

- Tool Points (described in *Tool configuration on page 85*).

Function activation

Safe Tool Zone can be activated by safe digital input signals or be permanently activated.

If the function for a zone is not configured to be permanently active and no safe digital input signal is assigned, the function is inactive for that zone.

Dependencies to other supervision functions

Safe Tool Zone can be used in combination with:

- Safe Stand Still
- Safe Axis Speed
- Safe Tool Speed

Continues on next page

- all monitoring functions

Limitations

WARNING

Be aware of that the braking starts when the tool or elbow exceeds the configured limit value. The braking distance depends on robot type, load, position and speed, and therefore an additional stopping distance may sometimes be required to achieve the desired safety.

2.5.6 Control Error Supervision

Control Error Supervision

Control Error Supervision is a function that supervises the difference between the reference value and the measured value of the motor position of each axis. Control Error Supervision is required to ensure the accuracy in the monitoring and supervision functions.

Supervision functionality

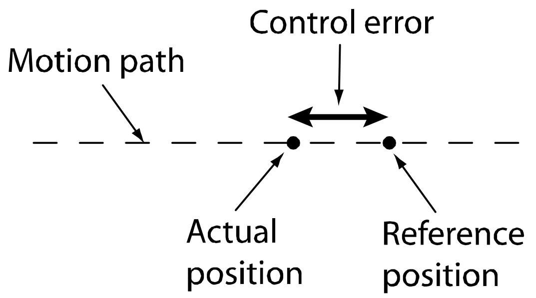
The control error (servo lag) is the absolute value of the difference between the reference value and the measured value of the motor position of each axis.

Control Error Supervision is activated automatically after the safety controller has been synchronized with the robot position.

When Control Error Supervision trips the following happens:

- The robot is stopped with a category 1 stop.
- An elog message (20454) is sent to the robot controller.
- A new synchronization is required.

Illustration of control error



en0700000723

Function activation

Control Error Supervision is always active. It can only be relaxed by Operational Safety Range.

Dependencies to other functions

If Operational Safety Range is active, then Control Error Supervision is relaxed according to user definitions.

Settings

Control Error Supervision settings are only required for additional axes.

For additional axes, the following settings need to be configured:

- Servo Lag
- Servo Delay Factor

How to define these settings is described in *Additional axis configuration on page 81*.

Continues on next page

Related information

Operational Safety Range on page 25.

2.6 Monitoring functions

2.6.1 Monitor Stand Still

Monitor Standstill

Monitor Stand Still is a passive monitoring function used to verify that none of the monitored axes are moving.

Monitoring functionality

Monitor Stand Still can monitor if all axes stand still. If any monitored axis starts to move, a safe digital output signal goes low. If the axis is moved outside the supervision limit and then stops, the output signal will go high after a short time.

4 different sets of up to 9 axes in each set can be defined. Monitor Stand Still monitors the axis position for all axes in a set.

Settings

For each set of axes the following parameters need to be configured for Monitor Stand Still:

- Assignment of safe digital output signal.
- Which axes to monitor.

How to define these settings is described in *Monitor Stand Still configuration on page 105*.

Function activation

Monitor Stand Still is always active.

Dependencies to other supervision functions

Monitor Stand Still can be used in combination with all other SafeMove functions.

2.6.2 Monitor Axis Range

Monitor Axis Range

Monitor Axis Range is a monitoring function that determines if all axes are within the defined ranges. Safe digital output signals are used to indicate when all axes are within their defined ranges.

Note

Monitor Axis Range can only safely determine that the monitored axes are within the defined ranges (i.e. when the output signal is high). It is not safe to assume that an axis is outside the defined range when the signal is low.

Monitoring functionality

Monitoring of up to 9 axes (robot axes and additional axes) in each set. Up to 8 sets can be configured.

If an axis is outside its defined range, a safe digital output signal goes low. Each set of axes can be allocated an output signal.

Settings

The following settings need to be configured for Monitor Axis Range:

- Axis ranges (degrees or mm) for each axis.
- Assignment of safe digital output for each set of axis ranges.
- Invert range for each axis.
- Allow inside for each set of axis ranges.

How to define these settings is described in *Monitor Axis Range configuration on page 106*.

Dependencies to other supervision functions

Monitor Axis Range can be used in combination with all other SafeMove functions.

The ranges are defined independently of the stop ranges defined in the function Safe Axis Range.

Related information

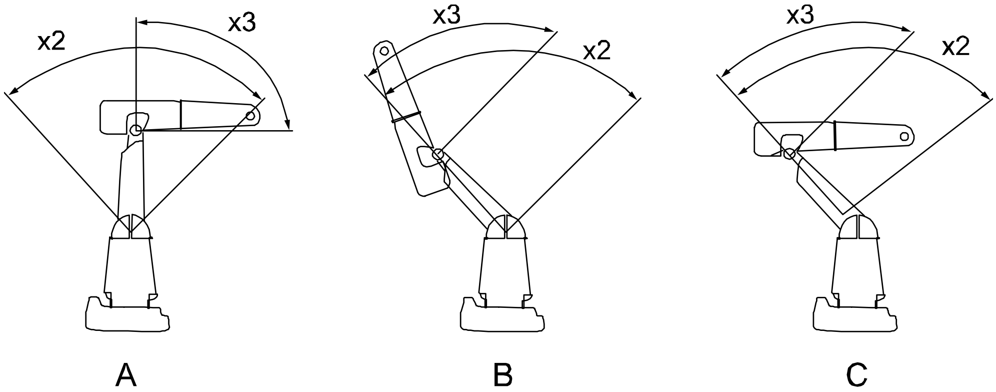
Safe Axis Range on page 39

Continues on next page

Example of ranges

This example shows a robot with defined axis ranges for axes 2 and 3 in three different positions. The function Monitor Axis Range monitors that axis 2 is within range x2 and that axis 3 is within range x3.

In positions A and B, all monitored axes are within the defined ranges. In position C, axis 3 is not within the defined range.



xx0600003331

x2	Defined axis position range for axis 2.
x3	Defined axis position range for axis 3.
A	Robot position A. Both axis 2 and axis 3 are within the defined ranges.
B	Robot position B. Both axis 2 and axis 3 are within the defined ranges.
C	Robot position C. Axis 2 is within the defined range but axis 3 is not within its defined range.

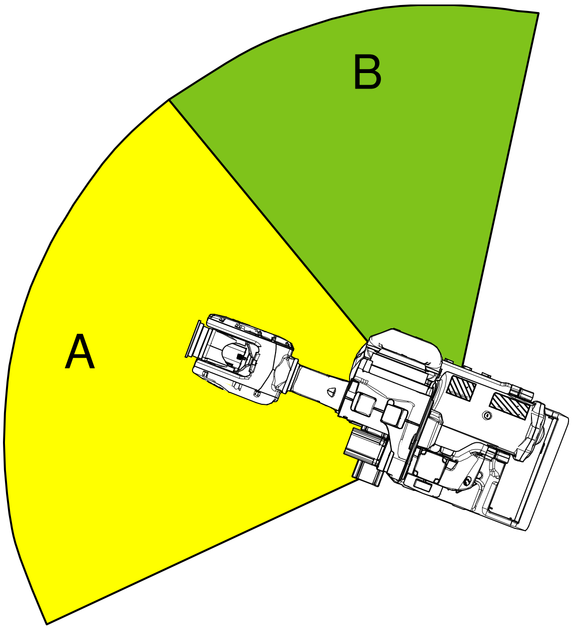
In this example, if range x2 and x3 are defined for the same signal, this signal will go low if any of the axes is outside its defined range.

Note! The ranges define axis angles, not the position of the TCP. In robot position C, the TCP is still within what seems to be a safe range, but axis 3 is outside its defined range.

Continues on next page

Example of usage

Define two ranges for axis 1 and let a safety PLC decide when the axis must be inside range A and when it must be inside range B.



xx0700000144

A	Range for axis 1 defined for safe output signal 1.
B	Range for axis 1 defined for safe output signal 2.

2.6.3 Monitor Tool Zone

Monitor Tool Zone

Monitor Tool Zone is a passive supervision function that determines if the robot TCP, elbow, tool and tool orientation are within their defined zones, while moving at allowed speed.

> **Note**
>
> Monitor Tool Zone can only safely determine that the TCP, tool and elbow are within their defined zones (i.e. when the output signal is high). It is not safe to assume that the TCP is outside the defined zone when the signal is low.

> **Note**
>
> The resultant robot TCP speed could in some situations be higher than the programmed TCP speed. This could happen for some robot types if the move instructions are of type `MoveJ` or `MoveAbsJ`. If this occurs, either increase the MTZ **Max Speed**, or try to add intermediate robot targets in the RAPID program.

> **Note**
>
> When the robot is running in manual mode, neither the elbow point nor the TCP point will exceed 250mm/s. When the robot is running in auto mode, IRC5 will not consider the elbow speed when generating the path, only the defined TCP speed and reorient speed. (If additional axis exists in the system, the speed data for this will also be considered.) The result from this is that the elbow speed is sometimes higher than the programmed TCP speed. Since MTZ supervises TCP, tool0 and the elbow, the speed of these points must be taken into account when configuring MTZ or creating the RAPID program.

Monitoring functionality

Up to 8 zones can be configured. Each zone consists of:

- a geometrical shape in space, that the TCP, tool and elbow point should be inside or outside
- a tool orientation with a tolerance
- a maximum speed for the TCP and elbow.

If the TCP, elbow, tool, tool orientation, tool speed or elbow speed is outside its defined zone, a safe digital output signal goes low.

The functionality also includes axis ranges for additional axes per zone.

Settings

The following parameters need to be configured for Monitor Tool Zone:

- TCP data and tool geometry.
- Tool zones (shape, height, position).
- Tool orientation and tolerance for each zone.

Continues on next page

- Tool speed limits.
- Assignment of a safe digital output signal for each zone.
- Elbow position supervision activation.
- Elbow offset parameters.

How to define these settings is described in *Monitor Tool Zone configuration on page 108*.

If more tool points than TCP should be monitored, also configure:

- Tool Points (described in *Tool configuration on page 85*).

Function activation

Monitor Tool Zone is always active.

Dependencies to other supervision functions

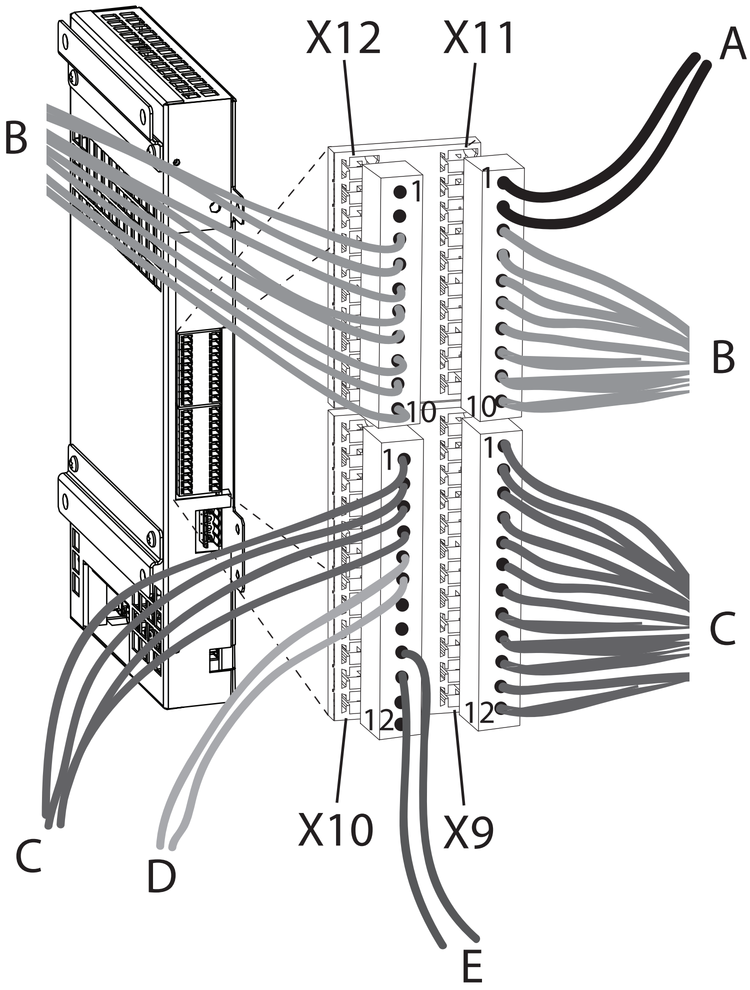
Monitor Tool Zone can be used in combination with all other SafeMove functions.

3 Installation

3.1 Hardware installation

3.1.1 I/O connector data

Location



xx0700000640

A	Power supply
B	8 safe outputs (16 signals)
C	8 safe inputs (16 signals)
D	Sync switch (dual signal)
E	Manual operation input (dual signal)

Continues on next page

Note

Make sure the cables from X9-X12 are not damaged by the normally bunched cable cover, and vice versa. The cables from X9-X12 should be bunched with straps together with other cables against the controller wall.

I/O connector pin descriptions

Contact X9

Pin	Signal	Description
1	Activation input signal 1A	Input signal used for activation of supervision functions. Which functions to activate with this signal is configured in the SafeMove Configurator. Signals 1A and 1B are equivalent signals, i.e. both are set low to activate the supervision functions.
2	Activation input signal 1B	-"-
3	Activation input signal 2A	-"-
4	Activation input signal 2B	-"-
5	Activation input signal 3A	-"-
6	Activation input signal 3B	-"-
7	Activation input signal 4A	-"-
8	Activation input signal 4B	-"-
9	Activation input signal 5A	Input signal used for activation of supervision functions. Which functions to activate with this signal is configured in the SafeMove Configurator. Signals 5A and 5B are antivalent signals, i.e. 5A is set high and 5B is set low to activate the supervision functions.
10	Activation input signal 5B	-"-
11	Activation input signal 6A	-"-
12	Activation input signal 6B	-"-

Contact X10

Pin	Signal	Description
1	Activation input signal 7A	Input signal used for activation of supervision functions. Which functions to activate with this signal is configured in the SafeMove Configurator. Signals 7A and 7B are antivalent signals, i.e. 7A is set high and 7B is set low to activate the supervision functions.
2	Activation input signal 7B	-"-

Continues on next page

Pin	Signal	Description
3	Activation input signal 8A	-"-
4	Activation input signal 8B	-"-
5	Sync switch input signal A	Input signal for synchronization check. A synchronization pulse is defined by this signal connected to ground (0 V). If dual channel sync switch is not used, this signal is not used. See *Sync switch input signal on page 59*.
6	Sync switch input signal B	Input signal for synchronization check. A synchronization pulse is defined by this signal connected to 24 V.
7	Not used	
8	Not used	
9	Manual operation input signal A	Manual Operation is activated by having this signal connected to ground (0 V). For information about Manual Operation, see *Manual Operation on page 24*.
10	Manual operation input signal B	Manual Operation is activated by having this signal connected to 24 V.
11	Not used	
12	Not used	

Contact X11

Pin	Signal	Description
1	Power input 24 V	Plus pole for power to the I/O connector.
2	Power input 0 V	Minus pole for power to the I/O connector.
3	Monitoring output signal 1A	Monitored high side output signal for monitoring functions. The monitoring output signals are configured in the SafeMove Configurator. Switches on or off 24 Volts supplied by the power input (pin 1 and 2 on contact X11). All monitoring outputs are equivalent signals, i.e. both signals are set high when the monitoring functions are not violated.
4	Monitoring output signal 1B	-"-
5	Monitoring output signal 2A	-"-
6	Monitoring output signal 2B	-"-
7	Monitoring output signal 3A	-"-
8	Monitoring output signal 3B	-"-
9	Monitoring output signal 4A	-"-

Continues on next page

Pin	Signal	Description
10	Monitoring output signal 4B	-"-

Contact X12

Pin	Signal	Description
1	Not used	
2	Not used	
3	Monitoring output signal 5A	Monitored high side output signal for monitoring functions. The monitoring output signals are configured in the SafeMove Configurator. Switches on or off 24 Volts supplied by the power input (pin 1 and 2 on contact X11).
4	Monitoring output signal 5B	-"-
5	Monitoring output signal 6A	-"-
6	Monitoring output signal 6B	-"-
7	Monitoring output signal 7A	-"-
8	Monitoring output signal 7B	-"-
9	Monitoring output signal 8A	-"-
10	Monitoring output signal 8B	-"-

Connecting to equivalent input signals

Activation input signals 1-4 are equivalent (both are set low to activate functions). SafeMove has no way of detecting if there is a short circuit between the A and B signal.

Connect these signals from a safety output that has a cross short detection.

Electrical data

Description	Min value	Max value
Voltage for I/O power supply[i]	21.6 V	26.4 V
Voltage for low value on digital input	-3 V	+2 V
Voltage for high value on digital input	+21 V	+27 V
Current for antivalent digital inputs	~2 mA	~2 mA
Current at high value for Sync switch input	~10 mA	~10 mA
Current at high value for all inputs except Sync switch	~2 mA	~2 mA
Max output current by one digital output	-	0.8 A
Sum of output current by all digital outputs	-	3.5 A

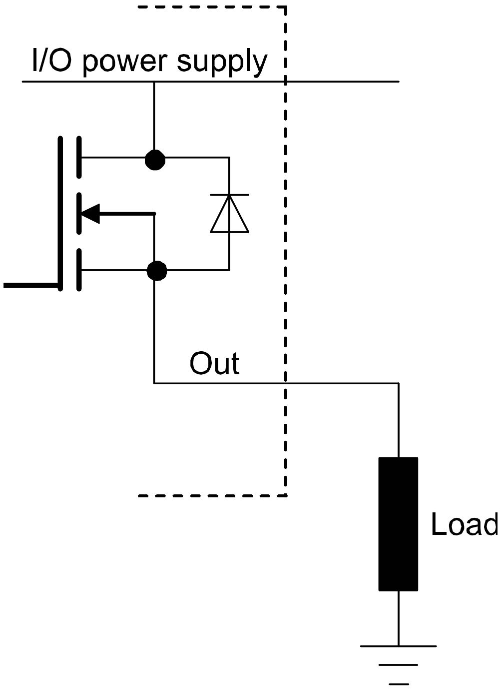
Continues on next page

Description	Min value	Max value
Output inductive load	-	200 mH

i The I/O power supply must be fused with 3.5 A.

Output type: N-channel high side switch

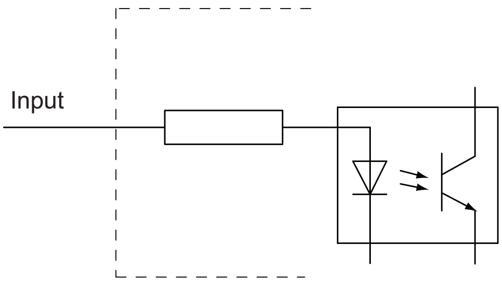
Simple schematic of safety controller outputs:



en0800000063

Input type: equivalent

Simple schematic of safety controller equivalent inputs:

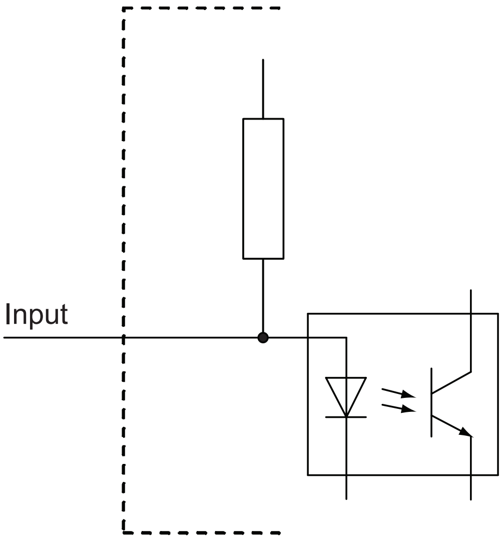


xx1400000645

Continues on next page

Input type: antivalent

Simple schematic of safety controller antivalent inputs:



xx1400000646

> **Note**
>
> The antivalent inputs use internal pull-up resistors, and will therefore output 24 VDC if connected directly to external equipment.
>
> The antivalent inputs must be electrically isolated. When pulled-down, a current of ~2 mA is drawn from the input.

Signal redundancy

Output signals

All monitoring output signals have redundancy as a safety measure, i.e. output signal 1A and output signal 1B should always be identical. If they differ for more than approximately 100 ms, there is an internal error and the signals are set low. Always handle this error by stopping all mechanical units.

If one signal has been set low, the other signal in the signal pair will also be set low before the signal can be set high again.

Activation input signals

Activation input signals 1-4 use redundancy with equivalent input signals. That means input signal 1A and 1B should always be identical. The signals are set low to activate the supervision functions. If the A and B signals differ, the supervision functions are activated. However, if they differ for more than 2 seconds, there will be an I/O error elog and the error must be removed and a warm start performed.

Activation input signals 5-8 use redundancy with antivalent input signals. That means input signal 5A should always be the inverted signal of input signal 5B. Signal A is set high and signal B is set low to activate the supervision functions. If the A and B signals are identical, the supervision functions are activated. However, if they are identical for more than 2 seconds, there will be an I/O error elog and the error must be removed and a restart is required.

Continues on next page

If both the A and B input signal are open (unconnected) the assigned safety function will be activated. This is valid for both the equivalent and the antivalent activation input signals and will not be interpreted as an I/O error as long as both A and B are open.

A signal used for activation of a safety function must be stable, otherwise a stop is generated and a restart is required.

Sync switch input signal

If configured for dual channel sync switch, the sync switch input signal uses redundancy with antivalent inputs. That means input signal A should always be the inverted signal of input signal B. Signal A is pulsed to low and signal B is pulsed to high to activate the function. The pulses on the A and B signals must be simultaneous and last for at least 16 ms. If the A and B signals are identical, the function is NOT activated. If they are identical for more than 2 seconds, there will be an I/O error elog and the error must be removed and a restart is required. (Open inputs have by default different potential, so unconnected signals does not create an error that requires a restart.)

Manual Operation input signal

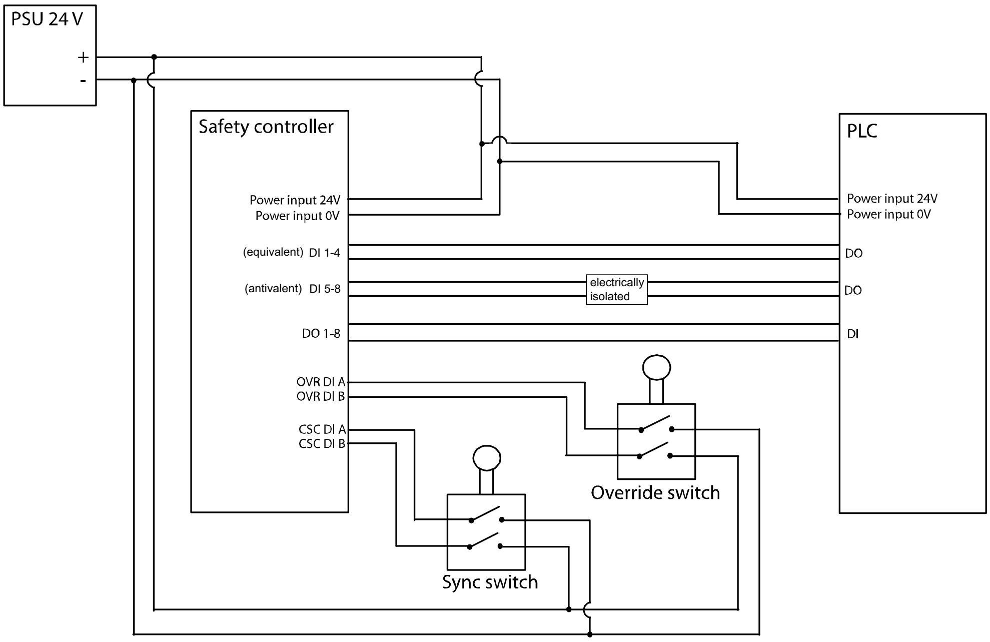
Manual Operation input signal uses redundancy with antivalent inputs. That means input signal A should always be the inverted signal of input signal B. Signal A is set to low and signal B is set to high to activate the function. The function is active as long as the signals keep this state. If the A and B signals are identical, the function is NOT activated. If they are identical for more than 5 minutes, there will be an I/O error elog and the error must be removed and a restart is required. (Open inputs have by default different potential, so unconnected signals does not create an error that requires a restart.)

Note

When no safety configuration is activated, the redundancy supervision of the I/O signals is also disabled. This is a way to prevent safety errors during commissioning.

3.1.2 Connecting to a safety PLC

Principle for connecting signals to a safety PLC



en0700000712

Note

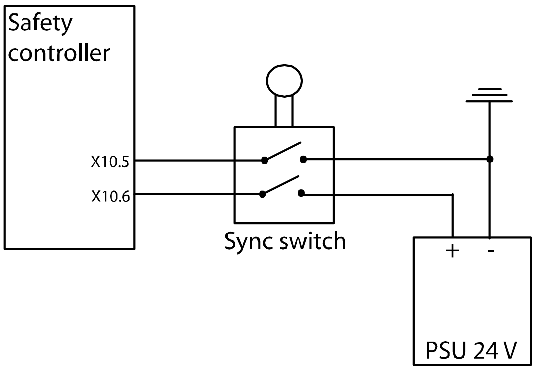
The digital inputs DI 1-4 on the safety controller are equivalent and the digital inputs DI 5-8 are antivalent. For more information, see *I/O connector data on page 51*.

3.1.3 Sync switch input signal

Using the sync switch input signal

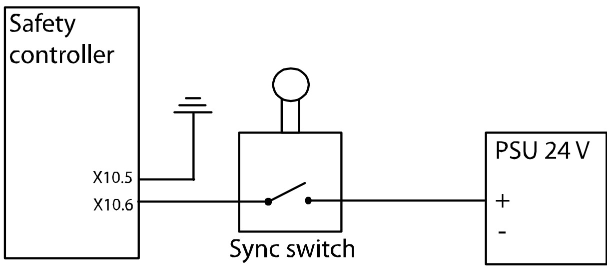
If using Cyclic Sync Check, the safety controller requires a sync switch input signal. Connect a signal from a sync switch. When the robot is in sync position, pin X10.6 should be set high and pin X10.5 should be set low. If dual channel wiring is not used, connect only pin X10.6.

Principle for sync switch connected to the safety controller using dual channel sync switch:



en0700000658

Principle for sync switch connected to the safety controller using single channel sync switch:



en0700000659

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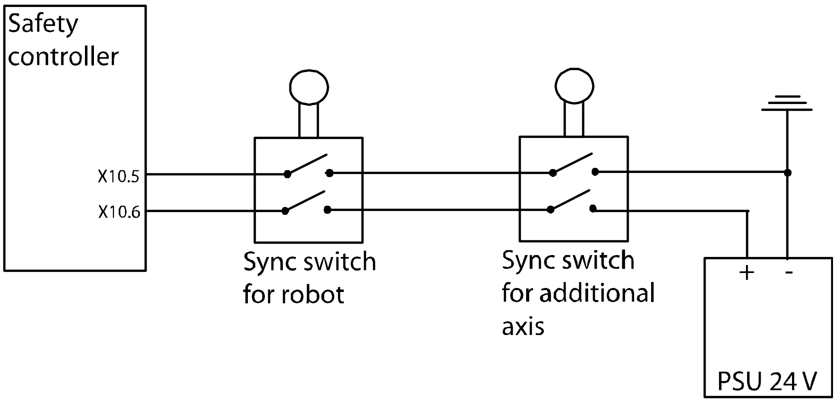
Additional axis

When synchronizing an additional axis and a robot, use a separate sync switch for the additional axis and connect it in series with the sync switch for the robot.



en0700000656

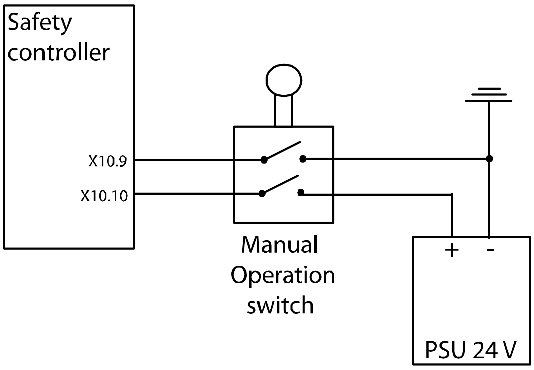
Exception: If the additional axis is a track motion or a robot-held tool, it can use the same sync switch as the robot. These types of additional axes can be treated as a 7th robot axis. Note that this makes it more complicated to find a non-singularity sync check position.

3.1.4 Manual Operation input signal

Using the Manual Operation input signal

To activate Manual Operation, close the switch that is connected to the Manual Operation inputs, pin X10.9 and pin X10.10. This switch can be implemented with, for example a key switch, button, contact strapping or safety PLC. When activating Manual Operation, pin X10.9 should be set low (0 V) and pin X10.10 should be set high (24 V).

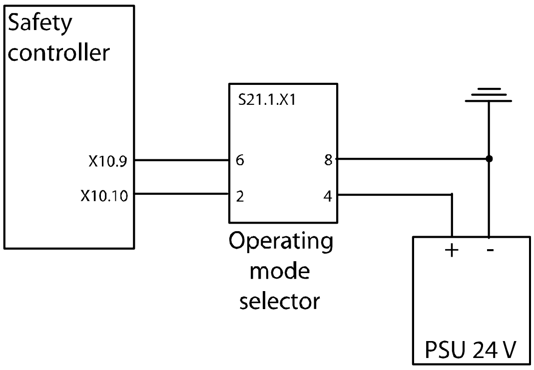
Principle for connecting an external Manual Operation switch to the safety controller:



en0700000713

If the controller has the option for customer connection to operating mode selector (735-3, 735-4) these terminals can be used to control the Manual Operation function, for example, to keep it active when manual mode is selected. For more information, see *Product manual - IRC5* section *The MOTORS ON/MOTORS OFF circuit-Connection to operating mode selector*.

Principle for connecting the robot controller's operating mode selector to the Manual Operation input on the safety controller:



en0900000911

Tip

To make it obvious if Manual Operation is in use, the virtual signal PSC1OVERRIDE (see *Virtual signals on page 145*) can be cross connected to a visual indication (for example a warning light).

3.1.5 Function activation input signals

Using the activation input signals

The safety controller has 8 dual input signals for activation of supervision functions. An activation input signal can be configured to activate one or several supervision functions.

The safety controller works with redundancy (dual input signals, dual processors, etc.). Unless both input signals indicate that a supervision function should be inactive, it will be active (for highest safety). Make sure that redundancy is used for the signals connected to the safety controllers input signals.

Power failure of an external equipment that sets all input signals low will result in all configured supervision functions being active.

Test pulses

The input signals filter signals with duration shorter than 2 ms. Test pulses can be used on these signals, as long as they are shorter than 2 ms, without affecting the SafeMove functions.

3.1.6 Monitoring output signals

Using the monitoring output signals

The safety controller has 8 dual output signals. These can be used to indicate status for the monitoring functions. They can be used to stop the robot if a dangerous status is detected. The robot cell responsible must make sure that the robot and all additional axes are stopped if there is a risk of danger. Connect the output signals to a safety PLC, or similar equipment, that can stop the robot based on signals from SafeMove and other safety equipment in the cell, e.g. light curtains.

The safety controller works with redundancy (dual processors, dual output signals, etc.). Safe robot behavior (e.g. robot inside defined range) is indicated by high value on the output signal, so that a power failure will be interpreted as unsafe and stop the robot.

Make sure that the output signals from the safety controller are connected in such a way that the redundancy is preserved (if one of the dual signals goes from 24 V to 0 V, the system should stop). Also make sure that a low signal always represents the safe state that stops the robot, so that a power failure on the safety PLC also stops the robot.

What the different output signals indicate is defined in the SafeMove Configurator, see *Configuring SafeMove on page 77*.

Test pulses on output signals

Test pulses during start-up

At the beginning of each system start-up there are test pulses on the outputs present. This must be considered at installation and commissioning so that it is not interpreted as, for example, an axis being outside its defined range.

Test pulses during operation

Due to safety reasons there are test pulses on the output signals during operation. The pulses have a maximum length of 2 ms and are only present when the outputs are high. This must be considered at installation and commissioning so that it is not interpreted as, for example, an axis being outside its defined range. Make sure the safety PLC or safety relay does not react on pulses shorter than 2 ms.

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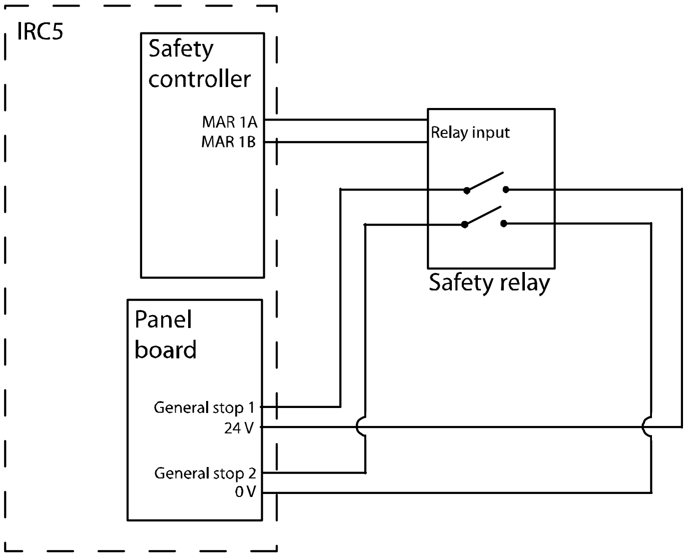
Using a safety relay

An output signal from the safety controller can be connected to a safety relay which can stop the robot immediately. This is implemented by letting the safety relay open the circuit for, for example, the general stop signal 1 and 2 on the panel board of the IRC5 controller.



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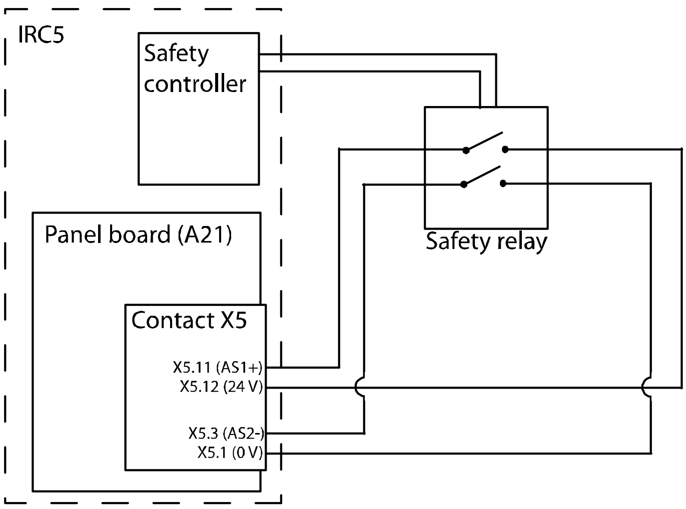
Connect to Auto Stop on the panel board

A signal from a safety relay or a safety PLC can be connected to the Auto Stop signal of the panel board in the IRC5 controller. If the Auto Stop circuit is open, the robot cannot move in auto mode. However, it is still possible to move the robot in manual mode.



en0600003336

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Connect to General Stop on the panel board

A signal from a safety relay or a safety PLC can be connected to the General Stop signal of the panel board in the IRC5 controller. If the General Stop circuit is open, the robot cannot move either in auto or manual mode.

The connection are the same as for Auto Stop except General Stop 1 is connected to X5.10 and General Stop 2 is connected to X5.2.

Note that when the General Stop circuit is open, there is no way of jogging the robot back to the defined range. Recovery from this state is performed in the same way as *Recovery after a supervision function has triggered in Automatic mode on page 143*.

3.1.7 Power supply

Use IRC5 ground or isolate the I/O

The safety controller requires one system power supply and one I/O power supply. These two power sources must have a common ground potential. Besides, the I/O power supply must be fused with 3.5 A.

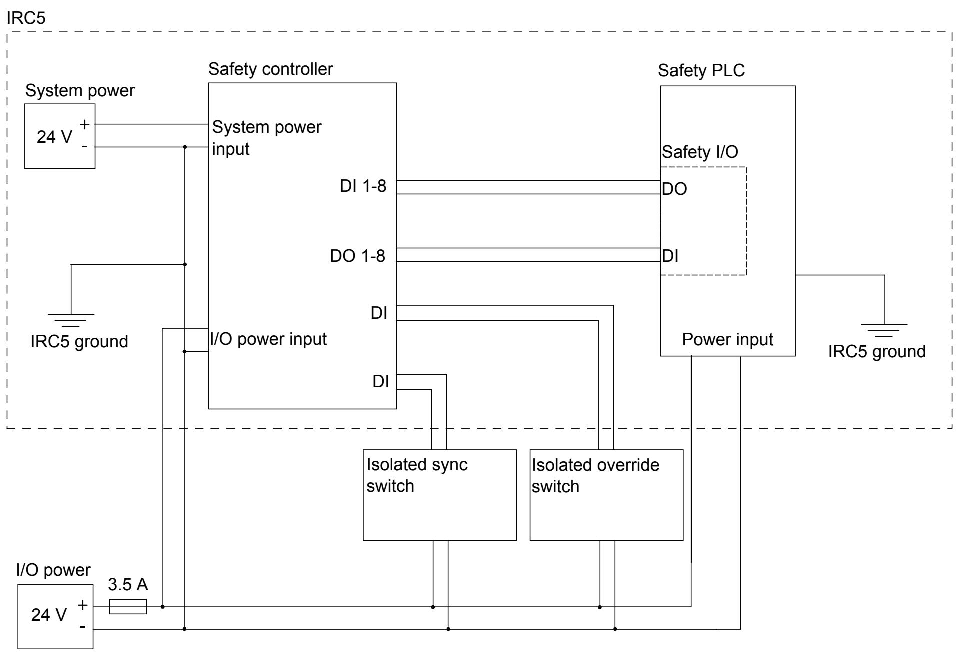
The I/Os of the safety PLC must either have the same ground potential as the safety controller (i.e. as the IRC5 cabinet), or the I/Os of the safety PLC must be galvanically isolated from the safety controller. This can be achieved in different ways as seen in the examples below.

Note

The I/O power supply must be connected with SafeMove to be able to close the limit switch chain when it is disabled. If the limit switch chain is open, the robot cannot operate.

Example with common ground

In this example the I/Os of the safety controller, the sync switch, the limit switch, and the safety PLC has a common ground potential. The ground of the I/O power supply is connected to the ground of the system power supply (i.e. the ground of the IRC5 power supply).



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For a single cabinet IRC5 controller, the I/O power supply can be an internal power supply located in the IRC5 cabinet. For a dual cabinet IRC5 controller, an external power supply needs to be used.

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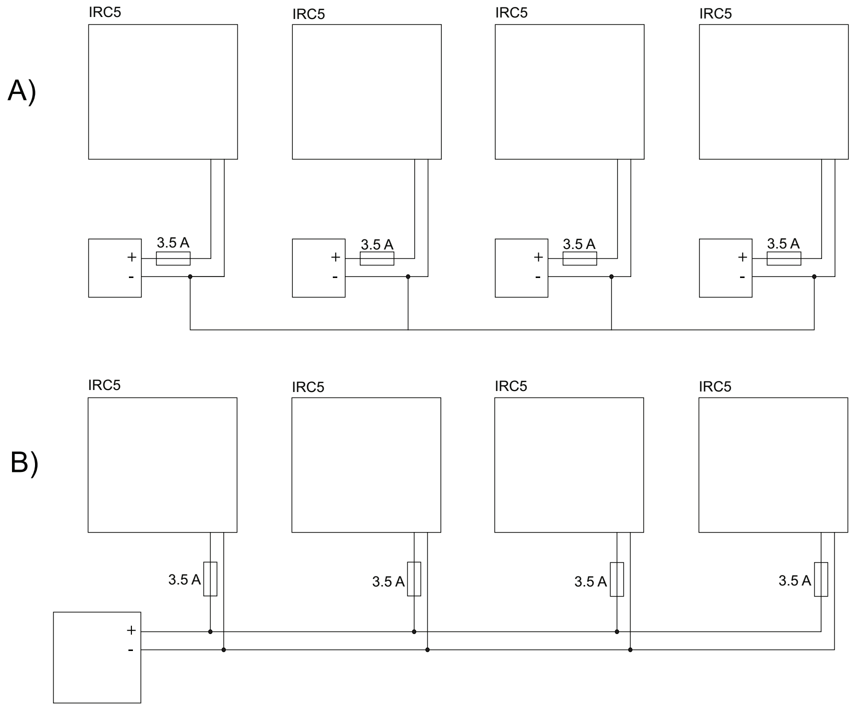
For MultiMove, see the examples below.

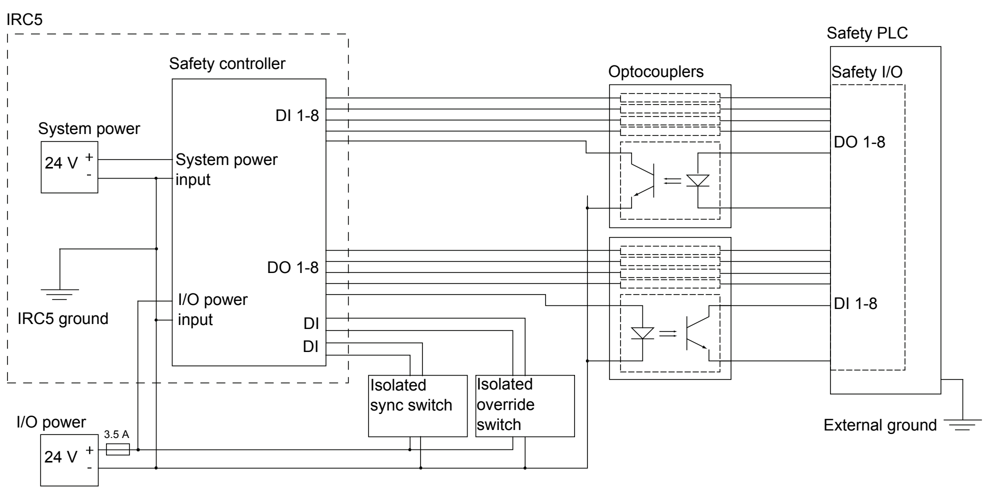


xx1400000652

Example with isolated I/O

In this example the I/O connector of the safety controller is isolated from the safety PLC with optocouplers. The ground of the safety controller (i.e. the ground of the IRC5 power supply) is isolated from the ground of the safety PLC

This setup is usable up to a distance of 30 meters between the IRC5 cabinet and the safety PLC.



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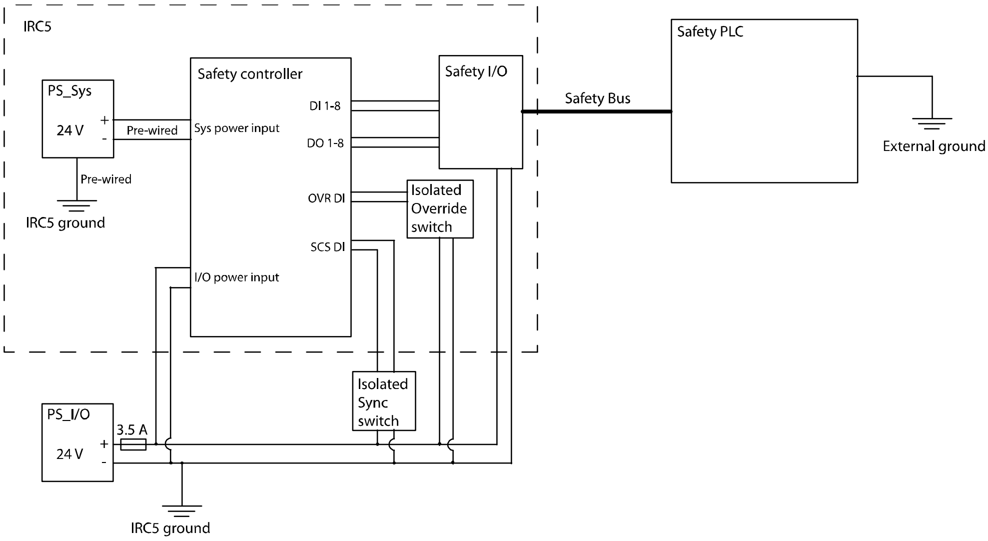
Example with safety bus

A solution with a safety bus will automatically solve the problem of galvanic isolation from the safety PLC. It will also allow the distance between the IRC5 and safety PLC to be greater than 30 meters. The maximum distance for this solution depends on the safety bus used by the safety PLC.



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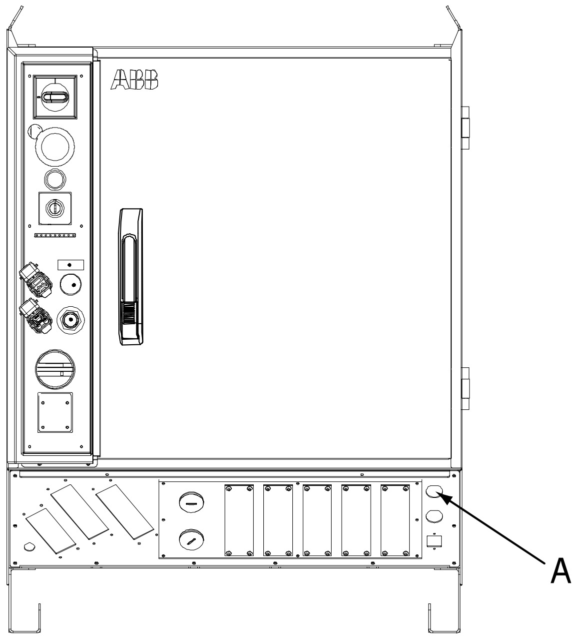
3.1.8 SMB connection for additional axis

Connect additional axis to SMB link 2

When a robot is ordered together with an additional axis, the drive module or single cabinet controller is equipped with a contact for SMB link 2 (A4.XS41). Connect the SMB cable from the additional axis to this connection.



xx0700000715

A	Contact A4.XS41 for SMB link 2.

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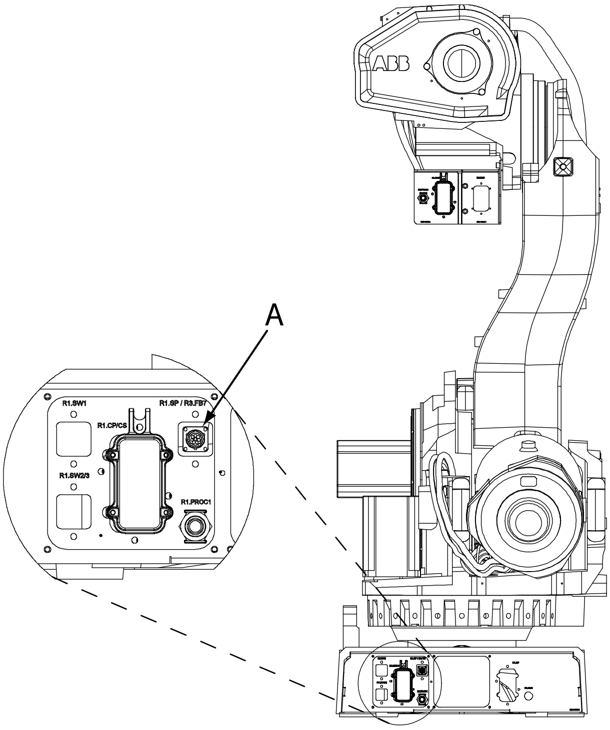
Connect additional axis to SMB link 1 directly on the robot

Connect the SMB cable from the additional axis to the SMB connection on the robot. By connecting the additional axis here, it will be read as axis 7 on the SMB cable from the robot to the safety controller.



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A	SMB connection on robot base, where the additional axis can be connected as the 7th axis in SMB link 1.

This contact may be present for IRB 660, IRB 66XX and IRB 7600.

A similar contact exists for IRB1600, but is on a cable coming out of the robot base.

For other robot models, there is no prepared contact for a 7th axis on SMB link 1.

More information about SMB connections

More descriptions of the SMB connections can be found in *Application manual - Additional axes and stand alone controller*.

3.2 Software installation

3.2.1 Installing required software

Note

RobotStudio must be of the same version or later than the RobotWare used.

Install RobotStudio

The SafeMove Configurator is installed with RobotStudio. Install RobotStudio as described in *Operating manual - Getting started, IRC5 and RobotStudio*.

RobotStudio can be installed with the options *Minimal* or *Full*, and the SafeMove Configurator is installed with either of these installation options. The SafeMove Configuration tool is available in the Online tab of RobotStudio.

Create a robot system

Create a robot system as described in *Operating manual - Getting started, IRC5 and RobotStudio*. Use a drive module key that gives access to SafeMove and select the option *810-2 SafeMove*.

Configure IRC5

Configure the robot system (coordinate systems, tools, work objects, robot cell layout, etc.) before configuring SafeMove.

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4 Configuration

4.1 Configure system parameters

About the system parameters

The configuration of system parameters required for a robot system should be made before starting with the safety configuration.

In addition to the system parameters that need to be configured for a robot system without SafeMove, there are a few parameters that are specific for SafeMove. These are described in this section.

Type Mechanical Unit

All mechanical units for additional axes shall have the parameters *Activate at Start Up* and *Deactivation Forbidden* set to On. (All mechanical units must always be active.)

Type Arm

If an axis should be excluded from Cyclic Brake Check, set the parameter *Deactivate Cyclic Brake Check for axis* to On. This must correspond with the axes that are deactivated in the configuration of Cyclic Brake Check. See *Cyclic Brake Check configuration on page 89*.

The maximum working area for axes has to be limited according to limitations specified in section *Supported additional axes on page 17*. This must be taken into consideration when entering the parameters *Upper Joint Bound* and *Lower Joint Bound*. (The parameter values in radians or meters on arm side.)

Type Brake

If Cyclic Brake Check is executed on an additional axis, a lowest safe brake torque must be defined. A 5% margin is added during the test for setting the fail limit. The parameter used is *Max Static Arm Torque* defined in Nm on motor side. A warning limit is set with a higher torque value (depending on the brake).

System input signal, SafeMoveConfirmStop

The system input signal SafeMoveConfirmStop can be used as a complement to the Motors On button when restoring an error. See *Recovery after safety violation on page 143*. This system input can be configured as a physical or virtual I/O signal in IRC5. To configure SafeMoveConfirmStop, use the **Configuration Editor** in RobotStudio. For details about how to use the **Configuration Editor**, refer to *Operating manual - RobotStudio*.

Note

It is recommended to use the system input signal for interconnection with a press button, or similar, in the first place. Use caution if the PLC is used to control the signal. Avoid situations when pulsing the signal, since this may lead to a security risk.

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System input signal, LimitSpeed

The system input signal `LimitSpeed` can reduce the speed of the robot and any additional axes before entering a zone supervised by SafeMove.

The RAPID instructions `SpeedLimAxis` and `SpeedLimCheckPoint` are used to set a speed limit value that later on should be applied. The speed reduction is done when the system input signal `LimitSpeed` is set to 1.

For more information about the RAPID instructions `SpeedLimAxis` and `SpeedLimCheckPoint` see *Technical reference manual - RAPID Instructions, Functions and Data types*.

For more information about the system input signal `LimitSpeed` see *Technical reference manual - System parameters*.

4.2 Create a safety user

Why do you need a safety user

Configuring SafeMove is normally done initially and then never changed (until the robot is used for a different purpose). It is vital that the safety configuration is not changed by unauthorized personnel. It is therefore recommended to have specific safety users who are granted the right to configure SafeMove.

Prerequisites

You must have created a robot system with the option 810-2 SafeMove. How to create a system is described in *Operating manual - RobotStudio*.

How to create a safety user

	Action
1	Request write access from RobotStudio: In the **Online** browser, right-click on the controller and select **Request Write Access**. If in manual mode, confirm the write access on the FlexPendant.
2	Start UAS Administrative Tool: In the **Online** browser, right-click on the controller and select **Authenticate** and then **Edit User Accounts**.
3	Select the tab **Groups**.
4	Click **Add** and type a name for the group, e.g. "Safety".
5	Select the group you have created and select the check boxes for the controller grants: • **Execute program** • **Remote restart** • **Safety Controller configuration** • **Read access to controller disks** • **Write access to controller disks** The group may have more grants, but these are the minimum required.
6	Select the tab **Users**.
7	Click **Add** and type a name for the user, e.g. "SafetyUser", and a password for the user.
8	Select the user you have created and check the group you previously created, e.g. **Safety**. The user may belong to more groups.
9	Click **OK**.
10	Restart the controller.

Tip

Create different user groups as described in *Operating manual - RobotStudio*, section *Managing the user authorization system*. Make sure that one administrator has the grant *Manage UAS settings* and that the regular users (operators, Default user, etc.) do not have the grants *Safety Controller configuration*, *Write access to controller* or *Manage UAS settings*.

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Granting right to perform software synchronization

There must always be a safety user with the right to everything that has to do with the safety controller. The safety user can always perform a software synchronization. If you want someone else to be allowed to perform a software synchronization, this grant can be given to them.

	Action
1	Request write access, open the UAS Administrative tool and select tab **Groups** as described in *How to create a safety user on page 75*.
2	Select the group that should have the grant (for example Operator).
3	Select Application grants in the drop-down box.
4	Select the check box for **SafeMove**/**EPS software sync service routine**.
5	Click **OK**.

4.3 Configuring SafeMove

4.3.1 About Visual SafeMove

What is Visual SafeMove

Visual SafeMove is a 3D based configuration tool for SafeMove. The tool is completely integrated into the RobotStudio user interface and takes full advantage of the user interface elements such as tabs, browsers, and 3D graphics.

Visual SafeMove is enabled for robots with the SafeMove option. It offers an intuitive way to visualize and configure safety zones. Zones can be adjusted by direct manipulation in the 3D window. Users with previous experience from SafeMove will recognize the same terminology used as before.

Visual SafeMove works both with the real controller and the virtual controller. When working with a RobotStudio station, you have the additional benefit of being able to generate zones automatically. When not running a RobotStudio station, **Online Monitor** is used to visualize the robot.

The Visual SafeMove configurator is available alongside with the previous configurator, see section *Configuring SafeMove on page 77*. All base functionality from the previous configurator is available in Visual SafeMove.

For information about the different SafeMove functions, see section *SafeMove functions on page 23*.

Prerequisites

Only a safety user is allowed to download a configuration. A safety user must be created before configuring SafeMove (see *Create a safety user on page 75*).

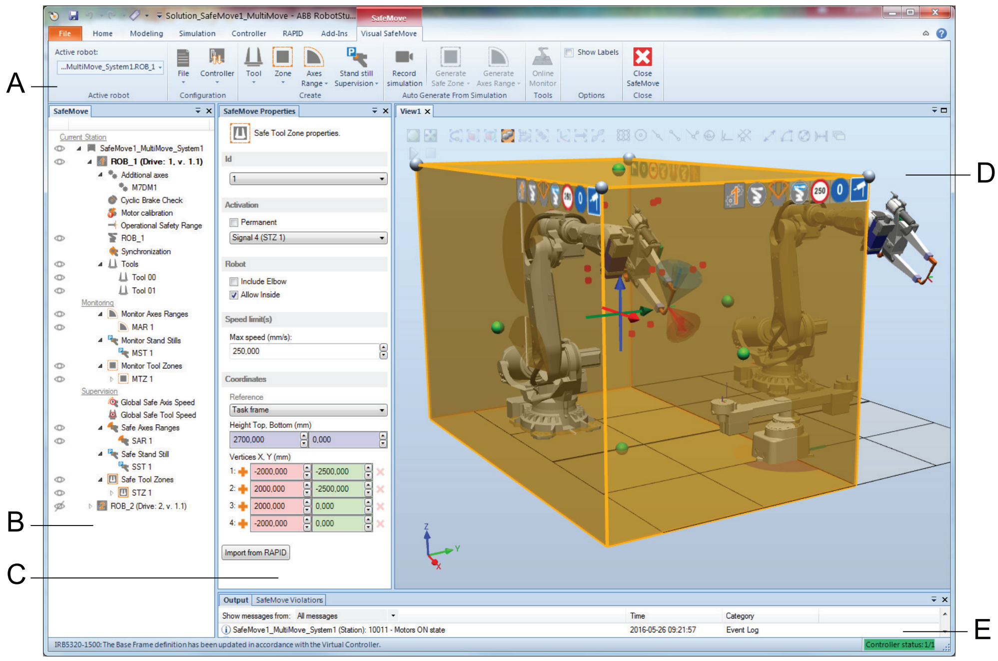
4.3.2 The Visual SafeMove user interface

Starting Visual SafeMove

	Action
1	Start a RobotStudio station, a virtual controller, or connect to a real controller.
2	In the RobotStudio **Controller** browser, right-click on the controller and select **Authenticate** and then **Login as a Different User**.
3	Select the safety user, e.g. **SafetyUser**. Type the password and click **Login**.
4	In the **Controller** tab, click **Online Monitor**. (Not needed when running a RobotStudio station.)
5	In the **Controller** tab, click **Safety**, then select **Visual SafeMove**.

Overview

This section presents an overview of the Visual SafeMove graphical user interface.



xx1400002018

	Parts	Description
A	Ribbon	Displays groups of icons organized in a logical sequence of function.
B	SafeMove browser	Displays all available SafeMove functions.
C	SafeMove properties browser	Displays all available properties and settings of the selected SafeMove function.
D	Graphics window	Is used to to visualize and configure safety zones in the RobotStudio station. When not running a RobotStudio station, **Online Monitor** is used to visualize the robot.

Continues on next page

	Parts	Description
E	Output window	The output window displays information about events that occur in RobotStudio, both general events and Visual SafeMove events.

The SafeMove browsers

The configured SafeMove functions are available from the **SafeMove** browser. When a function is selected by clicking the node in the browser, the properties and settings are displayed in the **SafeMove Properties** browser.

Use the **SafeMove** browser, or standard keyboard shortcuts, to cut, copy, and paste zones both between zone types and between robots.

The graphics window

In general the Visual SafeMove graphics window is navigated using the same commands as in RobotStudio. A few additional navigation tools are available in Visual SafeMove for editing zones, those are listed below.

For more information on navigating RobotStudio, see *Operating manual - RobotStudio*.

Editing zones in the graphics window

Zones are displayed as semi-transparent (opaque) planes with different color for different zones. Supervised zones have yellow border, monitored have blue border.

The following navigation options are available in Visual SafeMove for editing zones:

- Drag and drop on spheres in the graphics window (at corners and surfaces) to modify a zone.
- Double click vertices or surfaces in the graphics window to create new corners/vertices at that location.
- Delete vertices that are no longer desired by selecting and deleting them from the graphics window.
- Move a zone by dragging the zone frame arrows in the graphics window (x, y, z).

Symbols in the graphics window

The following symbols are used in the graphics window to illustrate the properties of the zones.

 xx1600000241	 xx1400002023	 xx1600000618	 xx1400002063	 xx1400002022	 xx1600000245	 xx1600000246
Drive module number	Monitored zone	Elbow included in monitoring and supervision	Zone minimum speed limit	Zone maximum speed limit	Robot allowed inside zone	Robot not allowed inside zone

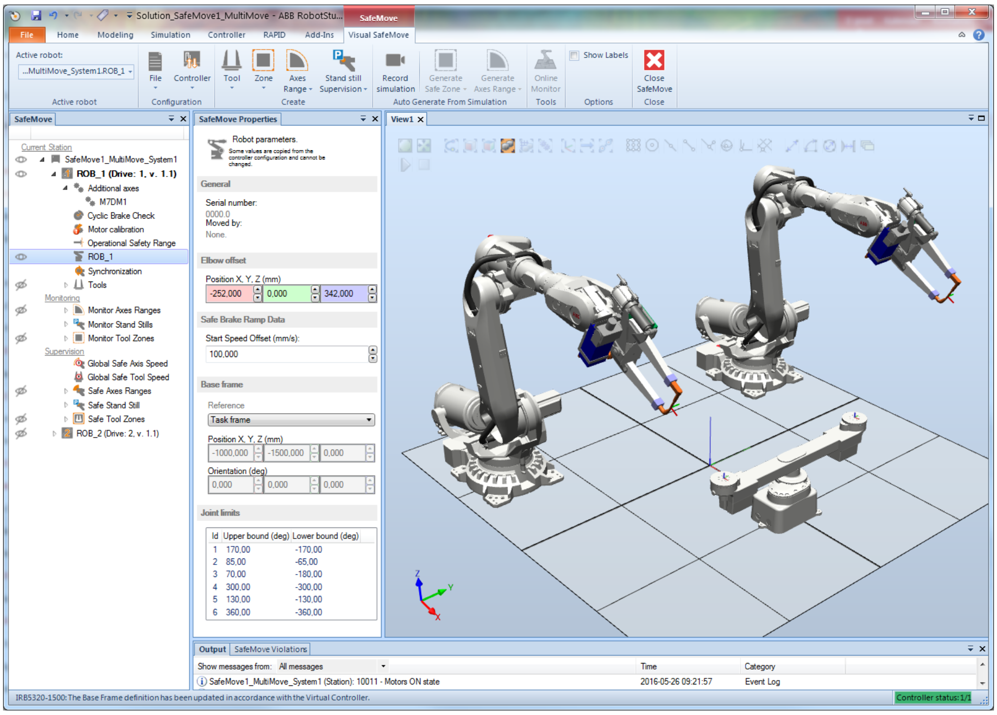
4.3.3 Mechanical Units configuration

Robot configuration

In the SafeMove browser, select the robot to configure (e.g ROB_1).

	Action	Note/illustration
1	Click on **ROB_1** in the SafeMove browser to specify the robot properties in the SafeMove Properties browser.	
2	Under **Elbow offset**, set the **X**, **Y** and **Z** values for the elbow point.	See *Elbow offset on page 81*. **Note** The values that are entered into **Elbow Offsets** should also be entered into the parameter *Arm Check Point*, topic *Motion*. This is to avoid different speed calculations between IRC5 and SafeMove in manual reduced speed mode. For more information, see *Technical reference manual - System parameters*.
3	Under **Safe Brake Ramp Data**, set the **Start Speed Offset**.	See *Brake Data on page 82*.
4	Under **Base frame**, select reference coordinate system.	See *Explanation of Base Frame on page 81*.

The joint limits are shown here but cannot be changed.



xx1600000585

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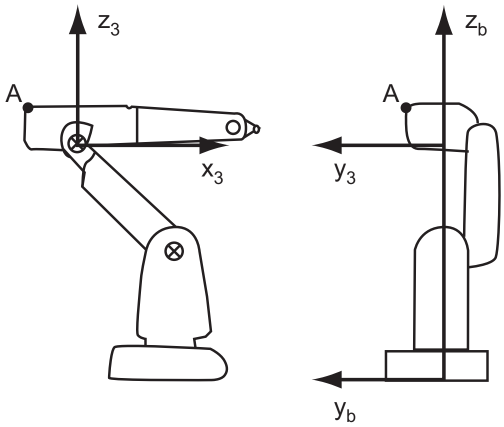
Elbow offset

When an elbow point is considered for Safe Tool Zone or Monitor Tool Zone, that elbow point can be configured with an offset. Specify the elbow point's x, y and z offsets relative to the center of robot axis 3. Note that the X value should always be negative.



xx1300002628

A	Elbow point
x_3, y_3, z_3	Axis 3
y_b, z_b	Robot base

Explanation of **Base Frame**

All values for the base frame are automatically loaded from the robot controller and cannot be changed from the **Visual SafeMove** browser.

Setting	Description
Base frame • **Reference**	Zone can be defined in either task frame, world coordinate system, user coordinate system, or robot base frame. These coordinate systems are often identical, but for MultiMove systems it may be desired to do the configuration in the robot base frame.
Base frame • **Position X, Y, Z**	X, Y and Z values for the selected reference frame's origin, expressed in the world coordinate system.
Base frame • **Orientation**	Defines the orientation of the selected reference frame, compared to the world coordinate system.

Additional axis configuration

	Action	Note/illustration
1	If the axis should be part of the SafeMove supervision, select the check box **Is supervised**.	
2	Specify **Standstill Tolerance**.	Used for Safe Stand Still. The motor is in regulation during Safe Stand Still, and a small movement may be allowed. The size of the allowed movement is specified in **Standstill Tolerance** (in radians on motor side).

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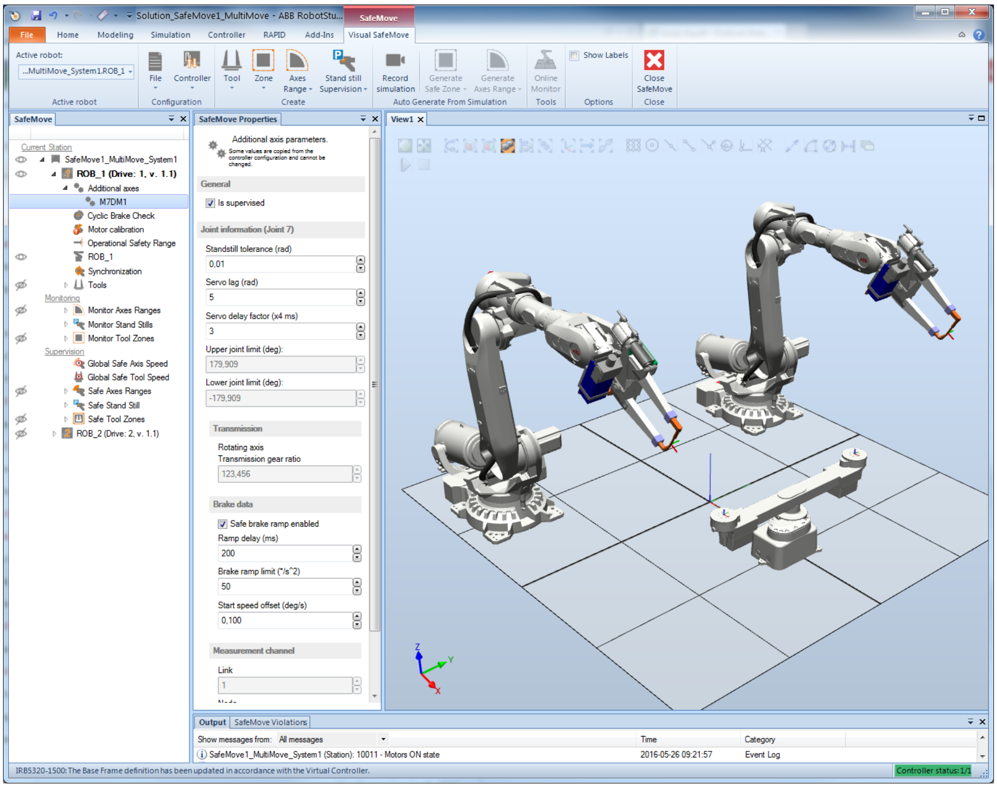
	Action	Note/illustration
3	Specify **Servo lag**.	**Servo lag** is the estimated lag (in radians on motor side) for the additional axis. For more information, see *Servo Delay Factor and Servo Lag on page 215*.
4	Specify **Servo delay factor**.	Estimated delay factor between reference position and measured position (number of 4 ms units) when moving the additional axis. (See TuneMaster, signal number 17 and 18.) For more information, see *Servo Delay Factor and Servo Lag on page 215*.
5	If safe brake ramp should be used for the axis, select the check box **Safe brake ramp enabled**. Set the values for **Ramp delay**, **Brake ramp limit** and **Start speed offset**.	See *Brake Data on page 82*.

Some information about the additional axis is shown, but cannot be changed. This includes joint limits, transmission gear ratio and measurement channel information.



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Brake Data

Ramp delay	Delays the Safe Brake Ramp function. See figure below. Default value: 200 ms.
Brake ramp limit	Used for Safe Brake Ramp function. If the actual deceleration is lower than the specified Brake Ramp Limit, then Safe Brake Ramp will cause a category 0 stop. The value to type should be for the arm side.
Start speed offset	Affects the Safe Brake Ramp function. See figure below.

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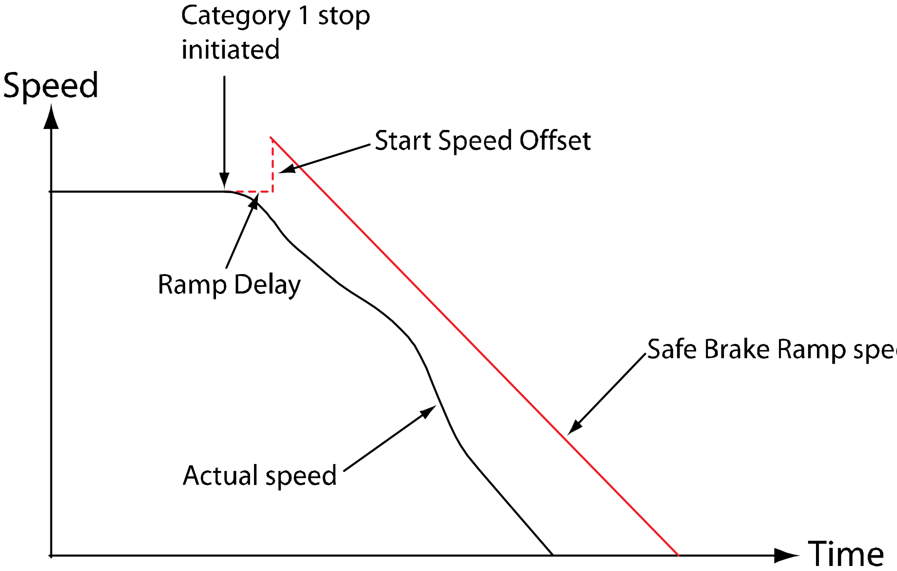
The brake configuration affects the function Safe Brake Ramp. **Ramp Delay** and **Start Speed Offset** affect where the ramp should start and **Brake Ramp Limit** affects the gradient of the Safe Brake Ramp speed limit.



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For a category 1 stop, a drive module that controls both robot and additional axes will adjust the deceleration for all units to the unit with the slowest deceleration. The Safe Brake Ramp speed limit is also adjusted to the unit with the slowest deceleration. If one of the additional axes has Safe Brake Ramp deactivated, the Safe Brake Ramp speed limit will be calculated from the ramp delay time 1 second.

For a robot standing on a track motion, the Safe Brake Ramp speed limit is calculated from the slowest deceleration of the robot and the track motion.

Note

Due to the Safe Brake Ramp functionality it is important that a correct value of Brake Ramp Limit is typed for the additional axes.

How to calculate the Brake Ramp Limit

The method described below is possible to use for additional axes that are configured and tuned by the customer. Note that the values of ACC_DATA in the IRC5 configuration file for the additional axes must be set correctly.

The value of wc_dec belonging to ACC_DATA is the deceleration value in rad/s^2 or m/s^2 on the arm side, and is used by IRC5 during a category 1 stop. Reduce this deceleration value by approximately 20% to get a suitable margin.

Example for rotational motor:

```
Brake Ramp Limit=0.8*wc_dec*180/pi
```

Continues on next page

The Brake Ramp Limit parameter can also be obtained by doing the test on the system. Follow the steps in this procedure:

	Action	Note
1	Configure the IRC5 to generate a category 1 stop when the emergency stop button is pressed.	See *Operating manual - IRC5 with FlexPendant*, section *Safety signals*.
2	Start the TuneMaster, and then log the joint speed.	
3	Run the axis with maximum speed value (or near maximum).	
4	Press the emergency stop button.	In TuneMaster, the resulting graph shows the speed (rad/s on motor side) versus time (s). The gradient of the deceleration part gives the deceleration.
5	To get the deceleration value on the arm side, divide the motor deceleration value with the transmission ratio, and then convert the value to degrees/s^2.	
6	To get a suitable margin, reduce the resulting deceleration by approximately 20%.	

Brake data for ABB robots and ABB tracks

For more information about **Ramp delay**, **Start speed offset** and **Brake ramp limit**, see *Configuring brake data - with ABB robots and ABB tracks on page 211*.

Additional information for ABB track motions

The following table gives system parameter values for the track motions (IRBT 104, IRBT 4004, IRBT 6004, and IRBT 7004):

Type	Parameter	Parameter value
Measurement Channel	**Link**	**2**
	Board Position	**1**
	Node	**1**
Transmission Data	**Transmission Gear Ratio**	**182.73096 (-182.73096)**

The following table gives system parameter values for the robot travel track (RTT):

Type	Parameter	Parameter value
Measurement Channel	**Link**	**1**
	Board Position	**2**
	Node	**7**
Transmission Data	**Transmission Gear Ratio**	**295.6793 (-295.6793)**

Note

The negative sign for **Transmission Gear Ratio** means mirrored carriage or double carriage on the same track.

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> **Tip**
>
> Recommended configuration values for ABB tracks of type IRBT are:
> - **Servo Lag** = 5
> - **Servo Delay Factor** = 3

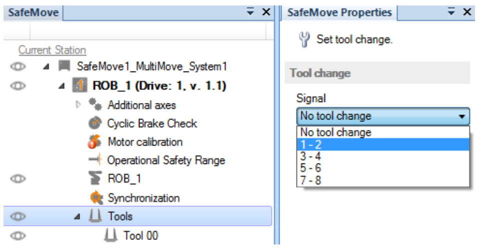
Tool configuration

Up to four tools can be defined. To be able to configure more than one tool, first select the input signals for the tool changer. If both tool change input signals go low, *tool 00* is selected. A tip is to configure the largest tool as *tool 00*.

> **Note**
>
> All defined tools must have the same number of supervision points.

Tool changer

If a tool changer is used, it is necessary to define which input signals define which tool is used.

	Action	Note/illustration
1	In the SafeMove browser, click on **Tools**.	
2	In the SafeMove properties browser, select which input signals to use for tool selection.	 xx1600000588

> **Note**
>
> It is not possible to define more than one tool until tool change signal is specified.

Automatically set tool parameters

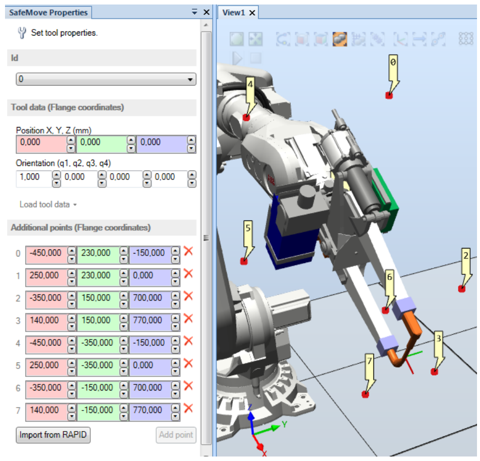
If a tool is already defined in RAPID, SafeMove tool parameters can be automatically configured.

	Action	Note/illustration
1	In the SafeMove ribbon, click on the **Tool** menu, select **Encapsulate** and then select the tool to use.	The TCP and additional supervision points surrounding the tool is automatically configured.

Manually set tool parameters

	Action	Note/illustration
1	In the SafeMove ribbon, click on the **Tool** menu and select **New**.	

Continues on next page

	Action	Note/illustration
2	In the SafeMove properties browser, select **Id** for the tool (0-3).	Used to identify active tool if a tool changer is used.
3	Under **Tool data**, fill in the position and orientation of the tool's TCP in relation to tool0 (the mounting flange). The tool data can also be imported from RAPID by clicking **Load tool data** and selecting the tool to use.	**CAUTION** Since the tool data is determined by the programmed tool, it is very important that the active tool in SafeMove corresponds to the active tool of the robot program.
4	Specify **Additional points**. Click on **Add point** until you have the number of speed supervision points you want (max. 8). Fill in the X, Y, and Z values for each supervision point. A supervision point is specified by its X, Y and Z coordinates in the tool0 coordinate systems (mm from the mounting flange). The supervision points are supervised by Safe Tool Zone and Monitor Tool Zone, so that all configured tool points stay within the allowed zone. **Note** It is only the configured points that are supervised, not the volume between the points.	 xx1600000587

Import tool points

Tool supervision points can be imported from the system module, *PSC_Define_Safety_Zones*.

In the SafeMove ribbon, click on the **Tool** menu, select **Import from RAPID** and select a tool.

This system module contains data for supervising tool points on the TCP, Safe Tool Zone configuration, and Monitor Tool Zone configuration. For more information, see *Importing points on page 101*.

Calibration Offsets configuration

The first time you configure a new robot you must provide the motor calibration offsets. These values are required to achieve a high precision in the supervision of the axes positions.

	Action	Note/illustration
1	Click on **Motor Calibration** in the SafeMove browser.	
2	In the SafeMove Properties browser, click on the button **Update calibration from controller configuration**.	The calibration offset parameters are fetched from the system parameter *Calibration Offset* in type *Motor Calibration*, topic *Motion*.

4.3.4 Synchronization configuration

Synchronization configuration

	Action	Note/illustration
1	Click on **Synchronization** in the SafeMove browser.	
2	Select **Synchronization method.**	If a dual input signal is used for the synchronization check, connected to pin X10.5 and X10.6 on the I/O connector, select **Dual Channel.** If a single input signal is used, connected to pin X10.6, select **Single Channel.** If the Software Sync Check function is used, select **Software Synchronization.** **Note** Software synchronization should only be used if the robot process makes it obvious if there are any errors in the robot position.
3	Specify **Synchronisation cycle, Prewarning time** and **Max time limit.**	**Synchronisation cycle** defines the maximum allowed time (in hours) between synchronization checks. A value up to 720 hours can be configured. Before the cycle time has expired, a warning will be shown on the FlexPendant. **Prewarning time** defines how long before the cycle time is up this warning should occur. When the cycle time has expired without a sync check, the robot is stopped. By pressing the motors on button on the robot controller, the robot can be moved for a short period of time with reduced speed, which should be enough to perform a synchronization. **Max time limit** specifies the length of the period in which an unsynchronized robot can be moved after pressing the motors on button. A value between 60 and 3600 seconds can be configured.
4	Jog the robot to the synchronization position. In the SafeMove properties browser, click on **Read current values.**	It is also possible to specify the axis position values manually.

Tip

Save the synchronization position as a `jointtarget` in your RAPID program. For more information, see *Synchronization guidelines for Cyclic Sync Check on page 133*.

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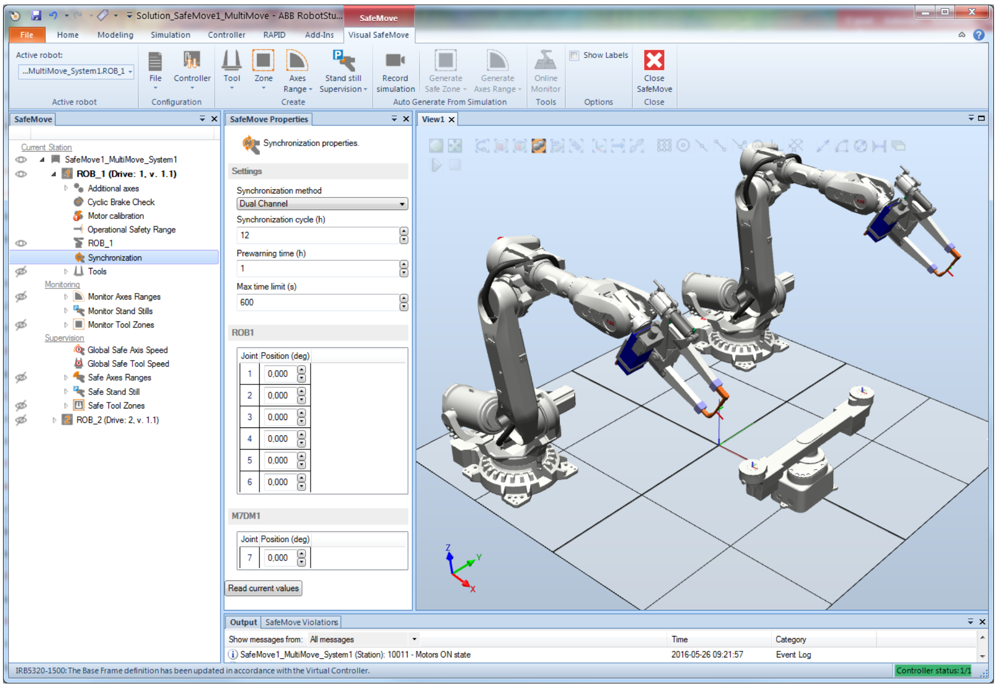

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4.3.5 Cyclic Brake Check configuration

Cyclic Brake Check configuration

	Action	Note/illustration
1	In the SafeMove browser, click on **Cyclic Brake Check**.	
2	If Cyclic Brake Check should not be used for any axis on the drive module (robot or additional axis), clear the check box **Enable Cyclic Brake Check**.	
3	If the robot should not be stopped when the test interval has elapsed, select the check box **Warning only, no stop**.	
4	In **Max CBC test interval**, set the maximum allowed time (in hours) between brake checks.	
5	In **Pre warning time**, set how long before the end of the interval a warning should be shown on the FlexPendant.	
6	In **Reduced max speed,** set maximum allowed TCP speed if the brake test has failed or the brake test interval has expired.	
7	Do not change the default value for **Standstill tolerance** unless absolutely necessary.	**Standstill tolerance** is used for Stand Still Supervision during brake test. The motor is in regulation during brake test, and a small movement may be allowed. The size of the allowed movement is specified in **Standstill tolerance** (in radians on motor side). Typical value is 2 radians.
8	Do not change the default value for **Supervision threshold** unless absolutely necessary.	**Supervision threshold** defines the threshold to verify that a brake check has been made.
9	If one axis should be excluded from the Cyclic Brake Check, clear the check box **Enabled** for that axis.	This must correspond with the axes that has the system parameter *Deactivate Cyclic Brake Check for axis* set to *On*. For axes not included in SafeMove, deactivation of the axes must be done by setting the parameter *Deactivate Cyclic Brake Check for axis* to *On* via RobotStudio for all axes not included.

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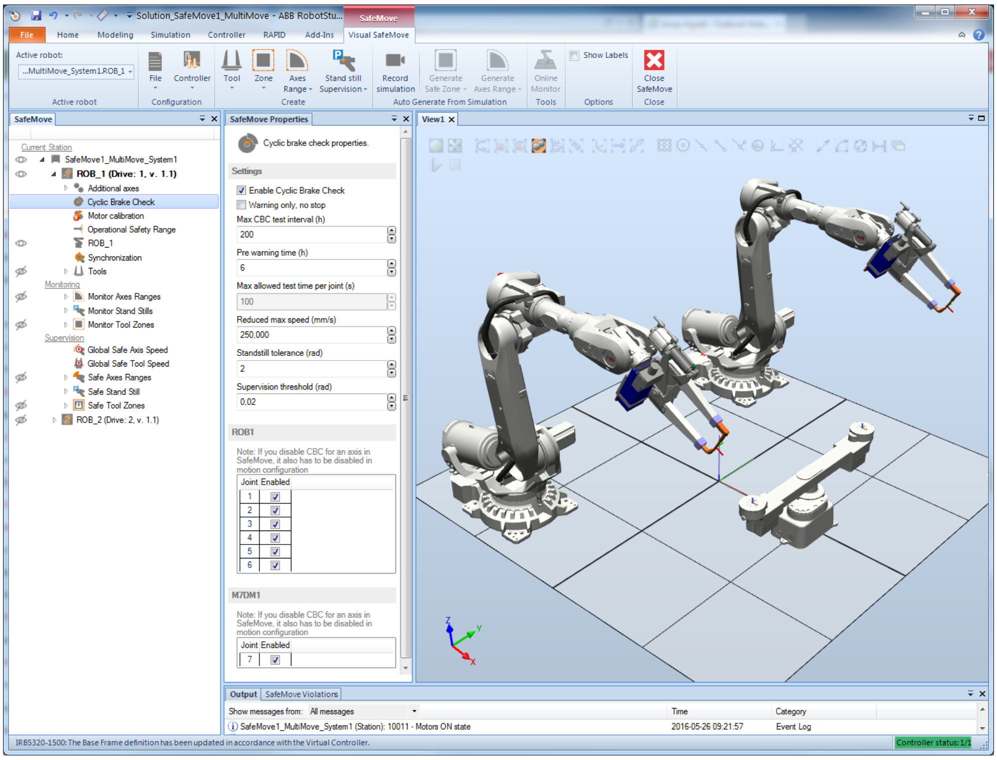

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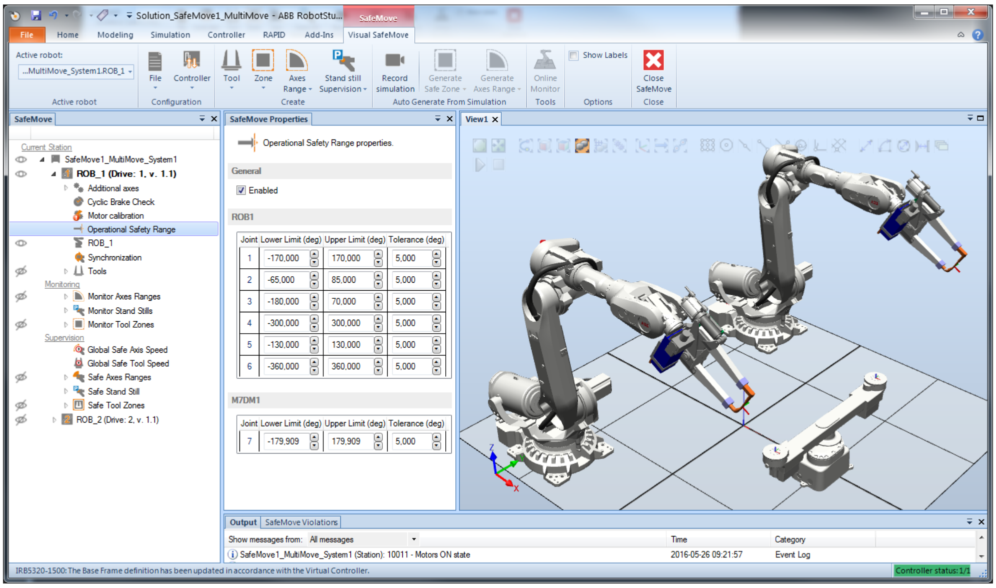
4.3.6 Operational Safety Range configuration

Operational Safety Range configuration

If using soft servo or Force Control, the servo lag can easily exceed the limits for the function Control Error Supervision. In this dialog you can set axis ranges where the tolerance for Control Error Supervision is higher.

	Action
1	In the SafeMove browser, click on **Operational Safety Range**.
2	Select the check box **Enabled**.
3	For each axis, set the range where the tolerance of the Control Error Supervision should be higher. Also set how high this tolerance should be. The tolerance (in degrees on arm side) is specified in **Tolerance**.



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4.3.7 Supervision functions configuration

4.3.7.1 Safe Stand Still configuration

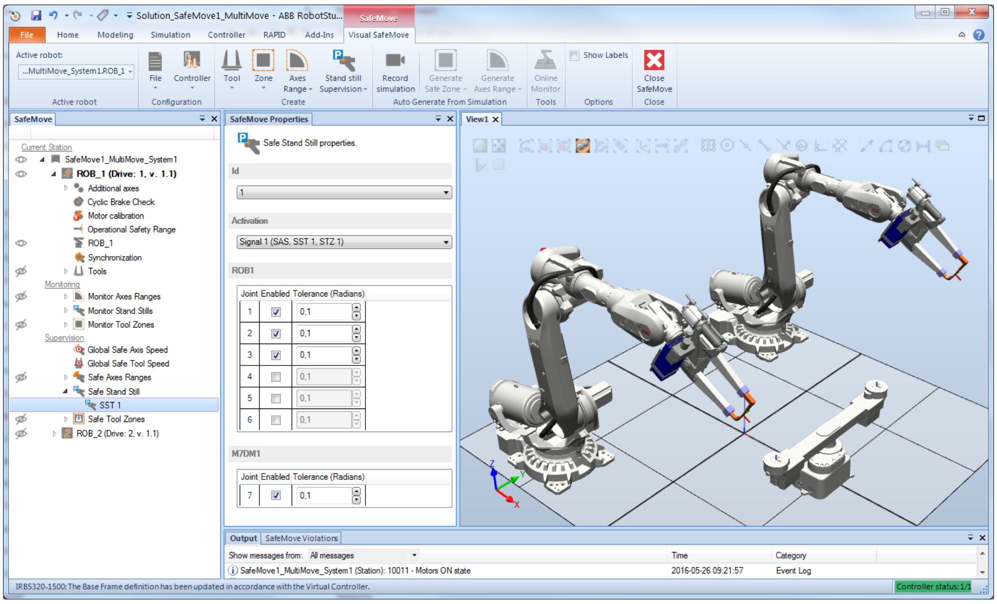
Safe Stand Still configuration

Up to four Safe Stand Still functions can be configured.

	Action	Note/illustration
1	In the SafeMove ribbon, click on the **Stand still Supervision** menu and select **Safe Stand Still**.	
2	In the SafeMove properties browser, select **Id** for this Safe Stand Still function (1-4).	
3	In **Activation**, select the signal to activate the function.	Input signal definitions: 0 = activate function 1 = deactivate function
4	Select the check box **Enabled** for each axis that should be included in the Safe Stand Still function.	
5	For each axis, specify the maximum allowed tolerance for that axis (in radians on axis side).	Do not use larger tolerance values than necessary. A larger value increases the robot movement if an error occurs.

Note

The Manual Operation function will override the Safe Stand Still function. Therefore, Safe Stand Still may not guarantee that the robot is standing still in manual mode.



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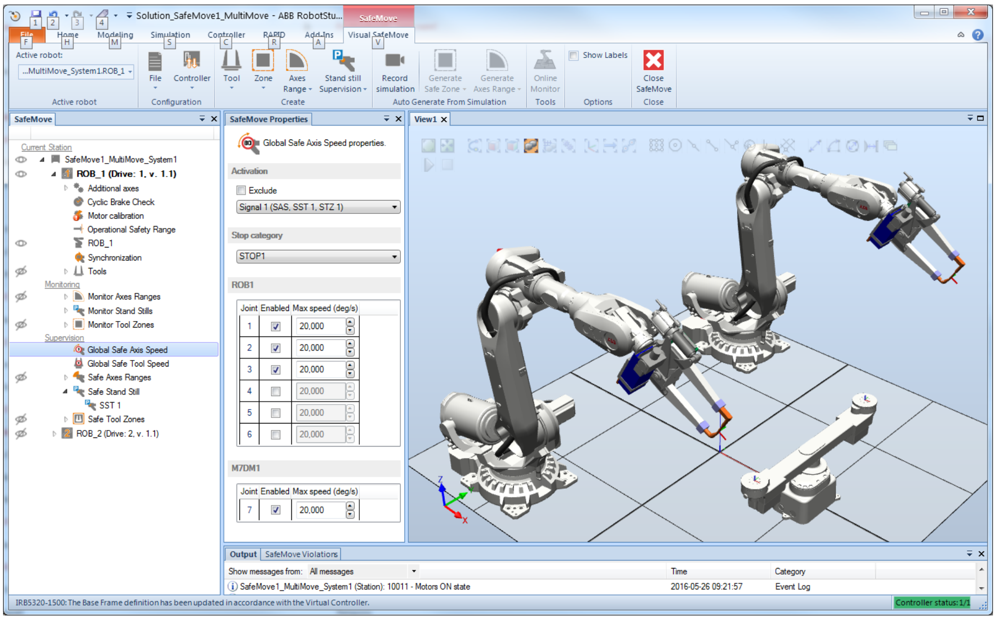
4.3.7.2 Safe Axis Speed configuration

Safe Axis Speed configuration

	Action	Note/illustration
1	In the SafeMove browser, click on **Global Safe Axes Speed**.	
2	In the SafeMove properties browser, clear the check box**Exclude**.	
3	Under **Activation**, select the signal to activate the function.	Input signal definitions: 0 = activate function 1 = deactivate function
4	In **Stop category**, select if violation of the function should stop the robot with category 0 stop or category 1 stop.	
5	For each axis that should be included in the speed supervision, select the check box **Enabled**.	
6	For each axis, specify the maximum speed, **Max Speed**.	The values are given for arm side in deg/s for rotating axes and mm/s for linear axes.



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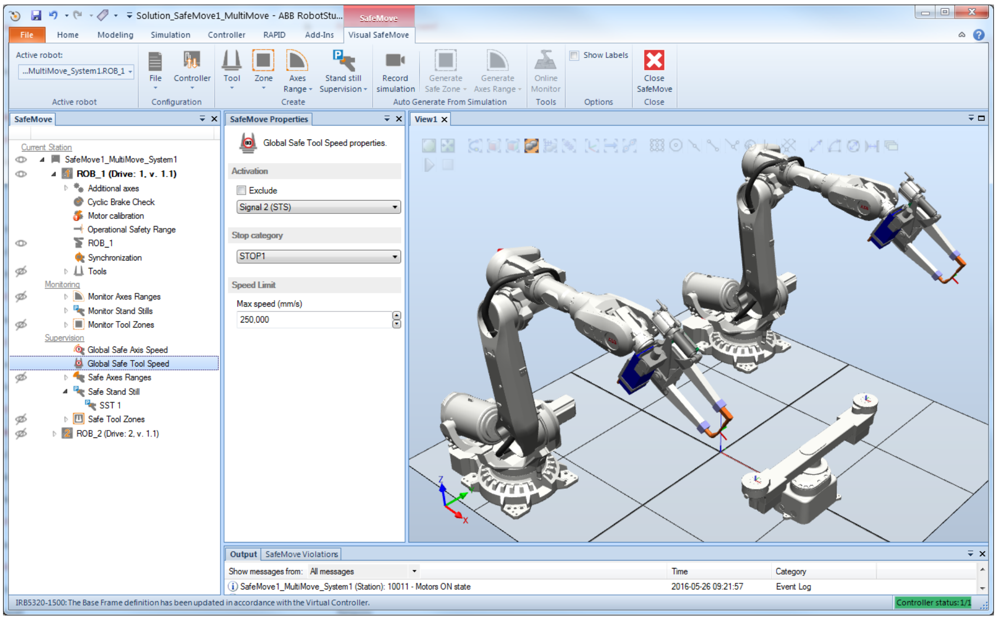
4.3.7.3 Safe Tool Speed configuration

Safe Tool Speed configuration

	Action	Note/illustration
1	In the SafeMove browser, click on **Global Safe Tool Speed.**	
2	In the SafeMove properties browser, clear the check box **Exclude.**	
3	Under **Activation**, select the signal to activate the function.	Input signal definitions: 0 = activate function 1 = deactivate function
4	In **Stop category**, select if violation of the function should stop the robot with category 0 stop or category 1 stop.	
5	Specify the maximum tool speed, **Max Speed**, in mm/s.	Note that the tool must be correctly declared in order for the TCP speed to be calculated correctly.



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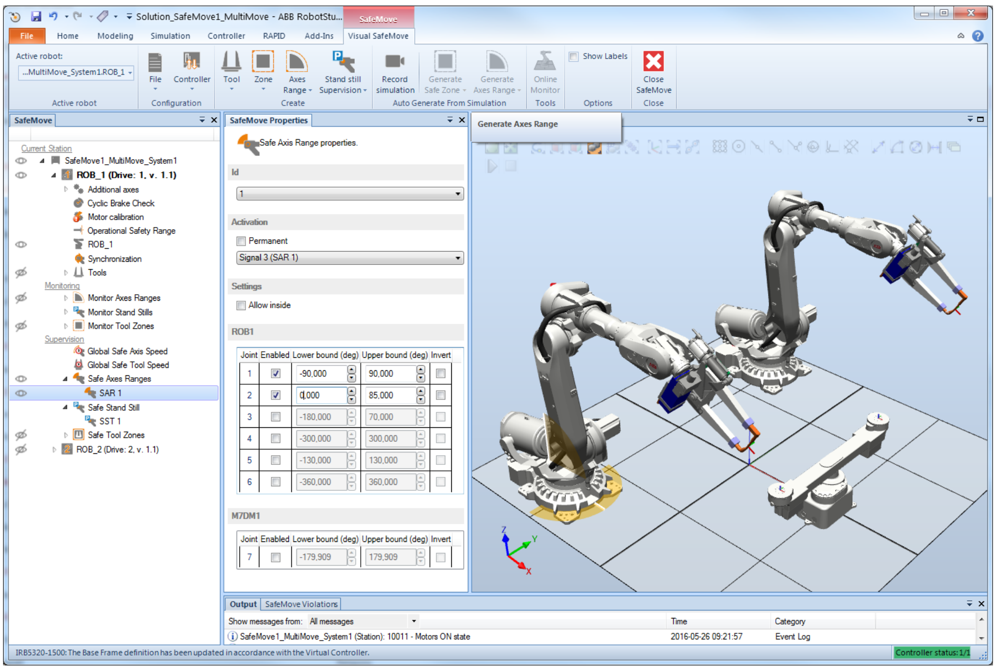
4.3.7.4 Safe Axis Range configuration

Safe Axis Range configuration

	Action	Note/illustration
1	In the **Visual SafeMove** ribbon, click on the **Axes Range** menu and select **Supervised**.	A range of default size is shown for each axis in the graphics window.
2	In the SafeMove properties browser, select **Id** for this Safe Axis Range function (1-8).	
3	Under **Activation**, either select the check box **Permanent** or select the signal to activate the function.	Input signal definitions: 0 = activate function 1 = deactivate function
4	For each axis that should be included in the function, select the check box **Enabled**.	
5	Specify **Lower bound** and **Upper bound** for each axis.	
6	To supervise the inverted range for an axis (below **Lower bound** and above **Upper bound**) select the check box **Inverted** for that axis.	
7	If a robot position should only be considered forbidden if all configured axes are inside their defined ranges, clear the check box **Allow inside**.	For an explanation of all the complex cases when Allow inside is not selected, see *Explanation of Allow inside on page 96*.



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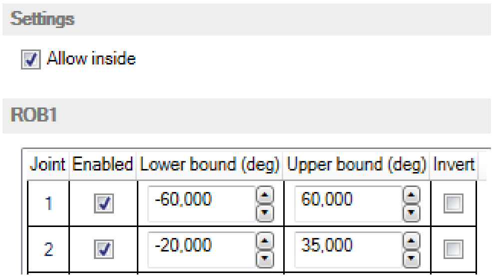
Explanation of Allow inside

By unchecking **Allow Inside**, the logical output of the function is inverted. This means that a robot position is only considered forbidden if all configured axes are inside their defined ranges.

Allow inside checked and not inverted axis ranges

If **Allow inside** is checked and the axis ranges are not inverted, the robot's allowed section (where the robot can move) is when all axes are inside their defined ranges.



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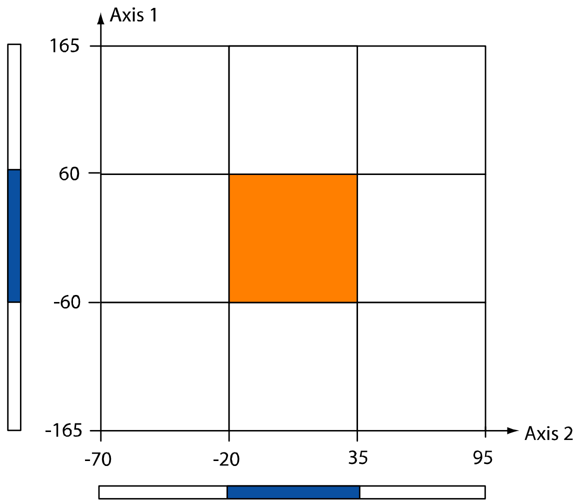
The robot's allowed section corresponds to the orange area in the graph below.



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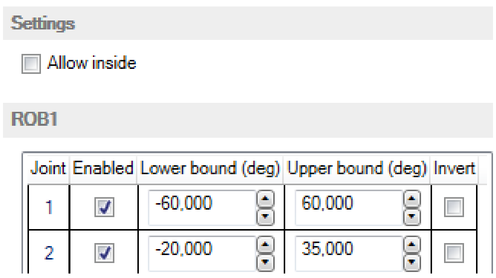
Allow inside unchecked and not inverted axis ranges

If **Allow inside** is unchecked and the axis ranges are not inverted, the robot's allowed section is everywhere except where all axes are inside their defined ranges.



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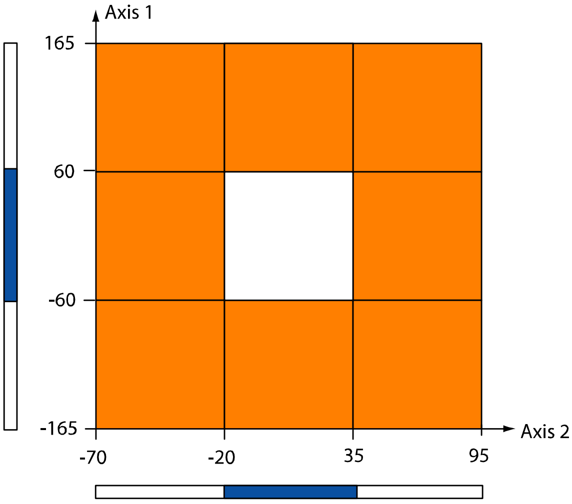
The robot's allowed section corresponds to the orange area in the graph below.



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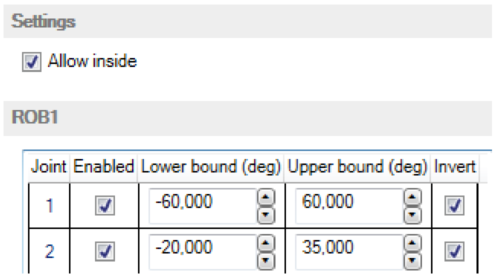
Allow inside checked and inverted axis ranges

If **Allow inside** is checked and the axis ranges are inverted, the robot's allowed section is when all axes are inside their defined ranges (below lower bound or above upper bound).



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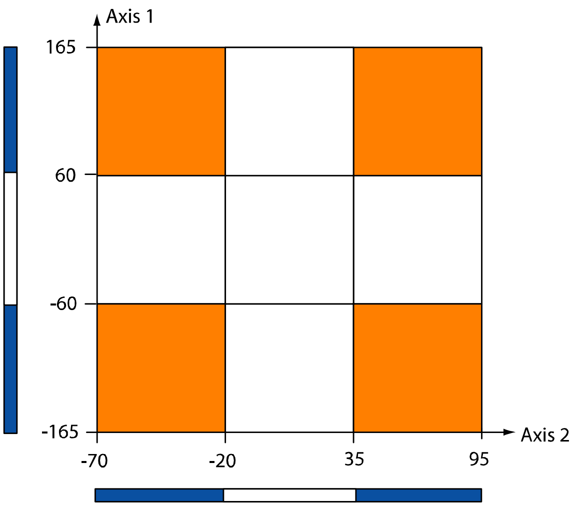
The robot's allowed section corresponds to the orange area in the graph below.



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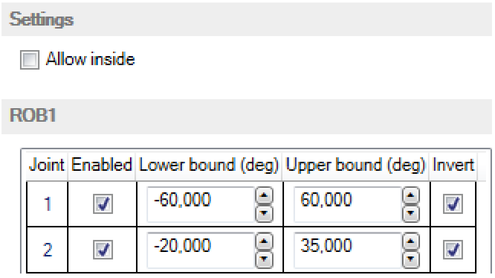
Allow inside unchecked and inverted axis ranges

If **Allow inside** is unchecked and the axis ranges are inverted, the robot's allowed section is when one of the axes is outside the defined range (i.e. one axis is between the lower bound and the upper bound).



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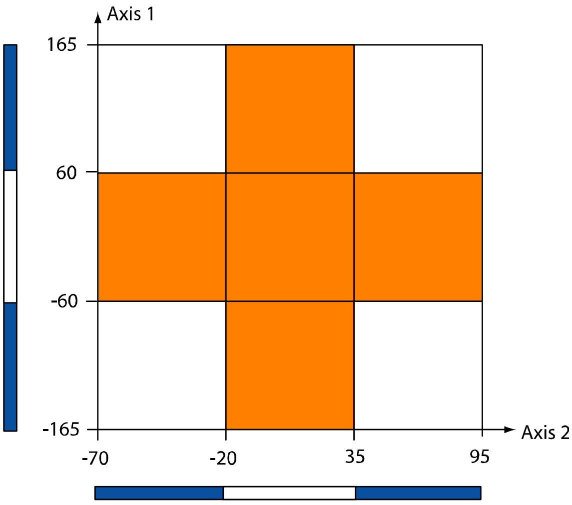
The robot's allowed section corresponds to the orange area in the graph below.



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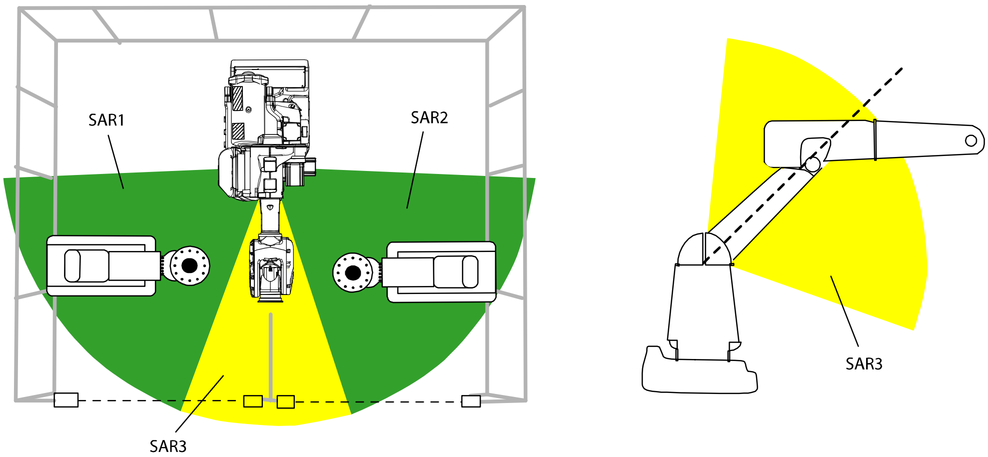
Example of how to use allow inside

A robot may have two working areas defined by axis ranges for axis 1 (SAR1 and SAR2). To be able to move between these two working areas, axis 1 may be in the range in between, under the condition that axis 2 is pointing up or backwards. By defining SAR3 as axis one being between SAR1 and SAR2 and axis 2 pointing forward, and inverting the function, the SAR3 function will stop the robot if both axis 1 and axis 2 are pointing strait forward.



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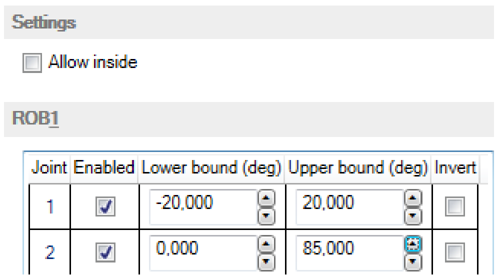

Joint	Enabled	Lower bound (deg)	Upper bound (deg)	Invert
1	☑	-20,000	20,000	☐
2	☑	0,000	85,000	☐

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Stop category

To change if the Safe Axis Range functions stop with a category 0 stop or a category 1 stop, click on **Safe Axis Range** in the SafeMove browser and select **Stop category** in the SafeMove properties browser.

4.3.7.5 Safe Tool Zone configuration

Safe Tool Zone configuration

	Action	Note/illustration
1	In the **Visual SafeMove** ribbon, click on **Safe Zone** and select **Supervision** and then **Box**.	A zone of default size is shown in the graphics window.
2	In the SafeMove properties browser, select **Id** for this Safe Tool Zone function (1-8).	
3	Under **Activation**, either select the check box **Permanent** or select the signal to activate the function.	Input signal definitions: 0 = activate function 1 = deactivate function
4	If the elbow point should be supervised, as well as the tool, select the check box **Include Elbow**.	
5	If the robot must be inside the zone, select **Allow Inside**. If the robot must be outside the zone, clear the check box **Allow Inside**.	
6	Set the maximum allowed tool speed in **Max speed**. The robot will stop if this speed is exceeded.	
7	Fill in the height of the box and the X and Y values for each corner. To import corner points from RAPID, see *Importing points on page 101*.	If you want to state the coordinates in another coordinate system, select it in the field **Reference**. If the zone base should have another shape than square, add a corner point by clicking on a **+** button. For example, to add a new point between point 2 and 3, click on the **+** button at point 2. An alternative to writing coordinates in the SafeMove properties browser, is to click and drag on the corners or sides. By pressing the key X while dragging a corner, the dragging is done along the X-axis while the Y value remains unchanged. By pressing the key Y while dragging a corner, the dragging is done along the Y-axis while the X value remains unchanged.

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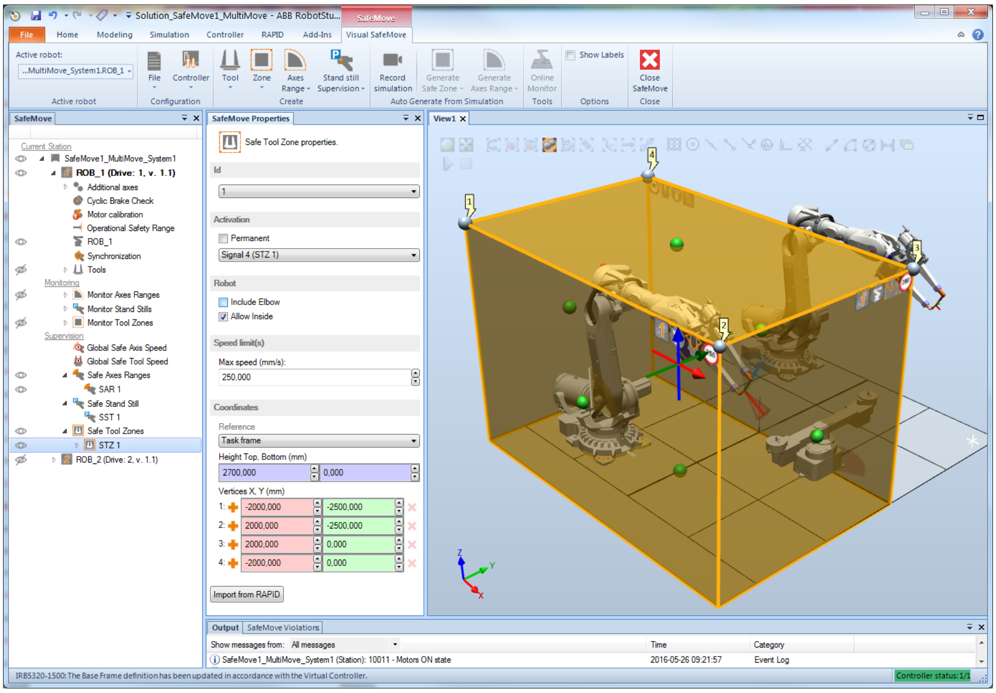

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Importing points

Safe Tool Zone points can be imported from the system module, *PSC_Define_Safety_Zones*, by clicking the **Import from RAPID** button. This system module also contains data for supervising tool points on the TCP, and Monitor Tool Zone configuration, see *Tool configuration on page 85* and *Monitor Tool Zone configuration on page 108*.

A prerequisite is that the system module has been installed to the IRC5 controller, and that the data has been edited to match the current configuration.

Use this procedure to edit and install the system module.

	Action
1	The system module is found in a template file in the RobotStudio distribution: *Utilities\SafeMove\PSC_Define_Safety_Zones_Template.sys*. **Note** There is also a *readme* file with examples and explanations on how to use the template file: *Utilities\SafeMove\README_PSC_Define_Safety_Zones.TXT*.
2	Edit the system module and add the points for the desired safety zone configuration. The following configurations are available: • Supervising tool points on the TCP, see *Tool configuration on page 85*. • Safe Tool Zone configuration • Monitor Tool Zone configuration, see *Monitor Tool Zone configuration on page 108*.

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	Action
3	Copy the template file to the *HOME* directory of the IRC5 controller. **Note** The template file can be renamed, but not the system module.
4	Load the system module *PSC_Define_Safety_Zones* to the IRC5 controller.
5	Now it is possible to import the points by using the corresponding import functions in Visual SafeMove.

Limitations

Note

- Safety zone configurations can only be imported.
- The system module *PSC_Define_Safety_Zones* is not updated when editing the safety zone configuration in Visual SafeMove.

Stop Mode

To change if the Safe Tool Zone functions stop with a category 0 stop or a category 1 stop, click on **Safe Tool Zone** in the SafeMove browser and select **Stop mode** in the SafeMove properties browser.

Additional axes ranges

Additional axes cannot use a zone in space, but specified axis ranges can be combined with the Safe Tool Zone functionality.

	Action
1	In the SafeMove browser, click on the arrow to expand the **STZ** function and select **Additional axes range**.
2	In the SafeMove properties browser, select the check box **Enabled** and specify **Lower bound** and **Upper bound** for the additional axis.

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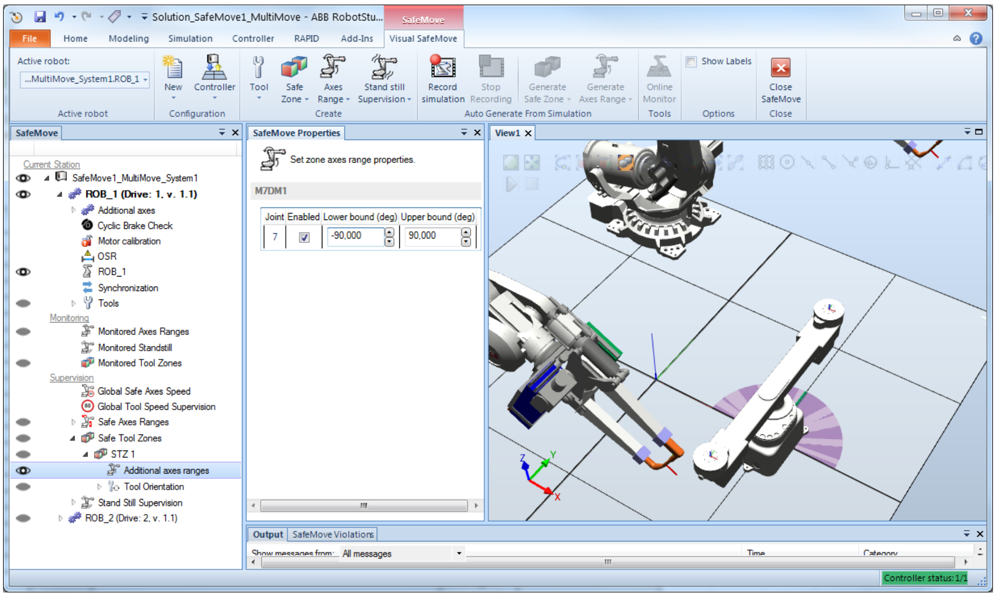

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Tool Orientation Configuration

If tool orientation should be included in the Safe Tool Zone function, follow these steps to activate the functionality.

	Action
1	In the SafeMove browser, click on the arrow to expand the **STZ** function and select **Tool Orientation**.
2	In the SafeMove properties browser, select the check box **Enabled**.
3	Jog the robot so that the tool gets the orientation it should have. Click on **Get Current Tool Vectors**. Now the values for the reference vectors are updated, and these vectors coincide with the tool coordinate vectors for the current robot position and the current active tool on the IRC5 controller. The vectors can also be entered manually.
4	Specify the allowed tool orientation cone around each vector by setting **Tolerance** for the X and Y vectors.

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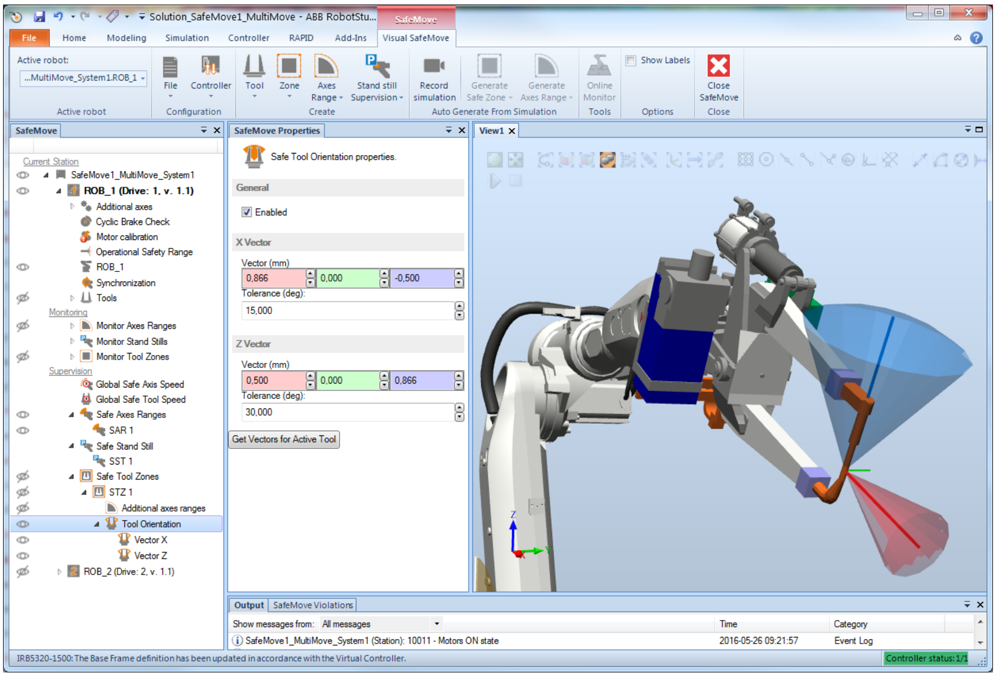

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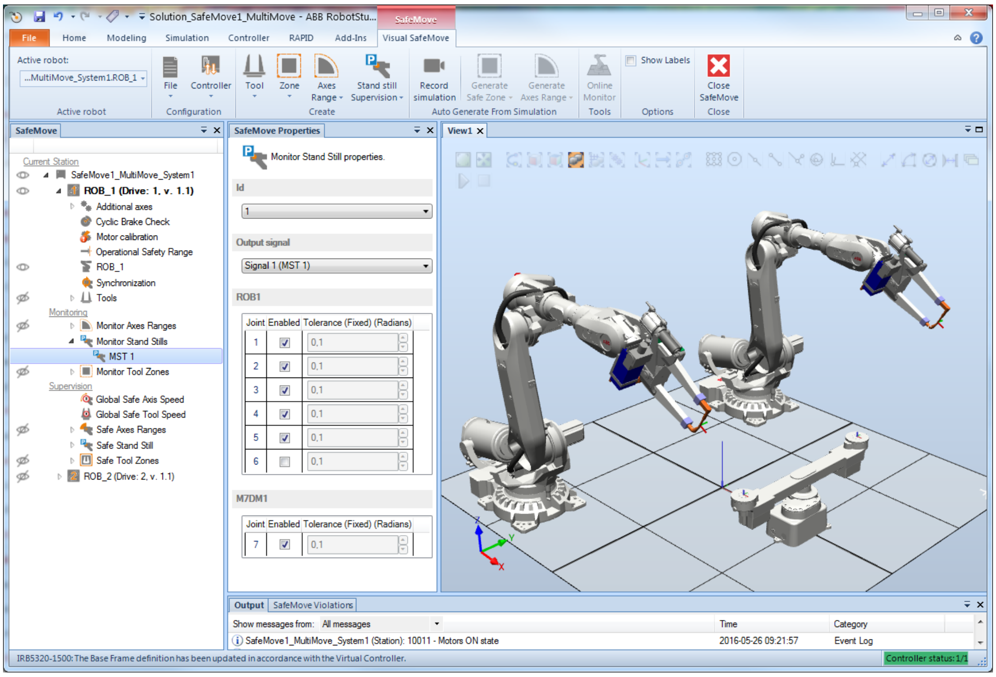
4.3.8 Monitoring functions configuration

4.3.8.1 Monitor Stand Still configuration

Monitor Stand Still configuration

Up to four Monitor Stand Still functions can be configured.

	Action	Note/illustration
1	In the SafeMove ribbon, click on the **Stand still Supervision** menu and select **Monitor Stand Still**.	
2	In the SafeMove properties browser, select **Id** for this Monitor Stand Still function (1-4).	
3	In **Output signal**, select the signal to be set at function violation.	Signal definitions: 0 = violation 1 = no violation
4	Select the check box **Enabled** for each axis that should be included in the Monitor Stand Still function.	



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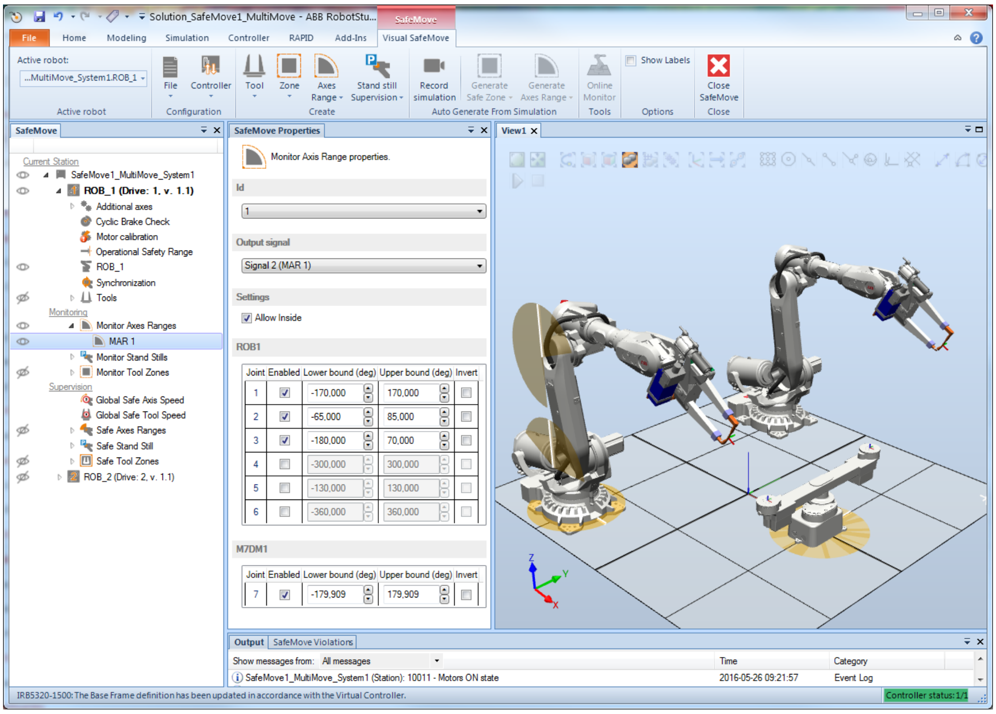
4.3.8.2 Monitor Axis Range configuration

Monitor Axis Range configuration

	Action	Note/illustration
1	In the **Visual SafeMove** ribbon, click on the **Axes Range** menu and select **Monitored**.	A range of default size is shown for each axis in the graphics window.
2	In the SafeMove properties browser, select **Id** for this Monitor Axis Range function (1-8).	
3	In **Output signal**, select the signal to be set at function violation.	Signal definitions: 0 = violation 1 = no violation
4	For each axis that should be included in the function, select the check box **Enabled**.	
5	Specify **Lower bound** and **Upper bound** for each axis.	
6	To monitor the inverted range for an axis (below **Lower bound** and above **Upper bound**) select the check box **Inverted** for that axis.	
7	If a robot position should only be considered forbidden if all configured axes are inside their defined ranges, clear the check box **Allow inside**.	For an explanation of all the complex cases when Allow inside is not selected, see *Explanation of Allow inside on page 96*.



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Stop category

To change if the Monitor Axis Range functions stop with a category 0 stop or a category 1 stop, click on **Monitor Axis Range** in the SafeMove browser and select **Stop category** in the SafeMove properties browser.

4.3.8.3 Monitor Tool Zone configuration

Monitor Tool Zone configuration

	Action	Note/illustration
1	In the **Visual SafeMove** ribbon, click on **Safe Zone** and select **Monitored** and then **Box**.	A zone of default size is shown in the graphics window.
2	In the SafeMove properties browser, select **Id** for this Monitor Tool Zone function (1-8).	
3	In **Output signal**, select the signal to be set at function violation.	Signal definitions: 0 = violation 1 = no violation
4	If the elbow point should be monitored, as well as the tool, select the check box **Include Elbow**.	
5	If the robot must be inside the zone, select **Allow Inside**. If the robot must be outside the zone, clear the check box **Allow Inside**.	
6	Set the maximum allowed tool speed in **Max speed**. If the speed is above this limit, a function violation is triggered.	
7	Set the minimum allowed tool speed in **Min speed**. If the speed is below this limit, a function violation is triggered.	
8	Fill in the height of the box and the X and Y values for each corner. To import corner points from RAPID, see *Importing points on page 101*.	If you want to state the coordinates in another coordinate system, select it in the field **Reference**. If the zone base should have another shape than square, add a corner point by clicking on a **+** button. For example, to add a new point between point 2 and 3, click on the **+** button at point 2. An alternative to writing coordinates in the **SafeMove** properties browser, is to click and drag on the corners or sides. By pressing the key X while dragging a corner, the dragging is done along the X-axis while the Y value remains unchanged. By pressing the key Y while dragging a corner, the dragging is done along the Y-axis while the X value remains unchanged.

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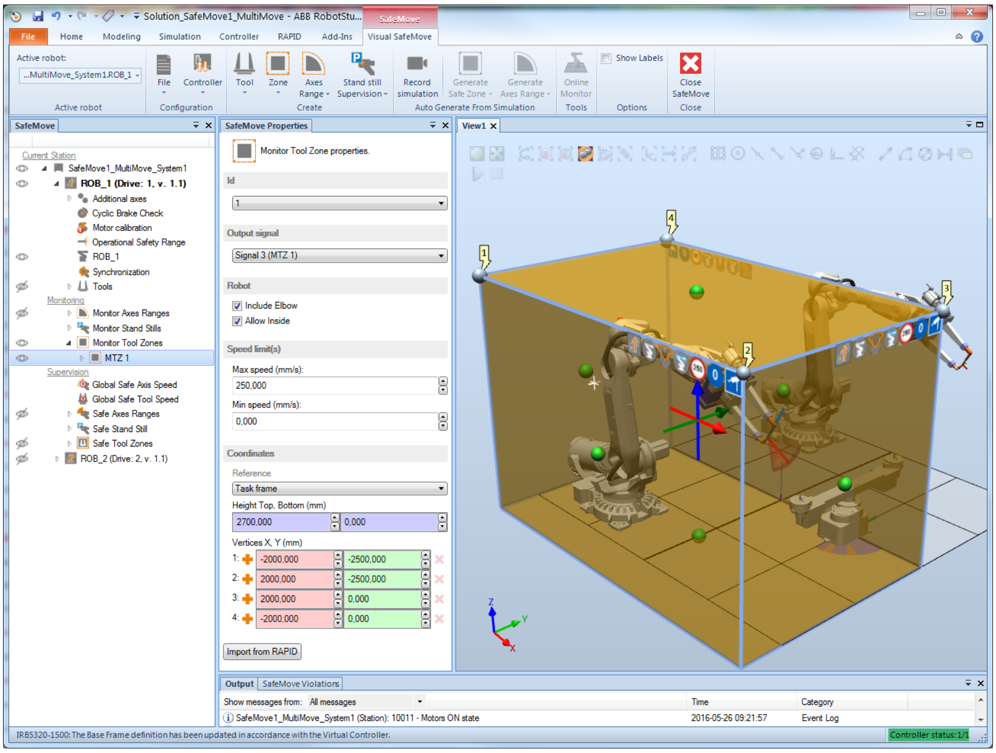

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Stop Mode

To change if the Monitor Tool Zone functions stop with a category 0 stop or a category 1 stop, click on **Monitor Tool Zone** in the SafeMove browser and select **Stop mode** in the SafeMove properties browser.

Additional axes ranges

Additional axes cannot use a zone in space, but specified axis ranges can be combined with the Monitor Tool Zone functionality.

	Action
1	In the SafeMove browser, click on the arrow to expand the **MTZ** function and select **Additional axes range.**
2	In the SafeMove properties browser, select the check box **Enabled** and specify **Lower bound** and **Upper bound** for the additional axis.

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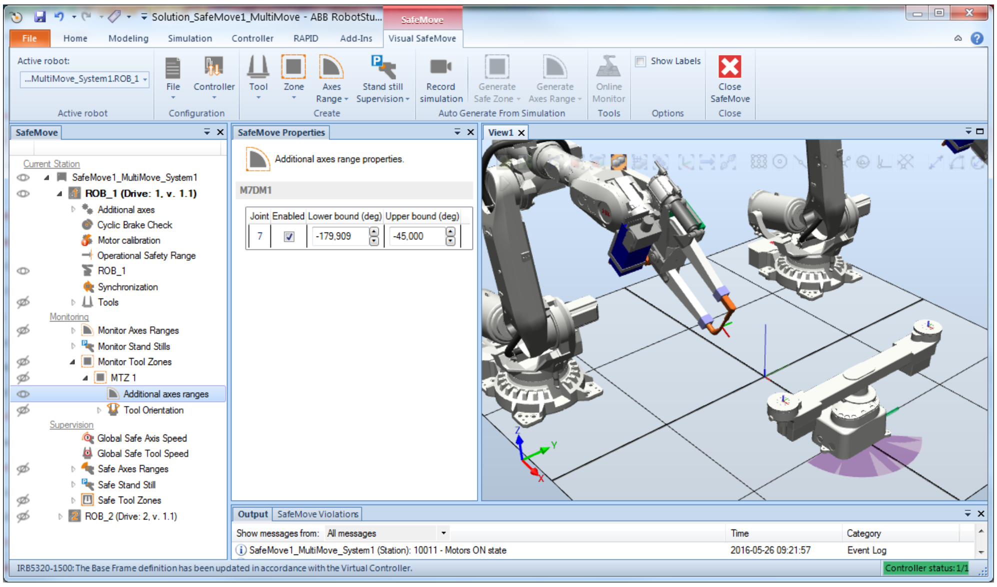

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Tool Orientation Configuration

If tool orientation should be included in the Monitor Tool Zone function, follow these steps to activate the functionality.

	Action
1	In the SafeMove browser, click on the arrow to expand the **MTZ** function and select **Tool Orientation**.
2	In the SafeMove properties browser, select the check box **Enabled**.
3	Jog the robot so that the tool gets the orientation it should have. Click on **Get Current Tool Vectors**. Now the values for the reference vectors are updated, and these vectors coincide with the tool coordinate vectors for the current robot position and the current active tool on the IRC5 controller. The vectors can also be entered manually.
4	Specify the allowed tool orientation cone around each vector by setting **Tolerance** for the X and Y vectors.

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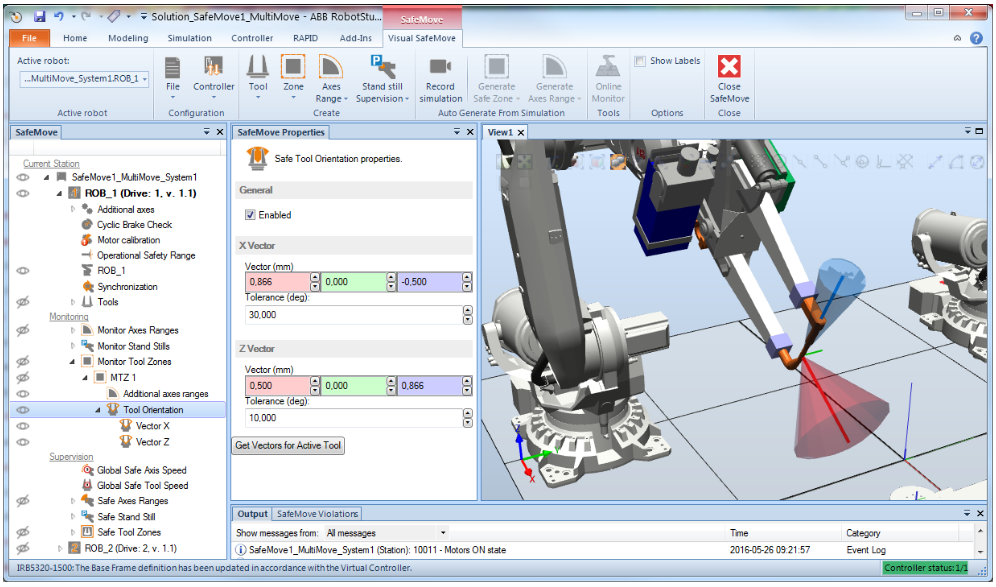
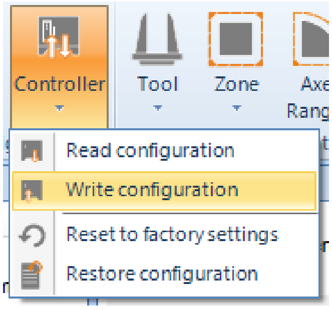


xx1600000608

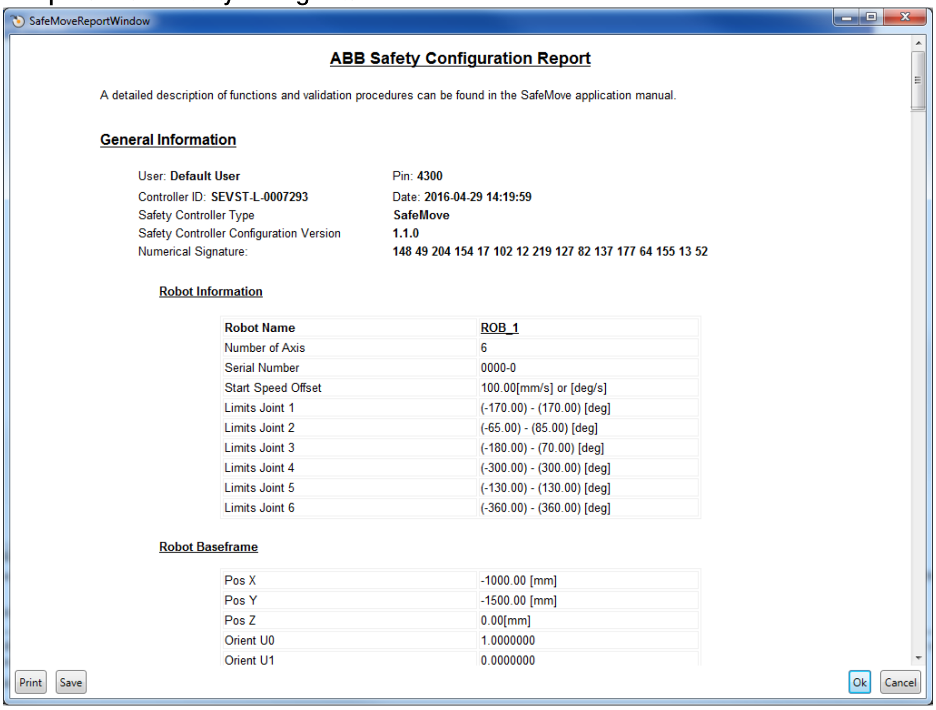
4.3.9 Save and download to safety controller

Download configuration to the safety controller

<table>
<tr><th></th><th>Action</th></tr>
<tr><td>1</td><td>In the SafeMove ribbon, click on Controller and then select Write configuration.



xx1600000609</td></tr>
<tr><td>2</td><td>A report of the safety configuration is shown.



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The report can be printed by clicking on Print (it is recommended to print the report since it should be used when validating the configuration as described in Validate the configuration on page 122).

The PIN code is available in the Safety Configuration Report. Write this PIN code down. You will need it when activating the safety configuration on your system, see Activating the safety configuration on page 120.

Click OK to close the report.</td></tr>
<tr><td>3</td><td>A dialog asks if you want to restart the controller.

Click Yes to restart now or No to restart the controller later. The SafeMove configuration cannot be activated until the controller has been restarted.</td></tr>
</table>

Continues on next page

Save the configuration

	Action
1	In the SafeMove ribbon, click on **File** and then select **Save**. It is possible to store the current configuration on your local file system.
2	Select a file name and location for the file. Click on **Save**.

Load a saved configuration

Note

If you try to load a configuration with the format version 1.1.0, and the legacy format 1.0.0 is the only format that can be supported, an error message appears. It is impossible to load or create a configuration format that is not supported by the SafeMove board.

	Action
1	In the **Visual SafeMove** ribbon, click on **File** and then select **Open**. It is possible to load a saved configuration from your local file system
2	Browse and select a file. Click on **Open**.

Get configuration from safety controller

It is possible to upload the configuration from the safety controller to Visual SafeMove. This makes it easy to view the configuration or to make changes to it and download it again.

In the **Visual SafeMove** ribbon, click on **Controller** and then select **Read configuration.**

Start a new safety configuration

To reset the SafeMove configuration to its default values and start a new configuration:

In the **Visual SafeMove** ribbon, click on **File**, select **New** and then **Version 1.1.**

Note

Version 1.1 is the standard format and the recommended selection. In some rare cases, for example when you receive a new SafeMove unit as a replacement of an old unit that is supporting the version 1.0 format, select version 1.0.

4.3.10 Restore configuration

Restore configuration from backup

When performing a system backup, a SafeMove safety configuration file is included. This file gives the possibility to restore the SafeMove safety configuration without changing it. The advantage is that the configuration and the pin code is identical, so the SafeMove safety configuration does not have to be validated and no new safety report has to be generated.

The file has to be restored separately from the system backup by using the **Restore configuration** function in Visual SafeMove.

	Action
1	Open Visual SafeMove.
2	In the **Visual SafeMove** ribbon, click on **Controller** and select **Restore configuration**.
3	Browse to the *BACKINFO* folder in the backup. The SafeMove safety configuration file is named *psc_user_1.sxml*. For a MultiMove system there will be one file for each controller, numbered from 1 to 4.
4	Select the correct *psc_user_ .sxml* file, and click **Open**.
5	The **Numeric Signature** dialog is shown. Verify that the numeric signature is the same as in the safety report. Click **Yes** to download the configuration.
6	The **Restart Controller** dialog is shown when the safety configuration has been downloaded. Click **Yes** to restart the controller.
7	The safety configuration must now be activated on the controller. Follow the instructions in section *Activating the safety configuration on page 120*.

WARNING

Modification of a backed-up safety configuration file, *psc_user_ .sxlm*, should only be done by loading the file in the configuration tool in RobotStudio, which will give a new check-sum and PIN code.

Modifying the file using another tool than RobotStudio, such as a text editor or equivalent, is considered to be misuse. In this case it might still be possible to restore the configuration file to the controller. However it will not be possible to activate it, and the original configuration will remain active without the user being notified!

4.4 Additional Visual SafeMove functionality

4.4.1 Additional Visual SafeMove settings

Reset to factory settings

WARNING

When using the function **Reset to factory settings**, the currently active configuration on the selected safety controller will be disabled. All safety supervision and monitoring will be disabled. The safety controller will not react to any inputs or take any actions.

To prevent accidental disabling of the wrong safety controller in a MultiMove system, it is recommended to verify the safety configuration of any still enabled safety controllers.

To reset to factory settings, in the SafeMove ribbon, click on **Controller** and select **Reset to factory settings**.

Configuring zones

Both supervised and monitored zones can be created. After creation, the zone properties and settings can both be modified from the SafeMove properties browser and the graphics window. For more information, see *The Visual SafeMove user interface on page 78*.

Function	Description
Box	Create a new SafeMove zone.
Encapsulate	Create a new SafeMove zone that encapsulates the selected geometries. The zone might be larger than the selected geometries but never smaller.
Import from RAPID	Tool Zone points can be imported from a predefined RAPID system module, for more information see *Importing points on page 101*.

Visual SafeMove has some additional functionality for configuring zones. Right-click the zone in the SafeMove browser to access the following settings:

Function	Description
Cut, Copy, Paste	Use the **SafeMove** browser, or standard keyboard shortcuts, to cut, copy, and paste zones both between zone types and between robots.
Translate	Translate a zone in any direction with the given amount.
Reduce number of vertices	Tries to reduce the number of vertices in a SafeMove zone to the specified amount. The new zone might be larger than the selected geometries but never smaller.
Expand / Contract	Expand or contract a zone in all directions with the given amount.

4.4.2 Simulating SafeMove using Visual SafeMove

Introduction

Automatic generation of safety parameters from simulation is a quick and easy way of creating zones and axes ranges. The function creates a zone or axes range that encapsulate the recorded simulated path.

A prerequisite is that there has to be at least one SafeMove tool in the configuration, and a simulation has to be defined.

Limitations

The simulation functions are only available when running a RobotStudio station.

Record a simulation

A simulation is setup, started, and stopped using the same commands as in RobotStudio. For more information, see *Operating manual - RobotStudio*.

The simulation has to be recorded to be able to automatically generate safety parameters from the simulation. Before the simulation is started, the **Record simulation** button must be pressed. It is possible to end the recording before the simulation stops by pressing the **Stop recording** button.

When there is a recorded simulation available, the **Generate Zone** and **Generate Axis Range** buttons become active.

Generate zones

The function creates a zone that encapsulates the path of the tool, or the tool and elbow, from the recorded simulation.

Function	Description
Tool only	Create a new SafeMove zone that encapsulates the path of the tool from the recorded simulation.
Tool and elbow	Create a new SafeMove zone that encapsulates the path of the tool and elbow from the recorded simulation.

Generate axis ranges

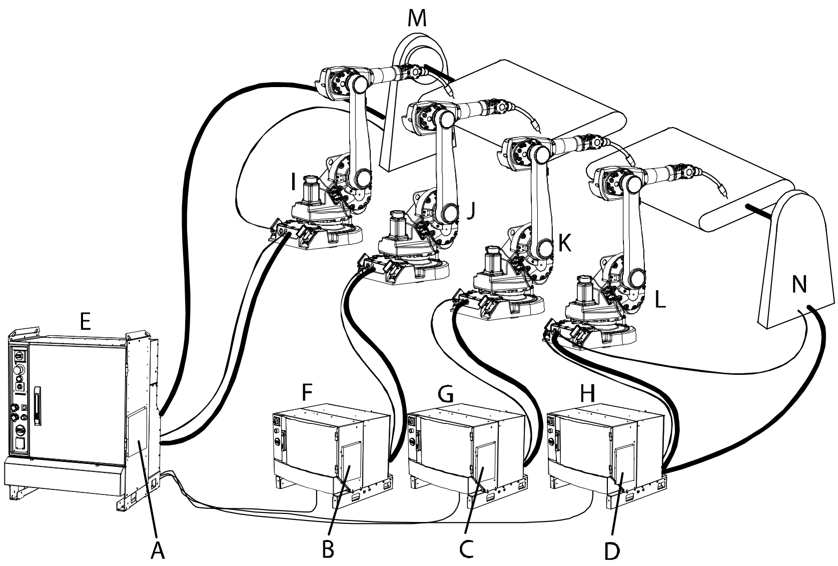
The function creates an axes range with the max and min values of each joint set to the max and min value from the recorded simulation.

4.5 Configuration for MultiMove

Configuration file corresponding to drive module

In a MultiMove system there is one safety controller for each drive module that uses SafeMove. A configuration file must be downloaded to each safety controller.

MultiMove system with 4 safety controllers



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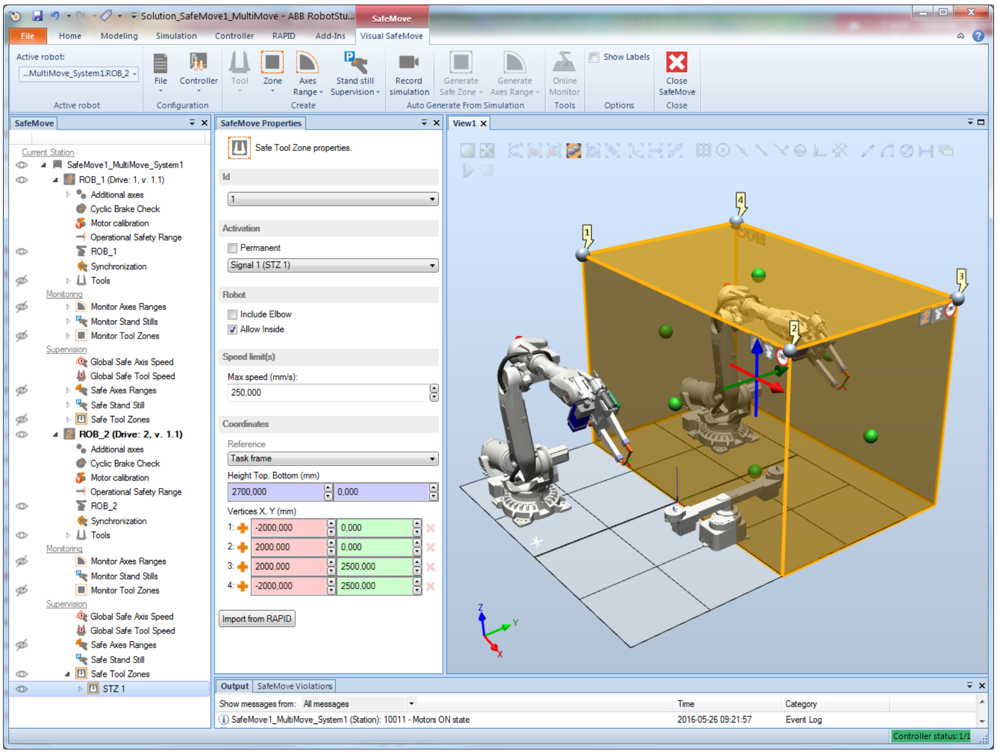
A	Safety controller 1 placed in the controller cabinet. Used to monitor robot 1 and additional axis 1.
B	Safety controller 2 placed in drive module 2. Used to monitor robot 2.
C	Safety controller 3 placed in drive module 3. Used to monitor robot 3.
D	Safety controller 4 placed in drive module 4. Used to monitor robot 4 and additional axis 2.
E	Controller cabinet
F	Drive module 2
G	Drive module 3
H	Drive module 4
I	Robot 1
J	Robot 2
K	Robot 3
L	Robot 4
M	Additional axis 1
N	Additional axis 2

Continues on next page

How to configure SafeMove for MultiMove

When configuring a MultiMove system, configure each safety controller as described in *Configuring SafeMove on page 77* (in the example above: robot 1 and additional axis 1). The robots are shown under each other in the SafeMove browser.

When using a function in the SafeMove ribbon (e.g. creating a zone), the function is always performed for the active robot. The active robot is shown in the **Active robot** drop-down menu in the ribbon. To change active robot, either select robot in **Active robot**, or select any node under the robot in the SafeMove browser.



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Brake test

As default all axes in a MultiMove system are executed during brake test. If not all drive modules are equipped with safety controllers, it is possible to exclude brake test for axes not supervised in SafeMove. This is done by setting the motion configuration parameter *Deactivate Cyclic Brake Check for axis* to On. See *Configure system parameters on page 73*.

Download configuration for all robots to safety controller

	Action
1	Select the first robot in the **Active robot** drop-down menu in the SafeMove ribbon.
2	In the SafeMove ribbon, click on **Controller** and then select **Write config**.
3	Print the safety configuration report and click **OK** to close it.
4	Answer **No** when asked if you want to restart the controller.
5	Select the next robot in **Active robot** and repeat the procedure for each robot.

Continues on next page

	Action
6	When the configurations for all robots are written to the safety controllers, restart the controller.

Save configuration for all robots

	Action
1	Select the first robot in the **Active robot** drop-down menu in the SafeMove ribbon.
2	In the SafeMove ribbon, click on **File** and then select **Save**.
3	Select a file name and location for the file. Click on **Save**.
4	Select the next robot in **Active robot** and repeat the procedure to save one configuration file for each robot.

4.6 Activation of safety configuration

4.6.1 Activating the safety configuration

Prerequisite

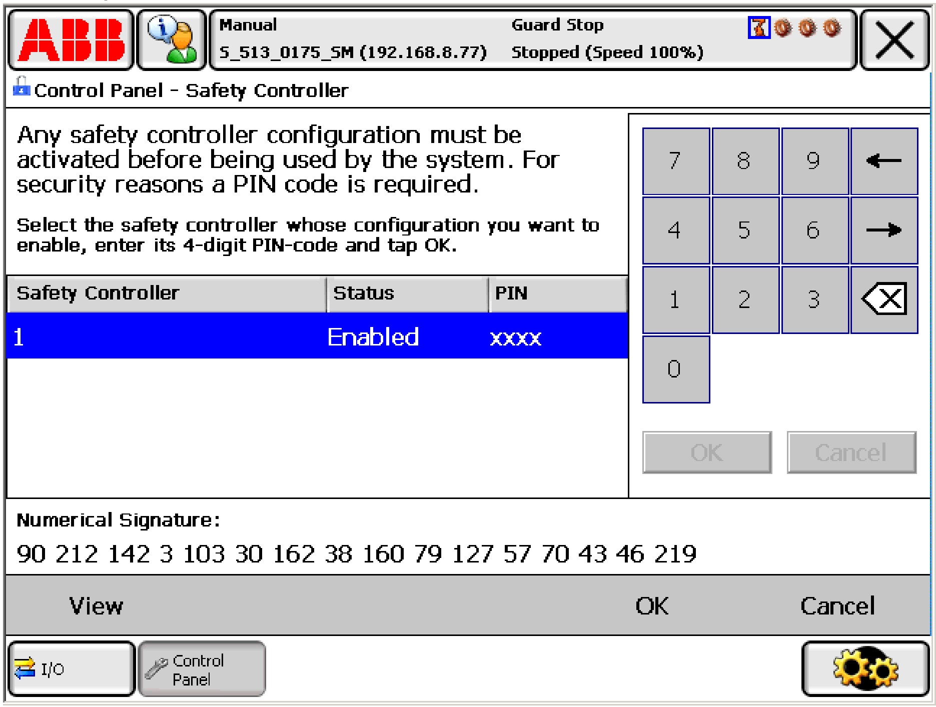
Before activating the safety configuration you must create the safety configuration file and remember the PIN code for that file (see *Configuring SafeMove on page 77*).

Activation procedure

<table>
<tr><th></th><th>Action</th></tr>
<tr><td>1</td><td>When a safety configuration is downloaded to your robot system, the controller must be restarted.</td></tr>
<tr><td>2</td><td>When the controller starts up, an elog message (20266) will ask for a safety controller PIN code. Acknowledge this message.</td></tr>
<tr><td>3</td><td>Change user on the FlexPendant:

On the ABB menu, select Log off.
Tap Yes to confirm.
Select the safety user, type the password and tap on Login.
</td></tr>
<tr><td>4</td><td>Make sure the controller is in manual mode.</td></tr>
<tr><td>5</td><td>On the FlexPendant:

On the ABB menu, tap Control Panel and then Safety Controller.
Tap the line and type the PIN code for the safety configuration file (see Download configuration to the safety controller on page 112). Tap OK.
For a MultiMove system, enter one PIN code for each configuration file.
Tap OK.



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</table>

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	Action
6	When the PIN code is entered, a dialog will tell you if the PIN is correct. Tap **Restart** in this dialog and the controller will restart. If you typed an incorrect PIN code, the controller will restart anyway. Then you must start over from step 2 of this procedure.
7	The robot is now unsynchronized and cannot be moved. Press the motors on button to be allowed to move the robot in reduced speed for a configured time between 60 and 3600 seconds.
8	When the controller starts up, an elog message (20451) will say that a synchronization is required. Acknowledge this message. Perform a sync check. Note that the output signals are low and supervision functions are deactivated until the sync check is performed. When the sync check is performed, an elog message (20452) will say that the robot is synchronized. The SafeMove functionality is now active (supervision functions only active if activation input signals are set).

4.7 Validate the configuration

DANGER

A SafeMove configuration must always be validated to verify that the desired safety is achieved. If no validation is performed, or the validation is inadequate, the configuration cannot be relied on for personal safety.

Tip

Do the following checks before you start the validation procedure:

1. Check the I/O signals according to section *I/O connector data on page 51*.
2. Create a safety user in the user authorization system and log in as a safety user.
3. Carry out the synchronization procedure and connect the sync switch according to description in section *I/O connector data on page 51*.
4. Set up the synchronization position in the SafeMove Configurator. Also carry out a calibration offset.
5. Run the service routine for the function Cyclic Break Check.
6. Start the validation procedure.

About the validation

The safety configuration must be validated. This validation must be performed every time a safety controller is configured. The validation should verify that all axis ranges, tool zones, etc. are configured correctly in relation to the physical robot cell (operator stations, equipment, fences, etc.).

DANGER

When validating the actual safety zones, brake distances must be taken into consideration, so that the SafeMove functions are configured with enough margin. If the robot hits the zone limit, it starts to brake and needs the brake distance to stop. This occurs outside the zone.

Note that if the robot starts accelerating strongly just before reaching a configured speed zone or position zone there will occur a speed overshoot before decelerating. This may result in a somewhat increased speed and extended braking distance compared to a smoother speed situation.

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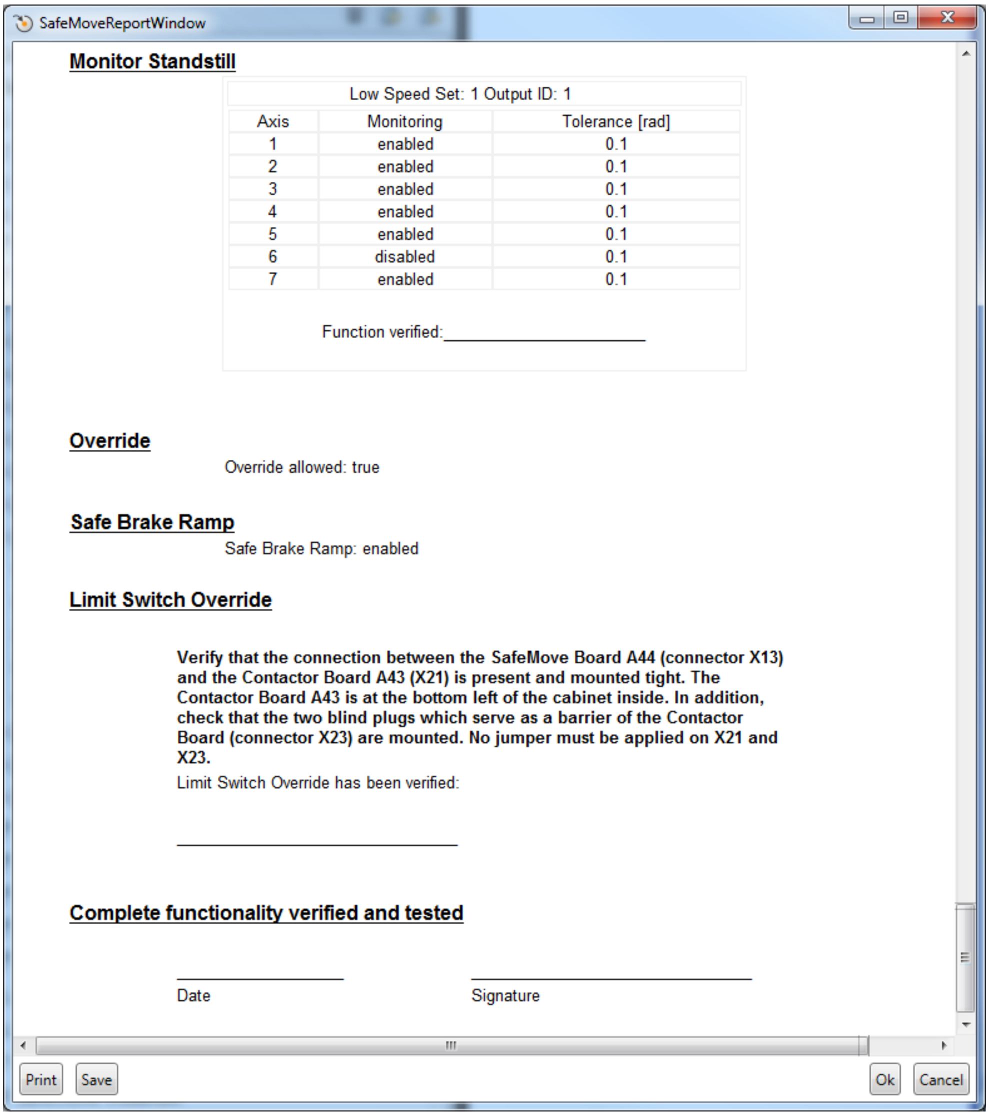
Sign the validation

The ABB Safety Configuration Report must be printed and used as a formal document for the validation. The document has rows where dates and signatures should be written when the configuration is validated.



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Recovery after safety violation

The validation procedures test when the safety functions trigger. When a supervision function triggers, the robot will stop. Before you start this validation procedure make sure the robot system installation is ready, for example, cables must be connected etc.

To be able to move the robot again, the following must be performed:

	Action	Note
1	Activate the Manual mode input signal.	

Continues on next page

	Action	Note
2	Press the motors on button on the robot controller to confirm the violation.	For speed violations, it is enough with this confirmation. Steps 1,3 and 4 are not necessary.
3	Jog the robot back to a position that does not trigger any supervision function.	
4	Deactivate the Manual mode input signal.	

Tool points validation

	Action	Expected result
1	Use a zone function (preferably Monitor Tool Zone) to verify one tool point at a time.	
2	Jog the robot and rotate the tool so that the first tool point gets inside the configured zone.	The signal configured for the Monitor Tool Zone function will go low.
3	Rotate the tool and repeat the test with one tool point at a time.	
4	Repeat the tool points validation for all configured tools.	

Operational Safety Range validation

Operational Safety Range only needs to be configured when using Soft Servo, Force Control or when external forces are applied to the robot. It cannot be verified unless it is used in one of these ways.

	Action	Expected result
1	Make sure that Soft Servo is active and set the stiffness low.	
2	Test the min limit of the axis range. Create RAPID program with a `MoveAbsJ` instruction moving the first configured axis with speed `vmax` from just inside the range for Operational Safety Range to a position outside the range.	
3	Run the program. The Control Error Supervision will stop the robot as soon as the reference value reach the range limit of Operational Safety Range. Verify that this stop occurs where the min limit for this axis is supposed to be.	Elog 20464 shows that the robot has reached the limit of the range for Operational Safety Range.
4	Test the max limit of the axis range. Create RAPID program with a `MoveAbsJ` instruction moving the first configured axis with speed `vmax` from just inside the range for Operational Safety Range to a position outside the range.	
5	Run the program. The Control Error Supervision will stop the robot as soon as the reference value reach the range limit of Operational Safety Range. Verify that this stop occurs where the max limit for this axis is supposed to be.	Elog 20464 shows that the robot has reached the limit of the range for Operational Safety Range.
6	Repeat the procedure for each axis configured for Operational Safety Range.	

Continues on next page

Safe Stand Still validation

	Action	Expected result
1	Prepare a RAPID program with `MoveJ` instructions that move one axis at a time. Let the program wait for user input between each move instruction to let you validate each move instruction. If there are additional axes in the system, include instructions that move these axes, one at a time, as well.	
2	Activate the activation input signal for the Safe Stand Still set you want to validate. Deactivate all other supervision functions that are signal activated.	
3	Run the program and verify that Safe Stand Still triggers for every move instruction.	Safe Stand Still will trigger.

Safe Axis Speed validation

Tip

There is no easy way of ordering an axis to move at a specified angle speed. Use a `MoveAbsJ` instruction, rotating an axis 180 degrees, and clock the movement to get an estimated angle speed for the selected `speeddata`.

	Action	Expected result
1	Activate the activation input signal for Safe Axis Speed. Deactivate all other supervision functions that are signal activated.	
2	Create and run a RAPID program with a `MoveAbsJ` instruction moving the first configured axis with a speed slower than the configured Max Speed for that axis.	No triggered function.
3	Change the program so that the axis is moved with a speed higher than the configured Max Speed.	Safe Axis Speed will trigger.
4	Repeat the procedure for all axes configured for Safe Axis Speed.	

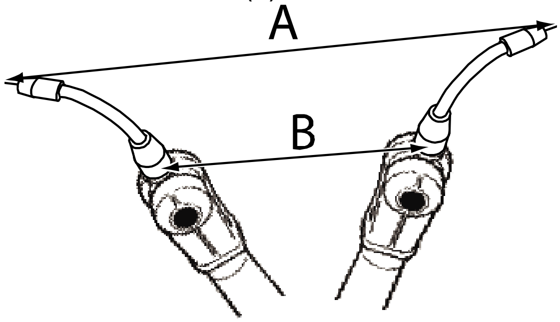
Safe Tool Speed validation

Validate all three points supervised by Safe Tool Speed:

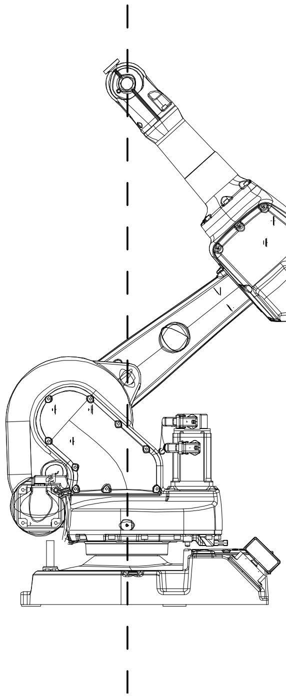
- tool center point (TCP)
- tool0
- robot elbow (somewhere around axis 3)

	Action	Expected result
1	Activate the activation input signal for Safe Tool Speed. Deactivate all other supervision functions that are signal activated.	

Continues on next page

	Action	Expected result
2	Create and run a RAPID program with a `MoveL` instruction. The `Speed` argument should be slightly higher than the configured max speed. The `Tool` argument should be set to the tool that is to be supervised by Safe Tool Speed. To make sure it is the TCP that causes the speed violation, and not tool0, select the `robtargets` so that the TCP moves faster than the max speed, but tool0 does not. This can be accomplished if the distance the TCP moves (A) is greater than the distance tool0 moves (B).  xx0700000697	Safe Tool Speed will trigger.
3	Change the RAPID program so that the `Tool` argument in the MoveL instruction is set to `tool0`. Set the speed so that tool0 moves slightly faster than the configured max speed.	Safe Tool Speed will trigger.

Continues on next page

	Action	Expected result
4	Jog the robot to a position where the elbow is pointing out as much as possible, while the tool is close to the rotation axis of axis 1.  xx0700000696 Create and run a RAPID program with a `MoveAbsJ` instruction moving axis 1 fast enough for the elbow to exceed the configured max speed.	Safe Tool Speed will trigger.

Safe Axis Range validation

	Action	Expected result
1	Activate the activation input signal for the Safe Axis Range set you want to validate. Deactivate all other supervision functions that are signal activated.	
2	Jog the robot, one axis at a time, to the limit of the configured range. Verify that Safe Axis Range triggers when the axis is moved outside the configured range.	Safe Axis Range will trigger.
3	Repeat this for all axes configured for Safe Axis Range, including additional axes.	

Safe Tool Zone validation

	Action	Expected result
1	Activate the activation input signal for the Safe Tool Zone set you want to validate. Deactivate all other supervision functions that are signal activated.	

Continues on next page

	Action	Expected result
2	Jog the robot (linear jogging) to the border of the configured tool zone. Move the robot across all borders of the zone, including the max and min values in z direction. Verify that Safe Tool Zone triggers every time a border is crossed. If system is equipped with a track motion, check that the tool zone border is in correct position for different positions of the track motion.	Safe Tool Zone will trigger.
3	Create and run a RAPID program with a `MoveL` instruction that moves inside the tool zone. The `Speed` argument should be slightly higher than the configured Max Tool Speed in Zone.	Safe Tool Zone will trigger.
4	If a tool orientation supervision is configured, jog the robot (reorient jogging) to the tolerance limits of the tool orientation. Verify that Safe Tool Zone triggers for violation of both the tool's x direction and the tool's z direction.	Safe Tool Zone will trigger.
5	Jog the configured additional axes, one axis at a time, to the limit of the configured range. Verify that Safe Tool Zone triggers when the axis is moved outside the configured range.	Safe Tool Zone will trigger.

Monitor Stand Still validation

	Action	Expected result
1	Move the axis with medium high speed.	Monitor Stand Still output signals will go low.
2	Stop movement of all axes.	After a short time the Monitor Stand Still output signals will go high.
3	Move the axis with medium high speed.	Monitor Stand Still output signals will go low.
4	Repeat the procedure for all axes configured for Monitor Axis Speed.	

Monitor Axis Range validation

Jog the robot, one axis at a time, to the limit of the configured range. Verify that the signal configured for the Monitor Axis Range function goes low when the axis is moved outside the configured range.

Repeat this for all axes configured for Monitor Axis Range, including additional axes.

Continues on next page

Monitor Tool Zone validation

	Action	Expected result
1	Jog the robot (linear jogging) to the border of the configured tool zone. Move the robot across all borders of the zone, including the max and min values in z direction. Verify that the signal configured for Monitor Tool Zone goes low every time a border is crossed. If system is equipped with a track motion, check that the tool zone border is in correct position for different positions of the track motion.	The signal configured for the Monitor Tool Zone function will go low.
2	Create and run a RAPID program with a `MoveL` instruction that moves inside the tool zone. First let the `Speed` argument be slightly higher than the configured Max Tool Speed in Zone. Then let the `Speed` argument be slightly lower than the configured Min Tool Speed in Zone.	The signal configured for the Monitor Tool Zone function will go low.
3	If a tool orientation monitoring is configured, jog the robot (reorient jogging) to the tolerance limits of the tool orientation. Verify that the signal configured for Monitor Tool Zone goes low both when the tool's x direction exceeds its tolerance and when the tool's z direction exceeds its tolerance.	The signal configured for the Monitor Tool Zone function will go low.
4	Jog the configured additional axes, one axis at a time, to the limit of the configured range. Verify that the signal configured for Monitor Tool Zone goes low when the axis is moved outside the configured range.	The signal configured for the Monitor Tool Zone function will go low.

Cyclic Brake Check validation

	Action	Expected result
1	Call the service routine `CyclicBrakeCheck`.	No error messages.
2	Wait the time specified in Brake Check Cycle, e.g. 24 hours, without performing a brake check.	Elog 20483 will appear when the prewarning time is reached. Elog 20484 will appear when the interval has elapsed.
3	If additional axes are used, check the loaded brake parameters in the configuration.	

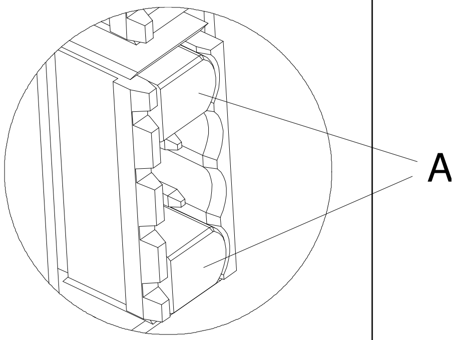
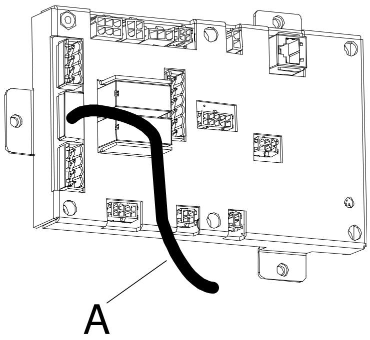
Safe Brake Ramp validation

If additional axes are used, verify that the **Brake Data** parameters are configured according to descriptions in section *Brake Data on page 82*.

For more information about brake data, also see *Configuring brake data - with ABB robots and ABB tracks on page 211*.

Continues on next page

Verify that the connector for the limit switch override is plugged or not strapped

	Action	Note
1	Look at the contactor unit and verify that the plug in the limit switch override connector (X23) is intact.	The limit switch override must be plugged and not used when using SafeMove.  xx0800000035 • A: plug (2pcs)
2	Make sure the limit switch cable from the safety controller is connected to connector X21 on the contactor interface board.	 xx0800000105 • A: limit switch cable

DANGER

If connector X23 is strapped or if the limit switch cable is not connected to X22, no SafeMove functionality will provide any safety.

At validation, it may appear to be safe, because an Elog may stop the robot. However, this does not provide any safety when the robot is running at full speed.

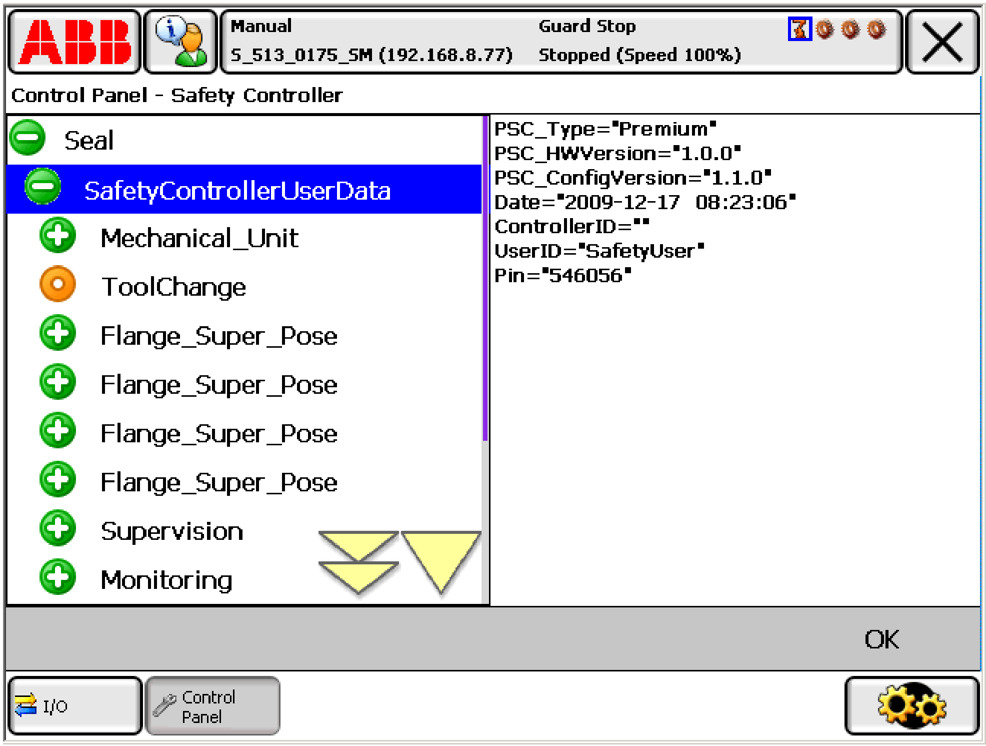
4.8 View configuration on FlexPendant

4.8.1 Viewing the configuration on the FlexPendant

Accessing the configuration information

	Action
1	On the **ABB** menu, tap **Control Panel** and then **Safety Controller**.
2	Tap the line for the safety controller you wish to view.
3	Tap **View**.

Configuration presentation



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5 Guidelines for synchronization and brake check

5.1 Synchronization guidelines for Cyclic Sync Check

Dual channel or single channel

Verify that the right type of synchronization (dual channel or single channel) was selected in the configuration.

See *Synchronization configuration on page 87*.

Uniquely defined position

The robot position for the sync check must be chosen so that the position of the robot axes are unambiguously defined. One way to make sure the sync check position is well-defined for all axes is to use the instruction `MoveAbsJ` to move to the sync position. See *Technical reference manual - RAPID Instructions, Functions and Data types*.

Note that the sync position should be allowed by all active functions. For example, all axes must be inside their defined ranges for the active Safe Axis Range functions.

Small sync switch surface

For physical synchronization, the sync switch surface that the robot touches must be small. The surface of the tool touching the sync switch must also be small. If any robot axis moves one motor revolution, the robot must be out of reach for the sync switch.

Always activate sync switch in the same way

For physical synchronization, always use the same tool. The robot should always touch the sync switch with the same point on the tool.

Create RAPID program for synchronization

Create a RAPID program to perform a synchronization.This can be initiated from a PLC or the main RAPID program. Perform the synchronization when the digital output signal `PSC1CSPREWARN` goes high. The `PSC1CSPREWARN` signal is only activated when Dual channel or Single channel synchronization has been selected in the configuration. When Software synchronization has been selected, it is only necessary to do a synchronization if the safety controller or the robot controller has become asynchronous.

Write the program so that the robot first goes to a position close to the sync switch and then approach it slowly from the desired direction. If the approach is too fast, the accuracy of the robot position may be too low.

Example

In a system module elog 20470 is caught and an output signal is set. This signal can be used by a PLC or a RAPID program.

```
MODULE SYNCINIT (sysmodule)
  LOCAL VAR intnum irSyncPreWarn;
```

Continues on next page

```
  LOCAL TRAP tpSyncPreWarn
    setDO doSyncPreWarn, 1;
    TPWrite "SYNCHRONIZATION PRE WARNING. ";
    RETURN;
  ENDTRAP

  PROC initSync()
    CONNECT irSyncPreWarn WITH tpSyncPreWarn;
    ! 20470 SC 1 Synchronization Pre-warning
    IError SYSTEM_ERR\ErrorId := 470,TYPE_ALL,irsyncPreWarn;
  ENDPROC

ENDMODULE
```

Synchronization on closing edge

The synchronization is executed 1 second after the sync switch is closed. The 1 second delay is implemented to avoid synchronization pulses before the manipulator has stopped in its synchronization position.

Nothing happens when the sync switch is opened again.

Cyclic Sync Check output

Virtual output signals can be connected to physical output signals for communication with a PLC. See also *Virtual output signals from main computer on page 146*.

5.2 Synchronization guidelines for Software Sync Check

Selecting software synchronization

Verify that **Software Synchronization** was selected in the configuration.

See *Synchronization configuration on page 87*.

Uniquely defined position

The robot position for the sync check must be chosen so that the position of the robot axes are unambiguously defined. One way to make sure the sync check position is well-defined for all axes is to use the instruction `MoveAbsJ` to move to the sync position. See *Technical reference manual - RAPID Instructions, Functions and Data types*.

Note that the sync position should be allowed by all active functions. For example, all axes must be inside their defined ranges for the active Safe Axis Range functions.

Use easily verified sync position

Select a sync position where it is easy to verify the position of the robot axes. It is helpful to use a position where the TCP touches a spike or something where it is easy to see if the robot is in the correct position or not.

Use service routine to perform synchronization

WARNING

If the robot position is not visually verified, to make sure all robot axes are in correct position, the synchronization can jeopardize the safety.

Note

Software synchronization can only be performed by a user with grants that allow this, see *Create a safety user on page 75*.

	Action	
1	Move the robot to its sync position (for example with `MoveAbsJ`).	
2	Visually verify that the robot is in its sync position (all axes must be in correct position).	If an axis is in wrong position, the revolution counters are most likely incorrect.
3	In the program view, tap **Debug** and select **Call Routine**.	
4	Select the service routine **SoftwareSync** and tap **Go to**.	
5	Follow the instructions in the service routine.	

5.3 Brake check guidelines

Prerequisites for brake test

- The robot and all additional axes must be moved to a safe and relaxed position (away from people, equipment and not too much stretched) before performing a brake check. Normally the robot moves only a few centimeters during the brake tests.
- Move the robot to a stop point before performing a brake check.
- A brake check can only be performed at normal execution level (not from a trap routine, error handler, event routine or store path level).
- Brakes are tested consecutive order and each test takes 10-15 seconds.
- Do not change the speed from the FlexPendant and do not use `VelSet`, `AccSet`, `SpeedRefresh`, or any other instruction that affects motion performance in `TRAPS` or event routines while `CyclicBrakeCheck` is active.

Note

The RAPID function `IsBrakeCheckActive` can be used to check if `CyclicBrakeCheck` is active.

For information about parameters used for additional axes, refer to *Configure system parameters on page 73*.

Activate brake check

There are two ways of initiating a brake check:

- Calling the service routine `CyclicBrakeCheck`. Robot system must be in manual mode.
- A RAPID program calls the procedure `CyclicBrakeCheck`.

Example of RAPID program

A signal `diPSC1CBCPREWARN` is defined and cross connected to the safety signal `PSC1CBCPREWARN` in the I/O parameters. This cross connection is required because there is a restricted usage of safety signals in the RAPID program. The `PSC1CBCPREWARN` signal will be set to a logical high state when the prewarning time interval expires. It will be kept high until a successful brake check has been carried out. The status of the `diPSC1CBCPREWARN` signal is checked in the Main loop in the application program.

```
PROC main()
  IF diPSC1CBCPREWARN=1 THEN
    MoveAbsJ *, v1000, fine, tool1;
    ! Call to the predefined service routine CyclicBrakeCheck
    CyclicBrakeCheck;
  ENDIF
  ....
ENDPROC
```

Continues on next page

Cyclic Brake Check for MultiMove systems

> **Note**
>
> Make sure that all mechanical units are standing still before ordering a `CyclicBrakeCheck`.

One of the motion tasks call the routine `CyclicBrakeCheck` to perform Cyclic Brake Check for all mechanical units in all tasks.

The brake check must not be performed while any tasks are in synchronized mode (coordinated movement). It is necessary to synchronize all motion tasks with `WaitSyncTask` instructions before and after the actual brake check. If running a movement instruction when one motion task is execution a `CyclicBrakeCheck`, you will have an error (41888) and all execution will stop. Instruction `ExitCycle` is also forbidden to use during an active `CyclicBrakeCheck`.

The RAPID function `IsBrakeCheckActive` can be used to check if there is an ongoing `CyclicBrakeCheck`.

Only one call to `CyclicBrakeCheck` can be done at a time. This is checked by the service routine and if more than one RAPID task or client try to execute the routine, you will have an error (41886).

Program example

```
T_ROB1
PERS tasks task_list{2} := [ ["T_ROB1"], ["T_ROB2"] ];
VAR syncident sync1;
VAR syncident sync2;
...
IF PLC_di1_DO_CBC = 1 THEN
  WaitSyncTask sync1, task_list;
  CyclicBrakeCheck;
  WaitSyncTask sync2, task_list;
ENDIF

T_ROB2
PERS tasks task_list{2} := [ ["T_ROB1"], ["T_ROB2"] ];
VAR syncident sync1;
VAR syncident sync2;
...
IF PLC_di1_DO_CBC = 1 THEN
  WaitSyncTask sync1, task_list;
  ! Wait for T_ROB1 to be ready with CyclicBrakeCheck
  WaitSyncTask sync2, task_list;
ENDIF
```

Brake check output

An error or warning message is logged for each axis with low brake torque. A status message is also logged for each complete brake cycle. See also *Cyclic Brake Check configuration on page 89*.

Continues on next page

Virtual output signals can be connected to physical output signals for communication with a PLC. See also *Virtual output signals from main computer on page 146*.

Brake maintenance

Brake maintenance is a feature in the `CyclicBrakeCheck` functionality.

`CyclicBrakeCheck` automatically detects if maintenance of the mechanical brakes is needed and activates the *Brake maintenance* functionality during execution. *Brake maintenance* applies the brake and turns the motor shaft 1 radian five times, which gives a movement of the robot arm of less than 1 degree.

There are event logs that tell if *Brake maintenance* is needed, and if it has been run.

For more information see parameter *Brake Maintenance*, type *General Rapid*, topic *Controller*, in *Technical reference manual - System parameters*.

6 Maintenance

6.1 Required maintenance activities

Internal functions are self tested

All internal functionality in the SafeMove safety controller is subject to self tests and requires no maintenance activities.

Test the safety relays for category 0 stop

Verify that a category 0 stop opens the safety relays.

Perform this test every 6 months:

	Action	Note
1	Turn off the power to the safety controller's I/O power input.	This will cause a category 0 stop.
2	Verify that the robot is stopped.	
3	Check elog list to verify that a normal category 0 stop was performed.	If only one relay opens, elog 20222 will be shown.

Verify that the contact for the limit switch override is plugged or not strapped

DANGER

If contact X23 is strapped or if the limit switch cable is not connected to X22, no SafeMove functionality will provide any safety.

At validation, it may appear to be safe, because an Elog may stop the robot. However, this does not provide any safety when the robot is running at full speed.

For information on how to do the verification, please refer to *Verify that the connector for the limit switch override is plugged or not strapped on page 130*.

Perform this activity every 6 months.

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7 Running in production

7.1 Reaction time

Supervision function response time

When a supervision function is triggered, the reaction time until a stop is ordered is maximum 22 ms. This reaction time must be added to the stopping time of the manipulator, specified in the product specification for the manipulator, to get the complete stopping time for the manipulator.

Monitor function response time

When a monitoring function is triggered, the reaction time until the safe digital output signal goes low is maximum 12 ms.

7.2 Restarting the controller

Restart modes

None of the restart modes **Restart**, **Reset RAPID**, or **Reset system** will affect the safety configuration.

For more information about restart procedures, see *Operating manual - IRC5 Integrator's guide*.

Removing the current system

If a backup is available, then the SafeMove safety configuration can be restored without the need of a validation, see *Restore configuration on page 114*.

DANGER

Installing a new system, without downloading or restoring the safety configuration to the safety controller, leaves the robot system without any of SafeMove's safety functions. It can easily be perceived as if the robot system still has SafeMove active, which causes a dangerous situation.

Tip

Set up the User Authorization System so that only the safety user is allowed to administrate installed systems.

Restarting in unsychronized mode

If the safety controller and the robot controller are not synchronized, the robot controller must not be in auto mode when performing a restart. Perform a synchronization in manual mode before switching to auto mode.

Backup and restore

Performing a backup and restore of the system does not affect the SafeMove safety configuration.

The SafeMove safety configuration file is included in the backup. For information on how to restore the SafeMove safety configuration, see *Restore configuration on page 114*.

7.3 Recovery after safety violation

Recovery after a supervision function has triggered in Automatic mode

When a supervision function triggers, the robot will stop. To be able to move the robot again, the following must be performed (all output signals will also be set high):

	Action	Note
1	Press the motors on button on the robot controller, or activate the signal `SafeMoveConfirmStop`, to confirm the violation.	The stop can also be confirmed by a restart. For speed violations, it is enough with this confirmation. Steps 2-5 are not necessary.
2	Switch to Manual mode on the robot controller.	
3	Activate the Manual Operation input signal, if a separate switch is used.	This signal is automatically set if the input signal is connected to the operation mode selector on the robot controller (option 735-3 or 735-4).
4	Jog the robot back to a position that does not trigger any supervision function.	
5	Deactivate the Manual Operation signal.	

Recovery after a supervision function has triggered in Manual mode

When a supervision function triggers, the robot will stop. To be able to move the robot again, the following must be performed (all output signals will also be set high).

	Action	Note
1	Release the three-position enabling device on the FlexPendant.	For speed violations, is it enough to release the enabling device on the FlexPendant and then activate it again to confirm the violation. Steps 2 and 4 are required after a zone violation.
2	Activate the Manual Operation input signal, if a separate switch is used.	This signal is automatically set if the input signal is connected to the operation mode selector on the robot controller (option 735-3 or 735-4).
3	Press the three-position enabling device again and jog the robot back to a position that does not trigger any supervision function.	
4	Deactivate the Manual Operation signal, if a separate switch is used.	

Recovery from unsynchronized state

Unsynchronized state can, for example, occur:

- When Cyclic Sync Check has timed out
- When Control Error Supervision has triggered (for example a too large servo lag due to a collision)

Continues on next page

	Action	Note
1	Press the motors on button on the robot controller, or activate the signal `SafeMoveConfirmStop`.	This allows the robot to be moved at reduced speed for a time period specified in **Max Time Limit** in the **Synchronization** configuration (60-3600 seconds). Maximum reduced speed is 18 degrees/s.
2	Perform a synchronization.	

Recovery after Cyclic Brake Check has timed out

When a Cyclic Brake Check has timed out the robot can still be moved, but not faster than the **Max TCP Speed** configured for Cyclic Brake Check.

	Action	Note
1	Perform a brake check.	See *Brake check guidelines on page 136*.

Recovery after Cyclic Brake Check has failed

When a Cyclic Brake Check has failed the robot can still be moved, but not faster than the **Max TCP Speed** configured for Cyclic Brake Check.

	Action	Note
1	Repair the brake that failed.	
2	Perform a new brake check.	See *Brake check guidelines on page 136*.

7.4 Virtual signals

What is a virtual signal

The virtual signals can be viewed on the FlexPendant or in a RAPID program. They are communicated over the Ethernet connection and are not physical signals. They show the status of signals from the safety controller and cannot be set by the user, which is why they are represented as digital inputs (DI).

The virtual signals can be used by a RAPID program to produce helpful hints to the operator of why the robot has stopped.

For information about the system input signal that is a virtual signal, see *System input signal, SafeMoveConfirmStop on page 73*.

WARNING

The virtual signals must not be used for safety implementations. Only physical signals shall be used for safety implementations.

Note

The following virtual output signals from main computer are valid in combination with an executed Cyclic Brake Check operation:

- PSC1CBCOK
- PSC1CBCWAR
- PSC1CBCERR

List of signals

Virtual input signals

Signal name	Description	Virtual I/O state
PSC1DI1-PSC1DI8	Digital input.	0 = Physical input not driven 1 = Physical input driven
PSC1DIOVR	Manual operation input.	0 = Physical input not driven 1 = Physical input driven
PSC1SST	Shows violation state of active supervision.	0 = Configured and violated 1 = All other cases
PSC1SAS	Shows violation state of active supervision.	0 = Configured and violated 1 = All other cases
PSC1SAR	Shows violation state of active supervision.	0 = Configured and violated 1 = All other cases
PSC1STS	Shows violation state of active supervision.	0 = Configured and violated 1 = All other cases
PSC1STZ	Shows violation state of active supervision for all zones.	0 = Configured and no violation of any zone 1 = All other cases

Continues on next page

Signal name	Description	Virtual I/O state
PSC1STZ1 - PSC1STZ8	Shows violation state of active supervision for zone 1-8.	0 = Configured and violated 1 = All other cases
PSC1OVERRIDE	Manual operation mode status.	0 = PSC1DIOVR is not active 1 = PSC1DIOVR is active (Manual operation is active)
PSC1CSC	Cyclic Sync Check function reacts on closing edge (0 to 1 transition).	0 = Physical input low 1 = Physical input high

Virtual output signals

Signal name	Description	Virtual I/O state
PSC1DO1- PSC1DO8	Digital output.	0 = Physical output low 1 = Physical output high
PSC1STOP0	Relay output.	0 = Stop active
PSC1STOP1	Safety category 1 stop.	0 = Stop active (edge trig)
PSC1CSS	Cyclic sync status.	0 = Not synchronized
PSC1CBCREQSM	Request to do a brake test.	1 = Request (edge trig)
PSC1CBCACTSM	Brake test active.	1 = Test active
PSC1CBCOKSM	Brake test result.	1 = OK from brake test
PSC1CBCWARSM	Brake test warning.	1 = Warning from brake test.
PSC1CBCERRSM	Brake test error.	1 = Error from brake test.
PSC1CB-CPREWSM	Prewarning, time to do a brake test.	1 = Request (edge trig)

Virtual output signals from main computer

These signals appear like digital output signals on the FlexPendant, and are useful during troubleshooting.

Signal name	Description	Virtual I/O state
PSC1CBCREQ	Request to do a brake test.	1 = Request (edge trig)
PSC1CBCACT	Brake test active.	1 = Test active
PSC1CBCOK	Brake test result.	1 = OK from brake test
PSC1CBCWAR	Brake test warning.	1 = Warning from brake test.
PSC1CBCERR	Brake test error.	1 = Error from brake test.
PSC1CBCPREWARN	Prewarning, time to do a brake test.	1 = Request (edge trig)
PSC1CSPREWARN	Prewarning, time to do a synchronization.	1 = Request (edge trig)
PSC1CALIBRATED	Robot and additional axes are calibrated.	1 = All axes are calibrated
PSC1CALIBERROR	Motor calibration offset is downloaded to the safety controller.	1 = Calibration downloaded
PSC1RESETPB	Confirm from the motors on push button.	1 = Confirm (edge trig)

Continues on next page

Other signals

All other virtual signals starting with PSC are for internal use. Do not use them for applications.

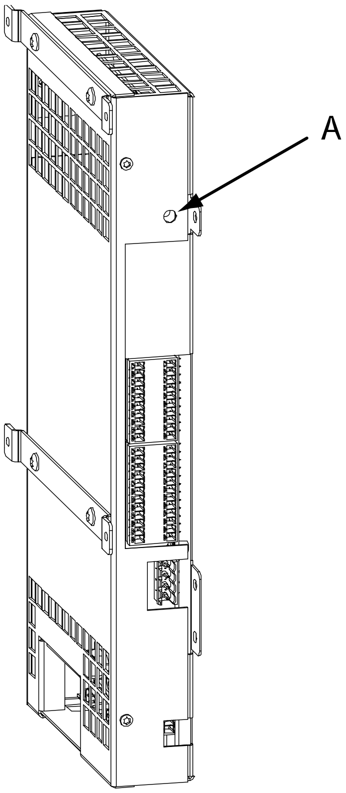
Signals for MultiMove system

In a MultiMove system there is one set of signals from each safety controller, i.e. from each drive module. Signals from drive module 1 have names starting with PSC1, signals from drive module 2 have names starting with PSC2, etc.

7.5 Status LED

Location of the status LED

A red/green status LED is placed on the front panel of the safety controller. It indicates the status of the safety controller.



xx0700000727

A	Status LED

Status indications

LED indication	Description
Solid green	Safety controller CPU is running and communication is ok.
Solid red	Internal hardware failure. Replace the safety controller.
Flashing green	Communication failure or I/O power supply missing.

7.6 Changes to robot or robot cell

Always update safety configuration

If the following is done the safety configuration must be updated and validated again:

- A new version of RobotWare is installed.

Update calibration file and perform synchronization

If the following is done the calibration file must be updated and a synchronization performed:

- Fine calibration

Evaluate if the safety configuration needs to be updated

If any of the following is done, the safety responsible person must evaluate if the safety configuration needs to be updated and validated again:

- The tool is replaced.
- Any robot part is replaced.
- The robot cell is rebuilt in any way.
- The relation between the world coordinate system and the robot base coordinate system is changed.
- The tool coordinate system is changed.
- Changes to system parameters.

Perform synchronization

If any of the following is done, a new synchronization is required:

- Revolution counter update

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8 Safemove Visualizer

8.1 Introduction

Safemove Visualizer

SafeMove Visualizer is a FlexPendant application that gives assistance to the robot operator or programmer in using SafeMove, and provides quick access to all SafeMove-related signals and data.

The following data is displayed in tabular form for this purpose:

- Safety signals
- Safety messages
- Synchronization and brake check (definition, status and call-up of service routines)

The following data is shown in graphical or tabular form:

- Tool definitions
- Tool zones for STZ and MTZ
- Axis ranges for SAR and MAR

All zones are displayed together with the TCP and the monitored tool points in the graphical display of the tool zones, which allows you to quickly recognize the cause of a zone violation.

The permitted and prohibited axis ranges are displayed together with the current positions of the individual axes in the graphical display of the axis ranges, so that you can also recognize the cause of a range violation here.

8.2 Starting the graphical user interface

The user interface

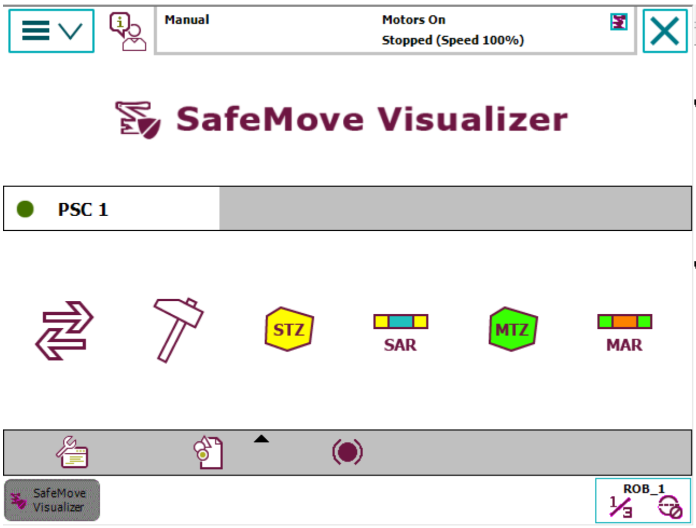
Use this procedure to start the graphical user interface

	Action
1	Tap the ABB menu.
2	Tap Safemove Visualizer.
3	The main menu of Safemove Visualizer is displayed.

For more information on how to use the FlexPendant in general, see *Operating manual - IRC5 with FlexPendant*.

Main menu for single controller

When the graphical user interface starts up, the main menu is displayed.



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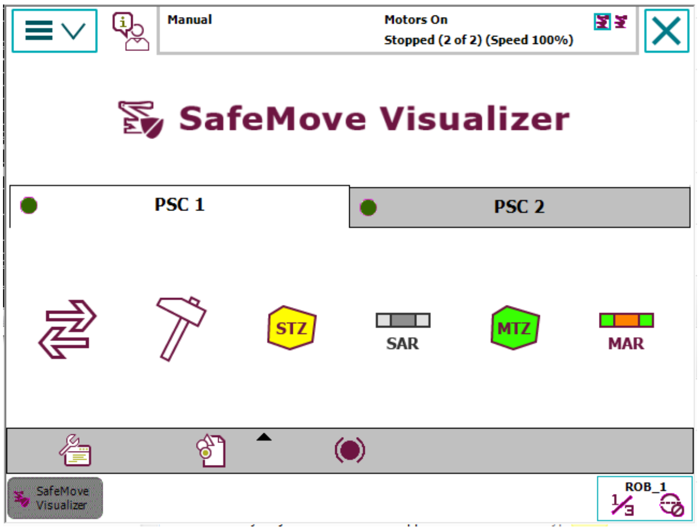
Main menu for MultiMove applications

For MultiMove applications, several tabs will be displayed for viewing individual safety functions depending on the number of safety controllers that are used.



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Using Safemove Visualizer in a virtual robot system

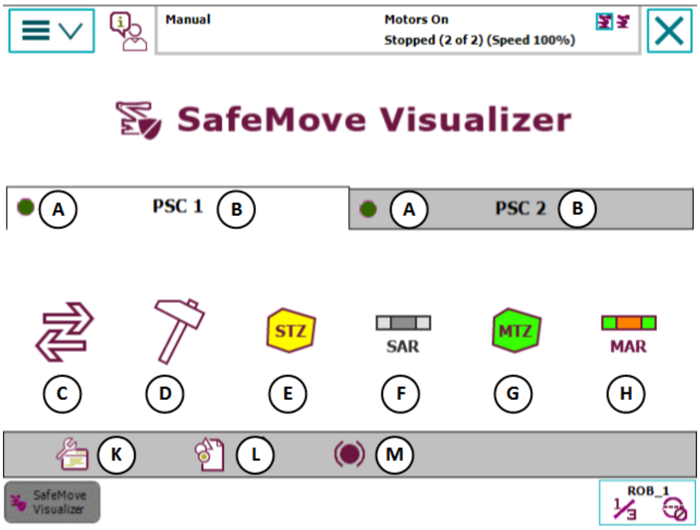
Safemove Visualizer can also be used on a virtual robot system in RobotStudio. To do this, it is necessary that the safety configuration is available in the virtual system.

Additional SafeMove-signals with prefix "v", (e.g. "vPSC1DI1") are loaded for each robot because the standard SafeMove-signals are set as read only.

All functions of the Safemove Visualizer in the virtual controller are related to these new signals (only digital outputs) which can be set or reset manually or program controlled.

8.3 The main menu

Overview of the main menu



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	Parts	Description
A	Status LED of safety controller(s)	No faults (green) Warning, e.g. brake check required (yellow) Safety violation (red)
B	Name of safety controller	Selection of safety controller whose data is to be displayed.
C	Safety signals	Safety signal display.
D	Tool data	Graphical display of tool data and its configuration data.
E	Safe Tool Zone (STZ)	Graphical display of the tool zones and their configuration data.
F	Safe Axis Range (SAR)	Graphical display of the safe axis ranges and their configuration data.
G	Monitor Tool Zone (MTZ)	Graphical display of the tool zones and their configuration data.
H	Monitor Axis Range (MAR)	Graphical display of the monitor axis ranges and their configuration data.
K	Configuration	Safety configuration display and input of the security PIN.
L	Safety messages	Display of SafeMove-related event messages.
M	Synchronisation and brake check	Display synchronization and brake check configuration

Safety Status

Green LED

No warning and no safety violation (error).

Continues on next page

Yellow LED (warning)

A warning is displayed if one of the following signals assumes the specified value.

Safety signal	Description	Value
PSCxDIOVR	Manual Operation Input (only in "Automatic" mode)	1
PSCxOVERRIDE	Manual Operation Status (only in "Automatic" mode)	1
PSCxCBCWAR	Brake check warning	1
PSCxCBCPREWARN	Pre warning for brake check	1
PSCxCSPREWARN	Pre warning for synchronization	1

Red LED (error or safety violation)

An error is displayed if one of the following signals assumes the specified value.

Safety signal	Description	Value
PSCxSST	Safety violation SST	1
PSCxSAS	Safety violation SAS	1
PSCxSAR	Safety violation SAR	1
PSCxSTS	Safety violation STS	1
PSCxSTZ	Safety violation STZ	1
PSCxCSS	Cyclic synchronisation required	0
PSCxCBCOK	Brake check result not OK	0
PSCxCALIBRATED	Robot and axes not calibrated	0
Deactivated	Safety controller is deactivated	-

Operator guidance in the event of a safety violation

Since a safety violation can be caused by different safety functions, the buttons that contain further information about the cause of the problem have a colored background.

In case of:

- a warning, the button for the safety signals shows a yellow background.
- a violation or an error, the button for safety signals shows a red background.
- a violation of an active supervised function, like safe tool zone (STZ) or safe axis range (SAR), the respective button shows a red background.
- a violation of a passive supervised function, like monitor tool zone (MTZ) or monitor axis range (MAR), the respective button shows an orange-red background.

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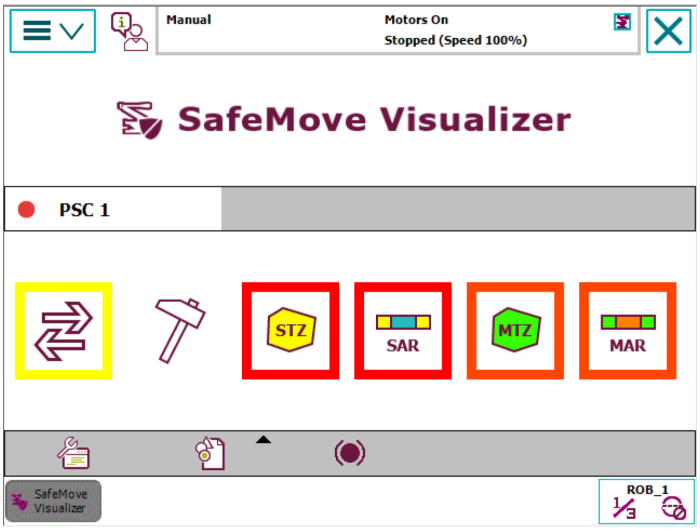

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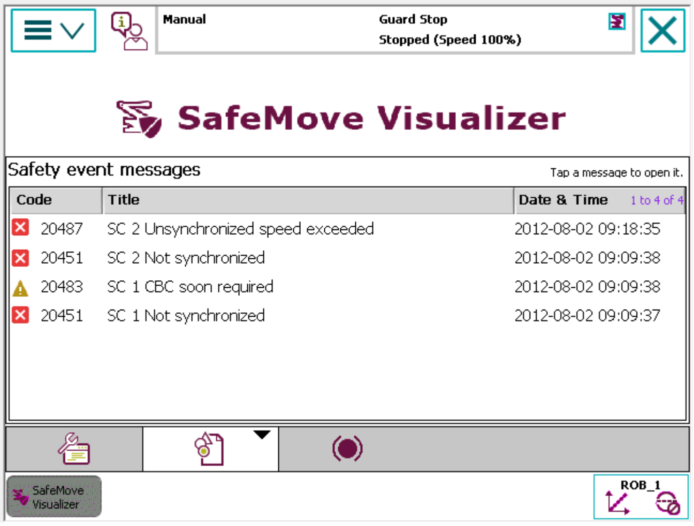
This means that the system operator can see immediately which button he has to press during fault analysis in order to obtain the required information.

8.4 Safety controller event messages

Overview of the safety controller event messages window

The event messages from the safety controller(s) for events that have occurred since the last restart of the robot controller or within the last 24 hours are displayed in the Safemove Visualizer, whereby the last message that occurred is always at the beginning of the list.

Tapping the safety messages button in the main menu causes the event message list to be displayed, tapping the button again hides the list.



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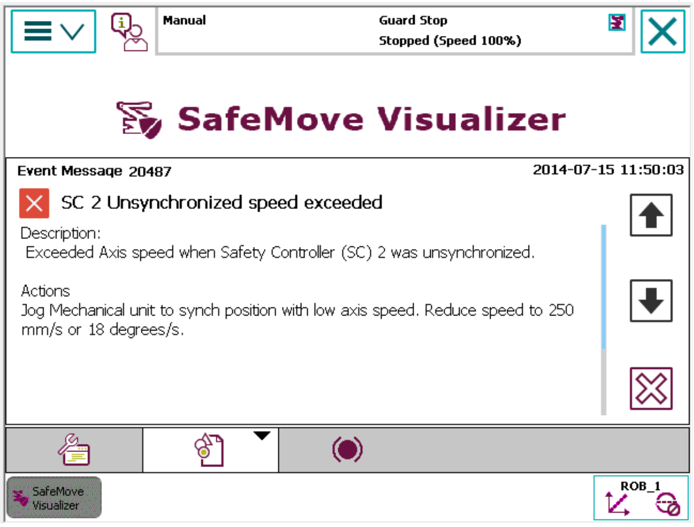
Clicking on an event message in the list opens up the detail window for the message containing all of the relevant message data.



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The following buttons are located at the right-hand edge of the detail window, and are used to navigate through the messages:

 Display previous message

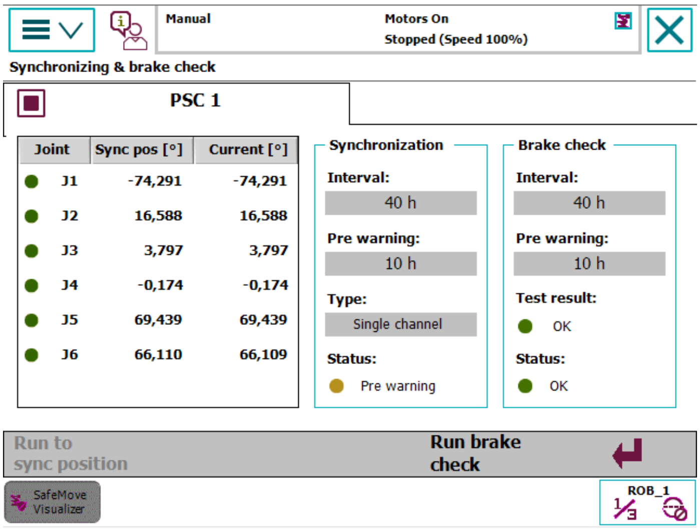
 Display next message

 Back to message list

8.5 Synchronization and brake check

Overview of the synchronization and brake check window

The window for synchronization and brake check is opened from the main menu and is used to display the adjusted parameters, the current status, and for calling up the required service routines.



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Synchronization

The monitoring and supervision functions are only active if SafeMove is not synchronized. In an unsynchronized state, movement is only possible with restricted speed and duration.

See *Sync check functions on page 27*.

Safe calibration position

The axis angle of the robot's safe calibration position is displayed in the table together with the current axis angles.

The status of the calibration position is displayed with a LED in front of the axis number with the following colors:

- Green LED - the axis is in calibration position
- Red LED - the axis is not in calibration position

Software synchronization status

If a switch is used for synchronization, the sync cycle time that is set in the configuration (12 - 720 hours) and the advance warning time (1 - 11 hours) are displayed as well as the type of synchronization.

The status of the synchronization is displayed with a LED with the following colors:

- Green LED - Synchronization okay
- Yellow LED - Pre warning time elapsed
- Red LED - Synchronization necessary

Continues on next page

Cyclic brake check

The robot must be moved to a safe position within a defined interval (brake cycle time) and a brake check carried out. See *Cyclic Brake Check on page 31*.

Brake check status

The adjusted times for the brake check, the result of the last brake check and the status for the next check are displayed.

The result of the last brake check is displayed with a LED with the following colors:

- Green LED - Check was error-free
- Yellow LED - Brake check detected warning
- Red LED - Brake check detected error

The status for the next brake check is displayed with a LED with the following colors:

- Green LED - Brake check unnecessary
- Yellow LED - Pre warning time elapsed
- Red LED - Brake check necessary

8.6 Service routines

Introduction

Movement to the calibration position, software synchronization and the brake check take place by executing **Service routines**.

As well as the facility that is provided by the robot system, the **Synchronization and brake check** window also provides a facility for performing the required service routines.

Service routine processing status

The processing status of a service routine is indicated separately for each safety controller by the following icons on the tab page.

 Service routine is executable.

 Service routine is being executed.

 Service routine was stopped.

 Service routine is blocked (Robot program is being executed).

Move to safe calibration position

The **Run to sync position** menu is active if the robot is not in the calibration position, and the operating mode of the robot is configured to *Manual ≤ 250 mm/s*.

This menu is used to call up service routine `RunToSyncPos`, with which the robot is moved to the calibration position.

As soon as the motors are switched on by pressing the three-position enabling device on the FlexPendant, the service routine can be started by tapping the menu and then pressing the **Yes** button in the dialog that follows.

If one or more movement tasks are used for axes 7-9 (e.g. for a positioner), the dialogue for moving to the calibration position of the next mechanical unit is displayed by tapping the **No** button.

This can be used if a certain order is required to move to the calibration position (e.g. the positioner must be in the calibration position before the robot can be moved there).

If only the robot task is used and the **No** button or the **Cancel** button is tapped, the move to the calibration position is aborted.

Generate routine RunToSyncPos

If the `RunToSyncPos` routine is not present in the movement task, a dialogue is displayed to create the routine.

Continues on next page

If the **Yes** button is tapped, the `RunToSyncPos` routine is created for the robot in the `SafetyVisu` system module with the required calibration position and the active tool.

```
PROC RunToSyncPos()
CONST jointtarget jtSyncPos:=[[…]];
MoveAbsJ jtSyncPos, v100, fine, tool0;
Waittime 0.5;
ENDPROC
```

If a positioner is used, the routine is created in its movement task.

```
PROC RunToSyncPos()
CONST jointtarget jtSyncPos:=[[…]];
MoveExtJ jtSyncPos\UseEOffs, v500, fine;
Waittime 0.5;
ENDPROC
```

Start software synchronization

If the *Software Sync Check* is used and the robot is in the calibration position, the *Software Sync* service routine can be executed by tapping on the **Run software sync** menu.

> **Note**
>
> The robot controller must be in *Manual ≤ 250 mm/s* mode and the motors must be switched on.

The service routine is started as soon as the dialogue has been confirmed with the **Yes** button.

Perform brake check

If the robot is in a safe position, the brake check can be started directly from Safemove Visualizer.

In order to do this, tap on the **Run brake check** menu, and after confirmation the `CyclicBrakeCheck` service routine is performed.

> **Note**
>
> The robot controller must be in *Manual ≤ 250 mm/s* mode and the motors must be switched on.

8.7 Safety controller status

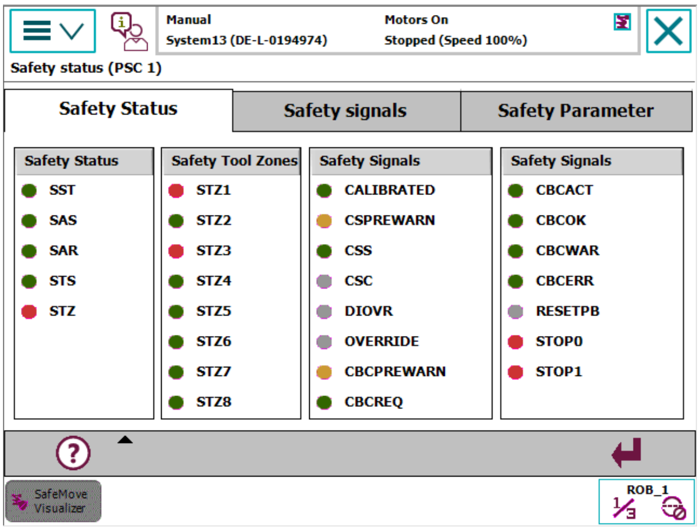
Safety signals

The status of the safety controller is indicated using virtual signals.

Depending on the functionality of a signal, the logical value 1 or 0 can indicate a safety violation. For example, a safety zone has been violated if the signal `PSC1STZ` is 1 or the `PSC1STZ1` signal is 0.

In order to be able to quickly interpret the status of the safety controller on the basis of the signals, it is not the logical signal statuses but the safety status that is indicated via a red LED and green LED.

This means that signal `STZ` is green if it has a logical value of 0 and red if it has a value of 1. On the other hand, the `STZ1` signal is green if it has a logical value of 1 and red if it has a value of 0.



xx1400001308

The `PSCxCSC` and `PSCxRESETPB` signals are not safety-related, since they indicate the current status of a switch. For this reason, the respective LED is grey if the switch is not operated, and green if it is operated.

The status of the `PSCxDIOVR` and `PSCxOVERRIDE` signals is indicated by the colors grey and yellow (override activated).

Virtual signals of the safety controller, SafeMove

Safety signal	Description	LED	
		0	1
PSCxCBCACT	Brake check active.		
PSCxCBCERR	Brake check error.		
PSCxCBCOK	Result of the brake check OK.		

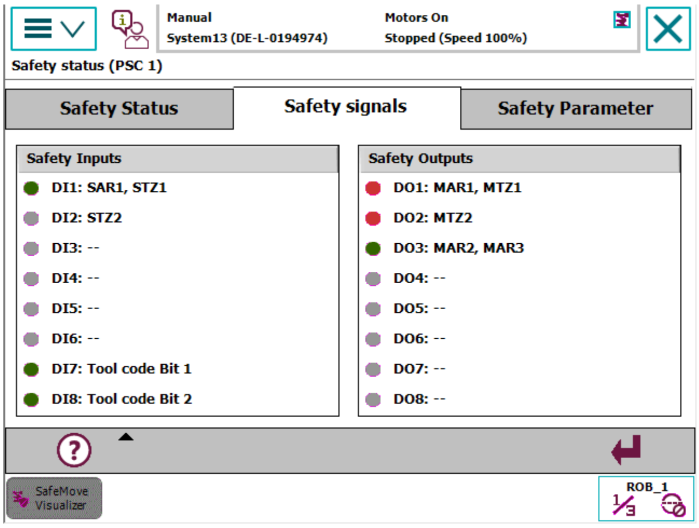
Continues on next page

Safety signal	Description	LED	
		0	1
PSCxCBCPREWARN	Advance warning, brake check should be performed.		
PSCxCBCREQ	Request for brake check.		
PSCxCBCWAR	Brake check warning.		
PSCxCSC	Switch input for *Cyclic Sync Check*.		
PSCxCALIBRATED	Robot and additional axes are calibrated		
PSCxCSPREWARN	Advance warning, synchronization should be performed.		
PSCxCSS	Cyclic synchronization status.		
PSCxDI1 - PSCxDI8	Digital inputs 1-8.		
PSCxDIOVR	Manual Operation Input.		
PSCxDO1 - PSCxDO8	Digital outputs 1-8.		
PSCxOVERRIDE	Manual Operation Status.		
PSCxRESETPB	Confirmation of MOTORS ON button..		
PSCxSAR	Indicates a safety violation of *Safe Axis Range* active monitoring.		
PSCxSAS	Indicates a safety violation of *Safe Axis Speed* active monitoring.		
PSCxSST	Indicates a safety violation of *Safe Stand Still* active monitoring.		
PSCxSTS	Indicates a safety violation of *Safe Tool Speed* active monitoring.		
PSCxSTZ	Indicates a safety violation of *Safe Tool Zone* active monitoring.		
PSCxSTZ1 - PSCxSTZ8	Indicates a safety violation for Zone 1-8 active monitoring.		
PSCxSTOP0	Safety category 0 stop (relay output).		
PSCxSTOP1	Safety category 1 stop.		

Continues on next page

Safety inputs and outputs

The safety functions are activated via the safe digital inputs and outputs.



xx1400001309

The signal functions are inverted so that with signal state "0" the safety function is activated and with signal state "1" the function is deactivated. If two digital inputs are used for tool activation, the functionality thereof is not inverted.

Up to 5 different monitoring and control functions can be assigned to each digital input and output. The names of the individual functions are listed next to the respective signal. If the signal does not have a function assigned to it, the text "—" is displayed.

Safety inputs

The digital inputs are displayed using the following colors:

- Grey LED - Safety function inactive or safety input not in use
- Green LED - Safety function activated

Safety outputs

The safety outputs are used as switching outputs for the passively monitored safety functions. The signal status of these signals is also inverted.

The safety status is displayed using the following colors:

- Grey LED - Safety output not in use
- Green LED - Monitoring function OK
- Red LED - Monitoring function violated

Safety parameters

Some safety functions are permanently activated via the safety configuration, and are displayed in the **Safety parameter** tab.

The calibration values for the individual motor axes that are stored in the safety configuration and in the robot controller system parameters are also displayed.

A red LED next to the axis number marks the axes for which the calibration values are different.

Continues on next page

Explanation of terms / help

Tap the help button and a list of the most common SafeMove abbreviations will be displayed. Tap the button again to hide the help.

8.8 Tool data

Introduction

Up to four tools can be used in "SafeMove", which are activated using two digital safety inputs.

The tool centre point (TCP) for each tool can be defined in relation to the wrist flange. Up to eight additional points can also be configured, which are monitored by Safe Tool Zone (STZ) and Monitor Tool Zone (MTZ). A tool zone is violated of either the TCP or one of the eight tool points leaves the zone.

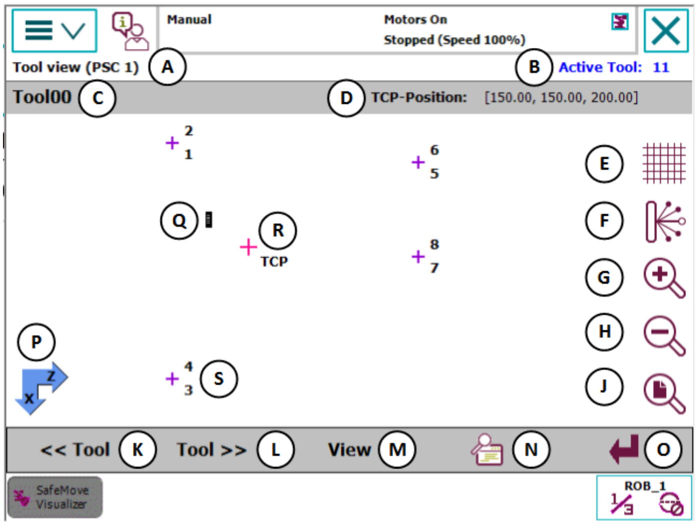
Note

Only the configured points are monitored, not the space between the points.

Graphical tool view

For each tool definition, the wrist flange, the TCP and up to eight tool points in the tool coordinate system in levels XY, XZ and YZ can be graphically displayed.

The active tool is displayed automatically when the window is opened.



xx1400001312

	Parts	Description
A	Title	Name of safety controller
B	Active tools	Binary code of the tools ("00","01","10" or "11"). If a zone is violated, it is not the active tool that is displayed, but the tool that was active when the zone violation occurred. In this case the active tool red inked. The active tool is displayed in "blue" lettering if the graphically displayed tool and the active tool are not identical. If both are identical, "green" lettering is used.
C	Tool	Name or coding of the displayed tool.
D	Position display	TCP or tool point coordinates.
E	Grid lines	Switch grid lines on and off.

Continues on next page

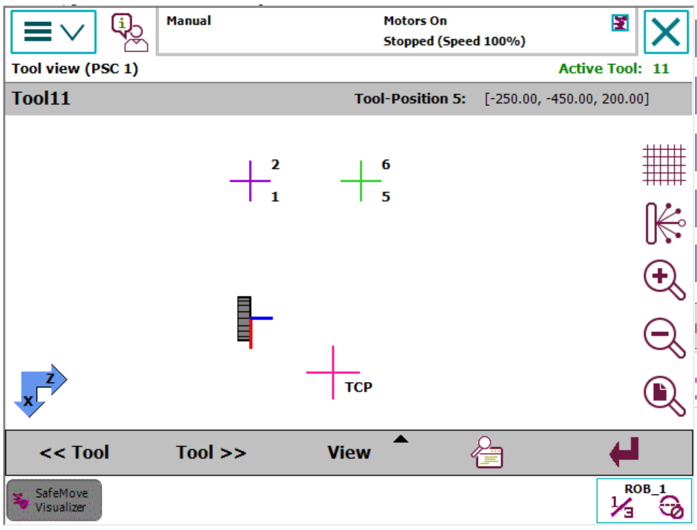
	Parts	Description
F	Tool lines	Switch connecting lines between tool position and wrist flange on and off.
G	Zoom In	Zoom into the diagram.
H	Zoom Out	Zoom out of the diagram.
J	Zoom All	Zoom level is modified in such a way so that all tool points, the TCP and the wrist flange are visible.
K	Display previous tool	If several tools are being used, the previous tool is graphically displayed using this menu button.
L	Show next tool	If several tools are being used, the next tool is graphically displayed using this menu button.
M	View	Menu button for switching the view level (e.g. XY, XZ and YZ).
N	Display details	Menu button for displaying the data declaration of the tools.
O	End	Menu button to return to the main menu.
P	Coordinate system	Directions of the axes in the selected view.
Q	Wrist flange	Position of wrist flange in the origin of the tool coordinate system.
R	TCP	Position of the TCP in the tool coordinate system.
S	Tool point	Position and number of tool point in tool coordinate system. If several points are located in the same position on one level, several tool numbers are displayed at the point.

Coordinate display of a tool point

The coordinates of a tool point are displayed by tapping the desired tool point in the position display together with the point number.

The marked tool point is shown in "Green".

If there are several tool points in the same position (e.g. points 1 and 2), the coordinates of the next point are displayed by tapping on the tool point again.



xx1400001313

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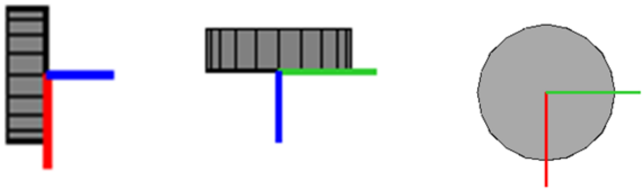
Coordinate direction of the wrist flange

The directions of the tool coordinate system are shown on the wrist flange with lines in the colors Red (X-axis), Green (Y-axis), and Blue (Z-axis).

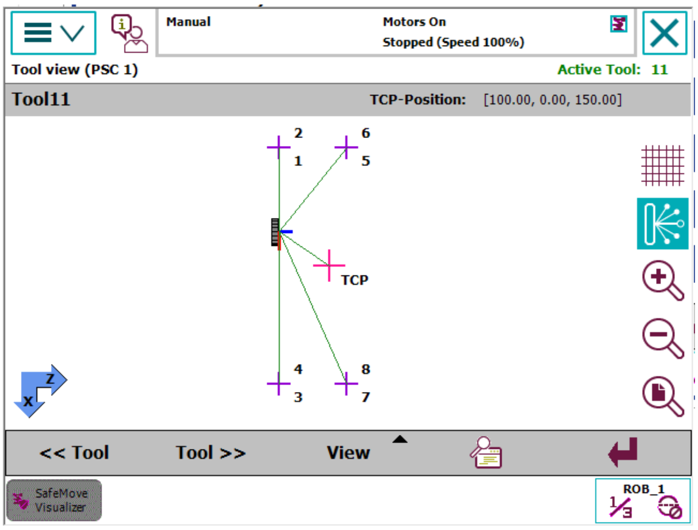


xx1400001314

Connecting lines to the tool points

In order get a better idea of the location of the tool points in relation to the wrist flange, you can display connecting lines from the wrist flange to the individual tool points.

The tool lines button on the right hand edge of the graphical display can be used. To switch off the connecting lines, the tool lines button must be pressed again.



xx1400001315

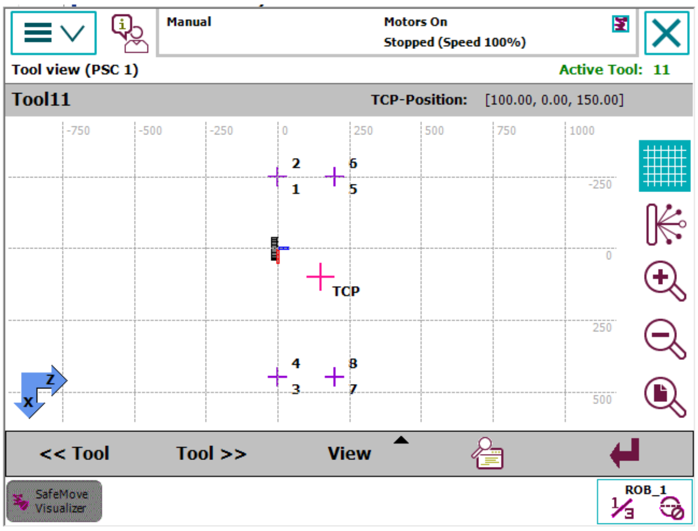
> **Note**
>
> When doing this it must be noted that only the tool points and not the spaces between the points are monitored.

Continues on next page

Grid lines

In order to estimate the location of the TCP and the tool points, grid lines can be displayed together with position information. The distances between the lines are oriented to the zoom level.

The grid lines are displayed and removed by tapping the grid lines button on the right-hand edge of the graphical display.

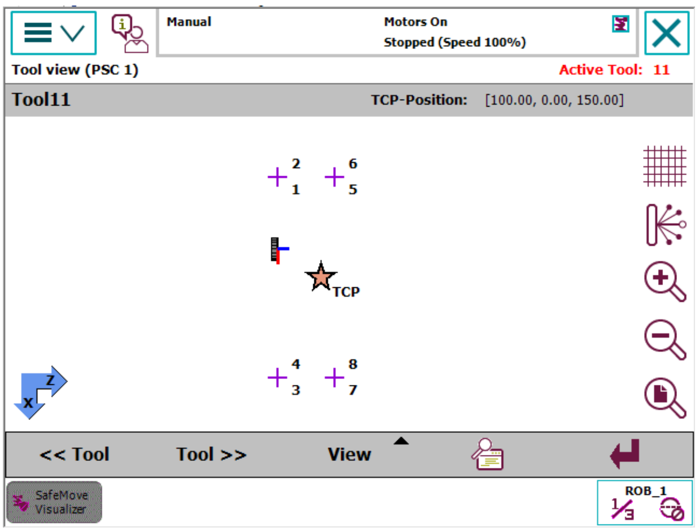


xx1400001316

Zone violation indication

If a tool zone violation is present, the tool that violated the zone is displayed, not the active tool. This is visualized by using red text color for the active tool.

In the diagram the tool point or the TCP that violated the zone is displayed as a star.



xx1400001317

Tool detail view

All tool definitions are displayed in tabs in the detail window of the tool view.

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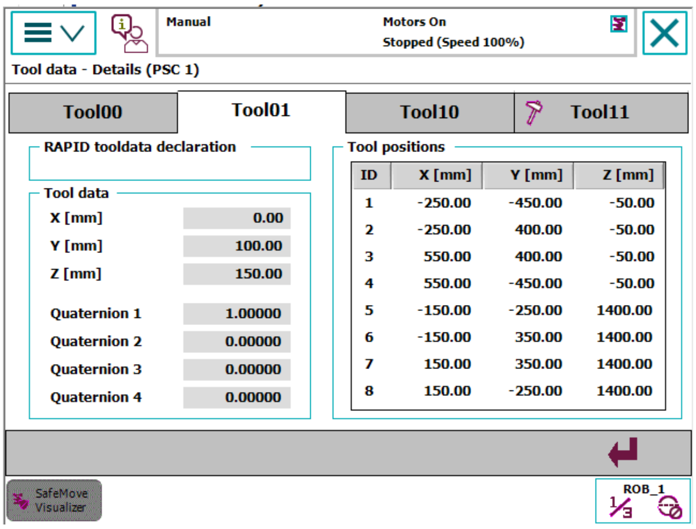
The active tool is displayed with the tool icon next to the tool name in the tab for the respective tool.

As well as the TCP declaration (tool data) and the coordinates of the tool points, the name of the tool used in the robot program is also displayed, if its declaration is identical to the one in the safety configuration.



xx1400001318

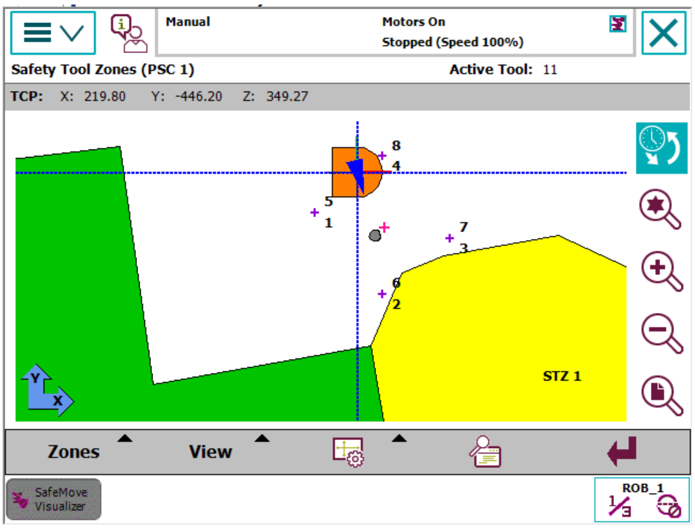
8.9 Safe Tool Zone and Monitor Tool Zone

8.9.1 The graphical view

General

The fact that tool zones are not visible makes troubleshooting in the event of a zone violation extremely difficult.

For this reason all tool zones, the base of the robot, a track motion that may be present, the world coordinate system and the wrist flange appear in the form of a 2D graphical display with TCP and all tool points in "SafeMove Visualizer".



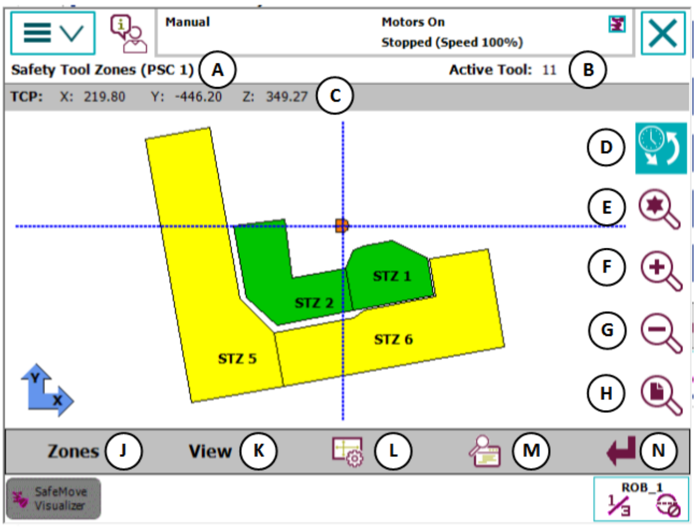
xx1400001319

The position of the robot can be updated manually or automatically so that you can see where the robot is in relation to the zones or which point has violated the safety range.

The view can be changed over in the XY, XZ and YZ planes in relation to the world coordinate system, meaning that you can view the robot position and the zones in all 3 dimensions.

Continues on next page

The graphical tool zones view



xx1400001320

	Parts	Description
A	Title	Name of safety controller
B	Active tools	Binary code of the tools ("00","01","10" or "11"). If a zone is violated, it is not the active tool that is displayed, but the tool that was active when the zone violation occurred.
C	Position display	TCP or tool point coordinates.
D	Update	The diagram is updated by tapping the button. Hold down the button, for at least 3 seconds, to activate automatic update.
E	Zoom TCP	The zoom level is adjusted so that the TCP is displayed in the middle of the diagram.
F	Zoom in	Zoom into the diagram.
G	Zoom out	Zoom out of the diagram.
H	Zoom all	The zoom level is adjusted so that all zones, the robot, and the track motion are visible.
J	Zone selection	Menu for displaying and hiding the zones.
K	View	Menu for changing the view level (e.g. XY, XZ and YZ).
L	Show graphical elements	Menu for displaying and hiding the following graphical elements: • Zone label • TCP and tool point label • Tool points • Grid lines • World coordinate system
M	Display details	Menu for displaying the zone parameters.
N	End	Menu for returning to the main menu.

Continues on next page

Tool zone status

The status of a tool zone is identified with the following colors in the graphical display:

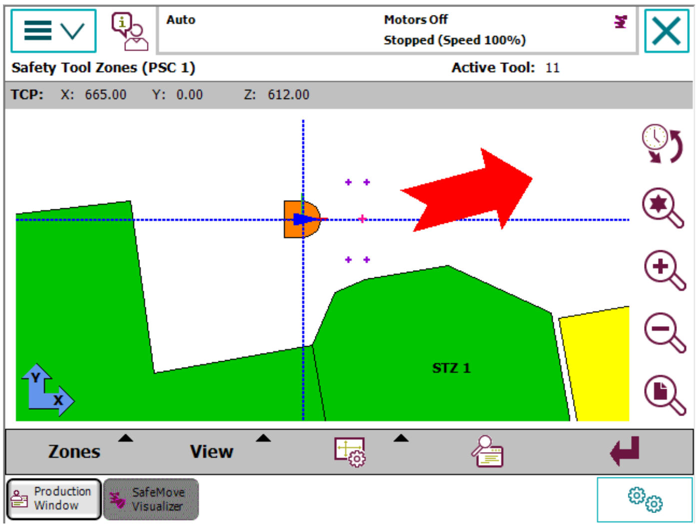
- Green - Tool zone is deactivated (only Safe Tool Zones)
- Yellow - Tool zone is active
- Red - Tool zone is active and violated

8.9.2 Navigating the graphical view

Moving the image detail

The visible image detail can be moved by tapping on the FlexPendant and then moving your finger.

As soon as you move your finger on the touch screen, a red arrow is displayed that shows the direction of movement and the length of which shows how far the graphic detail is going to be moved.



xx1400001321

Zoom

The size of the image detail can be increased and decreased by tapping the following buttons.

Function	Description
Zoom in  xx1400001322	Enlarging the image detail When the image detail is being enlarged, the visible area is always adjusted so that the graphical display is kept in the middle of the FlexPendant. For example, if you wish to enlarge a certain area, this must first be moved into the centre of the diagram before the zoom button is activated.
Zoom out  xx1400001323	Decreasing the size of the image detail When the picture detail is being decreased in size, the visible area is always adapted in such a way that the graphical display that is in the centre of the FlexPendant retains its position.
Zoom all  xx1400001324	Show entire graphical display If zones are displayed or hidden, the visible area is increased or decreased in size, i.e. if a zone is displayed that is outside the visible image detail, it is displayed when the button is activated.

Continues on next page

Function	Description
Zoom TCP  xx1400001325	Show TCP or tool position Tapping the button zooms in or out of the graphical display, meaning that the TCP always appears in the centre of the graphical display. If a tool position is the cause of a zone violation, the tool position is displayed in the middle of the diagram instead of the TCP.

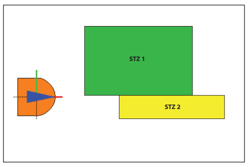
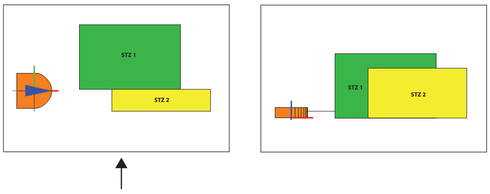
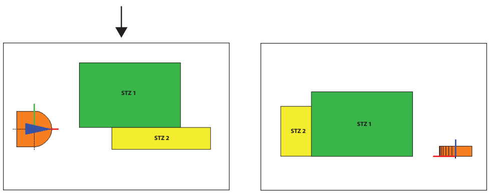
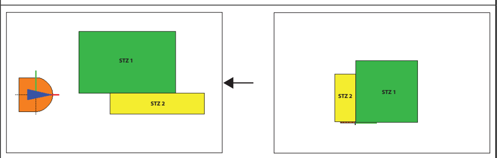
Changing the graphical display view

The graphical display view can be changed from the **View** menu, to view the graphical display from all sides.

The menu texts are changing according to selected rotating angle of the plan view (XY).

Note

The different side views refer to the plan view. For example, the left view shows a view as seen from the left when in the plan view, and does not refer to the left side of the Manipulator.

Diagram level	Menu selection (for XY-Rotation angle 0°)	Note/illustration
XY	Plan view	 xx1500000860
XZ	Front view	 xx1500000861
-XZ	Rear view	 xx1500000862
YZ	Side view from the right	 xx1500000864

Continues on next page

Diagram level	Menu selection (for XY-Rotation angle 0°)	Note/illustration
-YZ	Side view from the left	 xx1500000863

Display and hide zones

Each tool zone can be displayed and hidden individually using the **Zones** menu.

Furthermore, with the aid of the following menus, several zones can be displayed or hidden simultaneously.

- Display all zones
- Hide all zones
- Only display violated zones

Note

If a hidden zone is violated, it is displayed automatically.

Display and hide graphical elements

The following graphical elements or labels can be displayed or hidden using the **Show graphical elements** menu.

- Zone labels
- Tool position labels
- Tool points
- Grid lines
- World coordinate system

Depending on the selected zoom level, several graphical elements are not displayed and do not become visible until you zoom into the graphical display.

Rotating the plan view (XY)

Compared to where the FlexPendant is located at the robot cell the graphic may be displayed in the wrong orientation. That is the case if the world coordinate system of the robot and the FlexPendant do not have the same alignment.

To avoid the rotating of the FlexPendant the plan view can be rotated in 90° steps.

The rotating angle can be changed by using the sub menu **Rotation angle of the XY-view** from the **Show graphical elements** menu. The currently used rotating angle is indicated directly in the menu text. A dialog appears and the desired angle of rotation can be selected.

The graphic will be updated immediately when an angle is selected. Close the dialog by tapping the confirm button.

Continues on next page

Updating the graphical display

The diagram is updated if

- a tool is changed.
- the activation status of a zone changes.
- a zone is violated.
- the update button is tapped.
- automatic updating has been activated.

Activating automatic update

Automatic update is activated if the **Update** button is pressed for at least 3 seconds.

As soon as activation has taken place a message appears and the button can be released.

The following options are available:

 Manual update

 Automatic update active (every second)

 Automatic update inactive (when in motors off state)

Deactivating automatic update

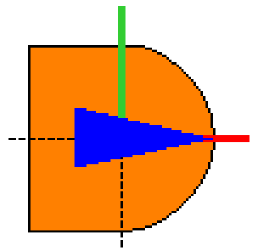
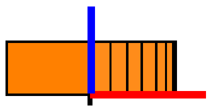
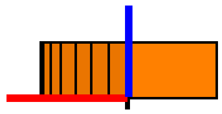
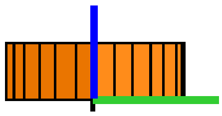
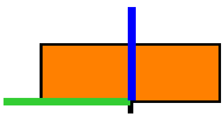
Automatic update is deactivated if:

- the operating mode of the robot is changed.
- 5 minutes has elapsed since activation.
- the activated **Update** button is pressed again.

8.9.3 Graphical elements

Base of the robot

The base of the robot is represented in the graphical display as follows:

View	Description
 xx1400001330	Plan view The blue triangle represents the direction of the first axis of the robot.
 xx1400001331	Side view from the left The vertical lines on the right hand side represent the curve (front) of the base of the robot.
 xx1400001332	Side view from the right
 xx1400001333	Front view
 xx1400001334	Rear view

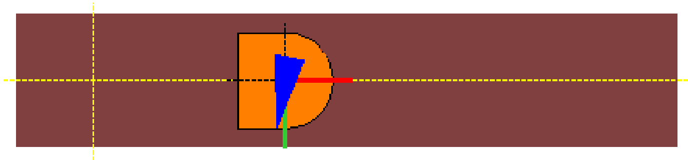
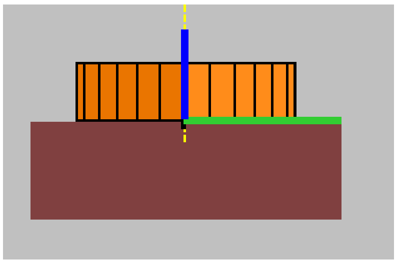
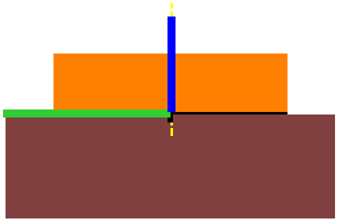
The directions of the base coordinate system of the robot are displayed as lines in the colors:

- Red (X-axis)
- Green (Y-axis)
- Blue (Z-axis)

Continues on next page

Track motion

If a track motion is used, it is displayed in the graphical display as follows:

View	Description
 xx1400001335	Plan view
 xx1400001336	Side view from the left
 xx1400001337	Side view from the right
 xx1400001338	Front view
 xx1400001339	Rear view

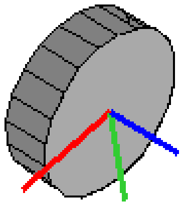
The base of the robot is moved along the travel axis.

Wrist flange, TCP, and tool points

The directions of the tool coordinate system are shown on the wrist flange with lines in the following colors:

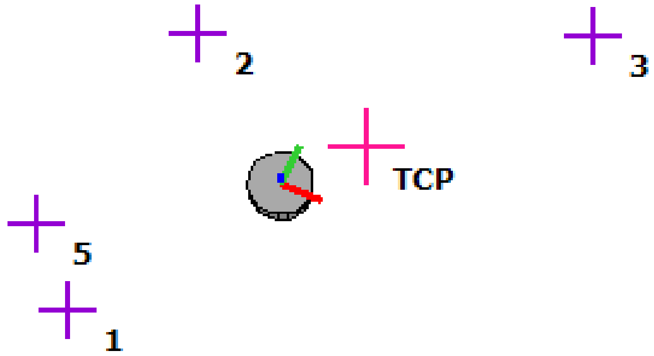
- Red (X-axis)
- Green (Y-axis)
- Blue (Z-axis)

Continues on next page



xx1400001340

The tool points are displayed as violet crosses, and the TCP as a magenta colored cross.



xx1400001341

Tool zones

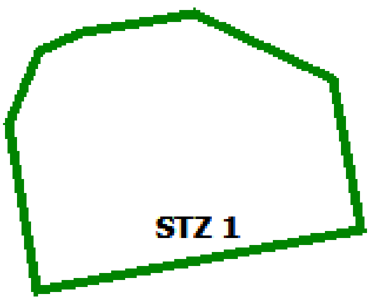
Tool zones can be defined in such a way that the robot must be located inside or outside the zone.

The status of a tool zone is identified in the graphical display in the following colors:

- Green - Tool zone is deactivated (only Safe Tool Zones).
- Yellow - Tool zone is active.
- Red - Tool zone is active and violated.

Zones permitted inside

In the graphical display, interior approved zones are represented as polygons without filling in the color of the zone status. The robot must be located inside the zone with this zone type.



xx1400001342

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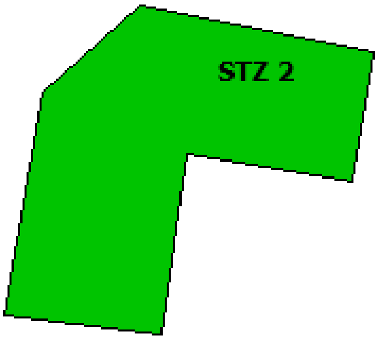
Zones permitted outside

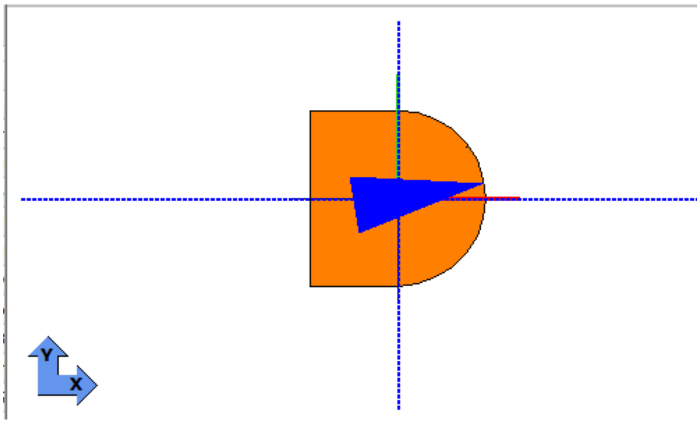
Zones approved outside are represented as filled-in polygons in the color of the zone status. The robot must be located outside the zone with this zone type.



xx1400001343

World coordinate system

The world coordinate system is displayed as a blue dotted line in the graphical display. All positions in the graphical display are displayed in relation to the world coordinate system.



xx1400001344

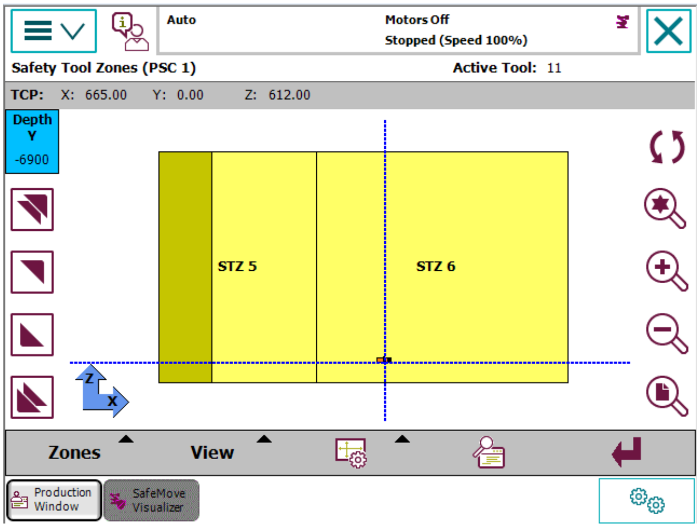
The two arrows at the bottom left of the graphical display specify the positive directions of the world coordinate axes.

8.9.4 Depth change in the side view of the graphical display

Overview of the side view

In the side view you examine the zones from the outside and cannot see where the robot is within the zones, as shown in the following figure.

Since inactive zones (green) can cover active zones (yellow) depending on their position, the inactive zones are drawn first and the active zones are drawn over them, even if they should be behind the inactive zones.



xx1400001345

You can move from front to back through the graphical display (depth change) along the third axis (e.g. "Y") using the buttons on the left-hand side of the graphical display.

Depending on the position of the coordinate system, the positive area is at the front (e.g. XZ) or the back (e.g. -XZ).

Depth change buttons

 Change depth by 1000 mm towards the rear.

 Change depth by 100 mm towards the rear.

 Change depth by 100 mm towards the front.

 Change depth by 1000 mm towards the front.

Continues on next page

Depth information

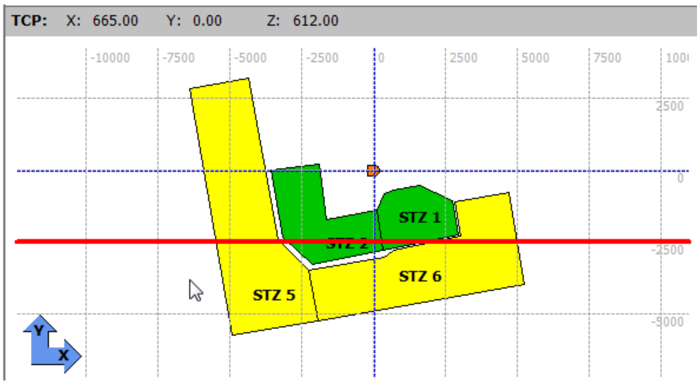
The depth that has been adjusted using the arrow buttons is displayed in the information box above the buttons in millimeters.

The blue filling also indicates the visible area of the graphical display. If the information box is completely blue, you are in front of the robot cell and are looking at the robot and the zones.

If the box is completely white, you have reached the end of the robot cell and all zones and the robot are behind you.

Example

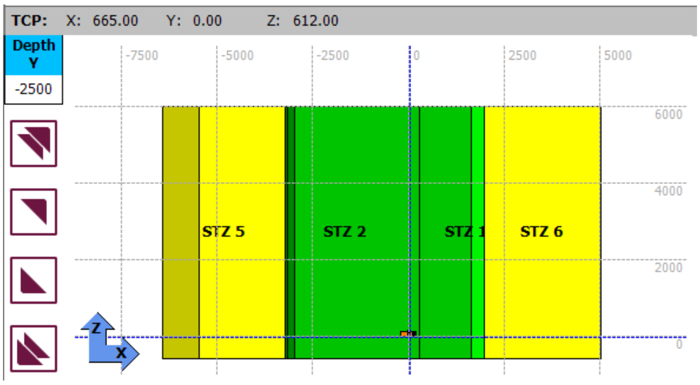
Basically, imagining that you cut off the graphical display at the selected depth and then look at the zones and the robot from the side gives you an idea of the depth change.



xx1400001350

For example, the diagram has been cut on the Y-axis at position -2500mm (red line).

You then look in the direction of the positive Y-axis in the XZ plane and only see the part of the graphical display that is behind the red line:

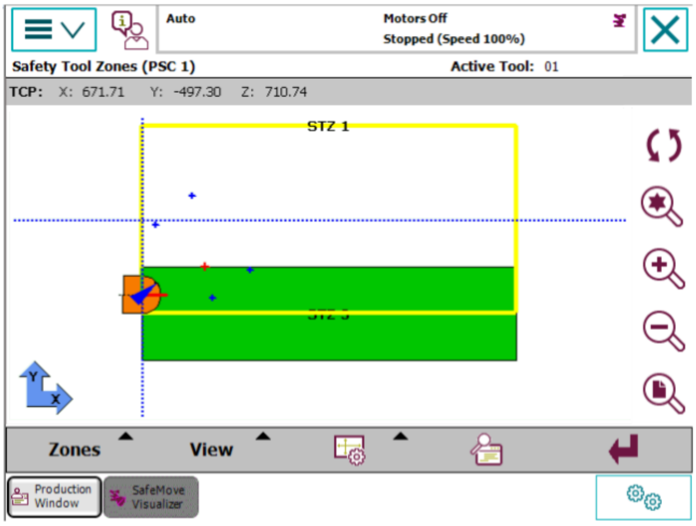


xx1400001352

8.9.5 Zone violation

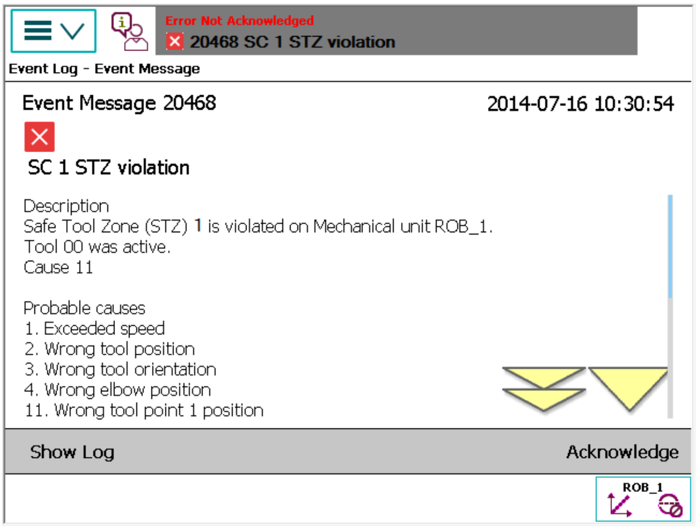
Violation in a safe tool zone

All inactive and active tool zones appear in the graphical display and are updated automatically if necessary.



xx1400001353

If the TCP of the robot or a tool point leaves the area of an active safe tool zone, the safety controller stops the robot with event message 20468.

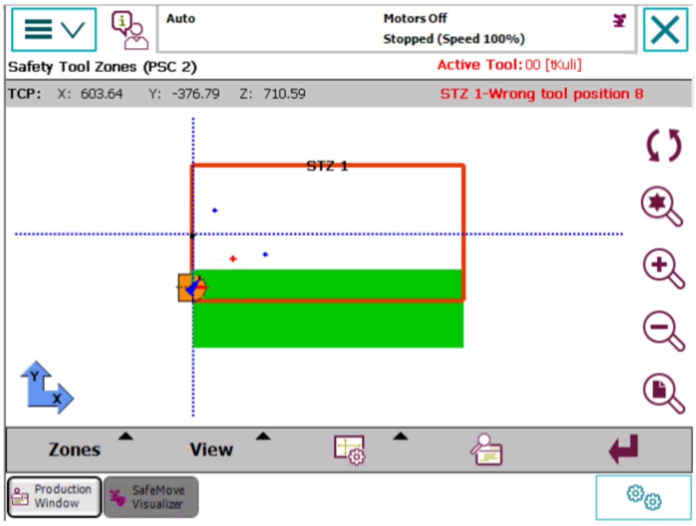


xx1400001354

The violated zone now appears on the graphical display in red, and if it was previously hidden it is now automatically displayed. The cause of the zone violation

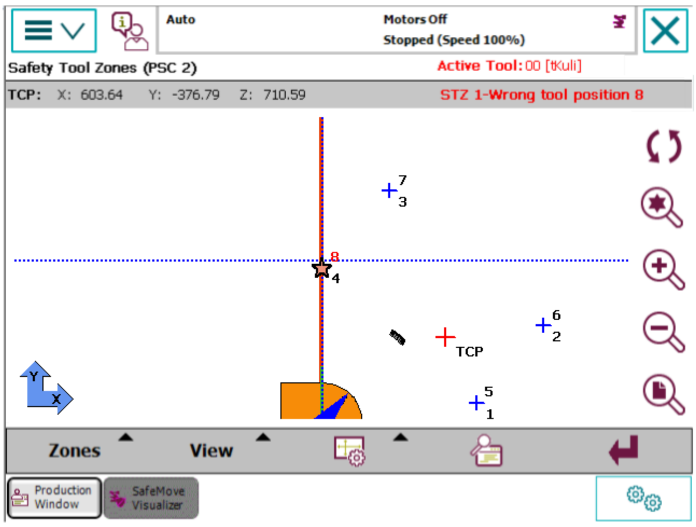
Continues on next page

and the tool that is being used are also displayed above the graphical display in red.



xx1400001355

Tapping on the **Zoom TCP** button zooms into the tool point or the TCP that caused the zone violation.



xx1400001356

The zone violation is marked by a star in the tool position and a red tool point number.

Note

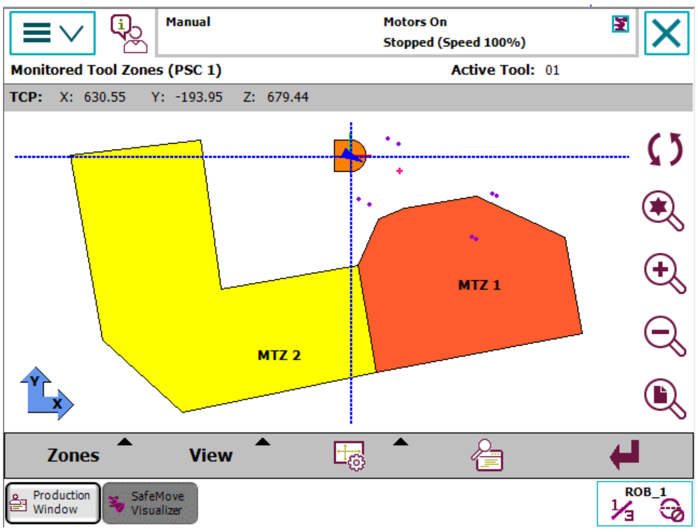
If the tool is switched over during a zone violation, it is ignored until the zone violation has been remedied again.

Continues on next page

Violation in a Monitor Tool Zone

If a monitor tool zone is violated, this is signalled by the safety controller via the assigned safety output.

- The zone is displayed in red.
- The program is not stopped by the safety controller.
- No event message is output.
- No evaluation takes place as to whether the TCP or a tool point has violated the zone.



xx1400001357

In order to ascertain whether the TCP or a tool point has violated the zone, the robot program must be stopped and the TCP zoomed to by tapping the **Zoom TCP** button. Then the cause of the zone violation must be determined visually by checking whether the TCP or a tool point is in the vicinity of the zone limit.

8.9.6 Zone data

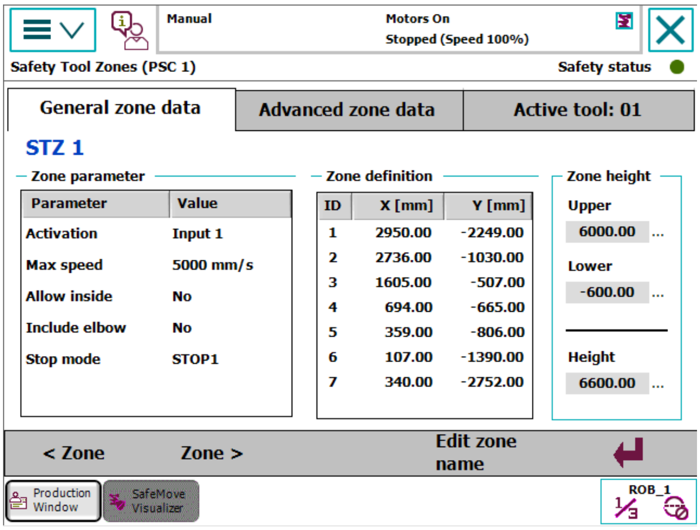
Zone data tabs

The parameters for the individual zones are displayed in two tabs in the zone detail display, and those for the active tool in a third tab.

You can switch between existing zones using the menu buttons "< Zone" and "Zone >".

General zone data

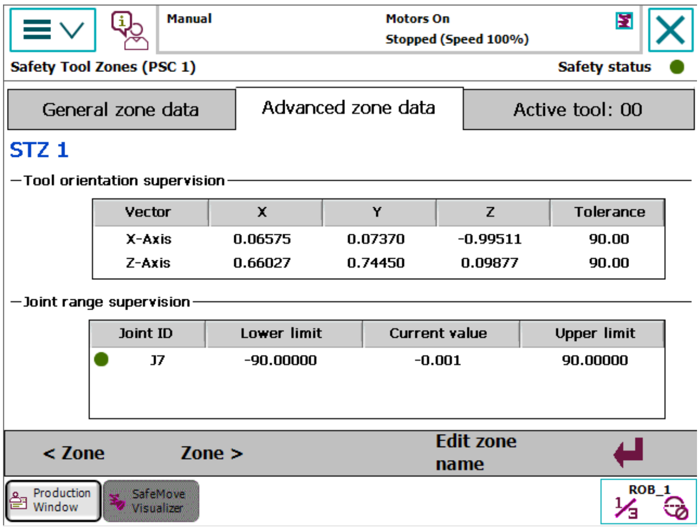
Zone activation, the zone points, the zone height and other zone data is displayed in the tab.



xx1400001358

Advanced zone data

The monitoring of the tool orientation, the axis area limits and the current position of axes 7-9 are displayed in the advanced zone data display.



xx1400001359

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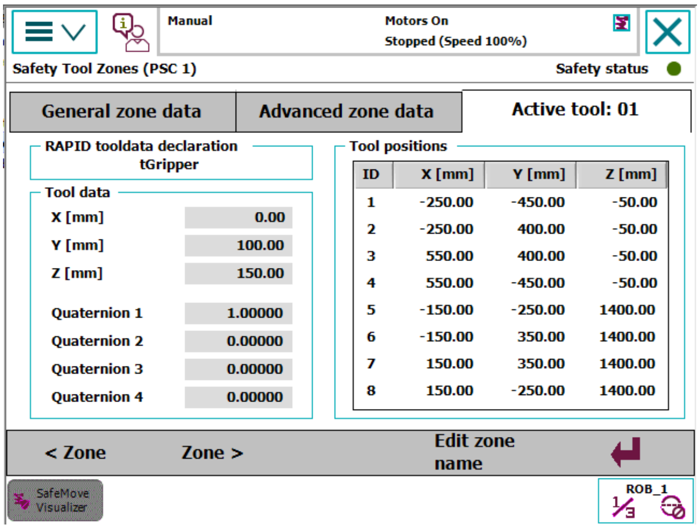
The LED in front of each axis range is green if the axis is within the selected limits, and red if the limits have been exceeded.

Active tool

The data for the active tool are displayed in the third tab page. If a tool zone violation is present, the tool that violated the zone is displayed, not the active tool.



xx1400001360

Display of zone safety status

The safety status of the displayed tool zone is indicated by an LED in the top right-hand corner with the following colors:

- Green LED - Monitoring is inactive
- Yellow LED - Monitoring is active
- Red LED - Zone is violated

8.9.7 Zone description

General

An additional text describing the function of the zone can be defined for each zone (e.g. injection moulding machine or IMM).

This description is also displayed in the graphical display in addition to the zone text.

Tapping on the menu button **Edit zone name** opens an alphanumeric input panel in which the description text can be entered.

The description texts of the zones are saved in the robot's home directory under *HOME:SafetyVisu* in a safety controller-related file (e.g. *psc_zones_1.xml* for safety controller PSC1).

XML data format

The descriptions for tool zones STZ and MTZ are saved in an XML file with the following format:

- The version of the SafeMove Visualizer and the date of saving are shown in the header.
- The rotation angle of the plan view and the activation flag for the serial number verification is located in the “settings” element.
- This is followed by the zone description for monitoring (MTZ) and supervision (STZ).

Each description is saved together with the zone number that was used in the safety configuration.

- MTZ1:
  ```
  <MTZ ZoneID="1" Description="Machine 1" />
  ```

Example

```
<?xml version="1.0" encoding="utf-16"?>
<!--SafeMove visualizer V1.0-->
<!--Tool zone descriptions-->
<ToolZones Date="Thursday, 10. May 2012">
  <SETTINGS CheckSerialNo="false" ViewXYrot="0" />
  <Monitoring>
    <MTZ ZoneID="1" Description="Maschine 1" />
    <MTZ ZoneID="2" Description="" />
  </Monitoring>
  <Supervision>
    <STZ ZoneID="1" Description="Maschine 2" />
    <STZ ZoneID="2" Description="" />
  </Supervision>
</ToolZones>
```

8.10 Axis range

8.10.1 Displaying the axis ranges

Description

All axes that are defined in an axis range group are visualized on the FlexPendant.

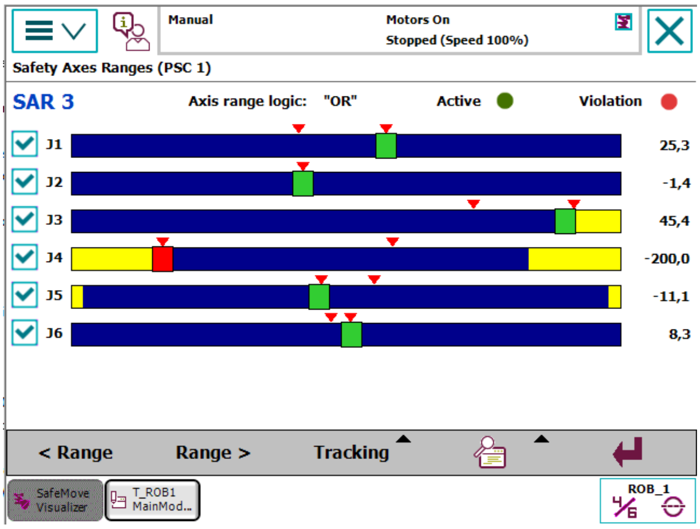
Axes 1 - 6 are always displayed, whereby non-configured axes are greyed out. Axes 7 - 9 are displayed if needed.

The permitted range of an axis is displayed in blue and the prohibited range in yellow. The current position of the axis is represented by a rectangle (pointer) and as text next to the axis range.

If axis range monitoring is active, the pointer is displayed in green if the axis is within the permitted range. If the axis has left this range the pointer is displayed in red.

If axis range monitoring is inactive, the pointer is displayed in grey.

Each configured axis can be deactivated for the display via the check box to the left of the axis range. However, deactivation does not affect the monitoring function and the recording of the axis ranges that are used.



xx1400001361

The following options are available from the menu buttons:

- Display previous axis range group
- Display next axis range group
- Record the used axis range limits
- Detailed view
- Close window

8.10.2 Safe Axis Range activation

Description

Safe Axis Range is either permanent or activated via a safe input. Activation is indicated via a LED at the top edge of the window with the following colors:

- Grey - Axis range supervision is inactive
- Green - Axis range supervision is active

Note

Monitor Axis Ranges are always active and therefore have no activation LED.

8.10.3 Exceeding the axis range limits

Safe Axis Range

If an axis leaves the defined range of a *Safe Axis Range*, the safety controller triggers a stop and displays an appropriate event message.

The violation of the axis range is indicated via the virtual signal *SAR*, which is displayed as an LED at the top edge of the window with the following colors:

- Grey - Axis range supervision is not activated.
- Green - All axes of the displayed axis range are inside the defined ranges.
- Red - At least one axis has exceeded the limits of the displayed axis range.

Monitor Axis Range

If an axis leaves the defined range of a *Monitor Axis Range*, the defined safety output is set to "0". This output is displayed as a LED at the top edge of the window with the following colors:

- Green - All axes are inside the displayed axis range.
- Red - At least one axis has exceeded the limits of the displayed axis range.

8.10.4 Axis range logic

Description

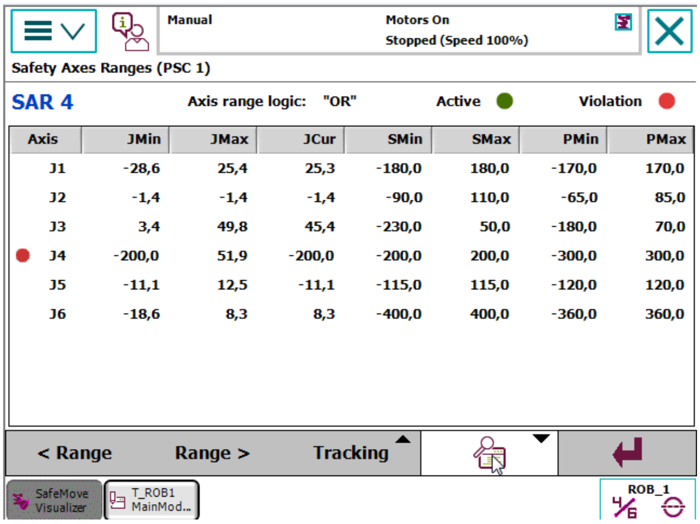
Axis ranges can be defined as allowed inside or allowed outside. If an axis range is allowed inside, a violation occur if only one axis is outside the defined range (OR-logic).

If an axis range is allowed outside, each range for an axis is shown inverted (means yellow and blue color is exchanged). A violation occurs if all axes are outside the defined range (AND-logic).

8.10.5 Tabular display of the axis ranges

Overview of the tabular display

By tapping the **Display details** menu, the display is switched between the graphical and the tabular display.



xx1400001362

> **Note**
>
> If an axis exceeds the selected limit, a red LED will be displayed in the table next to the axis number.

Data

The following data of the configured axes is displayed in the table:

Column	Description
Axis	Axis 1 to 9.
JMin	Minimum axis value that was moved to during robot movement.
JMax	Maximum axis value that was moved to during robot movement.
JCur	Current axis value.
SMin	Lower limit that was set in the safety configuration.
SMax	Upper limit that was set in the safety configuration.
PMin	Lower axis limit from the system parameters of the robot controller.
PMax	Upper axis limit from the system parameters of the robot controller.

> **Note**
>
> If you tap a table column in the window header, the description of the column is displayed. If you press the button again the help will disappear.

8.10.6 Recording the used axis range limits

Description

In order to check or optimize the selected axis range limits, it may be useful to record the axis limits that have actually been used.

This takes place using the logging functionality, using drag pointers (red triangles) which track the axis position and mark the minimum and maximum values that have been used.

In order to log the axis limits, the following settings and functions can be used:

- Reset axis limits
- Save recorded axis limits
- Show or hide drag pointer
- Switch logging on/off

Resetting the axis limits

The logged axis limits for the displayed axis range group can be deleted by tapping on **Tracking** and then selecting **Reset values**.

When this occurs, the minimum value is set to the upper limit and the maximum value to the lower limit of the axis.

The limits may need to be reset if, for example, the axis limits are to be re-determined.

Display/ hide drag pointers

The drag pointers can be hidden or displayed if necessary.

Note

The drag pointers are always displayed when the page is opened.

Switch logging on/off

The logging of the axis limits can be switched on or off if required, and is only active for as long as this page is open and visible.

If you switch to a different application (e.g. the production window), the recording of the limits is interrupted and continues as soon as the *SafeMove Visualizer* application is displayed again.

Only the axis limits of active axis range groups are recorded, which also occurs if they are not currently being displayed.

Note

Logging is switched off when the page is opened.

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Save recorded axis limits

The axis limits for all axis range groups can be saved in a safety control-related file (e.g. *psc_axisranges_1.xml* for the safety controller PSC1) in directory *HOME:SafetyVisu*.

However, it is also possible to save the axis limits in any other file using the file dialogue.

Note

The saved axis limits in files *HOME:SafetyVisu/psc_axisranges_n.xml* are loaded when the application starts and displayed as limits.

8.10.7 Format of XML file for axis ranges

Description

The data for limits for the axis ranges are saved together in an XML file with the following format:

- The version of the SafeMove Visualizer and the date of saving are stored in the header.
- All MAR data limits are saved in the MARS section.
- All SAR data limits are saved in the SARS section.
- Each axis group is saved with the number that was used in the safety configuration. For example, MAR1: `<MAR Range-ID="1">`
- The axis number and the logged minimum and maximum value are specified for each configured axis. For example, axis 1:

  `<Joint JointID="1" JMin="0.028" JMax="97.344" />`

Example

```
<?xml version="1.0" encoding="utf-16"?>
<!--SafeMove visualizer V1.0-->
<!--Tracking value for axis range supervision-->
<!---->
<JointRangeTracking Date="Friday, 11. May 2014">
  <MARS>
    <MAR RangeID="1">
      <Joint JointID="1" JMin="0.028" JMax="97.344" />
      <Joint JointID="2" JMin="5.357" JMax="63.950" />
      <Joint JointID="3" JMin="-21.751" JMax="-21.722" />
      <Joint JointID="4" JMin="-0.003" JMax="0.001" />
      <Joint JointID="6" JMin="22.947" JMax="22.950" />
      <Joint JointID="7" JMin="0.000" JMax="0.000" />
    </MAR>
  </MARS>
  <SARS>
    <SAR RangeID="1">
      <Joint JointID="1" JMin="170.000" JMax="-170.000" />
      <Joint JointID="2" JMin="85.000" JMax="-65.000" />
      <Joint JointID="3" JMin="70.000" JMax="-180.000" />
      <Joint JointID="4" JMin="300.000" JMax="-300.000" />
      <Joint JointID="6" JMin="360.000" JMax="-360.000" />
    </SAR>
      <SAR RangeID="2">
      <Joint JointID="1" JMin="0.028" JMax="97.344" />
      <Joint JointID="2" JMin="5.357" JMax="63.950" />
      <Joint JointID="6" JMin="22.947" JMax="22.950" />
    </SAR>
  </SARS>
</JointRangeTracking>
```

9 Example applications

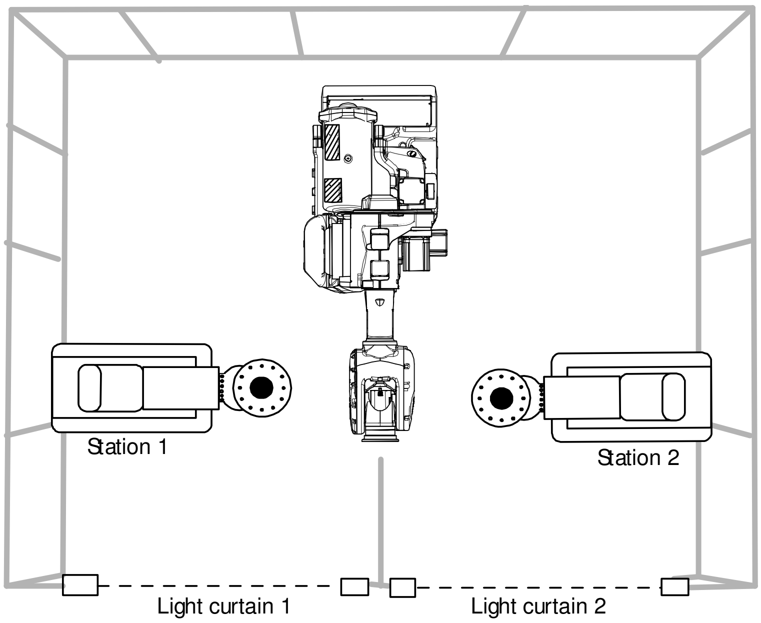
9.1 Safe Axis Range

9.1.1 Example with two work zones and light curtains

Assignment

A robot cell consists of one robot and two positioners. The robot should be able to work on a work piece held by one positioner while an operator change work piece held by the other positioner.

There are two light curtains protecting that no personnel enters the station where the robot is working.



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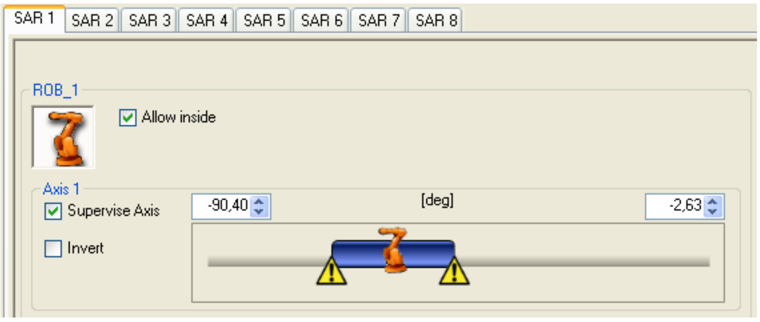
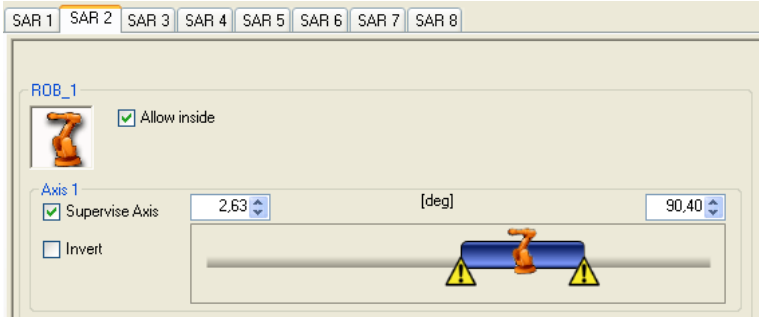
Configure Safe Axis Range

To implement the safety solution, two Safe Axis Range (SAR) functions must be configured. SAR1 should only allow the robot to be at station 1. SAR2 should only allow the robot to be at station 2.

The following picture illustrates how these two functions are configured for robot axis 1 in the SafeMove Configurator.

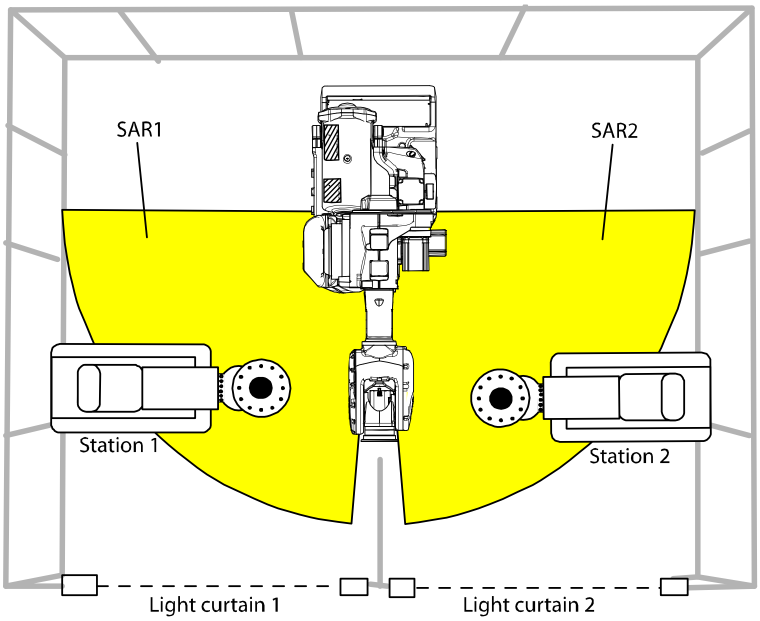


en0700000702



en0700000703

The following picture shows the angles for robot axis 1 where the SAR1 and SAR2 functions are shown with yellow where the robot is allowed to be.



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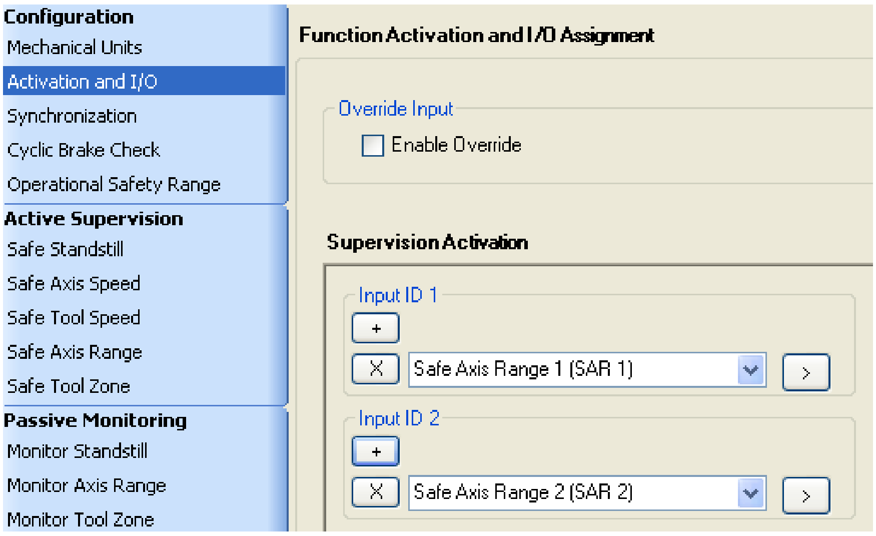
Configure activation input signals

Configure the SAR1 function to be activated by the activation input signal 1, and SAR2 to be activated by input signal 2.



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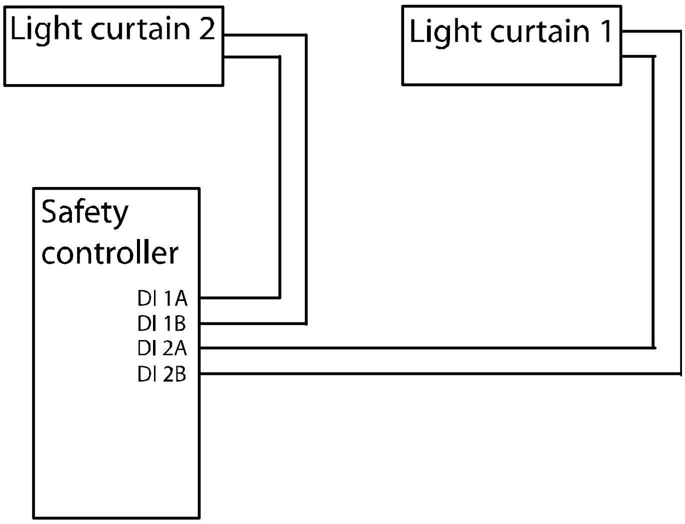
Connect the signals

Connect the output signals from the light curtains to the input signals of the safety controller. If light curtain 1 is broken, then SAR2 must be active (robot must be at station 2 when operator is at station 1). If light curtain 2 is broken, then SAR1 must be active (robot must be at station 1 when operator is at station 2).



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10 Safety aspects for SafeMove

10.1 Overview

Overview

SafeMove is an additional safety computer in the IRC5 robot controller, with the purpose of providing safety functionality for the robot. Safe output and input signals are typically connected to cell safety circuitry and/or a safety PLC which takes care of interlocking in the robot cell, for example, in order to prevent robot and operator to enter a common area simultaneously.

In this chapter we describe how SafeMove comply with relevant safety standards and regulations.

10.2 Standards conformance

Standards

SafeMove has been designed to fulfill applicable parts of the following standards.

- EN ISO 12100:2010 Safety of machinery - General principles for design - Risk assessment and risk reduction
- EN 60204-1:2006/A1:2009 Safety of machinery - Electrical equipment of machines - Part 1: General requirements
- EN ISO 10218-1:2011, Robots for industrial environments - Safety requirements - Part 1: Robot
- EN 61000-6-2:2005 EMC, Generic immunity
- EN 61000-6-4:2007/A1:2011 EMC, Generic emission
- EN ISO 13849-1:2008 Safety of machinery - Electrical equipment of machines - Part 1: General requirements

10.3 Specific safety requirements

Specific safety requirements for SafeMove

SafeMove complies with EN ISO 10218-1 in general and specifically complies with chapter 5.4.2, that is, the following requirements.

When safety related control systems are required, the safety related parts shall be designed so that:

- A single fault in any of these parts shall not lead to the loss of the safety function.
- Whenever reasonably practicable, the single fault shall be detected at or before the next demand upon the safety function.
- When the single fault occurs, the safety function is always performed and a safe state shall be maintained until the detected fault is corrected.
- All reasonably foreseeable faults shall be detected.

This requirement is considered to be equivalent to structure category 3 as described in ISO 13849-1. Category 3 is normally fulfilled by redundant circuits, such as dual channels, which is the case for SafeMove. SafeMove together with the robot controller also complies with performance level (PL) "d" according to ISO 13849-1. This safety level is equivalent to SIL 2 as defined in IEC 61508.

10.4 Safe design of SafeMove

Overview

SafeMove has two important types of supervision functionality.

The first one being to ensure that the axis computer and the drive system are working correctly, making the robot follow the ordered value from the main computer as expected.

The second being to supervise the robot position and speed and stopping the robot or setting output signals to indicate a hazard.

Supervision of axis computer and drive system

SafeMove is a separate and from the IRC5 independent device mounted in the drive part, close to the axis computer.

The SafeMove board is connected to the communication link between the main computer and the axis computer, thus reading the absolute motor position values sent as reference to the axis computer. The SafeMove board is also connected to the communication link between the Serial Measurement Board (SMB) and the axis computer, and thereby reading the actual rotational motor position values. Since these values are within one revolution, the absolute position is calculated by adding values from internal revolution counters in both the axis computer and in SafeMove.

By comparing these values, that is the ordered motor position and the actual motor position, SafeMove can detect any difference (outside a permitted lag deviation) between the two positions, thereby ensuring that the drive system is working properly according to the first supervision function as described above.

It is important to ensure that the safety controller and the robot controller are synchronized. The safe sync position is defined during configuration and stored in the safety controller. Synchronization can be done by activation of a switch or by software depending on the application.

To detect such errors, the robot can be ordered to go regularly to a synchronization switch, which will generate a synchronization pulse to SafeMove confirming that the robot revolution counter is correct. In some applications it is more feasible to do the synchronization check by software.

In this position SafeMove will also calculate the robot joint positions and check against a stored value to confirm that the synchronization is correct, covering the following points.

- SafeMove is working correctly with the right revolution counter value.
- The right manipulator is used.
- The calibration value is correct.
- The SMB is working correctly.

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Category 3 supervision

The supervision complies with category 3, that is, two separate channels shall always give the same result. One channel consists of the axis computer with the drive system, motors, resolvers, and measurement system. The second channel consists of the ordered value from the main computer. These channels are compared using the SafeMove evaluation circuits, which in itself is dual channel, see illustration below.

Additional safety design

Additional safety, over and above what is formally required, is brought to the concept by the inherent dual channel character of the resolver, thanks to its dual sine and cosine output, where the square sum is supervised to be close to 1.

Also the single channel synchronization check is complying with category 3, even if only one synch signal channel is used. The two channel requirement is in this case fulfilled in two ways:

1. Check that the input signal is changing its value, that is has a flank, indicating that the switch is working.
2. The double check of both receiving a physical synch pulse and the check that the actual robot position corresponds to the stored value for the sync position.

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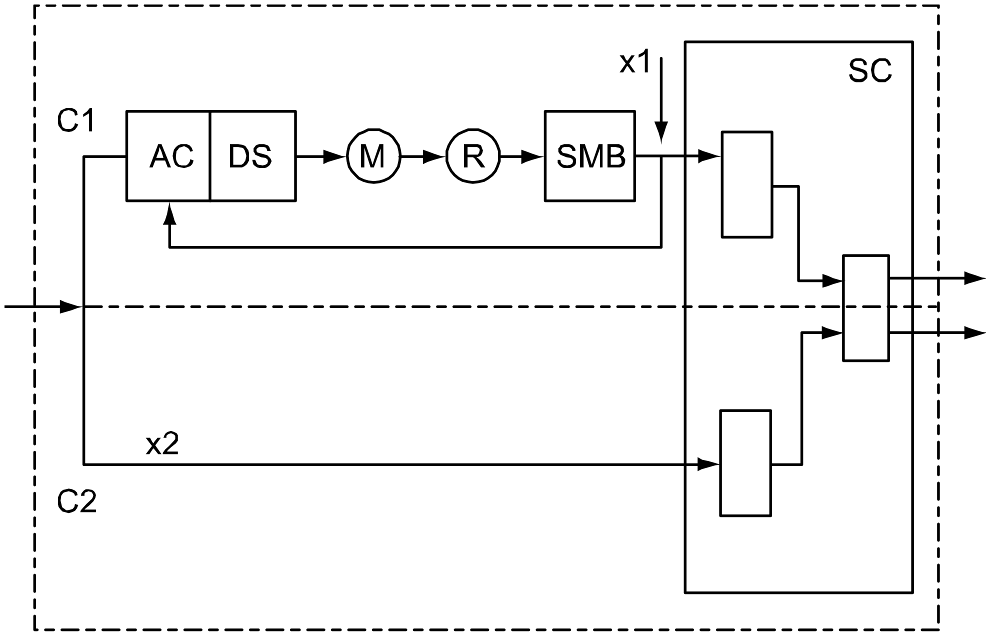
Illustration, dual channel concept



xx0800000198

C1	Channel 1
C2	Channel 2
x1	Actual value
x2	Ordered value
AC	Axis computer
DS	Drive system
M	Motor
R	Resolver
SMB	Serial measurement board
SC	Safety controller (SafeMove board)

Supervision of robot position and speed

The second type of supervision functionality (to supervise the robot position and speed) is fulfilled by letting SafeMove compare the robot position and speed with limit values configured by an authorized user (so called Safety User). If any value is outside its defined safe area, the supervision functions will stop the robot (or the monitoring functions will set an output signal low).

To ensure that also this supervision complies with the category 3 requirement, SafeMove is inside working with a two channel microprocessor based system, where one channel is handling the actual position and the other the ordered position. The input signals to SafeMove and the output signals from SafeMove are also each consisting of two channels, thus preserving the category 3 requirement.

10.5 Certifications

Overview

SafeMove has been certified by external organizations as described below.

BGIA concept certification

Berufsgenossenschaftliche Institut für Arbeitsschutz in Germany made a concept certification with the following result.

The concept of SafeMove complies with:

- SIL 3 according to EN 61508
- Cat. 4 and PL e according to EN ISO 13849-1:2008

Note

SafeMove as a part of the IRC5 controller is category 3 and PL d, even though the unit itself fulfills category 4 and PL e.

UL certification

SafeMove is approved by UL according to the following standards:

- UL 1740
- UL 1998
- ANSI / RIA R15.06
- CAN / CSA Z434-03
- ANSI / RIA 10218-1:2007 (which is the US harmonized ISO 10218-1:2006)

Note

Since ISO 10218-1:2006 thus is harmonized in EU as well as in North Americas, the UL certification clearly shows that SafeMove fulfills the EU Machinery Directive. In addition to this and since ISO 10218-1 refers to ISO 13849-1:1999 as a normative reference, it is also shown that SafeMove complies with the category 3 requirements.

SafeMove is also assessed to be compliant with updated versions of standards (see *Standards conformance on page 204*) and thus fulfills the current version of the EU Machinery Directive.

10.6 Conclusion

Conclusion

As has been shown above and confirmed by third party certifications, SafeMove fulfills all relevant current safety standards globally.

A Configuring brake data - with ABB robots and ABB tracks

About the brake data parameters

For a mechanical unit, such as a track, the brake ramp supervision always uses the fixed brake data parameters *Ramp Delay*, *Start Speed Offset*, and *Brake Ramp Limit* from the SafeMove configuration to setup the brake ramp supervision level (see the following illustration). In order not to get false alarms from the brake ramp supervision when using ABB robots and tracks, the parameters have a default conservative setting. Conservative means that the ramp should represent the worst case brake performance achieved by the track in combination with robot motion[1]. This section explains the available supervision parameters in detail, based upon the section *Additional axis configuration on page 81*, with additional information regarding the application to robot and track.

In the following illustration the parameters that define the brake ramp supervision level in SafeMove are illustrated. The *Ramp Delay* (ms) specifies the delay until the supervision should start after a category 1 stop is initiated. The *Start Speed Offset* (mm/s) gives an offset to the supervision level, in reference to the actual speed when the stop was triggered. The *Brake Ramp Limit* (mm/s^2) directly affects the slope of the brake supervision level curve illustrated. *Start Speed Offset* together with *Brake Ramp Limit* can be used to tune the supervision level such that it is safe and also conservative and robust to the working condition of the robot and track.

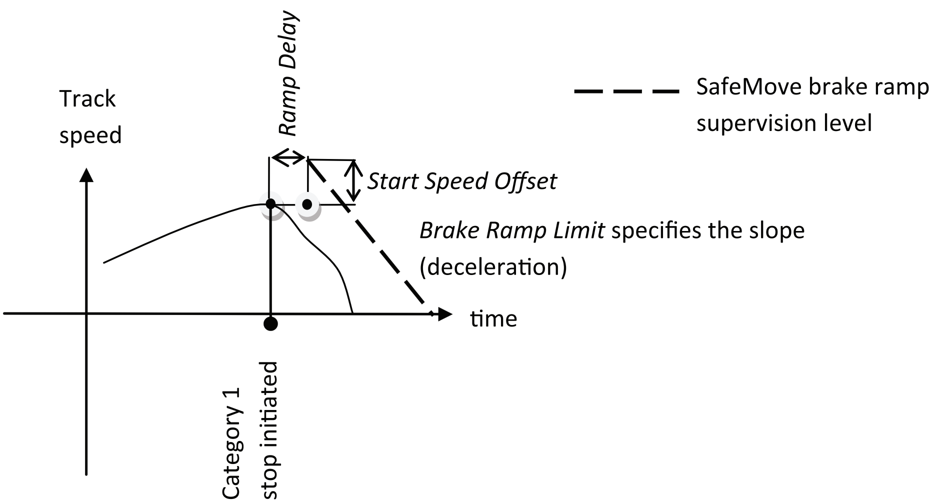


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Figure A.1: Illustration of the brake data parameters used to specify the brake ramp supervision level in SafeMove.

How to tune the parameters

1 In practice the worst case performance depends on the cross-coupling between the dynamics of the robot and the track. ABB uses a complete dynamic model of the robot and track when doing the trajectory planning, also in case of Category 1 stop. The default parameters are therefore chosen to be very conservative. If the braking distance with the default parameters is considered too conservative it is recommended to consider tuning the parameters *Start Speed Offset* and *Brake Ramp Limit*.

Continues on next page

The default values of the brake parameters in SafeMove are conservative and should work in all working conditions (maximum load, fully extended robot and maximum interaction torque from robot to track, etc), and for all combinations of robots and tracks from ABB[2]. In a work condition where, for example, the robot is not moved while track is moving or a small load is attached to robot, it is possible to make adjustments to the brake parameters to make the supervision less conservative. In the tuning of the parameters the safety concern (actual maximum brake distance and brake time given by the SafeMove supervision) should be considered together with the robustness concern given below. The parameters should be chosen such that, at normal operation, the supervision is not triggered. Triggering the supervision will make the stop change from type 1 to type 0 and this will decrease the life-time of the robot and the track (as well as additional application equipment on the robot) since very high load will be applied to the structure when the mechanical brakes are applied.

Safety concern

With the supervision concept used in SafeMove it is possible to compute the worst case brake distance, and the corresponding brake time, which can be acceptable without triggering the brake ramp supervision. Given the speed of the track the distance is computed as:

$$brakeDistanceLimit = rampDelay*trackSpeed + (trackSpeed + StartSpeedOffset)^2 / (2*BrakeRampLimit)$$

and the time:

$$brakeTimeLimit = rampDelay + (trackSpeed + StartSpeedOffset) / BrakeRampLimit$$

brakeTimeLimit is the maximum time it can take to stop the track given the track speed and the parameters in SafeMove brake ramp supervision. All values should be transformed into SI-units before making the computation above (speed should be positive and in m/s, time in seconds, and acceleration positive and m/s^2).

If the *brakeDistanceLimit* and stop time *brakeTimeLimit* are acceptable there is no reason to tune the parameters.

Robustness

If the SafeMove brake ramp supervision is triggered for the track, or the safety concern indicates that the *brakeDistanceLimit* and/or the stop time *brakeTimeLimit* are too large, then take the following actions to verify and possibly tune the parameters:

1. Check that the load of the robot and additional load on the track are included in the tool definition in the Rapid program and in the configuration (see *Technical reference manual - System parameters*, section *How to define arm loads*). With the wrong load specification the stop will not be optimal. If the wrong load was used, test the stop again to see if the brake parameters in SafeMove still have to be adjusted.
2. If brake supervision is triggered decrease the *Brake Ramp Limit* and increase the *Start Speed Offset* by a factor two, not to trigger the brake supervision while doing the tuning experiment described below. After the new robust

2 If the parameters relate to an additional axis not delivered by ABB, the parameters will have to be adjusted and this is explained in *Additional axis configuration on page 81*, how the parameters can be computed from tuning data in the MOC.cfg file.

Continues on next page

parameters are found update the SafeMove configuration with the new parameters.

a Use TuneMaster and the test signal number 6 (Speed) and signal number 67 (Category 1 stop). To get the speed in m/s, scale the speed by a factor 0.0055 for tracks T4004, T6004, and T7004 and 0.0034 for RTT.

b Log the two signals in TuneMaster while the track is moving and trig a category 1 stop. The result is shown in the following illustration where the resulting supervision level using the default parameters is also illustrated.

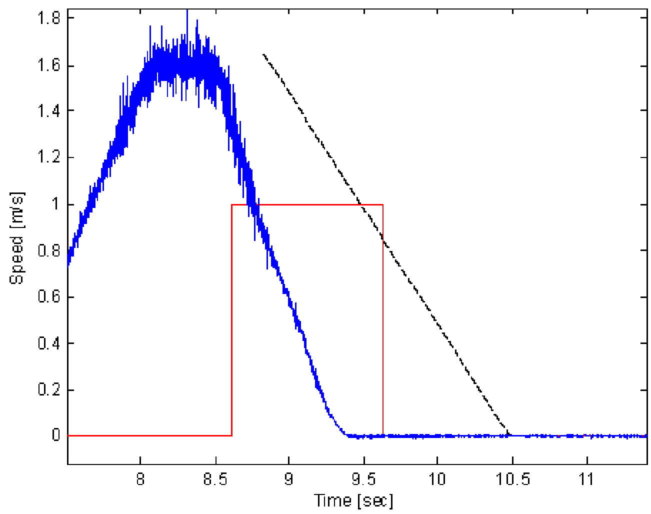

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Figure A.2: Illustration of the test signals speed (blue) and Category 1 stop state (red) for a track. The default values for the SafeMove supervision level is shown as black dashed line.

c The parameters according to *Figure 2* can now be adjusted to make the supervision more or less conservative, depending on the goal for the tuning.

The actual deceleration performance in the logged data can be computed from:

actualRamp = vTrack / actualBrakeTime

For the example in *Figure 3* the *actualRamp* value becomes 1.45 / 0.79 = 1.8 m/s^2 and default parameters (*Brake Ramp Delay* = 0.2 sec, *Start Speed Offset* = 0.1 m/s, *Brake Ramp Limit* = 1 m/s2) are considered safe and robust.

If the brake ramp supervision is triggered and TuneMaster is not available, the *Brake Ramp Limit* can be decreased[3] and the resulting

3 For safety reasons the *Brake Ramp Limit* should not be decreased to a lower value than necessary. It is therefore recommended to test several values (decreasing gradually or decreasing, then increasing) to achieve a robust but still not too low value. With the formulas in *Safety concern on page 212* it is possible to compute the worst case stop distance, given the track maximum speed as trackSpeed.

Continues on next page

brakeDistanceLimit can be computed using the actual maximum speed of the track.

B Servo Delay Factor and Servo Lag

System parameters Servo Delay Factor and Servo Lag

To explain what is affected by the parameters *Servo Delay Factor* and *Servo Lag* in the SafeMove configuration (see *Figure 1*) it is best to consider an example.

In graph (a) in *Figure 2* the *Servo Delay Time* is illustrated using a constructed example where a reference and a corresponding measured angular motor position is shown. The corresponding *Servo Delay Factor* can be computed using:

Servo Delay Factor = Servo Delay Time / 4

In graph (b) in *Figure 2* the *Servo Lag* parameter is illustrated when the measured signal is shifted with the *Servo Delay Time*. The measured position should now be within a distance of +/- *Servo Lag* from the reference at every time instance. If the measured position is outside the specified region the SafeMove position supervision is triggered.

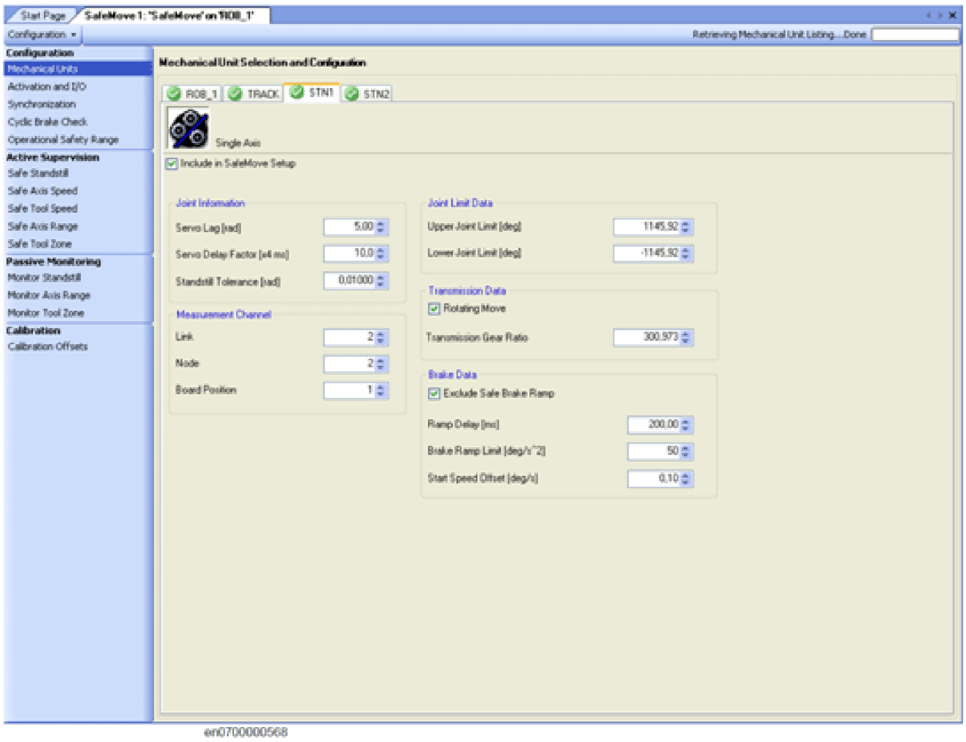

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Figure B.1: Additional axis configuration in SafeMove configuration.

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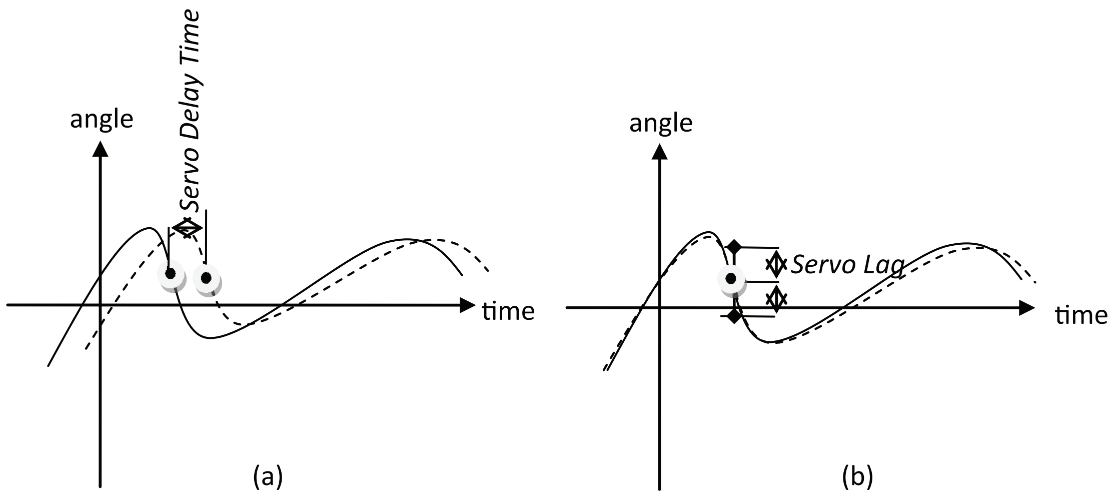

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Figure B.2: Illustration of Servo Delay Time (a) and Servo Lag (b). Solid line is motor angular position reference (test signal 17) and dashed is the corresponding measured motor angular position (test signal 18). In (b) the measured motor angular position signal is shifted Servo Delay Time in order to illustrate that it is the time shifted signal (samples) that should lie within +/- Servo Lag radians from the reference.

> **Note**
>
> The signals in *Figure 2* are only for illustrative purpose. The *Servo Delay Time* in a real system is small, typically in the range 12-16 ms, which means a *Servo Delay Factor* in the range 3-4. If the *Servo Delay Factor* is incorrect the *Servo Lag* has to compensate this since the difference between reference and measured motor angular position will be large when the track accelerates, runs at high speed, or decelerates.

Tuning the parameters

If the SafeMove position supervision is triggered for the track, take the following actions to verify and possibly tune the parameters:

1. Check that the load of the robot and additional load on the track is included in the configuration.
2. Make sure no mechanical problem is present, for example giving abnormal friction.
3. If possible use TuneMaster and log the test signals 17 (motor angular position reference) and 18 (measured motor angular position) for the track. If TuneMaster is not available, the *Servo Lag* can be increased (according to *3b*).
   a. Move the track and measure the *Servo Delay Time*. Compute the corresponding *Servo Delay Factor*:

      Servo Delay Factor = Servo Delay Time / 4

      where it is assumed that *Servo Delay Time* is measured in milliseconds. Use the value in the SafeMove configuration.

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b If the supervision is still triggered, increase the *Servo Lag* until supervision is not triggered.

Tuning a non ABB additional axis

If attempting to use a non ABB additional axis, start with doing a tuning of the axis. To be able to reduce servo lag below the configured maximum allowed value during the tuning, make sure to set the parameter *FFW Mode* (feed forward mode) to *Spd* (speed) or *Trq* (torque). For more information about tuning an additional axis see *Application manual - Additional axes and stand alone controller*.

WARNING

The system is unstable and therefore dangerous during the tuning process, since bad parameters or parameter combinations may be used! The safety procedures of the robot system must be carefully followed throughout the tuning process.

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C Reduced speed supervisions

Priorities for Elog messages

Priority from highest to lowest:

1. Tool Chg
2. Async
3. OVR

CBC is independent, so its message might come additionally.

Details

Speed supervision	Condition	Elog	TCP	Flange	Elbow	Axis Speeds
Tool Chg	After invalid tool id selected	20494	YES	YES	YES	NO
Async	CSS=0	20487	YES	YES	YES	YES
OVR	OVERRIDE=1	20490	YES	YES	YES	NO
CBC	CBCREQ=1	20450	YES	NO	NO	NO

Attn: If Async + Tool Chg is active, Tool Chg message is sent, but Async supervised. Reason: because SafeMove is Async, also axis speeds are supervised. But Elog message is sent depending on supervision with highest priority.

CBCREQ means that SafeMove requires a Brake test. DO from the main computer might not show that state correctly.

Speed restrictions

If the speed supervision is active (YES), the following speeds are allowed:

- TCP, tool0 and elbow < 250 mm/s
- Axes 1 - 3 < 20 °/s
- Axes 4 - 6 < 38 °/s

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D CBC signal description

Introduction

Description of different virtual signal states for CBC.

This signal description is valid for SafeMove firmware 1.019 or later, and RobotWare 5.14.03 or later.

Note

In general the signals with suffix 'SM' follows the status of the other signals but can have a delay.

Timing sequence for CBC signals

Description of which signals are set at different times during the CBC.

Beginning of CBC

The following signals are set in the beginning of the CBC.

Signal	Set to
PSC1CBCOK	0
PSC1CBCACT	1
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCOKSM	0
PSC1CBCACTSM	1

End of CBC

The following signals are set in the end of the CBC.

Signal	CBC test OK Set to	CBC test WARNING Set to	CBC test ERROR Set to
PSC1CBCOK	1	0	0
PSC1CBCREQ	0	0	1
PSC1CBCERR	0	0	1
PSC1CBCWAR	0	1	0
PSC1CBCACT	0	0	0
PSC1CBCPREWARN	0	0	No change[i]
PSC1CBCOKSM	1	0	0
PSC1CBCREQSM	0	0	1
PSC1CBCERRSM	0	0	1
PSC1CBCWARSM	0	1	0
PSC1CBCACTSM	0	0	0
PSC1CBCPREWSM	0	0	No change

i No change of value. The signal keeps the same value as before the test.

Continues on next page

Interrupted CBC

When the CBC is interrupted the following signal is set.

Signal	Set to
PSC1CBCREQSM	1

Program Pointer moved to Main after interrupted CBC

When the Program Pointer is moved to Main after an interrupted CBC the following signals are set.

Signal	Set to
PSC1CBCOK	0
PSC1CBCREQ	1
PSC1CBCACT	0
PSC1CBCOKSM	0
PSC1CBCACTSM	0

New Configuration downloaded. Synchronization done, no CBC done.

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	1
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCACT	0
PSC1CBCPREWARN	0
PSC1CBCOKSM	0
PSC1CBCREQSM	1
PSC1CBCERRSM	0
PSC1CBCWARSM	0
PSC1CBCACTSM	0
PSC1CBCPREWSM	0

Max. allowed speed: 250 mm/s (if configured in the SafeMove configuration)

During the first CBC test

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	No change
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCACT	1
PSC1CBCPREWARN	No change
PSC1CBCOKSM	0

Continues on next page

Signal	Signal state
PSC1CBCREQSM	No change
PSC1CBCERRSM	No change
PSC1CBCWARSM	No change
PSC1CBCACTSM	1
PSC1CBCPREWSM	No change

CBC done with the result OK

Signal	Signal state
PSC1CBCOK	1
PSC1CBCREQ	0
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCACT	0
PSC1CBCPREWARN	0
PSC1CBCOKSM	1
PSC1CBCREQSM	0
PSC1CBCERRSM	0
PSC1CBCWARSM	0
PSC1CBCACTSM	0
PSC1CBCPREWSM	0

Max. allowed speed: Max speed

CBC done with the result WARNING

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	0
PSC1CBCERR	0
PSC1CBCWAR	1
PSC1CBCACT	0
PSC1CBCPREWARN	0
PSC1CBCOKSM	0
PSC1CBCREQSM	0
PSC1CBCERRSM	0
PSC1CBCWARSM	1
PSC1CBCACTSM	0
PSC1CBCPREWSM	0

Max. allowed speed: Max speed

Continues on next page

CBC done with the result ERROR

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	1
PSC1CBCERR	1
PSC1CBCWAR	0
PSC1CBCACT	0
PSC1CBCPREWARN	No change
PSC1CBCOKSM	0
PSC1CBCREQSM	1
PSC1CBCERRSM	1
PSC1CBCWARSM	0
PSC1CBCACTSM	0
PSC1CBCPREWSM	No change

Max. allowed speed: 250 mm/s (if configured in the SafeMove configuration)

Prewarning time has expired

Signal	Signal state
PSC1CBCOK	No change
PSC1CBCREQ	No change
PSC1CBCERR	No change
PSC1CBCWAR	No change
PSC1CBCACT	No change
PSC1CBCPREWARN	1
PSC1CBCOKSM	No change
PSC1CBCREQSM	No change
PSC1CBCERRSM	No change
PSC1CBCWARSM	No change
PSC1CBCACTSM	No change
PSC1CBCPREWSM	1

Max. allowed speed: Max speed

Max CBC test interval is elapsed

Signal	Signal state
PSC1CBCOK	No change
PSC1CBCREQ	1
PSC1CBCERR	No change
PSC1CBCWAR	No change
PSC1CBCACT	No change

Continues on next page

Signal	Signal state
PSC1CBCPREWARN	1
PSC1CBCOKSM	No change
PSC1CBCREQSM	1
PSC1CBCERRSM	No change
PSC1CBCWARSM	No change
PSC1CBCACTSM	No change
PSC1CBCPREWSM	1

Max. allowed speed: 250 mm/s (if configured in the SafeMove configuration)

Interrupted CBC test, program pointer still in CBC routine

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	No change
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCACT	1
PSC1CBCPREWARN	No change
PSC1CBCOKSM	0
PSC1CBCREQSM	1
PSC1CBCERRSM	0
PSC1CBCWARSM	0
PSC1CBCACTSM	1
PSC1CBCPREWSM	No change

Interrupted CBC test, program pointer moved from CBC routine

Signal	Signal state
PSC1CBCOK	0
PSC1CBCREQ	1
PSC1CBCERR	0
PSC1CBCWAR	0
PSC1CBCACT	0
PSC1CBCPREWARN	No change
PSC1CBCOKSM	0
PSC1CBCREQSM	1
PSC1CBCERRSM	0
PSC1CBCWARSM	0
PSC1CBCACTSM	0
PSC1CBCPREWSM	No change

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Max. allowed speed: 250 mm/s (if configured in the SafeMove configuration)

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