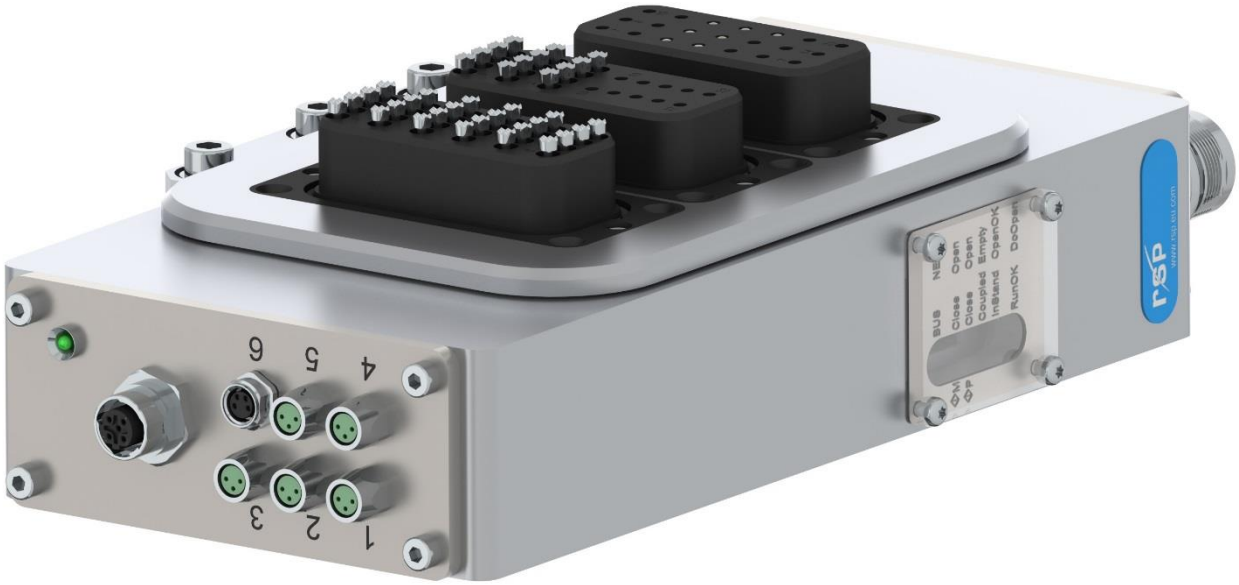
Product Manual

Safety signal module P7501-xxx

M8353-1

Tool changers | Swivels | Swivels with Tool changers | Grippers | Hose packages | Valve Units | Tool systems



rsp robot system products

Robot Systems Products AB
Isolatorvägen 4
SE-721 37 Västerås
Sweden

CONTENTS

1 INTRODUCTION

This document describes the RSP Safety signal module, with product number P7501-xxx, which combines transfer of control signals and power with a built-in safety unit. The Safety signal module is designed both for material handling and spot-welding applications.

For RSP tool changers equipped with the Safety signal module, all internal control signals are safely interlocked internally. Using the Safety signal module, the tool changer will not open – independent of control signal orders from the robot controller – unless it is empty or, alternatively, when the tool changer with tool attachment and tool docked is safely positioned in a tool stand.

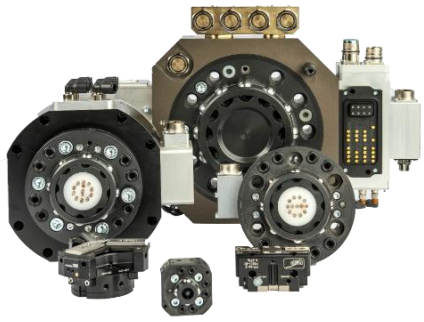
When tool changers equipped with the Safety signal module are utilised in robot cells it must comply with the Machinery Directive and the standards provided in section 1.1.1, meaning that the integrator must take required measures to eliminate the risks also outside the scope of the provided safety functions.

The Safety signal module is designated with: P7501-xxx, where xxx is dependent on different variants of signal interfaces.

1.1 About Robot System Products

Robot System Products is a front-rank provider of peripheral products for high performance robot applications. We provide complete tool systems solutions for your robot installations, aiming to improve your productivity with the most reliable and cost-effective tooling on the market. Continuously we explore emerging technologies, working with leading edge design.

Robot System Products has a wide range of standard robot peripheral products:



- Tool changers
- Swivels
- Swivel tool changers
- CiRo
- Grippers
- Hose Packages
- Valve units
- Tool systems
- Tool parking systems

Robot System Products' tool changers are constructed to maximize the flexibility and reliability of your robot fleet. Through our patented locking device TrueConnect™ robustness and high safety are combined with low weight and compactness. With our swivels compressed air, water, electrical and data signals as well as weld and servo power are transferred to your tools with robot motion capabilities fully maintained. Our Swivel tool changers unite the TrueConnect™ mechanism with our swivel technology, combining the best out of the two technologies. With RSPs unique CiRo-technology cables and hoses can be freely selected with high robot flexibility maintained, and the space requirements reduced. Our integrated Tool systems are delivered as complete plug-and-play solutions designed for quick and simple installation.

Robot System Products' product lines are available for all major robot brands and come with complete documentation. 3D-models for simulation are available for download at: robotsystemproducts.com.

1.2 Safety

1.2.1 General

The integrator installing the tool changer and the Safety signal module must follow the safety demands stated in standards and provisions applicable in the country the tool changer system is to be installed. The products are all prepared for CE-certification.

Since the Safety signal module will be a part of a tool changer – which will be a “partly completed machinery” – to be built into a robot cell, the EC declaration of conformity for the tool changer will include the Safety signal module.

The user of the RSP’s tool changer, and the Safety signal module, is responsible that law and directives applicable in respective countries, with regards to safety, are adhered to. The user is also responsible to guarantee that all safety devices are installed correctly.

WARNING!
Never carry out service work on a robot that has not been taken out of operation. See safety information for the robot.

WARNING!
Only perform work on grippers or tools attached to a tool changer if the air pressure is safely switched off.

WARNING!
Be aware that tool changers and Safety signal modules are heavy and may cause personal injury and equipment damage if dropped.

NOTE!
Tool changers shall always be in locked position, also when empty, to avoid unexpected locking if air pressure is lost.

1.2.2 Explanation of warnings

The warnings in this document are specific to the products in this manual. It is expected that the user also pay attention to certain notifications from the robot manufacturer and/or the manufacturers of other components used in the installation.

WARNING!
The warning sign will make you aware that a situation could result in potential serious injury or damage to equipment.

NOTE!
The note sign will alert you about something important to consider.

1.2.3 Unauthorized use

Warning! RSP takes no responsibility for equipment not utilized as intended! The Safety signal module shall not be used in other manners than specified in this manual. Overriding the safety function may cause harm, injury or death! Follow the maintenance plan given by RSP and only replace broken parts with spare parts as provided from RSP!

1.2.4 Available functionality of the Safety signal module

The following functionalities are available at the RSP Safety signal module:

- Independent of the tool changer opening signal" (DO_Open_TC) sent from the robot controller, the tool changer will not open unless:
    - No tool is attached to the tool changer.
    - If a tool attachment is attached, the tool attachment must be positioned in a tool stand.
- The tool changer will automatically close after undocking if a tool is stuck in the tool changer when lifted up from the tool stand.
- Automatic shut-off from +24V supply to tool at tool change.
- For controlling the tool changer and sending information to the robot controller two alternatives are available, i.e. using an integrated bus unit or using discrete I/O.
- Opening of tool changer is controlled by redundant hardware per EN ISO 13849-1:2006 Category 3 PL d.
- A specific input connected to Run-chain of the robot will break power to the valves, if Run-chain is broken or if the enabling device is disabled in manual mode.

2 SYSTEM ARCHITECTURE

The safety unit integrated in the signal module, includes two boards. The safety board includes all safety related parts for the interlocking functions, as described in the text below, while the communication board is used for the signal interfacing with the robot.

The system is based on using valves of double NO/NC monostable 3/2 type, which in their passive, stable state keeps the tool changer closed. Due to system redundancy, both valves must be actuated in order for the tool changer to open. The valve control signals are referenced to as *Open_TC1* and *Open_TC2* in this document.

The safety board includes two separate and independent interlocking circuits, for *Open_TC1* and *Open_TC2* respectively, which are working independently for the logic control. To detect if the tool changer is empty, two sensors are used in parallel. One is using a normally closed switch *TC_Empty*, giving a high signal to detect if the tool changer is empty and the other is using a jumper *TA_Coupled*, via the tool attachment to detect if a tool is attached to the tool changer. The *TC_Empty* or *TA_Coupled* signals combined are referenced to as the *TA_Present* signal in this document.

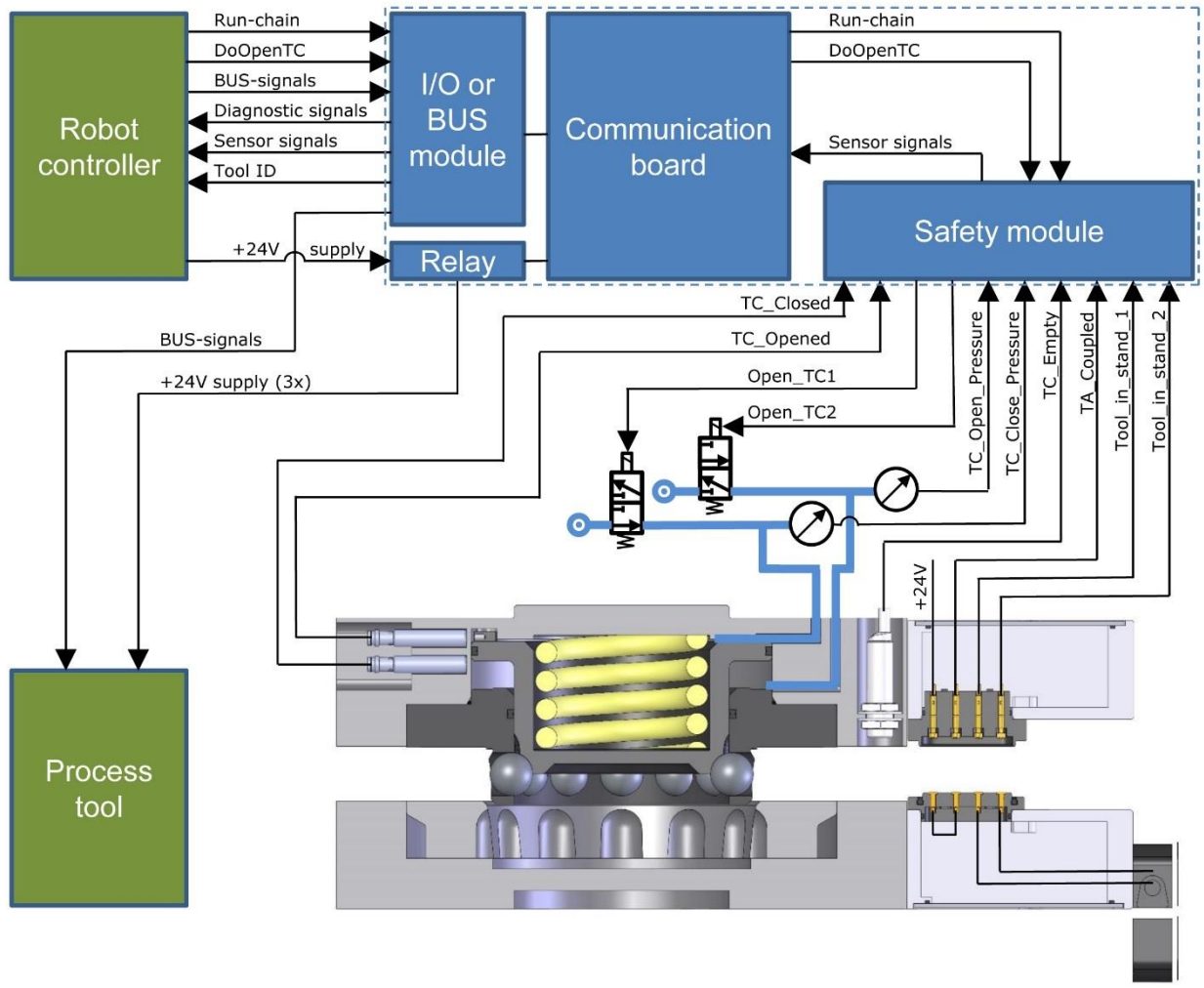
To detect if the tool changer with tool is positioned in the tool stand, double *Tool_In_Stand* signals are used. Both interlocking circuits are using the two *TA_Present* signals and the *Tool_In_Stand1* and *Tool_In_Stand2* signals. Since both signals, *Open_TC1* and *Open_TC2* must be active to open the tool changer, a fault in either circuit will prevent the tool changer to open in dangerous situations. Furthermore, the results from both circuits must be equal for the outputs to be set active.

For controlling the opening and closing of the tool changer, a single signal is used to alert the safety unit that an opening is ordered. Depending on the configuration of the safety unit, this signal could be sent in different ways but is always referred to as *DO_Open_TC*.

For internal supervision of the tool changer, magnetic sensors are used to establish the position of the tool changer locking piston, i.e. the *TC_Closed* and *TC_Opened* signals. Furthermore, the pressure on each side of the locking piston is supervised by two pressure sensors referred to as *TC_Close_Pressure* and *TC_Open_Pressure*.

In addition to the control signal interlocking as described above, all tool changers also have status monitoring, e.g. if a tool is attached (*TA_Present*) or if the tool is positioned in a tool stand (*Tool_In_Stand*). In addition to the signals mentioned above, diagnostic status of the tool changer is provided via combined signals of the tool changers sensors. Thus, the *Ok_To_Run* signal is produced by comparing sensor values to the expected values given the “close” input to the system (*DO_Open_TC*=0). The *TC_Open_Ready* signal is produced in the same manner as the *OK_To_Run* signal but gives the status of whether the tool changer is opened or closed.

The monitoring signals are not safety related, i.e. they are not part of the interlocking function of the safety unit. In this document, additional measures are described based on using these monitoring signals, thus facilitating fault recognition during work cycle run.



Signals in and out of the Safety signal module.

2.1 System parameters

	Minimum	Nominal	Maximum
Required voltage	18V	24V	30V
Current consumption		400 mA	800 mA
Ambient temperature (°C)	+10 °C		+50 °C
Air Pressure (bar)	3,5 bar	6 bar	10 bar
Max current trough power breakers at 24 V			5A

3 SAFETY REQUIREMENTS SPECIFICATION

3.1 Prevention of opening

The Safety signal module shall prevent the tool changer from opening, independent of external control signals, unless:

- The tool changer has no tool attached.
- The tool changer has a tool attached AND the tool is positioned in the tool parking stand.

3.2 Automatic closing

The tool changer shall automatically close after undocking if a tool attachment is stuck in the tool changer when lifted up from the tool parking stand.

3.3 Requirements according to ISO 13849-1

The requirements of ISO 13849-1:2006 Category 3 PL d are fulfilled by using redundant double circuits for the control of the valves, as has been described in chapter 3.

3.4 Behavior under fault conditions

In addition to the Safety unit, the tool changers also have sensors for monitoring the status of the tool changer. These monitoring sensor signals are available for internal supervision and fault diagnostics as described in chapter 3. These signals are further combined in a logic to verify that sensors, valves and piston are working correctly.

3.5 Resetting of I/O-bus module

At tool change, any tool mounted I/O-bus module should be Disabled/Enabled.

It is recommended to include an Error handling routine to verify a successful EIO access after tool change, such as:

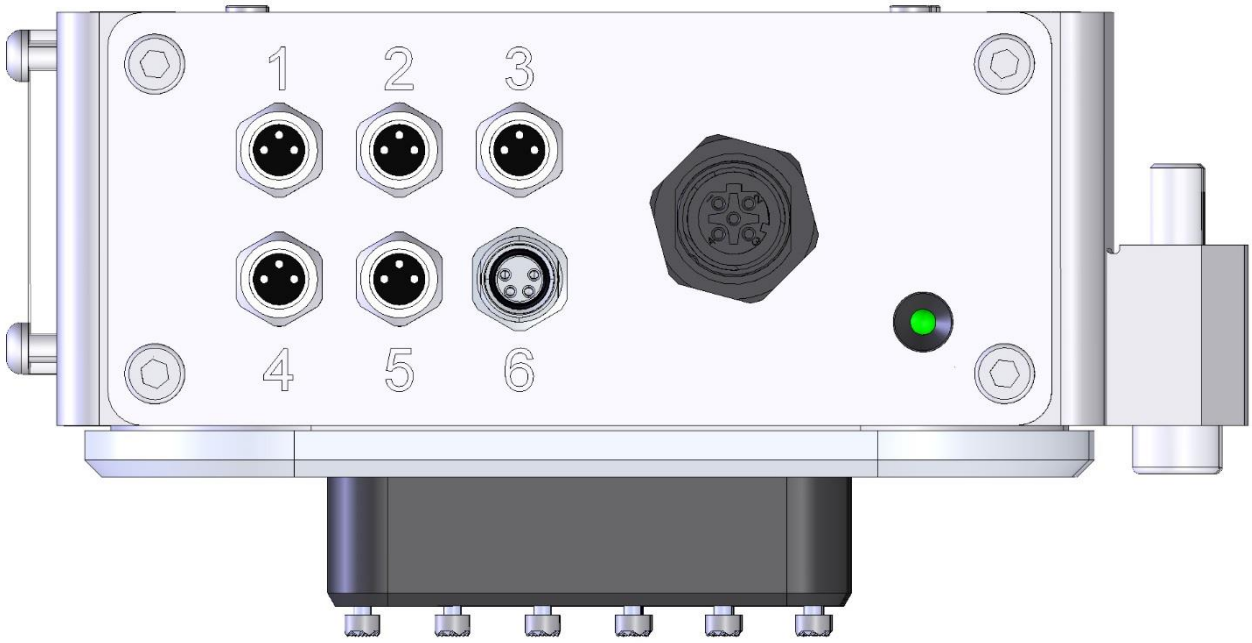
```
...
IOEnable "board1", 0;
SetDO board1_sig3, 1;
...
ERROR
IF ERRNO = ERR_IOENABLE THEN
    WaitTime 1;
    RETRY;
ENDIF
```

Before using signals on the I/O device board1, a test is done by trying to activate the I/O device with time-out after 0 (zero) seconds. If the test fails a jump is made to the error handler. In the error handler the program execution waits for 1 (one) second. and a new retry is made. After 4 retry attempts the error ERR_IOENABLE is propagated to the caller of this routine.

4 SYSTEM INTERFACES

The Safety signal module is provided with several control and monitoring signals available via either a common network interface (Bus unit) or via discrete IO (I/O unit). Diagnostic signals are used for communicating the status of the tool changer back to the robot controller system. The control signals are used for opening and closing of the tool changer.

4.1 Connections on tool changer side



Sensor and PROFINET connections on TC-side

Sensor and valve signals	Marking	Connection	Section
TC_Empty	1	M8 3S	7.8
TC_Opened	2	M8 3S	7.6
TC_Closed	3	M8 3S	7.6
TC_Open_Pressure	4	M8 3S	7.7
TC_Close_Pressure	5	M8 3S	7.7
Open_TC1	6	M8 4S	
Open_TC2	6	M8 4S	
TA_Coupled	n/a	Internal	7.8

4.2 Connections on tool attachment side

Sensor and PROFINET connections on TA-side

Sensor and valve signals	Marking	Connection	Section
Tool_In_Stand1	6	M8 8P	7.9
Tool_In_Stand2	6	M8 8P	7.9

4.3 Signals to and from robot controller

Depending on the configuration of the tool changer, several options are available for monitoring the Safety signal module, and thereby the tool changer. With an installed bus unit, the number of signals which are sent back to the control system are not limited by the number of conductors in the dress-pack - as is the case when using an I/O unit. Therefore, the bus unit offers more possibilities to monitor the tool change and to correct errors.

In the following text, control signals are input to the Safety signal module and status signals are outputs from the module.

4.3.1 Control and status signals available via I/O unit or via Bus unit

Signal	Type and unit	Description	Data type	Section
DO_Open_TC	Control signal via I/O or bus unit	Signal to be sent from control system to Safety signal module giving an opening order	Digital	7.14
Run-chain_Enabled	Hardcoded Control signal	Signal connected to the Run-chain of the robot that will break the power to the valves if broken	Digital	
Reset_TC	Control signal via bus unit	In case of a fault, the *Reset_TC* Input can be used to reset the Safety signal module from a fault state.	Digital	7.20
Reset_TC_Counter	Control signal via bus unit	Input to reset the Safety signal module cycle counter	Digital	7.19
OK_To_Run	Status signal via I/O or bus unit	Monitoring signal for closed state of the tool changer	Digital	7.11
TC_Open_Ready	Status signal via I/O or bus unit	Monitoring signal for signaling an open tool changer	Digital	7.10
TA_Present	Status signal via I/O or bus unit	Monitoring signal for signaling a tool changer when tool is present	Digital	7.16
Tool_In_Stand	Status signal via I/O or bus unit	Monitoring signal going high when a tool is present in the tool changer and the tool is positioned in the tool stand.	Digital	7.9

4.3.2 Supplementary signals available only via the Bus unit

Signal	Type and unit	Description	Data type	Section
TC_Closed	Status signal via bus unit	Magnetic sensor connected to the locking piston position	Digital	7.6
TC_Opened	Status signal via bus unit	Magnetic sensor connected to the locking piston position	Digital	7.6
TC_Close_Pressure	Status signal via bus unit	Pressure sensor connected to the locking side of the piston	Digital	7.7
TC_Open_Pressure	Status signal via bus unit	Pressure sensor connected to the opening side of the piston	Digital	7.7
TA_Coupled	Status signal via bus unit	Jumper on the tool attachment, part of signal *TA_Present*	Digital	7.8
TC_Empty	Status signal via bus unit	Inductive sensor sensing a present tool, part of signal *TA_Present*	Digital	7.8
Tool_In_Stand1	Status signal via bus unit	First part of the redundant tool stand sensor	Digital	7.9
Tool_In_Stand2	Status signal via bus unit	Second part of the redundant tool stand sensor	Digital	7.9
TC_Enabled	Status signal via bus unit	Monitoring signal indicating if the Safety signal module is in operational mode or in a fault state	Digital	7.12
Fault code	Status signal via bus unit	Gives information about why the Safety signal module went to fault state	Numeric	7.21
Tool_ID1 **(see note below)**	Status signal via bus unit	Option. A tool identification number set by the integrator	Numeric	5.3
Tool_ID2 **(see note below)**	Status signal via bus unit	Option. A tool identification number set by the integrator	Numeric	5.3
TC_Counter	Status signal via bus unit	A counter on the Safety signal module incrementing for each opening and closing of the tool changer	Numeric	7.17
TC_Counter_Total	Status signal via bus unit	Same as *TC_Counter* but not resettable	Numeric	7.18
Run-chain Enabled	Status signal via bus unit	Determines the state of the run-chain signal	Digital	

NOTE! As an option for required safety, Tool_ID1 / Tool_ID2 may be hardcoded via I/O to the robot controller. See section 5.3.

4.3.3 Automatic break of 24V power at tool change

Up to 5A of continuous current and peak levels of 15A will be switched OFF automatically prior to tool change, to eliminate sparking. The power supply channels remain switched OFF during the tool change sequence. Switch ON is delayed until the tool changer is fully closed.

NOTE! When inductive loads are used on the tooling, make sure a free-wheeling diode is mounted in parallel with the load. This will protect the breaker from potentially hazardous voltages.

5 INSTALLATION

The following sections describes the hardware and software installation of the system.

5.1 Hardware installation

Follow the instructions regarding hardware installation given in the Installation and Maintenance manual M0720 -1. Make sure all connectors from the tool changers sensors are correctly connected to the Safety signal module, see the circuit diagram in the Technical description of respective unit.

NOTE! Make sure that the tool changer and the connecting cables are properly grounded to avoid electromagnetic interference (EMI).

5.2 Software installation

The software installation procedure is depending on the configuration, the Safety signal module is either equipped with a digital network (PROFINET) unit, in the following called Bus unit, or alternatively discrete signals, called I/O unit.

5.2.1 Installing the Safety signal module with I/O unit

The I/O connections of the Safety signal module are found in the circuit diagram in the Technical description of respective unit. Use the table below for signals between the robot controller and Safety signal module.

Signals to and from the robot controller via I/O unit

I/O	Signal	Type
O	*DO_Open_TC*	0/24V
I	*OK_To_Run*	0/24V
I	*TC_Open_Ready*	0/24V
I	*TA_Present*	0/24V
I	*Tool_In_Stand*	0/24V

5.2.2 Installing the Safety signal module with Bus unit (PROFINET)

RSP will provide a GSDML for import to your control system and configuration of the Safety signal module parameters. Make sure the Safety signal module has power during the configuration of the network. Give the Safety signal module a station name and make sure there are no IP conflicts on the network. Depending of your control system, the variables of the Safety signal module might need to be initialized manually. Once all the variables are accessible from your system the installation is done.

PROFINET signals for sensor data

I/O	Signal	Type	Offset (Siemens)	Offset (ABB)
I	*OK_To_Run*	BOOL	0.0	0
I	*TC_Open_Ready*	BOOL	0.1	1
I	*TA_Present*	BOOL	0.2	2
I	*Tool_In_Stand*	BOOL	0.3	3
I	*TC_Closed*	BOOL	0.4	4
I	*TC_Opened*	BOOL	0.5	5
I	*TC_Close_Pressure*	BOOL	0.6	6
I	*TC_Open_Pressure*	BOOL	0.7	7
I	*TA_Coupled*	BOOL	1.0	8
I	*TC_Empty*	BOOL	1.1	9
I	*Tool_In_Stand1*	BOOL	1.2	10
I	*Tool_In_Stand2*	BOOL	1.3	11
I	*TC_Enabled*	BOOL	1.4	12
I	*Run-chain_Enabled*	BOOL	1.5	13
I	Spare	BOOL	1.6	14
I	Spare	BOOL	1.7	15
		Control data		
O	*DO_Open_TC*	BOOL	0.0	0
O	*Reset_TC*	BOOL	0.1	1
O	*Reset_TC_Counter*	BOOL	0.2	2
O	Spare	BOOL	0.3	3
O	Spare	BOOL	0.4	4
O	Spare	BOOL	0.5	5
O	Spare	BOOL	0.6	6
O	Spare	BOOL	0.7	7
		Package data		
I	*Faultcode*	BYTE		16–23
I	*Tool_ID1*	BYTE		24–31
I	*Tool_ID2*	BYTE		32–39
I	*TC_Counter*	DWORD		64–71, 56–63, 48–55, 40–47
I	*TC_Counter_Total*	DWORD		96–103, 88–95, 80–87, 72–79

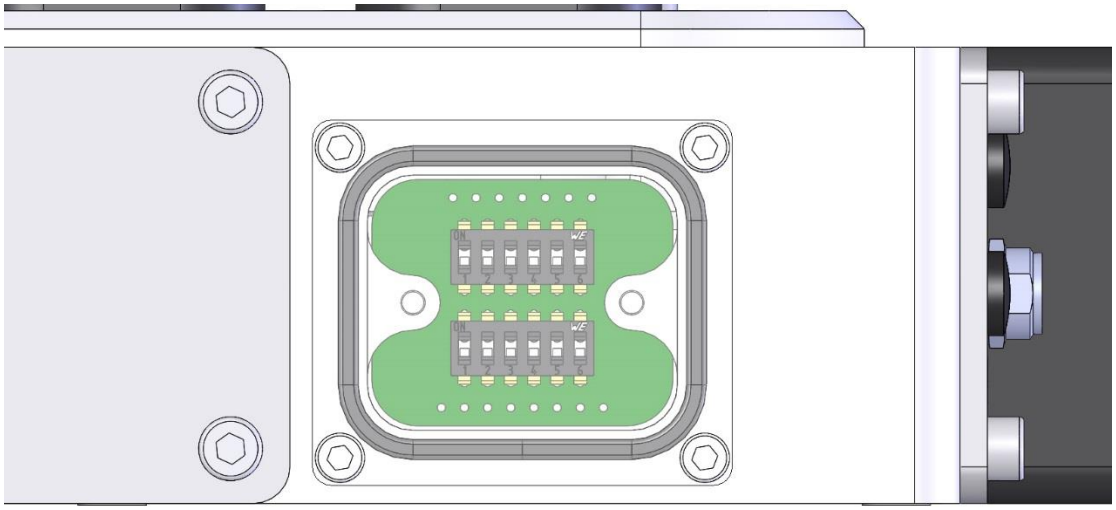
NOTE! Byte order for *TC_Counter* and *TC_Counter_Total* may vary between different controllers,

5.3 Tool_ID option

The Safety signal module can be equipped with a *Tool_ID* option which consists of two parts. The tool changer part transfers the signals from the tool attachment part and puts them either on the network or as hard wired I/O depending on configuration. The tool attachment part has customer specific DIPswitches where the system integrator can set unique ID: s on the tools. With the bus unit configuration, the ID of the tool can be presented directly in the control-system via a parameter on the PROFINET network. Figure 05 shows the TA side of the *Tool_ID* option.

A unique tool identifier can be set by the system integrator by setting the DIP switches accordingly (see figure below). When Bus module is present, two different PROFINET parameters are present related to each DIP switch group.

The TA side of the *Tool_ID* option



NOTE! To fulfill requirements for safe tool identification it is not possible to use transfer via Bus unit.

6 WORKING PRINCIPLE

The working principle of the Safety signal module is described by the two different operations performed by a robot with tool changer. Block schedules are provided in section 6.1.1 and section 6.2.1.

6.1 Signal logic for docking tool at tool stand

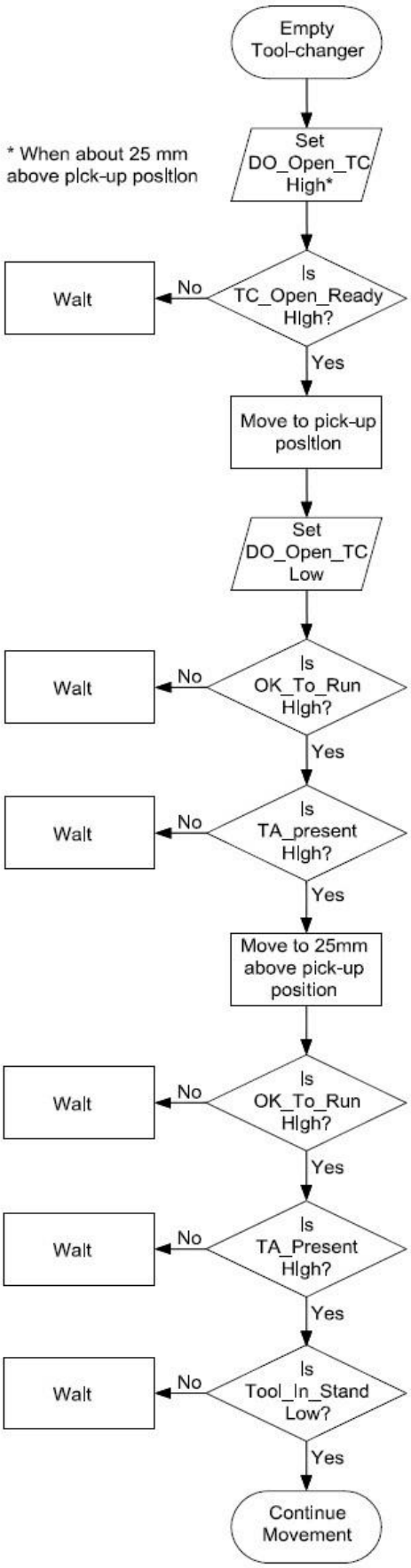
1. The robot is moving with an empty tool changer, which is closed.
2. When the robot is about 25 mm above the tool stand the controller shall set signal *DO_Open_TC* high. The safety unit will then check signals *TC_Empty* and *TA_Coupled* to verify that the TC is empty, before activating the valves.
3. The controller shall check that *TC_Open_Ready* is high before continuing movement. This means that the tool changer is opened and that the tool changer is allowed to move to the tool attachment.
4. The robot is moved to the pick up position in the tool stand.
5. The controller shall set signal *DO_Open_TC* low and the tool changer is closed.
6. The controller shall check that the signal *OK_to_run* is high indicating that the changer is closed.
7. The controller shall check that signal *TA_Present* is high, indicating that the tool changer has gripped the tool and that the robot can start to move.
8. The robot is moved about 25 mm up.
9. The controller shall check that the signal *OK_to_run* is high and that signal *TA_Present* is high and signal *Tool_In_Stand* is low to confirm that the tool is picked up by the tool changer and has left the tool stand.
10. The robot will continue movement.

Control and Sensor signals between robot controller and TC

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
DO_Open_TC	0	1	1	1	0	0	0	0	0	0
TC_Open_Ready	0	0	1	1	0	0	0	0	0	0
OK_to_run	1	0	0	0	0	1	1	1	1	1
TA_Present	0	0	0	x	x	1	1	1	1	1
Tool_In_Stand	0	0	0	x	x	1	x	x	0	0

NOTE! Yellow marking means setting control signal or checking status signal., “x” means that the signal value is undefined.

6.1.1 Flow chart for docking tool



6.2 Signal logic for undocking tool in tool stand

1. The robot is moved to the tool stand with a tool in the tool changer.
2. When in position the controller shall check that *Tool_In_Stand* is high.
3. The tool changer is opened by controller setting signal *DO_Open_TC* high. The internal safety circuit will check signals *Tool_In_Stand1* and *Tool_In_Stand2* to verify that the TC is in the tool stand, before activating the valves.
4. After the TC has opened, the controller shall check that signal *TC_Open_Ready* is high. This means that the tool changer is opened, and that the robot is allowed to move.
5. The robot is moved up 25 mm.
6. The controller shall check that signal *TC_Open_Ready* is high.
7. The controller shall check that signals *Tool_In_stand* and *TA_Present* are low to confirm that the tool is left in the tool stand and that the tool changer is empty.
8. The robot will continue movement.

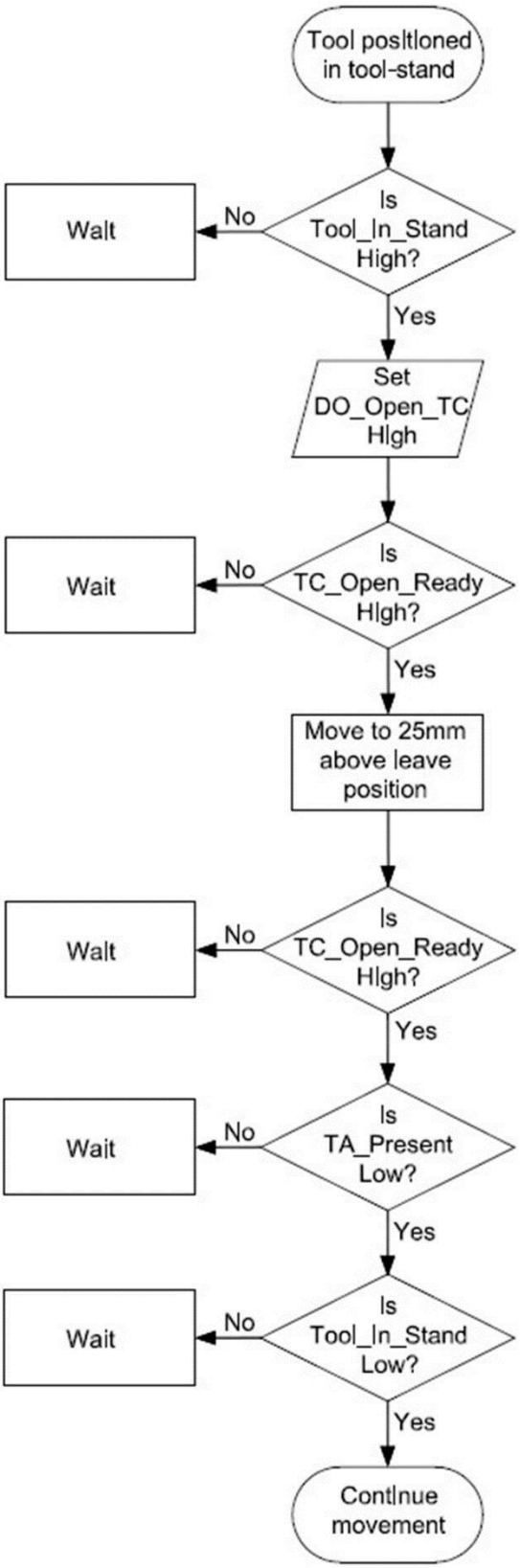
Control and Sensor signals between robot controller and TC

Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
DO_Open_TC	0	0	1	1	1	1	1	1
TC_Open_Ready	0	0	0	1	1	1	1	1
OK_to_run	1	1	0	0	0	0	0	0
TA_Present	1	1	x	x	0	0	0	0
Tool_In_Stand	0	1	x	x	0	0	0	0

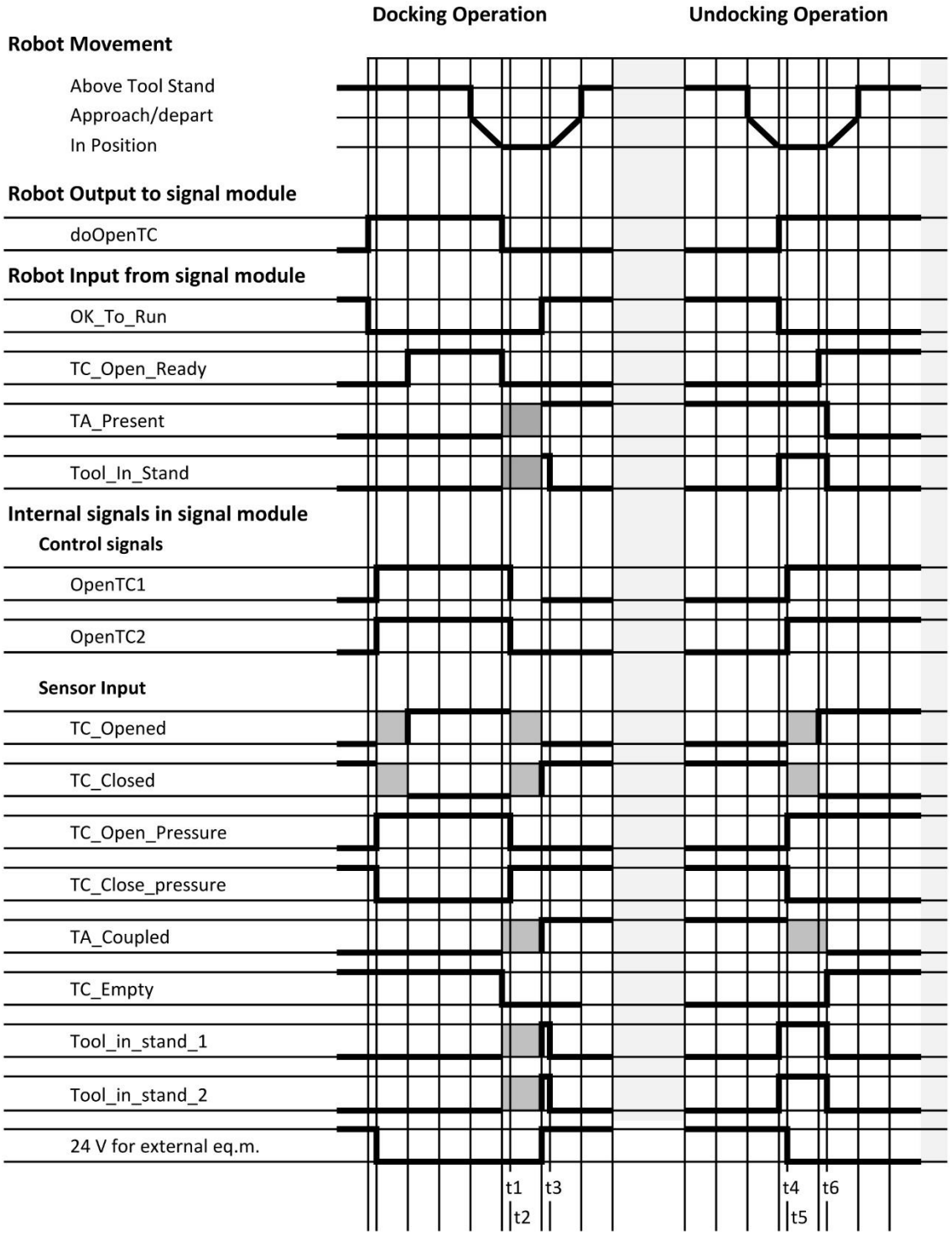
NOTE! Yellow marking means setting control signal or checking status signal., “x” means that the signal value is undefined.

WARNING! If the tool, for some reason, is not left in the tool stand but still kept in the opened tool changer in step 5 above, i.e. after the robot is moved up, the tool changer will enter the fault state and immediately close to safely hold the tool. This will set *OK_to_run* and *TC_Open_Ready* low and the robot controller must stop and enter an error handling routine.

6.2.1 Flow chart for undocking tool



6.3 Time diagram for docking and undocking at tool stand



t1, t4 internal time from order to start closing or opening tool changer < 3ms

t2, t5 time to close or open tool changer 200-500 ms dep. on TC

t3, t6 time for robot to start movement after closed or opened confirmation

means that signal value is undefined

The diagram shows signal values “high” or “low” in relation to different actions, such as an order to open from a robot, and for events, such as when a tool changer is opened and confirmation is returned to the robot. The time indications are relative and are showing relations to other signals, not the actual values.

7 TROUBLESHOOTING

This chapter describes how to diagnose and correct possible errors in the Safety signal module. When error occurs the fault codes provided via the Bus unit will indicate the type of error (section 7.21). All diagnostics and troubleshooting described below are valid upon the condition that the Safety signal module is fully operational and working correctly.

The Safety signal module has two features to support the operator to detect and locate errors in the tool changer.

1. Through the network PROFINET all sensor and status/control data are available (sections 7.6–7.21).
2. For fast and easy troubleshooting the Safety signal module is in in addition equipped with monitoring LED:s (sections 7.3–7.16),

7.1 General troubleshooting

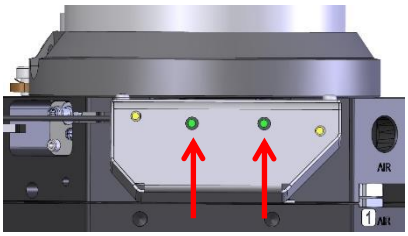
Symptom	**Possible cause**	**Actions**
All LED:s are OFF	No power to the system.	Check power supply and polarity.
Tool changer not opening	• Criteria for opening not satisfied. • Air pressure not sufficient. • Signal *DO_Open_TC* not reaching Safety signal module.	• Check status of all sensors. • Check air pressure. • Check system configuration.
Tool changer closes directly after opening	• Criteria for open tool changer not satisfied.	• Check status of *TC_Closed* and *TC_Opened* sensors. • Check status of *TC_Open_Pressure* and *TC_Close_Pressure* sensors.
Tool changer closes spontaneously without a fault state	• Sudden loss of air pressure. • Sudden loss of Run-chain signal.	• Check air pressure. • Make sure run-chain is active when tool changer shall remain open.
Tool changer closes spontaneously with a fault state	• Broken sensor.	• Check status of all sensors.

7.2 Manually over-riding safety functions

During troubleshooting it may be needed to test the sensor functions indicating that the tool changer is opened. However, the built-in logic of the safety unit will close the tool changer automatically when a sensor value differs from what is expected, resulting in a fault state. To test the functionality of the *TC_Opened* magnetic sensor and the *TC_Open_Pressure* pressure sensor, manual over-riding of the safety function might be necessary.

WARNING! During manual over-ride, the operator is fully responsible for the safety and that no physical harm, injury or death are caused to persons or equipment. RSP takes no responsibility when safety functions are over-ridden.

1. Make sure that opening the tool changer will not cause any harm or injuries. Undock, if possible, any tool attachment and tool in a tool stand.
2. Remove the two plugs covering the manual control switches of the tool changer valve.
3. Use two small screwdrivers to simultaneously push both manual control switches overriding controls.
4. The tool changer will remain open as long as the two manual control switches are pushed in.



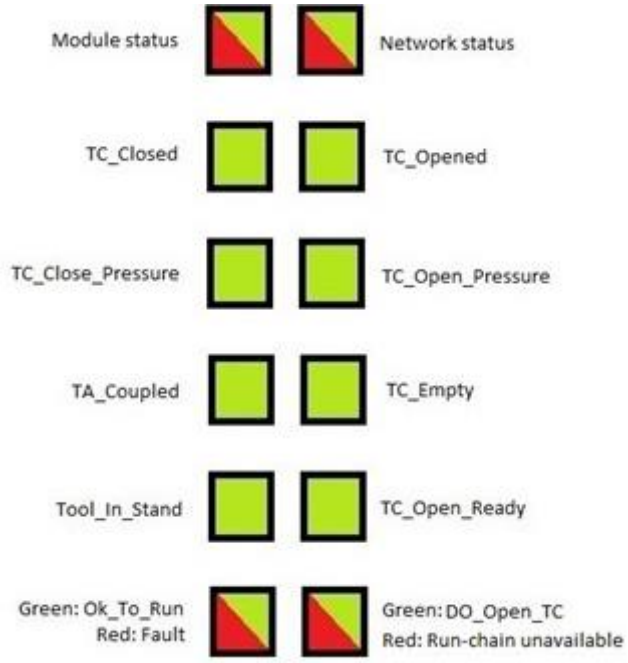
5. Remove the screwdrivers, this will cause the tool changer to close.
6. Remount the two bolts protecting the valve overriding controls and restart the safety unit by breaking and restarting the power to the system. This will reset the fault indication caused by the manual valve overriding.

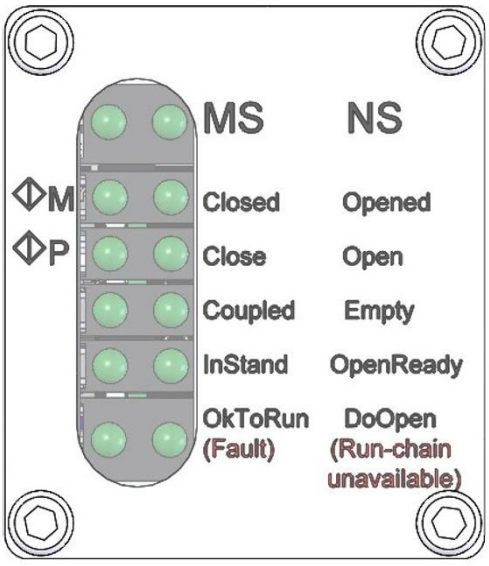
WARNING! In the rare case of release failure (7,21 *FaultCode* 4) during undocking see *APPENDIX A – release failure: suggested actions*.

7.3 Check function of the Safety signal module via LED:s

The diagnostic LED:s are located directly on the Safety signal module. See below.

7.3.1 Function and placement of monitoring LED:s





7.4 Module status / Network status

The Module status and Network status LED:s are only active when the Safety signal module is equipped with the digital network alternative, i.e. a bus unit.

Module status LED

State	Description	Comments
OFF	Not initialized	• No power • Module in 'SETUP' state or • Module in 'NW_INIT' state
Green	Normal operation	• Module has shifted from 'NW_INIT' state
Single green flash	Diagnostic Event(s)	• Diagnostic event(s) are present
Red	Exception Error	• Device in 'EXCEPTION' state
	Fatal event	• Major internal error (this indication is combined with a red network status LED)
Alternating red/green	Firmware update is ongoing	• Do not power off the module. Turning the module off during this phase could cause permanent damage!

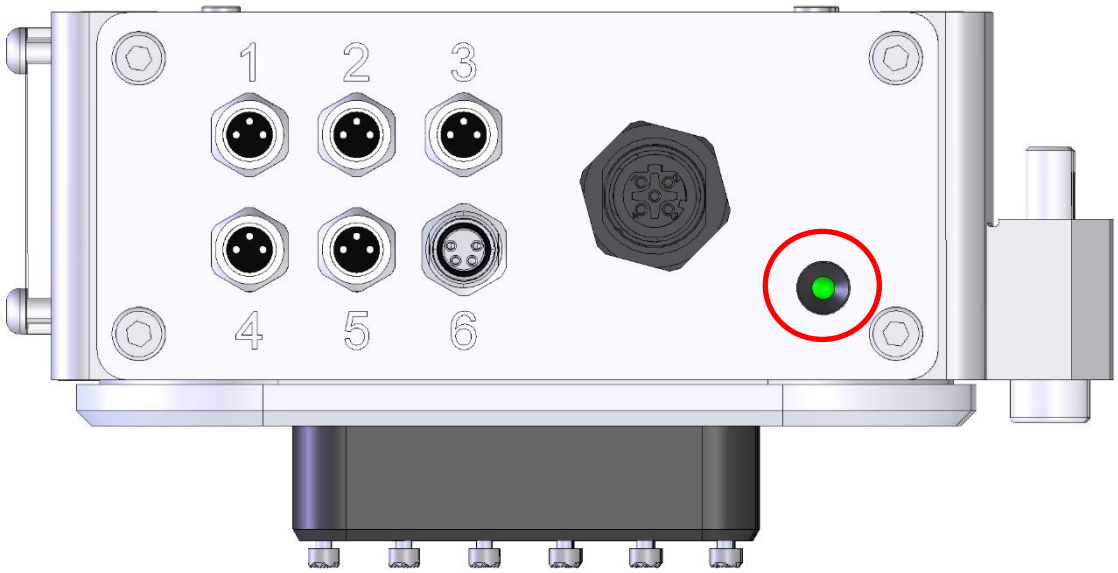
Network status LED

State	Description	Comments
OFF	Offline	• No power or • No connection to IO controller
Green	Online (RUN)	• Connection with IO controller is established, and IO controller in RUN state
Single green flash	Online (STOP)	• Connection with IO controller established • ID controller in STOP state • IO data bad or • IRT synchronization finished
Green blinking	Blink	Used by engineering tools to identify the node on the network
Red	Fatal Event	• Major internal error (this indication is combined with a red module status LED
Single red flash	StationNameError	• Station name not set
Two red flashes	IP address error	• IP address not set
Three red flashes	Configuration error	• Expected identification differs from Real identification

7.5 PROFINET Network LED

A green LED is placed close to the network connector. For a PROFINET protocol network the LED have the following function.

Function of the LED.



State	Description
OFF	No link, no communication present
Green	PROFINET link established, no communication present
Flickering green	PROFINET link established, communication present

7.6 TC_Closed / TC_Opened

The *TC_Closed* / *TC_Opened* signal and LED status corresponds to the sensor read back from the *TC_Closed* / *TC_Opened* magnetic sensors. The tool changer piston has magnets attached to it, the sensors react to the magnetic fields and could thereby establish whether the piston is in closed position or in open position.

***TC_Closed* and *TC_Opened* signal and LED**

Signal	State	LED	Description	Comments
TC_Closed	0	Off	Piston not in closed position	• Normal if TC is opened • Broken sensor or cable
	1	Green	Piston in closed position	• Normal if TC is closed
TC_Opened	0	Off	Piston not in opened position	• Normal if TC is closed • Broken sensor or cable
	1	Green	Piston in opened position	• Normal if TC is opened

7.7 TC_Close_Pressure / TC_Open_Pressure

The pressure sensors indicate the pressure on both sides of the tool changer piston. With an open toolchanger the *TC_Open_Pressure* sensor must indicate high, otherwise the logic will close the tool changer. With a closed tool changer the *TC_Close_pressure* sensor should indicate high. If the air pressure disappears or the sensor breaks. the logic will set the *Ok_To_Run* signal low. No fault state will be entered. If both the *TC_Close_Pressure* and *TC_Open_Pressure* sensor indicates high, the tool changer will go to fault state.

***TC_Close_Pressure* and *TC_Open_Pressure* signal and LED**

Signal	State	LED	Description	Comments
TC_Close_Pressure	0	Off	No pressure on piston closing side	• Normal if TC is opened • No or low pressure on air inlet (feed pressure) • Broken sensor or cable
	1	Green	Pressure on piston closing side	• Normal if TC is closed • Broken valve
TC_Open_Pressure	0	Off	No pressure on piston opening side	• Normal if TC is closed • No pressure on air inlet (feed pressure) • Broken sensor or cable • Broken valve
	1	Green	Pressure on piston opening side	• Normal if TC is opened

WARNING! The pressure sensors are analog, do not connect any other sensor than specified by RSP. Do not short circuit the sensor input to the Safety signal module.

7.8 TA_Coupled and TC_Empty

The *TA_Coupled* sensor is a jumper on the tool attachment giving a high output when the tool attachment is present (NO). The *TC_Empty* sensor is an inductive sensor giving a high output when a tool attachment is not present (NC).

***TA_Coupled* and *TC_Empty* LED**

Signal	State	LED	Description	Comments
TA_Coupled	0	Off	No tool attachment detected	• Normal if no tool is attached • Broken TA jumper (section 8.6)
	1	Green	Tool attachment detected	• Normal if tool is attached
TC_Empty	0	Off	Tool attachment detected	• Normal if tool is attached • Broken sensor or cable
	1	Green	No tool attachment detected	• Normal if no tool is attached

7.9 Tool_In_Stand

The *Tool_In_Stand* sensor gives a high output when the tool is safely parked in the tool stand and the tool changer and tool attachment is still connected (<6 mm apart).

***Tool_In_Stand* signal and LED**

Signal	State	LED	Description	Comments
Tool_In_Stand	0	Off	No *Tool_In_Stand* signal detected	• Normal if tool is not positioned in tool stand • Normal if no tool is attached to TC • Broken sensor or cable • Broken TA signal module
	1	Green	*Tool_In_Stand1* and *Tool_In_Stand2* signal detected	• Normal if tool is positioned in tool stand and tool is attached to TC

7.10 TC_Open_Ready

The *TC_Open_Ready* signal is not bound to any specific sensor but indicates that the tool changer is opened. The *TC_Open_Ready* signal should be read by the robot controller to establish that the tool changer is correctly opened.

***TC_Open_Ready* signal and LED**

Signal	State	LED	Description	Comments
TC_Open_Ready	0	Off	Tool changer not opened or not opened correctly	• Normal if *DO_Open_TC* is low • Normal when Run-chain signal is low (US2) • Safety unit entered Fault state • *TC_Closed* = 1 or *TC_Opened* = 0 • *TC_Close_Pressure* = 1 or *TC_Open_Pressure* = 0
	1	Green	Tool changer opened	• Normal if tool changer is opened

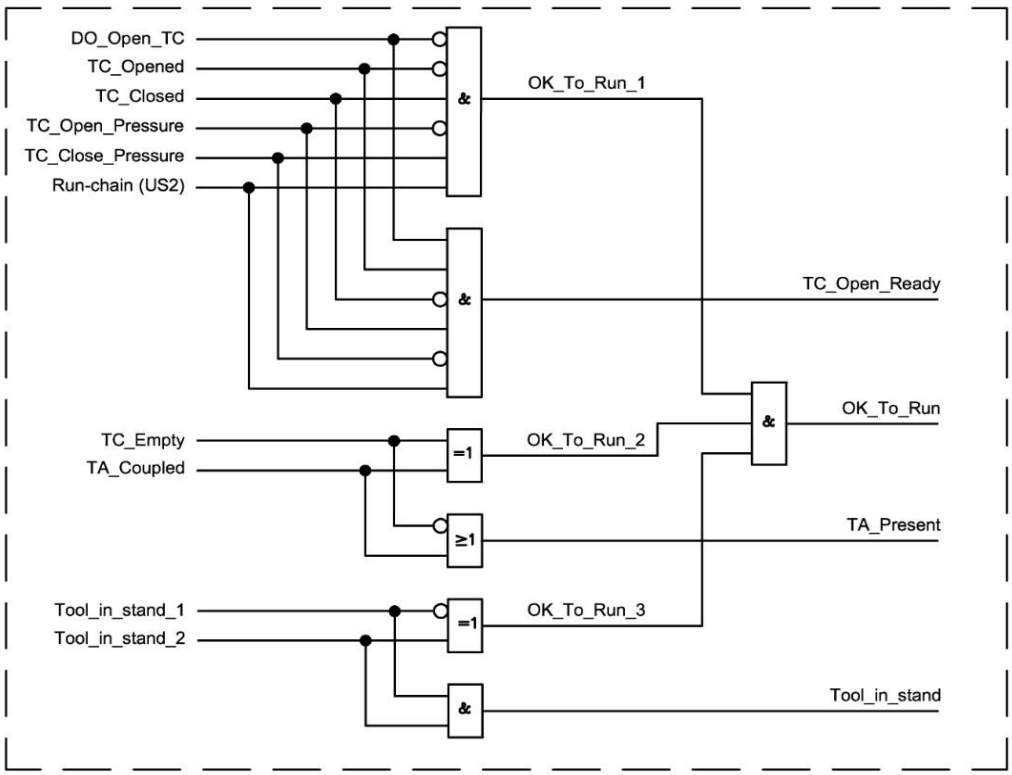
7.11 Ok_To_Run

The *OK_To_Run* signal gives feedback to the robot controller about the status of the tool changer. The signal will go high when the sensors indicates that the tool changer behaves as expected. *Ok_To_Run* will be high when the *DO_Open_TC* signal is low and the tool changer is closed correctly according to all the sensors including *TC_Empty*, *TA_Coupled* and *Tool_in_stand*. During a fault, a faulty sensor value or *DO_Open*_TC is set high when the logic does not allow an open tool changer the *OK_to_run* signal will go low. The *Ok_To_Run* signal will also go low during transitions between closed and opened tool changer. Refer to Figure 09 for the logic behind the signal.

OK_To_Run **signal and LED**

Signal	State	LED	Description	Comments
OK_To_Run	0	Off	Tool changer not yet in expected closed state	• Normal during opening and closing of TC • Normal when Run-chain signal is low (US2) • Normal if *DO_Open_TC* = 1 when tool changer is not allowed to open • Safety unit entered Fault state • *TC_Closed* = *DO_Open_TC* • *TC_Opened* = !*DO_Open_TC* • *TC_Close_Pressure* = *DO_Open_TC* • *TC_Open_Pressure* = !*DO_Open_TC*
	1	Green	Tool changer in expected closed state	• Normal state of tool changer

Signal logic for OK_To_run



7.12 TC_Enabled/Fault

The TC_Enabled signal and Fault LED indicates if any error has occurred in the tool changer. During a fault state, the tool changer cannot be opened by the logic. If the tool changer is open when a fault occurs the logic will try to close the tool changer immediately. In order to get the tool changer back to operating state a restart of the logic is required, preferably via the *Reset_TC* signal.

TC_Enabled signal and Fault LED

Signal	State	LED	Description	Comments
TC_Enabled	1	Off	Tool changer in operational mode	• Normal state of tool changer • No pressure on air inlet, *TC_Close_Pressure* = 0 AND *TC_Open_Pressure* = 0.
	0	Red	Tool changer in fault state	• Refer to fault code table, section 7.21 • The *TC_Closed* and *TC_Opened* sensors shows the same status for too long • The TC_*Close_Pressure* and *TC_Open_Pressure* sensors booth shows high status for too long • The *TA_Coupled* and *TC_Empty* sensors shows the same status for too long

7.13 Run-chain_Enabled

The Run-chain_Enabled signal is active when the run-chain power (US2) is present at the Safety signal module. The Run-chain power is broken whenever an emergency stop button is pressed or any other safety feature of the robot cell indicates an error or stop. During manual operation of the robot, jogging etc. the Run-chain signal will only be high when the enabling unit at the flex pendant is active. The I/O and LED indicating the Run-chain_Enabled is mainly used for troubleshooting.

Run-chain Enabled signal and Unavailable LED

Signal	State	LED	Description	Comments
Run-chain_Enabled	1	Off	Run-chain power present	• Normal during RUN-mode • Normal in manual mode when enabling unit is pressed
	0	Red	No run-chain power present	• Enabling unit not pressed in manual mode • Emergency stop button pressed or door interlock opened

WARNING! Risk for crush injury! The tool changer will close if the run-chain is broken. Take extra pre-cautions when jogging the robot manually with an open tool changer near the tool attachment.

7.14 DO_Open_TC

The DO_Open_TC signal is a control signal input from the robot controller telling the tool changer to open. If so is allowed the tool changer will set the output to the valves high and thereby open the tool changer. The DO_Open_TC LED can be used to confirm that the signal from the robot controller reaches the tool changer in a correct way.

DO_Open_TC control signal and LED

Signal	State	LED	Description	Comments
DO_Open_TC	0	Off	Tool changer will close	• Tool changer will try to close independent of sensor input
	1	Green	Tool changer has received an open control signal	• Tool changer will only try to open if: o No tool is attached o Tool parked in tool-stand • Tool changer will not try to open if: o Requirements above not satisfied o Run-chain enable (US2) is missing o Air pressure is missing o Safety unit in fault state

7.15 Checking the functionality of the Safety signal module via network

In addition to data described in section 7.6–7.14 the network alternative gives the user a greater number of control and status signals which can help the operator to troubleshoot the equipment. Listed below are the additional signals provided by the GSDML file from RSP, see section 4.3.2, Control and Status signals available via Bus unit.

7.16 TA_Present

The TA_Present signal is a combination of the two signals *TC_Empty* and TA_Coupled and will answer the question “is there a tool attachment connected to the tool changer”. If the *TC_Empty* sensor gives a high output and the *TA_Coupled* sensor gives a low output, the *TA_Present* will be set low.

***TA_Present* logic**

Signal	State	LED	Description	Comments
TA_Present	0	Off	Sensors indicate that no tool is present	• *TA_Coupled* = 0 AND *TC_Empty* = 1 • Broken sensors
	1	Green	At least one sensor indicate that a tool is present	• *TA_Coupled* = 1 OR *TC_Empty* = 0

7.17 TC_Counter

This value is incremented every time the safety logic successfully completes an opening cycle. The value is resettable, see section 7.20.

This value is bound to the safety signal module and not to the tool changer itself.

7.18 TC_Counter_Total

The *TC_Counter_Total* keeps track of the total number of openings of the tool changer. The value is not resettable.

This value is bound to the safety signal module and not to the tool changer itself.

7.19 Reset_TC_Counter

The *Reset_TC_Counter* is used to zero the *TC_Counter* tag. The tag must be set active and then inactive again for a zeroing to occur.

Reset_TC_Counter

Signal	State	LED	Description	Comments
Reset_ TC_Counter	0	-	*TC_Counter* will be incremented	• The *TC_Counter* tag will increment once every opening of tool changer
	1	-	*TC_Counter* will be zeroed	• The *TC_Counter* will remain zero as long as *Reset_TC_Counter* is active

7.20 Reset_TC

The *Reset_TC* signal is used for resetting a fault in the safety logic of the module. When an error has been investigated and corrected, use the *Reset_TC* signal to turn the safety logic off and thereby cause a reset. The *Reset_TC* signal must be set inactive again for the safety unit to start. The tool changer cannot be operated when the *Reset_TC* signal is active, nor will any sensor data be available.

***Reset_TC* signal**

Signal	State	LED	Description	Comments
Reset_ TC	0	-	Safety logic powered	• Tool changer will operate normally.
	1	-	Safety logic powered off	• Tool changer will not operate at all due to the loss of power in the safety unit.

7.21 FaultCode

If the logic has entered a fault state, some information about why that happened might be able to get from the *FaultCode* signal. The numeric *FaultCode* has a property linked to it according to table below.

Fault codes

Fault code	Fault state	Description	Possible reason for fault state	Suggested action
0	Operational mode	No fault codes received from the safety logic.	• An unexpected error has occured.	If the logic has entered fault state with fault code 0, replace Safety signal module.
1	*TA_Present* fault	Fault state will be entered if the *TA_Coupled* or *TC_Empty* signals shows inconsequent status for too long.	• The TC_Empty sensor is broken or has bad wiring. • The *TA_Coupled* jumper is broken.	• Replace the *TC_Empty* sensor and wirings. • Replace the Safety signal module.
2	*Tool_In_Stand* signal fault	Fault state will be entered if the two *Tool_In_Stand* signals gives inconsequent status for too long.	• *Tool_In_Stand* sensor is broken or has bad wiring.	• Replace the *Tool_In_Stand* sensor and wirings.
3	Tool changer Fault	Fault state will be entered if any of the sensors monitoring the state of the tool changer gives inconsequent status.	• *TC_Closed* and *TC_Opened* sensors booth shows either high or low status for too long. • The *TC_Close_Pressure* and *TC_Open_Pressure* shows high status for too long. • The tool changer valve is broken. • The state of either sensor differs from the expected value.	• Replace the *TC_Closed* or *TC_Opened* sensor and wirings. • Replace the *TC_Close_Pressure* or *TC_Open_Pressure* sensor and wiring. • Replace the tool changer valve. • Make sure the sensors give consequent status according to logic schematic

4	Release failure	Fault state will be entered if the tool attachment got stuck in the tool changer after undocking resulting in the tool changer closes.	• Tool attachment stuck in the tool changer because of rusty or sticky interfaces in-between. • The *TC_Empty* sensor is broken. • The *Tool_In_Stand* sensor is broken. • Faulty signal transfer between TA and TC.	• Perform maintenance of tool changer (se manual M0720-1). • Replace the *TC_Empty* sensor and wiring. • Replace the *Tool_In_Stand* sensor. • Replace the Safety signal module.
5	Cross monitoring fault	An internal error in the safety logic has occurred	• An unexpected error has occurred	• Replace the Safety signal module.
6	Output stage fault (Channel 1)	Fault state will be entered if a short circuit is detected on the output stage of the safety unit (Open_TC1 and Open_TC2 signals)	• The tool changer valve is broken. • The wiring between the safety logic and valve is faulty. • The safety unit is broken.	• Replace the tool changer valve. • Replace the cable between the safety logic and valve. • Replace the Safety signal module.
7	Output stage fault (Channel 2)	Fault state will be entered if a short circuit is detected on the output stage of the safety unit (Open_TC1 and Open_TC2 signals)	• The tool changer valve is broken. • The wiring between the safety logic and valve is faulty. • The safety unit is broken.	• Replace the tool changer valve. • Replace the cable between the safety logic and valve. • Replace the Safety signal module.
8	Watchdog error	An internal error in the safety logic has occurred	• An unexpected error has occurred.	• Replace the Safety signal module.
9	MCU error	An internal error in the safety logic has occurred	• An unexpected error has occurred.	• Replace the Safety signal module.
10	Output feedback fault	An internal error in the safety logic has occurred	• An unexpected error has occurred.	• Replace the Safety signal module.
11	Voltage fault	Fault state will be entered if the voltage falls outside required interval.	• Over/under voltage on 24V line.	• Ensure correct voltage interval (section 2.1)
Self resetting				
100	No air pressure	Missing air pressure	• No air pressure on air inlet.	• Turn on air pressure • Replace *TC_Close_Pressure* sensor

8 ERROR IDENTIFICATION

NOTE! Maintenance of the Safety signal module should only be carried out by authorized personnel. Contact RSP if there are uncertainties.

8.1 Set tool changer in maintenance mode

During maintenance and troubleshooting the tool changer should be closed, positioned in a serviceable position and undocked from tools and tool attachments. Follow these steps in order to put the tool changer in maintenance mode:

1. If a tool is attached to the tool changer, it shall be docked in a tool stand.
2. Position the tool changer in a position that makes it easy to access and service.
3. Make sure the tool changer is closed and without tool.
4. Power off the tool changer or robot.

8.2 Replacing a broken Safety unit

The safety unit of the Safety signal module shall only be replaced by Robot System Products. Contact your local representative.

8.3 Testing the TC_Empty inductive sensor

The following steps describes how to troubleshoot the *TC_Empty* sensor. For replacement of the sensor see separate Installation and Maintenance manual

Testing the TC_Empty sensor

	Action	**LED / Signal**
1	The tool changer shall be empty. Place tool attachment, with tool, in a tool stand.	
2	Move the tool changer to an easily accessible and serviceable position.	
3	Close the tool changer.	
4	The Safety signal module on the tool changer shall be powered ON, check LED-lights.	
5	When tool changer is empty check that the *TC_Empty* LED is ON.	LED: *TC_Empty* = 1 Signal: *TC_Empty* = 1
6	Place a metallic part, such as a screwdriver or similar, close to the sensor.	LED: *Fault* = 1 Signal: *TC_Enabled* = 0
7	The *TC_Empty* LED should now be OFF.	LED: *TC_Empty* = 0 Signal: *TC_Empty* = 0
8	If signals and tool changer does not react as expected, replace the *TC_Empty sensor*.	
9	Reset the safety unit by making POWER OFF followed by POWER ON.	LED: *Fault* = 0 Signal: *TC_Enabled* = 1

8.4 Testing the TC_Opened / TC_Closed sensors

The following steps describes how to troubleshoot the *TC_Opened* / *TC_Closed* sensors. For replacements of the sensors see separate Installation and Maintenance manual.

Testing of the *TC_Opened* / *TC_Closed* magnetic sensors

	Action	**LED / Signal**
1	The tool changer shall be empty. Place tool attachment, with tool, in a tool stand.	
2	Move the tool changer to an easily accessible and serviceable position.	
3	Close the tool changer.	
4	The Safety signal module on the tool changer shall be powered ON, check LED-lights.	
5	When tool changer is closed, check that the *TC_Closed* LED is ON and the *TC_Opened* LED is OFF.	LED: *TC_Closed* = 1 Signal: *TC_Closed* = 1 LED: *TC_Opened* = 0 Signal: *TC_Opened* = 0
6	Open tool changer by setting the *DO_Open_TC* signal to high.	Signal: *DO_Open_TC* = 1
7	When the tool changer is open check that the *TC_Closed* LED is OFF and the *TC_Opened* LED is ON.	LED: *TC_Closed* = 0 Signal: *TC_Closed* = 0 LED: *TC_Opened* = 1 Signal: *TC_Opened* = 1
8	If signals and tool changer react as expected the sensors are functional. If not and if the tool changer closes immediately after opening continue to point 9.	LED: *Fault* = 1 Signal: *TC_Enabled* = 0
9	Remove the *TC_Closed* / *TC_Opened* sensors from the tool changer.	
10	Use a weak magnet and place it in front of each sensor and check signals on the *TC_Closed* / *TC_Opened* LED:s.	
11	If sensors and signals do not react as expected replace the malfunctioning *TC_Closed* / *TC_Opened* sensors.	
12	If the sensors do react as expected with the magnet, return the entire tool changer unit to RSP for check.	
13	If the tool changer is in fault state reset the safety unit by making POWER OFF followed by POWER ON.	LED: *Fault* = 0 Signal: *TC_Enabled* = 1

8.5 Testing air pressure sensors

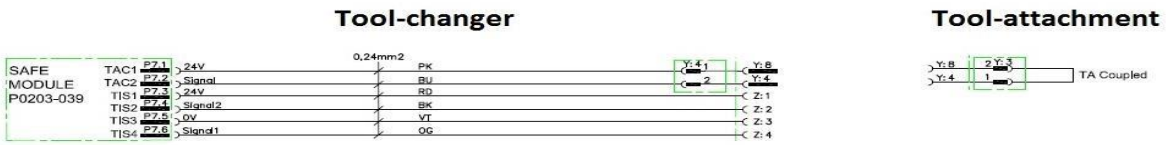
The following steps describes how to troubleshoot the *TC_Close_Pressure* and *TC_Open_Pressure* sensors. For replacements of the sensors see separate Installation and Maintenance manual.

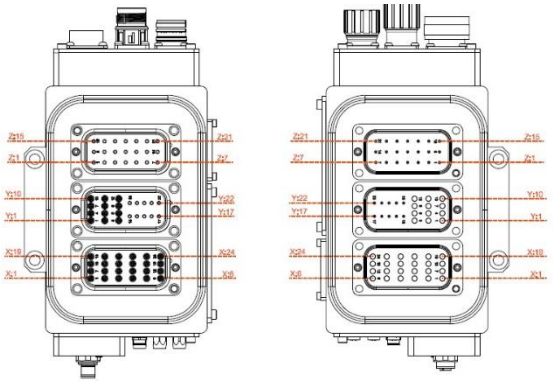
Testing the Air pressure sensors

	Action	**LED / Signal**
1	The tool changer shall be empty. Place tool attachment, with tool, in a tool stand.	
2	Move the tool changer to an easily accessible and serviceable position.	
3	Close the tool changer.	
4	The Safety signal module on the tool changer shall be powered ON, check LED-lights.	
5	When tool changer is closed, check that the *TC_Close_pressure* LED is ON and the *TC_Open_Pressure* LED is OFF.	Signal: *TC_Close_Pressure* = 1 Signal: *TC_Open_Pressure* = 0
6	Open tool changer by setting the *DO_Open_TC* signal to high.	Signal: *DO_Open_TC* = 1
7	When tool changer is open, check that the *TC_Close_Pressure* LED is OFF and the *TC_Open_Pressure* LED is ON.	Signal: *TC_Close_Pressure* = 0 Signal: *TC_Open_Pressure* = 1
8	If sensors and signals react as expected the sensors are functional. If not continue to point 9.	LED: *Fault* = 1 Signal: *TC_Enabled* = 0
9	Ensure that air pressure is sufficient, if so continue to point 10	
10	If the tool changer is closed and the *TC_Close_Pressure* LED is OFF, replace the *TC_Close_Pressure* sensor and/or cabling.	
11	If the tool changer closes immediately after opening replace the *TC_Open_Pressure* sensor and/or cabling.	
12	If the tool changer is in fault state reset the safety unit by making POWER OFF followed by POWER ON.	LED: *Fault* = 0 Signal: *TC_Enabled* = 1

8.6 Testing the TA_Coupled sensor

Testing of the *TA_Coupled* sensor is described below. For replacement of the sensor, see separate Installation and Maintenance manual. Circuit diagrams are found in the Product description of respective unit.





In the example figure the TA-coupled jumper is located on the tool attachment pins Y:4 and Y:8. The power supply and sensor feedback are found on the tool changer pins Y:4 and Y:8.

	Action	**LED / Signal**
1	The tool changer shall be empty. Place tool attachment, with tool, in a tool stand.	
2	Move the tool changer to an easily accessible and serviceable position.	
3	Close the tool changer.	
4	The Safety signal module on the tool changer shall be powered ON, check LED-lights.	
5	The *TA_Coupled* LED should be OFF.	Signal: *TA_Coupled* = 0
6	Identify the connection points for *TA_Coupled* in the circuit diagram on the tool changer side.	
7	Test connection by a short piece of electric wire between the tool changers connection points. The *TA_Coupled* LED should be ON	LED: *Fault* = 1 Signal: *TA_Coupled* = 1 Signal: *TC_Enabled* = 0
8	If step 7 was successful continue to step 9, otherwise replace the Safety signal module on the tool changer side.	
9	Identify the connection points for *TA_Coupled* on the circuit diagram for the tool attachment side.	
10	Use an Ohm-meter to measure the resistance between the points. The resistance should be close to zero.	
11	If the resistance is high (>10 Ω) replace the Safety signal module on the tool attachment side.	
12	If the tool changer is in fault state reset the safety unit by making POWER OFF followed by POWER ON.	LED: *Fault* = 0 Signal: *TC_Enabled* = 1

8.7 Testing the Tool_In_Stand sensor

The following steps describes how to trouble shoot the *Tool_In_Stand* sensor. Diagnostic LED:s are placed on the *Tool_In_Stand* sensor. For testing place the tool in the tool stand so the *Tool_In_Stand* sensor gets actuated. The table below explains the different statuses of the sensor according to the LED:s.

Testing the *Tool_In_Stand* sensor

	LED:s				
Sensor function	**Green**	**Red**	**Yellow**	**Output**	**Note**
Actuated	ON	OFF	OFF	LOW	Voltage ON
	ON	OFF	ON	HIGH	The yellow LED always signals the presence of the passive sensor.
Actuated in limit area	ON	OFF	Flashing	HIGH	Distance between passive and active sensor must be adjusted.
Error warning, sensor still actuated	OFF	Flashing	ON	HIGH	Goes to error mode after 30 minutes if the error warning is not rectified
Error	OFF	Flashing	ON	LOW	Replace the sensor

9 DISPOSAL AND RECYCLING

Taking care of spent equipment

Used equipment must be taken care of in an environmentally-friendly way.

When disposed of, a major share of the material, or its energy content, can be recycled. The quantities possible to recycle vary depending on technical resources and practises in respective country. Non-recyclable components shall be handed over to an authorized environmental waste treatment facility for destruction or disposal.

Electronics

Electronic equipment shall be sent to an authorized recycling company or sorted into different component materials and treated as such.

Metals

Metals can, in general, be melted down, recycled and used in new products. They shall be sorted according to type and surface coating and handed over to an authorized recycling facility.

Metal components made of steel, aluminium, and brass are substantial in size and easy to identify. Copper is primarily used in transmission of power for spot welding. Equipment for spot welding, specifically sliding contacts, may also contain small amounts of lead. Silver or gold plating of contact surfaces may occur.

Plastics

Thermoplastics can, in general, be re-heated an recycled without any major loss of quality. They shall be handed over to an authorized recycling facility. POM occurs in swivel housings, etc. PTFE in some sealings.

Rubber

Rubber shall be handed over to an authorized environmental waste treatment facility either for recycling, disposal or destruction. Rubber occurs in O-rings.

Other material

All other material shall be sorted and handed to an authorized environmental waste treatment facility in accordance with national legislation.

APPENDIX A – RELEASE FAILURE: SUGGESTED ACTIONS

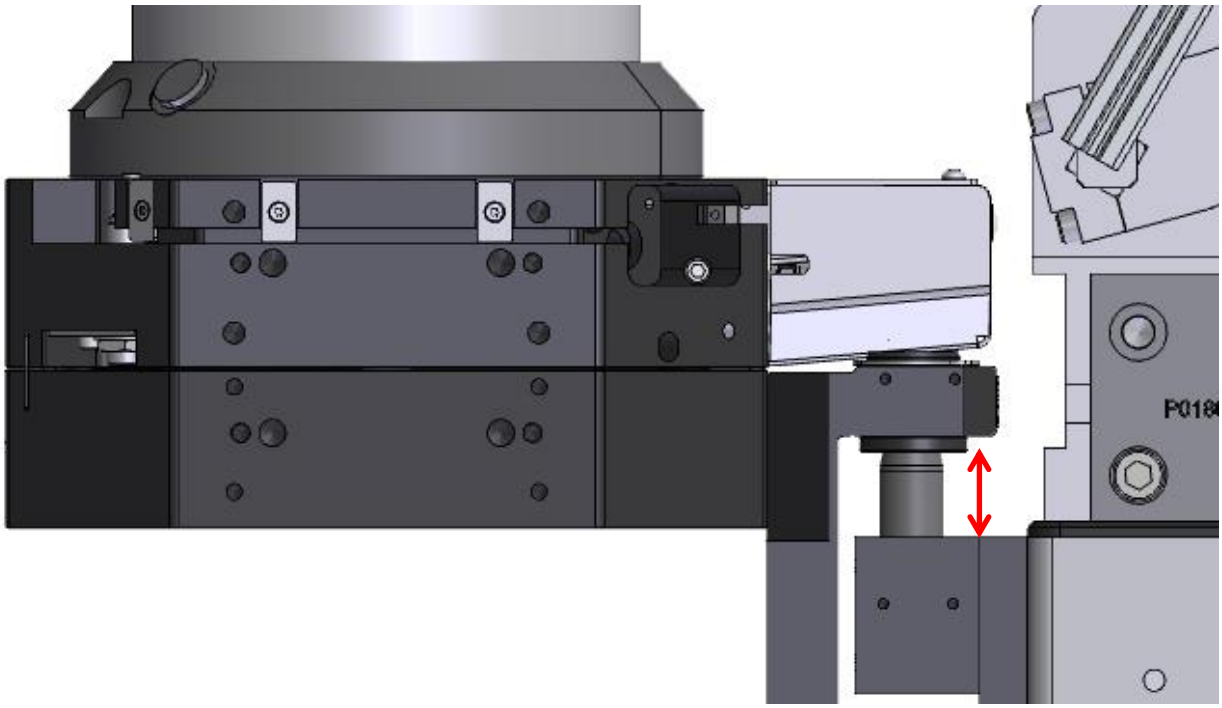
Background

The RSP Safety signal module, P7501-xxx, combines transfer of control signals and power with a built-in safety unit. When using the RSP Safety signal module, according to section 6.2.1 *Flow chart for undocking tool*, the tool changer will automatically lock and enter a fault state if the *Tool_In_Stand* signal is lost before the *TA_Present* signal during the initial 25 mm robot movement after undocking. This may happen (i) if the tool attachment/tool is stuck and follows the tool changer up from the RSP tool stand, (ii) if there is a sudden loss of air pressure, (iii) if there are sensor problems or (iv) if there are problems with signal transfer.

NOTE! Tool attachment positions within 25 mm above the docking position are considered as safe as the guide pins are still enclosed by the guide holes of the tool attachment.

If the *Tool_In_Stand* signal is lost before the *TA_Present* signal is received during the initial robot movement, three possible scenarios are identified, Depending on which the following actions should be taken:

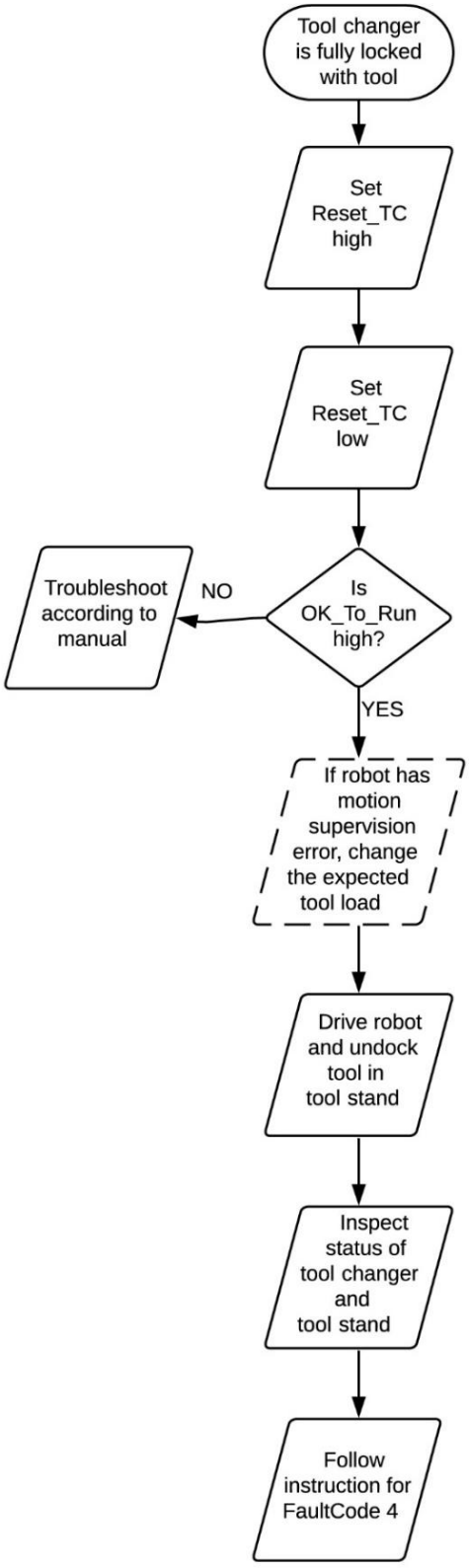
Scenario 1: Tool changer fully locked with TA above tool stand



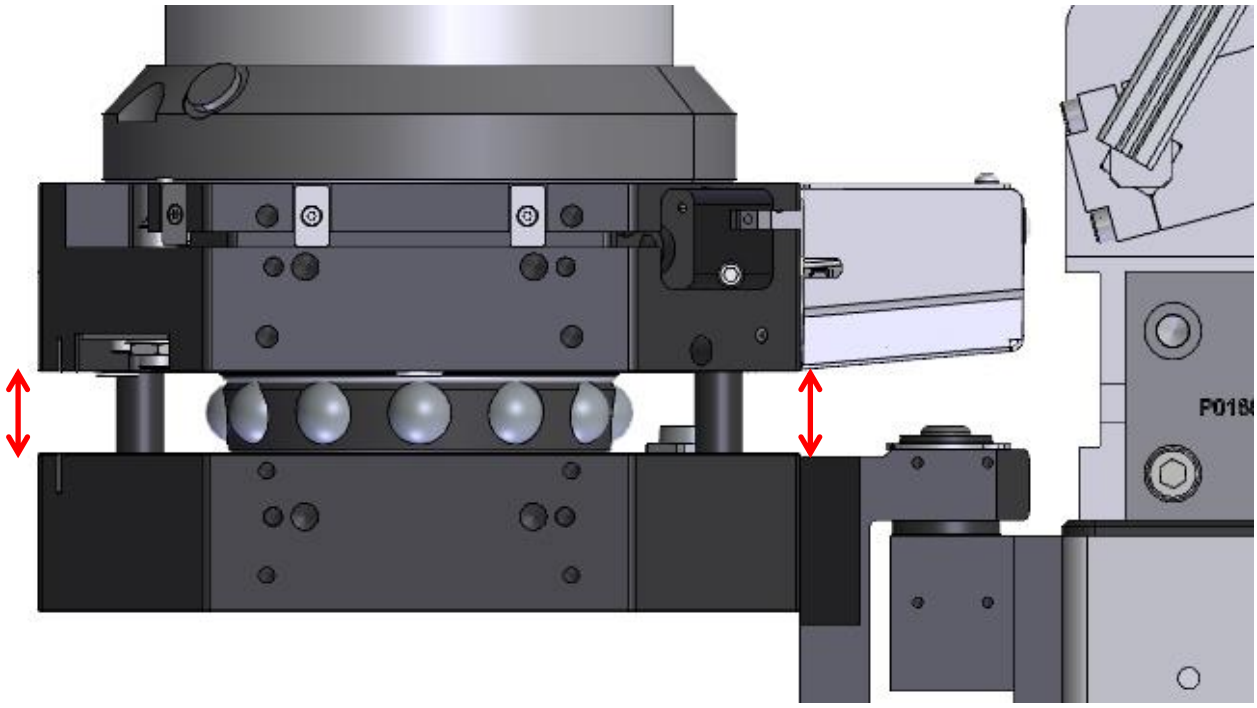
The tool changer is fully locked to the tool attachment, lifted above the docking position in the tool stand (with a gap within 25 mm, figure above) and is in fault state (see FaultCodes in section 7.21).

Step	Action
1	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
2	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
3	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).

4	In case the robot has motion supervision error, adjust the value of the expected load of the tool in the robot controller.
5	Undock tool attachment/tool from the tool stand by manually jogging or automatically driving the robot.
6	Visually inspect status of tool changer, tool attachment and tool stand.
7	Follow instructions in section 7.21 for *FaultCode* 4.

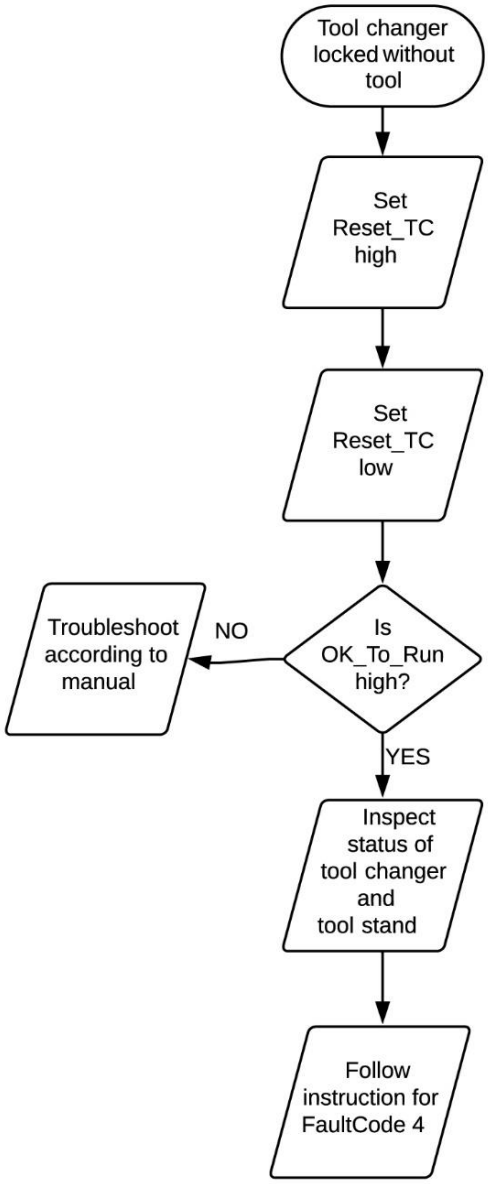


Scenario 2: Tool changer locked and lifted but TA remaining in tool stand

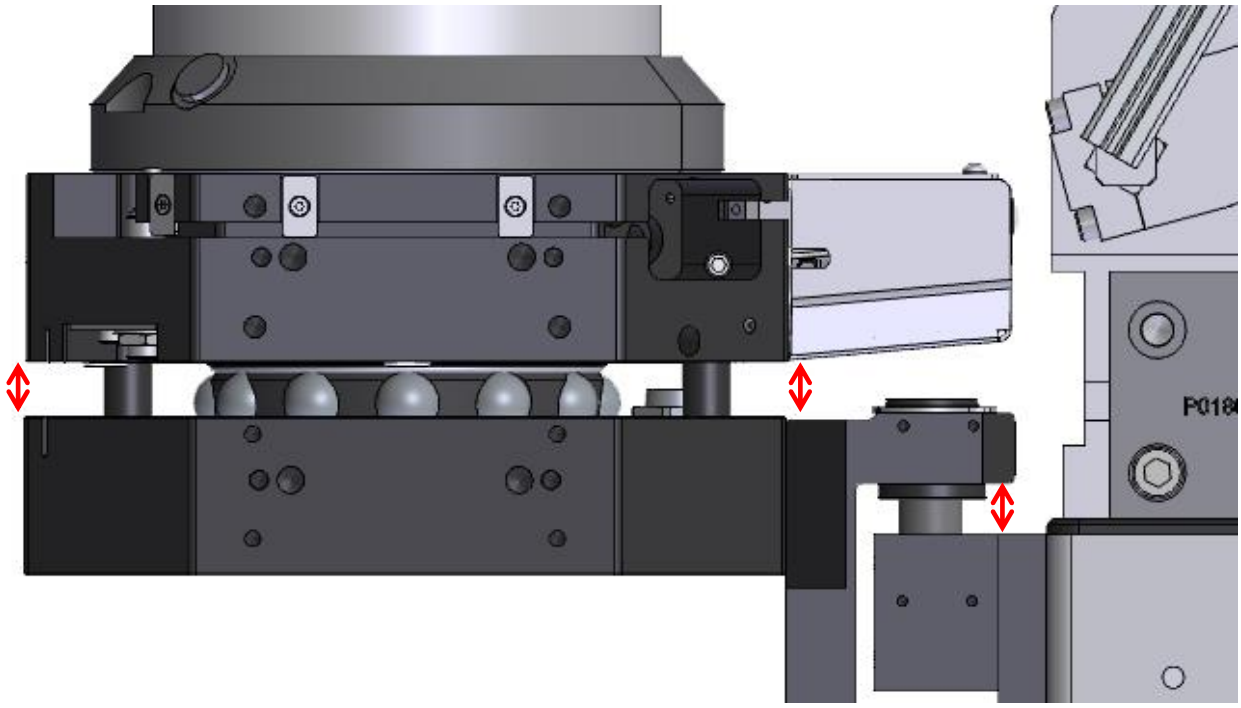


The tool changer is locked and lifted (within 25 mm, figure above) but with a gap against the tool attachment, which is remaining in the docking position at the tool stand, and is in fault state (see FaultCodes in section 7.21).

Step	Action
1	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
2	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
3	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).
4	Visually inspect status of tool changer, tool attachment and tool stand.
5	Follow instructions in section 7.21 for *FaultCode* 4.

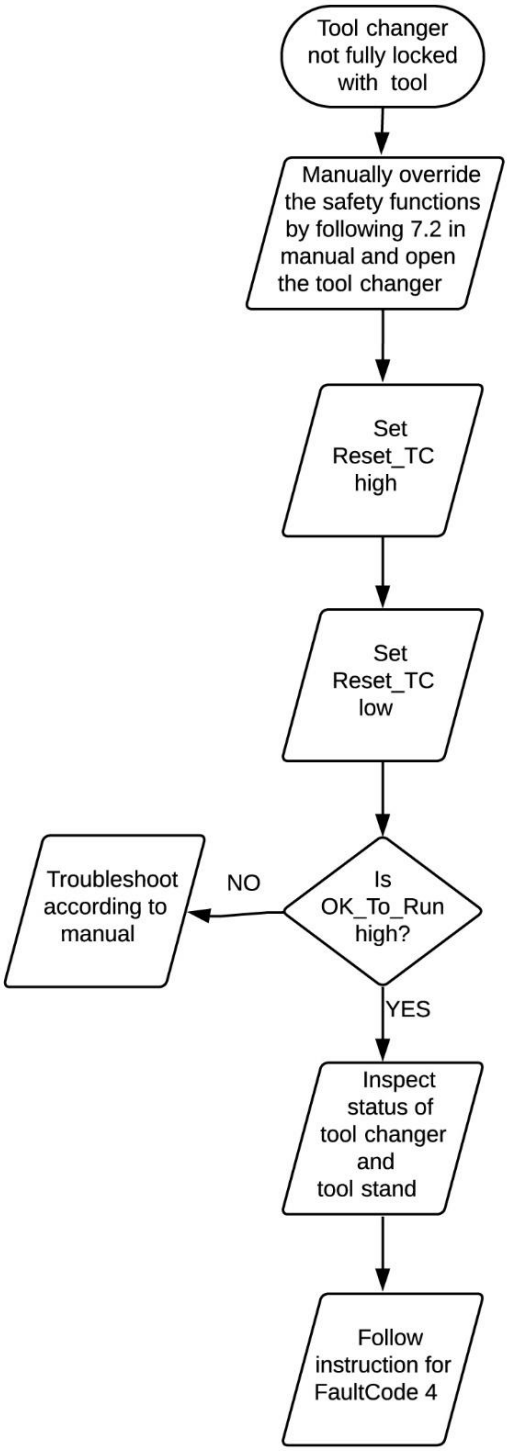

Tool changer locked without tool
Set Reset_TC high
Set Reset_TC low
Is OK_To_Run high?
NO
Troubleshoot according to manual
YES
Inspect status of tool changer and tool stand
Follow instruction for FaultCode 4

Scenario 3: Tool changer partially locked with TA above tool stand



The tool-changer is partially locked and lifted (within 25 mm, figure above) but with gaps both between tool changer and tool attachment and between tool attachment and the docking position at the tool stand and is in fault state (see FaultCodes in section 7.21).

Step	Action
1	Open the tool changer by manually overriding the safety functions (follow instructions in section 7.2). This will make the tool fall back into place in the tool stand. **WARNING!** Be aware of the risk of entrapment when manually overriding the safety functions. The tool attachment is heavy and may cause personal injury when falling into place.
2	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
3	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
4	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).
5	Visually inspect status of tool changer, tool attachment and tool stand.
6	Follow instructions in section 7.21 for *FaultCode* 4.


Tool changer not fully locked with tool
Manually override the safety functions by following 7.2 in manual and open the tool changer
Set Reset_TC high
Set Reset_TC low
Is OK_To_Run high?
NO
Troubleshoot according to manual
YES
Inspect status of tool changer and tool stand
Follow instruction for FaultCode 4

APPENDIX B – RELEASE FAILURE (HORIZONTAL DOCKING): SUGGESTED ACTIONS

NOTE! This appendix contains safety related recommendations for vertical tool parking with horizontal docking/undocking solutions. Such solutions are presently not supplied by Robot System Products but designed by our customers.

Background

The RSP Safety signal module, P7501-xxx, combines transfer of control signals and power with a built-in safety unit. When using the RSP Safety signal module, according to section 6.2.1 Flow chart for undocking tool, the tool changer will automatically lock and enter a fault state if the Tool_In_Stand signal is lost before the TA_Present signal during the initial 25 mm robot movement after undocking. This may happen (i) if the tool attachment/tool is stuck and follows the tool changer out of the RSP tool stand, (ii) if there is a sudden loss of air pressure, (iii) if there are sensor problems or (iv) if there are problems with signal transfer.

NOTE! It is the sole responsibility of the designer and system integrator of a tool parking system for horizontal docking/undocking to ensure a fully safe solution!

Tool parking design for horizontal docking/undocking

Occasionally vertical tool parking (with horizontal docking/undocking) is used, such solutions are typically required to save space in tight robot cells. When designing and implementing tool parking for horizontal docking/undocking the following should be carefully considered:

- The tool parking shall be constructed and built to have a maximum displacement of 0.5 mm of the docking position when a tool attachment with full tool load is docked.
- The tool must hang steady in place, at the tool parking position, by its own weight!
- Guide pins of minimum length of 25 mm shall be used and installed vertically.
- The tool parking system shall be designed to ensure that the tool hangs securely in its position even if impacted by forces during docking/undocking. Such forces may, for example, occur through minor collisions between TC and TA when the docking position is slightly off. Stability is especially important when using lightweight tools.
- The tool in stand sensor shall be placed according to instructions in applicable product manuals, and sensor signals confirming connection shall only occur when the tool is securely docked in its parking position. The tool in stand sensor must remain stable during docking/undocking without erroneous loss of connection.

NOTE! Inspect equipment for damages before taking any action!

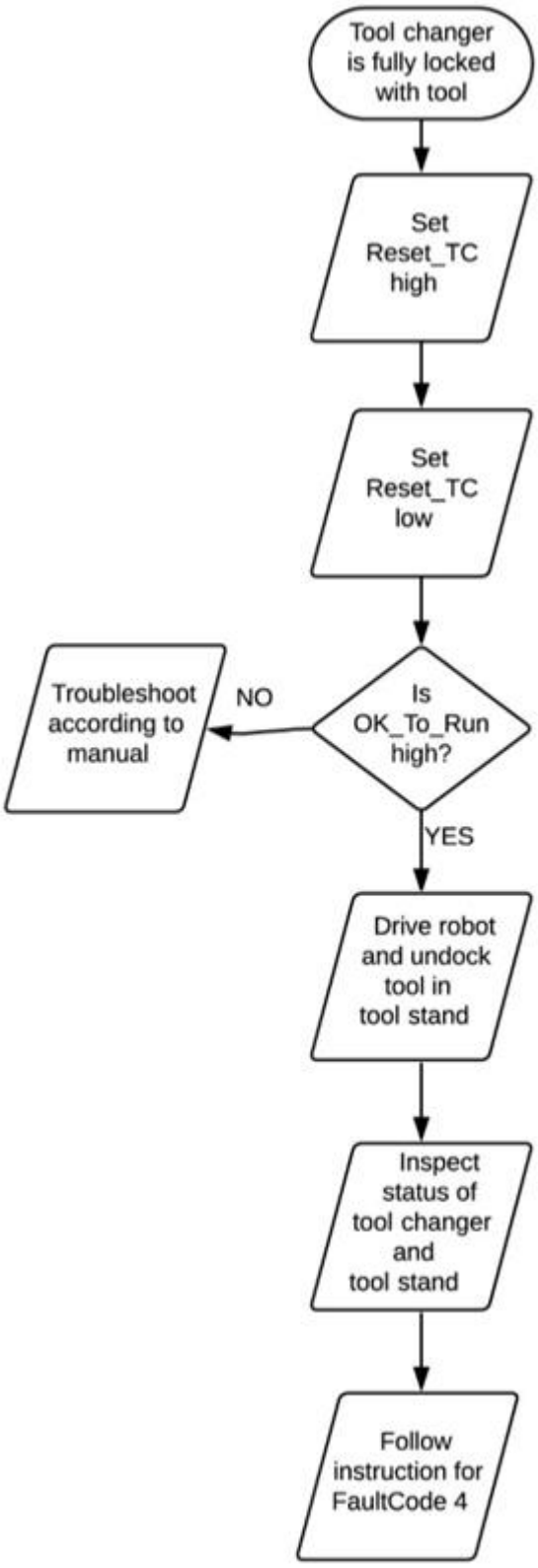
WARNING! The tool/tool attachment is heavy and can pose a serious danger to humans and equipment. Always ensure that the tool/tool attachment cannot fall down before any action is initiated!

The following three possible release fault scenarios are identified depending on which one the following actions should be taken:

Scenario 1: Tool changer fully locked with TA out of tool stand

Tool changer is fully locked to the tool attachment (with a gap within 25 mm) and in fault state.

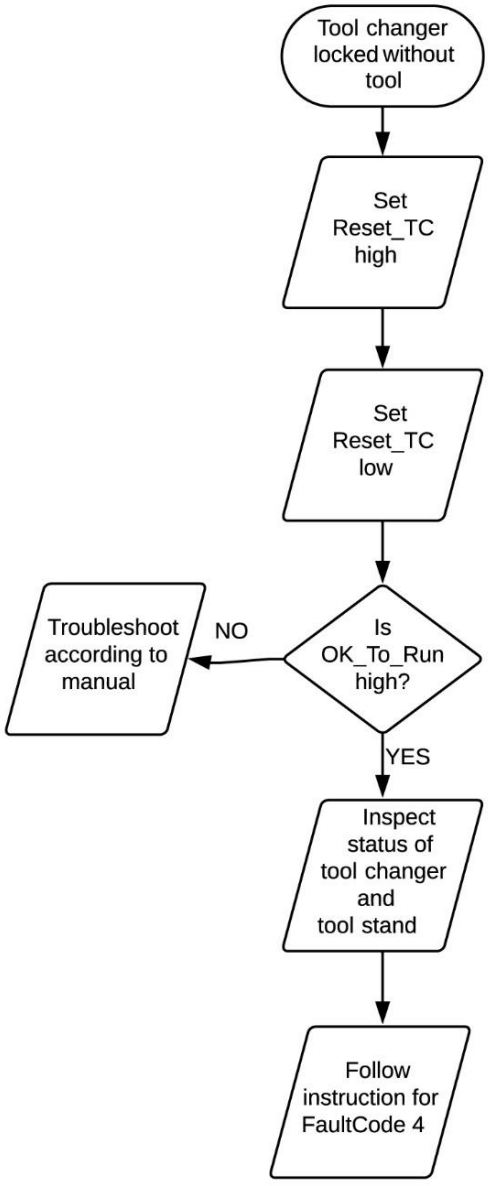
Step	Action
1	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
2	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
3	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).
4	Drive the robot to undock position and undock tool. If robot is in motion supervision, adjust expected load if needed. **NOTE!** Tensions between robot and tool stand may occur and restrain undocking
5	Visually inspect status of tool changer, tool attachment and tool stand.
6	Follow instructions in section 7.21 for *FaultCode* 4.


Tool changer is fully locked with tool
Set Reset_TC high
Set Reset_TC low
Is OK_To_Run high?
NO
Troubleshoot according to manual
YES
Drive robot and undock tool in tool stand
Inspect status of tool changer and tool stand
Follow instruction for FaultCode 4

Scenario 2: Tool changer locked but TA remaining in docking position

Tool changer is locked and moved (within 25 mm) out of docking position but with a gap against the tool attachment, which is remaining in the docking position at the tool stand, and in fault state (see FaultCodes in section 7.21).

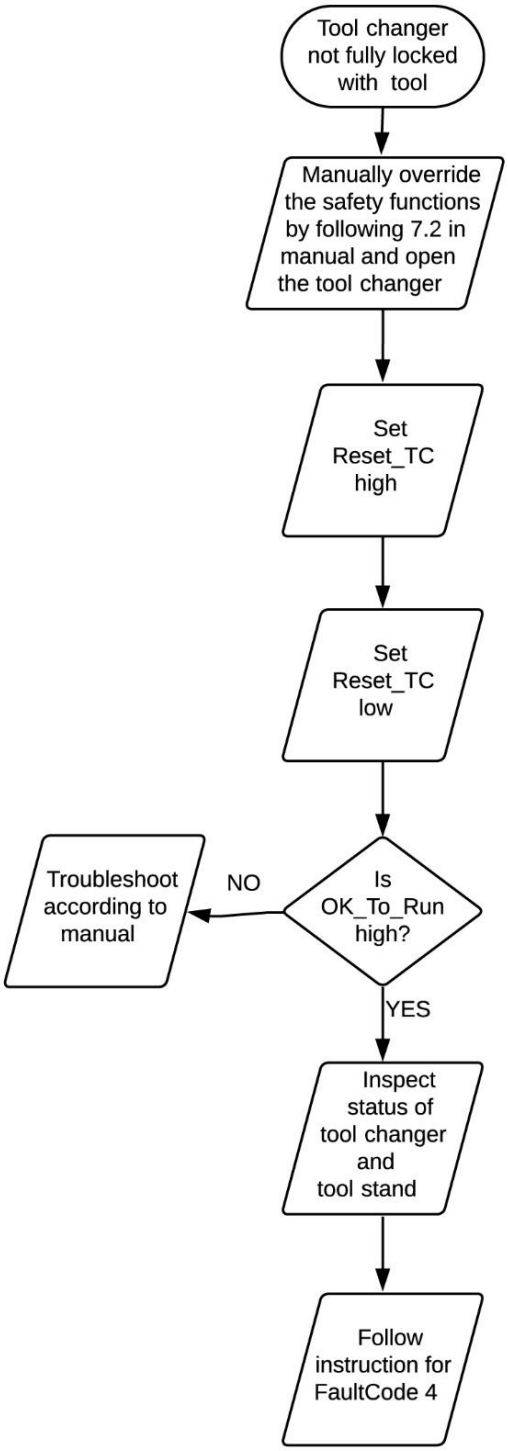
Step	Action
1	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
2	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
3	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).
4	Visually inspect status of tool changer, tool attachment and tool stand.
5	Follow instructions in section 7.21 for *FaultCode* 4.



Scenario 3: Tool changer partially locked with TA

The tool changer is partially locked and moved (within 25 mm) out of docking position but with gaps both between tool changer and tool attachment and between tool attachment and the docking position at the tool stand and is in fault state (see FaultCodes in section 7.21).

Step	Action
	NOTE! The tool attachment/tool must be firmly secured in its position before any further action is taken!
	WARNING! The tool/tool attachment is heavy and can pose a serious danger to humans and equipment! It is required to ensure that the tool/tool attachment cannot fall down before initiating any action!
1	Open the tool changer by manually overriding the safety functions (follow instructions in section 7.2). This should make the tool attachment/ tool fall into place in the tool stand. **WARNING!** Be aware of the risk of entrapment when manually overriding the safety functions. **NOTE!** If required, push the tool attachment/tool into place in the tool stand while overriding safety functions.
2	Reset tool changer by setting the *Reset_TC* to high (=1). This will turn the safety logic off and generate a reset. **NOTE!** While *Reset_TC* is high (=1) the tool changer is prohibited to operate, and no sensor data is available.
3	Set *Reset_TC* to low (=0), which will restart the Safety signal module.
4	If *OK_To_Run* is low (=0) troubleshoot according to section 7.21. If everything is okay the module will return signal *OK_To_Run* high (=1).
5	Visually inspect status of tool changer, tool attachment and tool stand.
6	Follow instructions in section 7.21 for *FaultCode* 4.


Tool changer not fully locked with tool
Manually override the safety functions by following 7.2 in manual and open the tool changer
Set Reset_TC high
Set Reset_TC low
Is OK_To_Run high?
NO
Troubleshoot according to manual
YES
Inspect status of tool changer and tool stand
Follow instruction for FaultCode 4