OMRON

Safety Manual

Software Version: 1.68.6800 or newer

TM ROBOT

Original Instruction

I625-E-02

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Revision History Table

Revision	Date	Revised Content
01	October 2018	Original Release
02	December 2018	Added alert statements in section 2.3.1, 3.1.1, 3.2.2, 3.2.2.3 and 3.2.3. Updated Chapter 4. Minor text fixes. Removed appendix for Declaration.

1. Comprehensive Information

1.1 Overview

This chapter describes the comprehensive important safety information of TM Robot. The user and system integrator of TM Robot must read and fully understand this chapter before using this robot.

1.2 Applicable Product Version

This document is only applicable to the combination of the following software and hardware versions of TM Robot. Users can check the hardware version and software version on “Techman Robot Product Brief Information” sheet in the control box carton, or through these methods: checking the hardware version on the product label on the control box and checking the software version from the software information button in the UI of TMflow. If the software version of the robot has been upgraded and is different from the original out-of-the-box one, users should only check the software version from the UI of TMflow.

Hardware version	HW 3.00
Software version	SW 1.68.6800 or newer

Users shall confirm whether the software and hardware version of the TM Robot is consistent with the applicable product version of this Safety Manual. OMRON is not responsible for any safety issues caused by referring to the safety instruction of an incorrect version.

1.3 Safety Warning Symbols

The following table defines the safety warning level symbols that are marked in each paragraph in this Manual. Read carefully and comply with each paragraph to avoid harm to people or equipment.

	**DANGER:** Identifies an imminently hazardous situation which, if not avoided, is likely to result in serious injury, and might result in death or severe property damage.
	**WARNING:** Identifies a potentially hazardous situation which, if not avoided, will result in minor or moderate injury, and might result in serious injury, death, or significant property damage.
	**CAUTION:** Identifies a potentially hazardous situation which, if not avoided, might result in minor injury, moderate injury, or property damage.
	**WARNING: ELECTROCUTION RISK** This identifies a hazardous electrical situation.

1.4 Safety Precautions

DANGER:
This product can cause serious injury or death, or damage to itself and other equipment, if the following safety precautions are not observed.

- All personnel who install, operate, teach, program, or maintain the system must read the “Hardware installation Manual”, “Software Manual”, and “Safety Manual” according to the software and hardware version of this product, and complete a training course for their responsibilities in regard to the robot.

Read Manual and Impact Warning labels

- All personnel who design the robot system must read the “Hardware installation Manual”, “Software Manual”, and “Safety Manual” according to the software and hardware version of this product, and must comply with all local and national safety regulations for the location in which the robot is installed.
- Observing the “Intended Use” section in “Safety Manual”
- If the installation and application does not observe human-robot collaboration regulations of the safety regulations, the user is responsible for providing safety barriers around the robot to prevent anyone from accidentally coming into contact with the robot when it is in motion.
- If any local or national electrical regulation requires, power to the robot and its power supply must be locked out and tagged out, or have means to control hazardous energy or implement energy isolation before any maintenance is performed.
- Dispose of the product in accordance with the relevant rules and regulations of the country or area where the product is used.

1.5 Validation and Responsibility

The information provided in this Manual does not include how to design, install and operate a complete arm application, nor does it include the peripheral devices that will affect the overall system safety. The design and installation of the complete system must comply with the standards and regulations for safety requirements in the country located. The robot integrator needs to understand safety laws and safety regulations in the local countries, in order to avoid major risks existing in the entire system.

This includes but is not limited to:

- Perform a risk assessment of the whole system
- Adding other machines and additional safety mechanisms based on the results of the risk assessment
- Building appropriate safety mechanisms in the software
- Ensuring the user will not modify any safety-related measures
- Ensuring all systems are correctly designed and installed
- Specifying instructions for use
- Clearly marking the installation of the robot and the contact information of the integrator
- Collecting all documents into the technology folder, including the risk assessment, and this Manual

CAUTION:
This product is a partly completed machinery. The design and installation of the complete system must comply with the safety standards and regulations in the country of use. The user and integrators of the robot should understand the safety laws and regulations in their countries and prevent major hazards from occurring in the complete system.

1.6 Limitation of Liability

Even if the safety instructions are followed, any safety-related information in the Manual shall not be considered as a guarantee that the product will not cause any personal injury or damage.

1.7 Overall Safety Warning

The following lists the overall safety warnings. Pay attention that in addition to the contents described in this section, there are still relevant safety warnings for this section in the rest of chapters in this Manual. Read them in detail.

DANGER:

1. Before transporting, installing, operating, maintaining and repairing this product, make sure to read the product specification and operation manual in detail. Confirm that all the conditions comply with the requirements of the specification and the Manual, to avoid unintended accidents (for example: improper operation or conditions of use that exceed the product specification) that resulted in harm to the people or this product.
2. Before installing and using this product, the installer must perform the necessary risk assessment according to the conditions of use to prevent accidents from happening during the operation of the machinery (for example: collision of machinery and people during operation) that resulted in serious injury to the people due to improper condition setting.
3. In case of emergency or abnormal situation, the users shall create a procedure to secure safety and operation of the robot system.
4. Before using this product, make sure that the machinery has at least one emergency stop device capable of stopping the motion of robot in the event of an accident, and must confirm that there is no abnormality in the function and operation of the device.

WARNING:

1. Before disassembling or repairing this product, make sure that the power has been turned off and disconnected first before proceeding with the subsequent operations to avoid injury to people or damage to machinery caused by inadvertent short circuit or electric shock.
2. When operating this product, the operator shall avoid wearing loose clothing or wearing other accessories (such as: necklaces, ties, bracelets, etc.) to avoid injury caused by clothing or accessories being entangled in the machine during operation of the implement.
3. If the product malfunctions, follow the correct procedures and channel in contact with the appropriate people for proper condition elimination and maintenance. Do not attempt to repair the product yourself, to avoid damage to the machinery due to improper assembly and disassembly.
4. Before the robot is in operation, make sure that each part has been completely mounted to avoid any possibility of accidents due to poor fixation during the operation.
5. Before starting the operation of the robot, confirm that there are no persons or obstacles that may intrude into the operating area during operation. If the operating environment uses human-robot cooperative operation, be sure to complete the due risk assessment before starting the operation.

6. It is forbidden for any unauthorized person to operate this product in order to avoid any possibility of injury to the person or damage to the machinery due to improper operation.
7. Do not install or operate this product in a hazardous area (for example: strong magnetic field, hazardous gas, fire source, or flammable product) In order to prevent the machinery from causing danger during operation resulted from the impact of external conditions.

CAUTION:

1. When the person is near the robot or operate the robot, confirm the prompt of machinery warning light before performing the subsequent operations.
2. After completing editing the task flow, operate in the Manual Mode first, and confirm that all the movements in the operation process are correct before switching the operation mode to Auto Mode.
3. During the operation of machinery, do not turn off the power supply if it is not necessary to prevent possible damage to the system.
4. For the robot noise levels and related environmental conditions, refer to the “Hardware Installation Manual” for the corresponding hardware version.

1.8 Intended Use

The TM Robot is designed so the hazards can be reduced to tolerable levels when applied as specified and operated under normal and intended use.TM robots have been designed and constructed in accordance with relevant safety standards. TM robots are intended for use in parts assembly and material handling for payloads (including end-effector and workpiece) up to the “Maximum Payload” specification of each model.

The TM Robot focuses on the safety of human-robot cooperative operation during design, but the cooperative operation is only for application procedures that have undergone a risk assessment including robots, related peripheral equipment and working environment.

Any use or application should consider the risk assessment. If the use is different from the intended application, OMRON will not bear any responsibility. OMRON clearly specifies but not limited to the following contents that are not suitable for the TM Robot.

- Use in a potentially hazardous environment
- Use in any applications that may threaten human lives
- Use in any application that may cause personal injuries
- Use before completion of the risk assessment and implementation of risk reduction measures
- Use for life support
- Use when the rated performance cannot be reached
- Use when the reaction time of safety functions is insufficient

- Use with inappropriate parameters for operations
- Applications which may cause damage to the robot itself
- Restricted movement of persons
- Loss of stability/ overturning of machinery
- Excessive oscillations when moving
- Without proper design of earthquake-prevention mounting when installed in earthquake zones
- Fall of persons during access to (or at/from) the work station
- Exhaust gases/lack of oxygen at the work position
- Fire (flammability of the cabinet, lack of extinguishing means)
- Mechanical hazards at the work position: a) rollover; b) fall of objects, penetration by objects; c) break-up of parts rotating at high speed; d) contact of persons with machine parts or tools (pedestrian controlled machines)
- Insufficient visibility from the work positions
- Inadequate lighting
- Inadequate seating
- Insufficient means for escape or entrapment avoidance
- Inadequate location of manual controls
- Inadequate design of manual controls and their mode of operation

1.9 Risk Assessment

Before installing and using this product, the user must first perform a risk assessments based on the conditions of use. Risk assessments can be in reference to the specifications of ISO 10218-2, ISO 12100 and ISO/TS 15066 documentations. The purpose of a risk assessment is to anticipate any accidents that may occur during the operation process and by means of appropriate protective measures to reduce the occurrence of accidents or to reduce the severity of injury to persons in the event of an accident. Therefore, the risk assessment needs to include any operational actions of the machinery within the scope of the assessment. After the risk assessment is completed, the user can use external related components (i.e. sensing components, emergency stop devices, fences or railings, etc.) as well as the parameter settings of safety functions in the operating system, to reduce possible occurrence of accidents. Additional safety-related components must be installed in accordance with the manufacturer's specifications for the required risk reduction. For operating system safety settings and other safety components usage, read and understand this Manual, the "Software Manual" and the "Hardware Installation Manual" of corresponding versions.

Potential hazards requiring additional risk reduction measures may include but are not limited to:

1. Finger(s) (especially in the case of hand guiding) caught between the rear end of the camera module and the joint module(s).
2. The palm or finger injured by the motion of the robot or the hand guide teaching, if caught between the robot end-effector (including the workpiece) and the robot body.
3. Being hit by a robot and injured.
4. Entrapment between a robot and a fixed surface.
5. Injury caused by the loosened screws of the base of the robot.
6. Incorrect human-robot collaborative workspace setup, parameter settings or project operation.

WARNING:
Ensure compliance with all local and national safety and electrical codes for the installation and operation of the robot system.

WARNING:
Provide appropriately-sized Branch Circuit Protection and Lockout/Tagout Capability in accordance with the National Electrical Code and any local codes.

WARNING: ELECTROCUTION RISK
AC power installation must be performed by a skilled and instructed person. During installation, unauthorized third parties must be prevented from turning on power through the use of lockout/tagout measures.
Failure to use appropriate power can lead to malfunction or failures of the robot or hazardous situations.

2. Safety Function

2.1 Overview

TM Robot incorporates multiple safety functions, and provides interfaces for additional external protective devices.

2.2 General Information

The following describes common information of the TM Robot system safety functions:

2.2.1 Safety Function Definition

Safety Function Definition of TM Robot System is shown as in the following table:

Safety Function Number	Name	Robot Stopping Function	Stop Category	Structure Category	PL
SF0	Emergency Stop	Emergency Stop	Cat. 1	Cat. 3	d
SF1	External Emergency Stop	Emergency Stop	Cat. 1	Cat. 3	d
SF2	Encoder Standstill	Protective Stop	Cat. 0	Cat. 2	d
SF3	External Safeguard	Protective Stop	Cat. 2	Cat. 2	d
SF4	Joint Torque Monitoring	Protective Stop	Cat. 2	Cat. 2	d
SF5	Joint Position Limit	Protective Stop	Cat. 2	Cat. 2	d
SF6	Joint Speed Limit	Protective Stop	Cat. 2	Cat. 2	d
SF7	TCP Speed Limit	Protective Stop	Cat. 2	Cat. 2	d
SF8	TCP Force Limit	Protective Stop	Cat. 2	Cat. 2	d
SF9	External Triggered Collaborative Mode	Protective Stop	Decrease the speed to collaborative speed	Cat. 2	d

Note 1. The structure category according to ISO 13849-1:2015.

Note 2. PL (Performance Level) in accordance with ISO 13849-1:2015.

Note 3. Emergency stop and protective stop in accordance with ISO 10218-1:2011.

Note 4. Stop categories in accordance with IEC 60204-1.

2.2.2 Stopping Time and Stopping Distance in the Safety System

Safe stopping time is the time required from when an emergency stop or protective device (i.e. internal or external) is activated and hazardous motion stops. In this system, activating the emergency stop button will apply Cat. 1 safety stop. Activation of a safety function or external safety protective device will be a Cat. 2 stop. It may be necessary for the user or system integrator to take these stop times into consideration when implementing risk reduction measures. The robot has speed during this time, which can transmit energy and present additional risk. Refer to Appendix A for stopping time and stopping distance.

2.2.3 Software Safety Setting Permissions

A change management process should be in place listing known acceptable setting and potential hazards. Changes are made in the permissions management function. The authorized user must log in with Administrator permission and set all levels of permissions appropriately. Cyber security measure should be implemented when using on a network connection. OMRON is not liable for the possible harm caused by malicious attacks or intrusion of network to modify the permissions management system or safety setup.

2.3 Explanation of Safety Functions

2.3.1 SF0 Emergency Stop and SF1 External Emergency Stop

The SF0 Emergency Stop refers to the built-in Emergency Switch on the Robot Stick of the TM Robot, and the SF1 External Emergency Stop refers to the Emergency Stop Port on the control box, which can be used to connect additional emergency switches.

The user can stop movement by pressing the emergency switch. After movement of the robot has ceased, the user must confirm that all hazardous conditions have been eliminated before manually releasing the emergency switch to allow reactivation of the robot. The Emergency Stop should only be used when a critical condition occurs. To stop the action of robot under normal operation, use the Stop Button on the Robot Stick.

If the risk assessment requires additional Emergency Stop Devices, the selected device must comply with the requirements of the ISO 60204-1. Additional Emergency Stop Devices connected to the Emergency Stop Port (SF1) shall be installed so they do not diminish the overall performance level of the Emergency Stop.

Activation of an emergency stop initiates a Cat. 1 stop. The Indication Light Ring of the robot will not display light and the three lights from the Robot Stick will be constantly blinking. The operation steps to reset the emergency stop state are as follows:

1. Rotate the Emergency Switch to the pop-up state. At this time, the robot arm will be re-powered. The Indication Light Ring will have the light blue light on to indicate the Safe Start up Mode.
2. Press the Stop Button on the Robot Stick for about three seconds. The robot will perform the calibration

action of the start-up process and return to the previous operating mode.

WARNING:
The power of the robot arm will be cut and the joint brake will be activated, if the Emergency Stop is triggered. The Indication Light Ring of robot's end module will not show light and the three lights from the robot stick will be constantly blinking. In this case, although each of the joint will be automatically locked through the breaking device on joints, the robot body will still drop slightly, before it completely stops. Pay attention to the existing risk that the end part of the robot may pinch human body or collide with other objects.

WARNING:
During an Emergency Stop, power to the end effector will be cut. If the system was integrated with power I/O enabled end effector, the emergency stop condition may cause the workpiece to be dropped.
This shall be taken into consideration when the user integrates the system and perform appropriate design in compliance with risk assessment. To prevent the unexpected dropping of work pieces, user can choose an end-effector with self-maintaining function, using pneumatic logic configuration of reverse logic, using the power supply/IO of control box, or connecting extra power supply. The user should be responsible for a correct integration.

CAUTION:
Person should be outside of the robot's operational space (areas that robot can reach) when recovering from emergency stop.

2.3.2 SF2 Encoder Standstill

This safety function is automatically activated after every Cat. 2 Stop. Encoders of each joint are monitored continuously to check if there is any unintended motion until the user acknowledges and manually resets the robot from Cat. 2 Stop status. If there is any unintended motion, this safety function will trigger a Cat. 0 Stop.

2.3.3 SF3 External Safeguard and SF9 External Triggered Collaborative Mode

These two safety inputs are provided on the Safeguard Port of the robot control box. For the related connection and usage, refer to the "Hardware Installation Manual". Resuming from the SF3 External Safeguard protective stop can be manual or auto. Refer to the relevant contents in the "Software Manual". Resuming from the SF9 External Triggered Collaborative Mode is automatic, which means the robot will be back to the original project speed.

2.3.4 SF4~SF8 Defined Safety Function

The name and description of SF4 to SF8 safety functions are shown below:

Safety Function	Name	Description
SF4	Joint Torque Monitoring	Each joint's torque limit condition can be set. When the robot exceeds its set value, it will trigger a Category 2 stop.
SF5	Joint Position Limit	Each joint's motion angle limit can be set. When the robot exceeds its set value, it will trigger a Category 2 stop.
SF6	Joint Speed Limit	Each joint's motion speed range can be set. When the robot exceeds its set value, it will trigger a Category 2 stop.
SF7	TCP Speed Limit	The tool center point speed limit can be set. When the robot exceeds its set value, it will trigger a Category 2 stop.
SF8	TCP Force Limit	The tool center point force limit can be set. When the robot exceeds its set value, it will trigger a Category 2 stop. The tool center point force is the external force at the tool center point.

Refer to the relevant contents in the "Software Manual" for the setting of each item. Users can use any method listed below to manually reset the robot from SF4 to SF8:

1. pressing the STOP button on robot stick
2. any operation on the icons in the left sidebar of the TMflow (except Shutdown)
3. pressing the FREE button in the end module of TM Robot
4. changing the mode on robot stick.

DANGER:
Pay attention that the "TCP Force" (Tool Center Point Force) is the external force at the tool center point estimated through the model by the robot system, not the protection value of the external force at the tool center point on the robot system. When the robot system exceeds the external force value at the tool center point, the robot will perform a category 2 stop. In this condition, applied forces will exceed this value. Therefore, clearly understand the amount of the external force applied before the robot comes to a complete stop. The degree that this value will be exceeded will increase as the robot speed increases. This cannot be the primary risk mitigation for human-robot collision.

CAUTION:
When the motion of TM Robot is passing the area near singular point, due to the nature of singularity, the TCP force may be over-estimated and triggers TCP Force Stop Criteria. Users can set the robot's motion properly, e.g. do not set the motion too close to the singular point, to avoid this situation.

3. Safety Related Operation

These are the operating instructions for Safety-related robot functions and designs.

3.1 Joint Movement without Drive Power

The conditions of robot without driving force are emergency stop, start up from the packing pose, and loss of power. The first two can enter Safe Start up Mode when the emergency switch resets, and the latter is the situation when the robot loses external power entirely. The following describes how to operate it:

3.1.1 During an Emergency Stop Procedure

The brake of each joint axis will automatically lock the joint, to avoid unlimited sagging of the robot's joints due to gravity. If you need to move the robot to resolve the condition, follow the steps listed below:

1. Releasing the Emergency Switch energizes the power to the robot.
2. Wait 10 seconds to enter the Safe Start Up Mode. The Indication Light Ring will turn light blue.
3. The FREE button can be continuously pressed to release the joint axis brake and move the robot.
4. After the situation is resolved, press the stop button on the Robot Stick for about three seconds, the robot will perform the calibration startup process and return to the original operating mode.

CAUTION:
Person should be outside of the robot’s operational space (areas that robot can reach) when recovering from emergency stop.

3.1.2 Extending the Robot from the Packing Pose

Refer to the "Software Manual" for the operation of extending the robot from the Packing Pose. Emergency stop reset method is found in Section 2.3.1.

DANGER:
When using the FREE button to release brakes without motor power, the robot may sag due to gravity. Be prepared to support the robot system. If it is found that it is not possible to support the robot system, release the FREE button immediately, which will lock the robot joint brakes.

3.1.3 Power Loss

If power loss to an end-effector can result in a hazardous condition (e.g. dropping of a workpiece), possible methods to reduce the risk may include but are not limited to:

- Use the 24V electrical output provided by the control box to supply the power to end effector instead of using the End Module of robot to supply power.
- Install independent power supply for the end effector.
- If the end effector is a pneumatic control design, the external design can be low potential actuation design.
- Select the end effector with self-maintaining function / mechanical design.

If it is necessary to manually move the arm joint:

1. Remove the joint module protective cover screw and the joint module protective cover
2. Press the brake solenoid valve to release the brake

Refer to the brake release illustration in the "Hardware Installation Manual".

3.2 Operation Mode and Mode Switching

TM Robot has two operation modes: Manual Mode (reduced speed and high speed) and Auto Mode. The modes are visually distinguished by the color of the mode indicator of Robot Stick and the Indication Light Ring on robot's end module . The robot is in Auto Mode when starting up.

3.2.1 Auto Mode

In Auto Mode the Indication Light Ring on the end module displays blue light and the Mode Indicator on Robot Stick is in Auto position. The user can press the Robot Stick Play/Pause button to play/pause the robot program. The robot speed plays according to the project speed. In Auto Mode, the FREE button on the end module does not actuate, and cannot perform Hand Guiding operation.

3.2.2 Manual Mode

In Manual Mode the Indication Light Ring on the end module displays green light and the Mode Indicator on Robot Stick is in Manual position. In Manual Mode, it can be divided into Manual Control Mode (Manual Reduced Speed), Manual Trial Run Mode (Manual High Speed), and Hand Guide Mode.

WARNING:
Wherever possible, the manual mode of operation shall be performed with all persons outside the safeguarded space.

3.2.2.1 Manual Control Mode (Manual Reduced Speed)

In Manual Control Mode, the user can jog the robot with controller UI in TMflow or the Robot Stick. All robot

motion will be limited to 250 mm/sec or less. If the robot speed exceeds 250 mm/sec, it will enter an error stop state. Hand Guiding Mode can only be activated from Manual Control Mode. Pressing the FREE button on the End Module will allow manual movement of the robot.

3.2.2.2 Hand Guide Mode

Hand Guide Mode can only be activated from Manual Control Mode. Press and hold the FREE button on the End Module to enter Hand Guide Mode, and release the FREE button to return to Manual Control Mode.

3.2.2.3 Manual Trial Run Mode (Manual High Speed)

In Manual Trial Run Mode, the user can test the robot program by going to the project editing page of TMflow and pressing the Play/Pause button on the Robot Stick. The initial project speed will be reduced to 10% during each trial run, forcing the path motion of the robot lower than 250mm/s in nature. The Add/Subtract buttons on the Robot Stick can be used to adjust the project run speed. Each button press increases or decreases project run speed by 5%.

WARNING:
Person should be outside of the safeguarded space when using Manual Trial Run Mode.

3.2.3 Switching Between Operation Modes

When switching from Auto Mode to Manual Mode, first press the Stop Button to stop robot operation, if the project is running. Then press the Mode Switch Button on the robot Stick.

When switching from Manual Mode (including Manual Control and Manual Trial Run Mode) to Auto Mode, first hold the Mode Switching Button for a few seconds. When the two Mode Indicators on the Robot Stick start blinking, press the Plus/Minus Button in the sequence of "Plus-Minus-Plus-Plus-Minus".

When the robot is in Manual Trial Run Mode, and when switched to Auto Mode, the Project Speed will be set to the last trial run speed. That is, without being modified again by another trial run, the Project Speed in Auto Mode is then recorded.

DANGER:
Prior to selecting automatic operation, any suspended safeguards shall be returned to full functionality.

3.3 Hold to Run

When the TM Robot is in Manual Control Mode the functions include:

- joint angle movement
- robot base end movement

- tool base end movement
- self-defined base end movement
- move to visual initial position
- visual servo action
- step run
- move to point
- hand guiding
- other functions

Hold to Run has two categories:

- Jog the robot by continuously pressing the Plus / Minus Button of the Robot Stick.
- Jog the robot by continuously pressing the Plus / Minus Button in TMflow software.

Once the Plus / Minus Button is released, the robot will stop operation immediately, and will continue operation when pressed again.

If TMflow is connected to the robot through Ethernet or Wi-Fi, the robot will automatically issue a protective stop when releasing the Plus / Minus Button or the connection is broken. Depending on the quality of connection, there may be a maximum detection delay of 800ms for loss of communication.

3.4 Singularity Point

The motion of articulated robot is often limited by the kinematic design, and cannot perform Cartesian motion control under all joint positions. The joint position that will cause the robot unable to perform Cartesian control is a singularity point. When the robot encounters a singularity point, it will stop motion and initiate a warning.

Three types of singularity point for TM Robot:

- Internal Singularity Point in Space
- Extensible Singularity Point in Space.
- Wrist Singularity Point in Space.

Internal Singularity Point in Space:

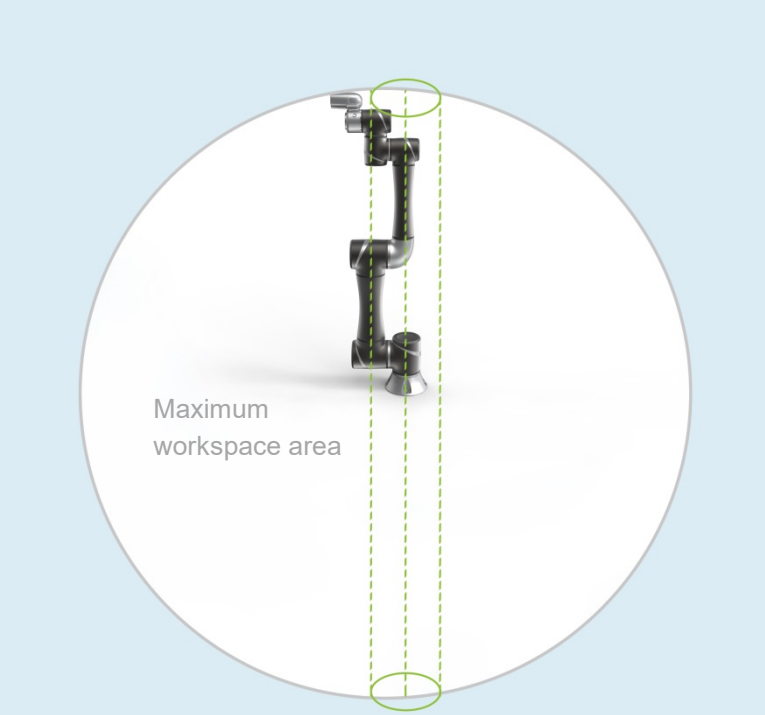
The distance from the intersection of the rotational axes of the fifth joint and the sixth joint to the extended line of the rotational axis of the first joint is defined as R_{offset}. The cylindrical space that formed by R_{offset} as radius and centered on the extended line of the rotational axis of the first joint is the Internal Singularity Point in Space. As soon as the robotic arm approaches the Internal Singularity Point in Space, the arm will stop and issue a warning. The R_{offset} value of each product series is shown in the following table:

Main model	R_{offset}
TM5 Series	122.3 mm
TM12/14 Series	156.3 mm

The definition of R_{offset}.

Extensible Singularity Point in Space:

When the third joint is almost at its zero degree, which means the robot is almost at the maximum working radius. The space exceeded this radius is the Extensible Singularity Point in Space. In this space, the robot will stop and report a warning due to exceeding the motion range of the robot..

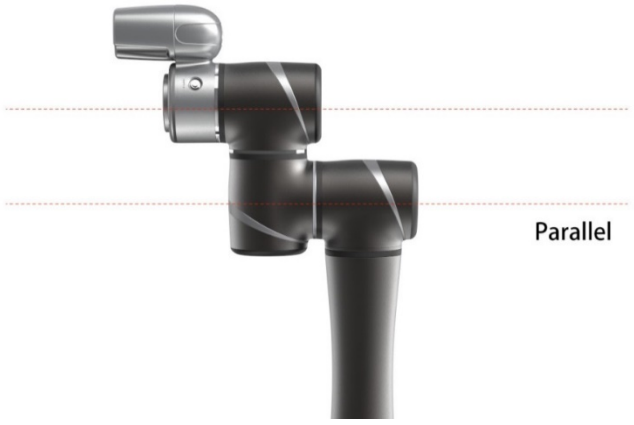


Extensible Singularity Point in Space

The maximum working range can be achieved when the third joint is almost at zero degrees

Wrist Singularity Point in Space:

When the rotational axes of the fourth and the sixth joint are in parallel, the robot will enter Wrist Singularity Point in Space. At this time, the motion of arm will cause a large-angle displacement of the fourth joint, but it will be stopped due to stop criteria of motion speed. Once the robot enters the Wrist Singularity Point in Space, it will stop and report an error.

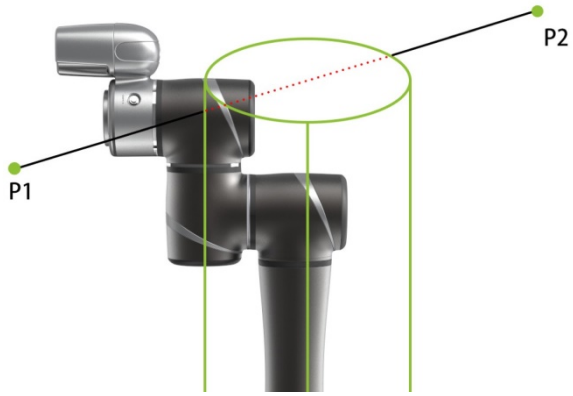


When the fourth and sixth joint are nearly parallel, is the robot is about to entering the Wrist Singularity Point in Space.

The Solution when Encountering Singularity Point in Space:

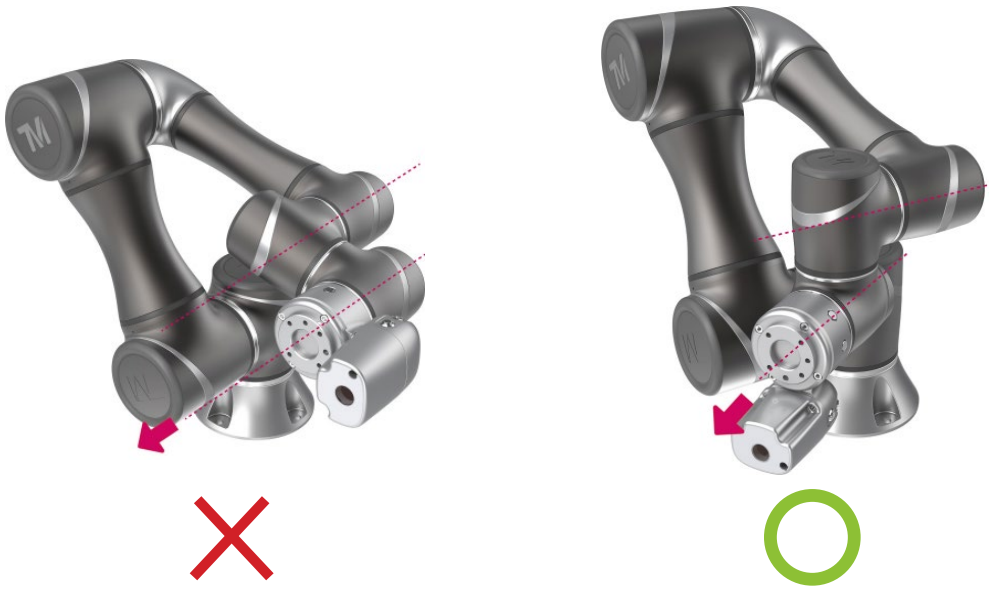
When the robot reports singularity, confirm the posture of the robot. If the tool end path crosses the internal cylinder as shown in the figure below, check the first point description. If the rotational axes of fourth and sixth joints of the robot are in parallel, check the second point description below.

1. When the arm reports a warning due to the Internal Singularity Point in Space, press the FREE button to release it from the posture. Re-consider the point position or change the motion type to PTP between the points to avoid the arm path between the points crossing the Internal Singularity Point in Space, as shown in the figure below.



When the path crossing the Internal Singularity Point in Space, singularity will be triggered. Adjust the path and confirm it will not cross the Internal Singularity Point in Space.

2. When the robot reports a warning because entering the Wrist Singularity Point in Space, press the FREE button to release it. When the rotational axes of the fourth and the sixth joint are in parallel, if users still try to perform Cartesian motion, the Wrist Singularity Point in Space will be encountered. At this time, the method in the following figure can be referred, to avoid the rotational axes of the fourth and the sixth joint being parallel.



This example demonstrates how to avoid the rotational axes of the fourth and sixth joint being parallel, when the user need to move the robot according to tool Z-axis.

4. Compliance of Safety Regulations

This section describes the compliance and certification of this product to international safety regulations.

This product complies with to the following international safety regulations:

ISO 10218-1:2011

ISO/TS 15066

ISO 13849-1:2015

Certification: New Third-party certification will be added by beginning of February, 2019

4.1 Compliance

This product complies with the combined scope of ISO 10218-1:2011 and ISO/TS-15066.

The relevant design and corresponding provisions in safety regulations of this part are listed in the following sections.

4.1.1 Requirement of Enabling Device

The power and force limiting functions provide the alternative measures for the requirement of an enabling device per ISO/TS 15066:2016.

Means are provided for connection of an Enabling device when required by the risk assessment.

4.1.2 Access of Safety Setting

TM Robot's safety setting has been integrated with the user's permission system of the entire product.

WARNING:
If the risk assessment indicates that the work cell should be designed as below: if there is an Emergency Stop to the robot, other work cell devices, such as PLCs or conveyors, should also be Emergency Stopped, user can achieve this through system integration of safety related components, such as safety controller.

5. Declaration of Incorporation

The following is based on the Declaration of Incorporation in application of 2006/42/EG, Annex II, No. 1 B

The robot product of the Corporation is a partly completed machinery. When it is put into automation applications, it needs to be integrated with other equipment, and appropriately installed with the safety related measures and design before it can be used. When the semi-finished products are to put on the market, the following requirements need to be achieved. It must be noted that since the TM Robot product is easy to use, the “system integrator” here refers to the end user who uses the product directly through simple installation.

A: Not related

B: Satisfied by machinery equipment provider

C: Must be responsible by the system integrator

Attention: in the following tables:

- Items marked as A: The scope of use of this product has been exceeded, and is not included into the consideration, or it is not directly related to this product.

- Items marked as B solely: The items that are to be satisfied by the machinery equipment provider, meaning the machinery provider has satisfied or has specified in each of the Software and Hardware / Safety Manual. In the latter case, the system integrator is still responsible for the full compliance with specification of machinery equipment provider. In addition, in the entire system, the satisfaction of machinery equipment belonging to the system but not belonging to this product is not included here, and the system integrator must be responsible for it.

- Items marked as C solely: The item cannot be satisfied by this product. The system integrator must implement additional measures.

- Items marked as both B and C:

    1. When the item can be satisfied in using this product itself, the machinery equipment provider of this product shall satisfy it.
    2. When the system integrator replaces the related functions of this product through system integration, the system integrator shall satisfy it. For example:
        - Replacing the emergency switch of the Robot Stick with an external emergency switch connected to the Emergency Switch Port
        - Replacing the Play/Stop Button of the Robot Stick with user-defined IO or the functions of equivalent functions.

When this type of design replaces the original function of this product, the system integrator shall be responsible for the equivalence of the replacement.

3. The machinery equipment provider satisfies this item in normal condition, but in extraordinary conditions, the satisfying of this item is the responsibility of the system integrator. For example:
   - The product does not have any concern of being cracked broken in normal operation without collision, but the situation that causes the robot to be cracked broken / tilted / even fallen in strong collision environment due to incorrect programming setup and safety setting during operation.

* A – Scope Exceeded, B – Manufacturer Provided, C – May Require Additional Risk Reduction Measures

Number	Original Language Items	A*	B*	C*
1.1	Essential Requirements			
1.1.1	Definitions		X	
1.1.2	Principles of safety integration		X	
1.1.3	Materials and products		X	
1.1.4	Lighting			X
1.1.5	Design of machinery to facilitate its handling		X	
1.1.6	Ergonomics		X	X
1.1.7	Operating positions			X
1.1.8	Seating			X
1.2	Control Systems			
1.2.1	Safety and reliability of control systems		X	X
1.2.2	Control devices		X	X
1.2.3	Starting		X	X
1.2.4	Stopping		X	X
1.2.4.1	Normal stop		X	X
1.2.4.2	Operational stop		X	X
1.2.4.3	Emergency stop		X	X
1.2.4.4	Assembly of machinery			X
1.2.5	Selection of control or operating modes		X	X
1.2.6	Failure of the power supply			X
1.3	Protection against mechanical hazards			
1.3.1	Risk of loss of stability			X
1.3.2	Risk of break-up during operation		X	X
1.3.3	Risks due to falling or ejected objects		X	X
1.3.4	Risks due to surfaces, edges or angles		X	
1.3.5	Risks related to combined machinery	X		
1.3.6	Risks related to variations in operating conditions			X
1.3.7	Risks related to moving parts		X	X
1.3.8	Choice of protection against risks arising from moving parts			X
1.3.8.1	Moving transmission parts			X
1.3.8.2	Moving parts involved in the process			X
1.3.9	Risks of uncontrolled movements			X
1.4	Required characteristics of guards and protective devices			
1.4.1	General requirements			X

1.4.2	Special requirements for guards			X
1.4.2.1	Fixed guards			X
1.4.2.2	Interlocking movable guards			X
1.4.2.3	Adjustable guards restricting access			X
1.4.3	Special requirements for protective devices			X
1.5	Risks due to other hazards			
1.5.1	Electricity supply			X
1.5.2	Static electricity			X
1.5.3	Energy supply other than electricity			X
1.5.4	Errors of fitting			X
1.5.5	Extreme temperatures	X		
1.5.6	Fire	X		
1.5.7	Explosion	X		
1.5.8	Noise		X	X
1.5.9	Vibrations			X
1.5.10	Radiation	X		
1.5.11	External radiation			X
1.5.12	Laser radiation	X		
1.5.13	Emissions of hazardous materials and substances		X	X
1.5.14	Risk of being trapped in a machine			X
1.5.15	Risk of slipping, tripping or falling			X
1.5.16	Lightning			X
1.6	Maintenance			
1.6.1	Machinery maintenance			X
1.6.2	Access to operating positions and servicing points			X
1.6.3	Isolation of energy sources			X
1.6.4	Operator intervention			X
1.6.5	Cleaning of internal parts	X		
1.7	Information			
1.7.1	Information and warnings on the machinery		X	
1.7.1.1	Information and information devices		X	X
1.7.1.2	Warning devices		X	X
1.7.2	Warning of residual risks		X	
1.7.3	Marking of machinery		X	
1.7.4	Instructions		X	
1.7.4.1	General principles for the drafting of instructions		X	
1.7.4.2	Contents of the instructions		X	
1.7.4.3	Sales collateral	X		

Appendix A. TM Robot Stopping Time and Distance for all Series Product Models

The stopping time and stopping distance of the Cat.1 stop functions of this product in different speeds and different end payloads are shown below.

WARNING:
Any moving robot requires some distance to stop. When stopping a robot, make sure that there is no interference with other equipment. This requires more distance at high operating speeds or heavier payloads.

TM5-700 Series

Stop Time and Stop Distance Table								
Percentage of Maximum Payload (%)	Extension(%)	Speed(%)	First joint		Second joint		Third joint	
			Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)
33	33	33	364	9.00	600	9.29	442	8.97
		66	377	17.96	516	18.15	466	17.91
		100	381	26.55	657	27.13	486	26.92
	66	33	455	8.99	567	9.17	422	8.96
		66	531	17.95	594	18.08	457	17.94
		100	610	26.34	528	27.72	457	23.41
	100	33	367	8.98	534	9.30	432	9.00
		66	396	17.94	501	18.19	530	18.02
		100	427	26.76	526	27.80	541	28.81
66	33	33	378	9.01	531	9.23	475	8.99
		66	401	17.95	547	18.12	478	17.97
		100	575	26.75	551	26.99	570	26.91
	66	33	496	8.96	529	9.29	433	8.97
		66	545	17.96	506	18.14	526	17.98
		100	563	26.46	526	28.36	583	27.73
	100	33	517	8.94	568	9.38	636	9.08
		66	598	17.90	524	18.10	545	18.16
		100	614	26.58	575	28.53	527	28.75
100	33	33	565	8.96	585	9.26	567	9.12
		66	570	17.92	585	18.16	675	18.28
		100	579	26.33	356	30.98	666	27.40
	66	33	566	8.95	588	9.34	625	9.28
		66	576	17.92	578	18.26	656	18.26
		100	570	26.88	343	31.10	550	27.56
	100	33	597	8.94	576	9.34	681	9.34
		66	593	17.86	516	18.14	555	18.09
		100	596	26.00	544	26.45	528	28.80

TM5-900 Series

Stop Time and Stop Distance Table								
Percentage of Maximum Payload (%)	Extension(%)	Speed(%)	First joint		Second joint		Third joint	
			Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)
33	33	33	519	8.96	626	9.24	457	8.99
		66	512	17.95	555	18.03	475	17.93
		100	466	25.68	563	27.20	476	27.09
	66	33	374	8.97	598	9.32	444	8.96
		66	719	17.95	510	18.11	636	18.12
		100	664	26.33	521	27.34	650	27.41
	100	33	366	8.98	524	9.25	428	8.97
		66	412	17.93	518	18.23	510	18.04
		100	442	26.57	508	24.20	498	28.66
66	33	33	508	8.98	660	9.19	629	9.23
		66	589	17.97	666	18.20	536	18.09
		100	476	26.86	575	27.62	635	27.06
	66	33	635	8.93	633	9.27	518	9.00
		66	645	18.00	640	18.16	647	18.19
		100	668	26.73	569	28.14	676	27.73
	100	33	366	9.02	506	9.22	565	8.96
		66	479	17.96	522	18.16	514	16.93
		100	503	26.58	517	23.61	485	28.62
100	33	33	474	8.99	572	9.15	662	9.21
		66	571	18.02	573	18.22	640	18.18
		100	568	26.94	563	28.00	637	27.36
	66	33	508	9.00	691	9.31	627	9.18
		66	566	18.10	641	18.23	652	18.26
		100	583	26.72	534	28.45	680	27.56
	100	33	549	9.04	542	9.28	436	8.97
		66	645	18.16	551	18.11	520	18.13
		100	594	26.60	569	23.15	499	28.78

TM14 Series

Stop Time and Stop Distance Table								
Percentage of Maximum Payload (%)	Extension(%)	Speed(%)	First joint		Second joint		Third joint	
			Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)
33	33	33	416	6.01	554	6.18	511	8.83
		66	662	12.00	650	12.33	621	17.84
		100	482	18.24	635	18.58	510	26.32
	66	33	374	5.99	637	6.41	527	8.94
		66	643	11.99	641	12.34	689	17.66
		100	644	18.18	654	18.65	545	26.54
	100	33	482	6.04	530	6.27	453	8.42
		66	531	11.90	657	12.37	589	18.28
		100	624	18.17	626	17.64	575	28.86
66	33	33	680	6.00	623	6.36	598	9.17
		66	684	11.98	605	12.20	632	18.91
		100	690	18.13	595	18.54	631	27.19
	66	33	595	5.99	576	6.35	635	9.28
		66	597	11.96	557	12.42	600	18.33
		100	581	18.13	557	18.51	599	27.50
	100	33	548	5.98	530	6.38	432	8.52
		66	568	11.84	576	12.41	567	18.32
		100	568	18.25	589	17.75	531	28.77
100	33	33	591	5.99	574	6.34	529	9.10
		66	608	11.97	575	12.38	557	18.22
		100	582	18.15	585	18.89	556	27.27
	66	33	611	5.99	594	6.48	575	9.12
		66	615	11.99	616	12.26	671	18.30
		100	618	18.23	604	18.98	571	27.34
	100	33	570	6.06	568	6.29	575	8.95
		66	567	12.06	552	12.34	587	18.20
		100	568	18.39	591	17.61	544	28.87

TM12 Series

Stop Time and Stop Distance Table								
Percentage of Maximum Payload (%)	Extension(%)	Speed(%)	First joint		Second joint		Third joint	
			Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)	Stop Time (ms)	Stop Distance (deg)
33	33	33	365	6.02	634	6.27	674	9.35
		66	364	12.00	557	12.18	588	18.12
		100	473	18.20	559	18.48	615	27.26
	66	33	368	6.01	563	6.27	584	9.19
		66	634	12.01	531	12.24	653	18.30
		100	621	18.17	541	18.45	552	27.73
	100	33	541	5.98	597	5.22	544	8.94
		66	564	12.01	587	12.21	532	18.14
		100	591	18.17	592	17.80	569	28.90
66	33	33	662	6.02	644	6.16	632	9.20
		66	657	12.01	645	12.26	657	18.10
		100	659	18.16	666	18.67	695	27.08
	66	33	501	6.03	664	6.12	680	9.36
		66	661	12.00	601	12.33	676	18.30
		100	661	18.16	588	18.91	570	27.50
	100	33	539	6.02	545	6.38	513	9.10
		66	543	12.01	545	12.36	520	18.15
		100	530	18.40	565	17.88	591	28.82
100	33	33	584	5.99	540	6.19	606	9.17
		66	596	11.99	560	12.52	592	18.01
		100	603	18.14	535	18.88	572	27.07
	66	33	579	6.06	549	6.26	613	9.33
		66	581	12.09	564	12.52	606	18.12
		100	585	18.27	556	19.24	582	27.75
	100	33	580	6.06	558	5.36	608	9.34
		66	548	12.12	537	12.39	547	18.15
		100	564	18.41	518	18.14	611	27.50

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