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WARNING

INSTALLATION SHOULD ONLY BE PERFORMED BY QUALIFIED INSTALLATION PERSONNEL AND MUST CONFORM TO ALL NATIONAL AND LOCAL CODES

Hyundai Robot

Hi5AR120301FMEN1

Hi5 Controller Function Manual

Detection of Inter-robot Arm Interference

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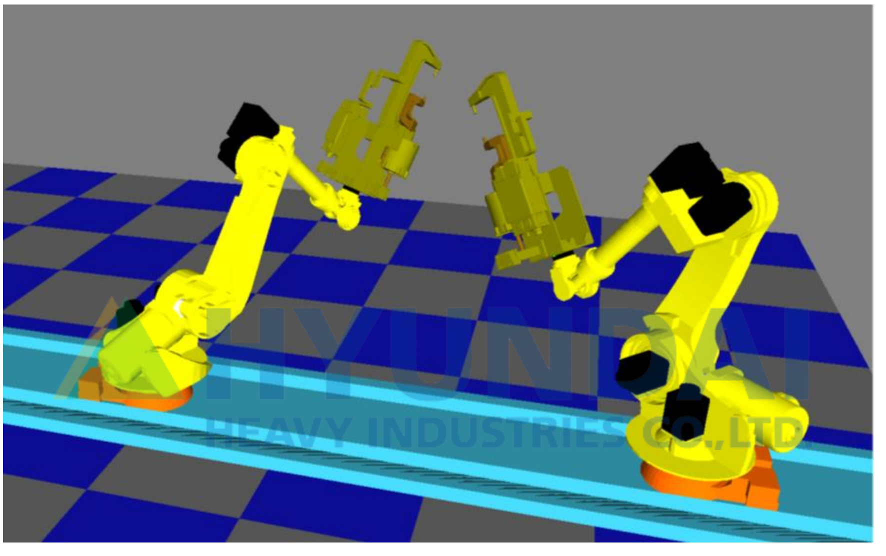
Overview

1.1. Detection of Inter-robot Arm Interference

1.1.1. Purpose of Function

The purpose is to prevent accidents by stopping the robot beforehand when an unintentional collision is expected between robot arms or tools due to programmatic error or user's control mistake (jog, mistake during program writing).

1.1.2. Scope of Function



Interference is detected by using a model that simplifies the interference of robot tools and arms in the form of cylinders. This is also applicable to robots using the drive axis.

- This function is supported for Hi5 Controller versions higher than MV31.14-00 (31 series) and MV32.02-00 (32 series).
- Robots that support interference detection must be connected to HiNet.
- The number of robots that support interference detection is equal to cooperation control. (MAX. 4EA)

1.1.3. Limits of Function

This function cannot be used to automatically evade inter-robot interference by using AI or to automatically determine and operate the inter-robot operation priority.

- This function does not use mutual interlock or support automatic evasion of arm interference.
- This function does not support automatic evasion of inter-robot dead lock.
- This function does not detect interference between a robot's own arms and tools.

1.1.4. Related Function

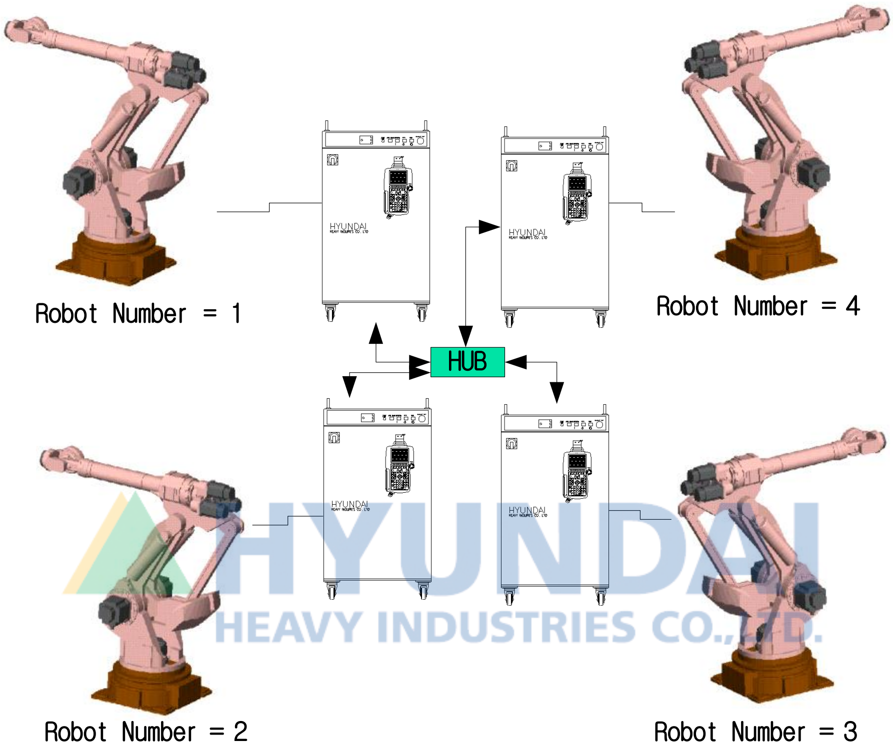
- Cooperation control function, HiNet
- Prevention of cube interference

2
Function

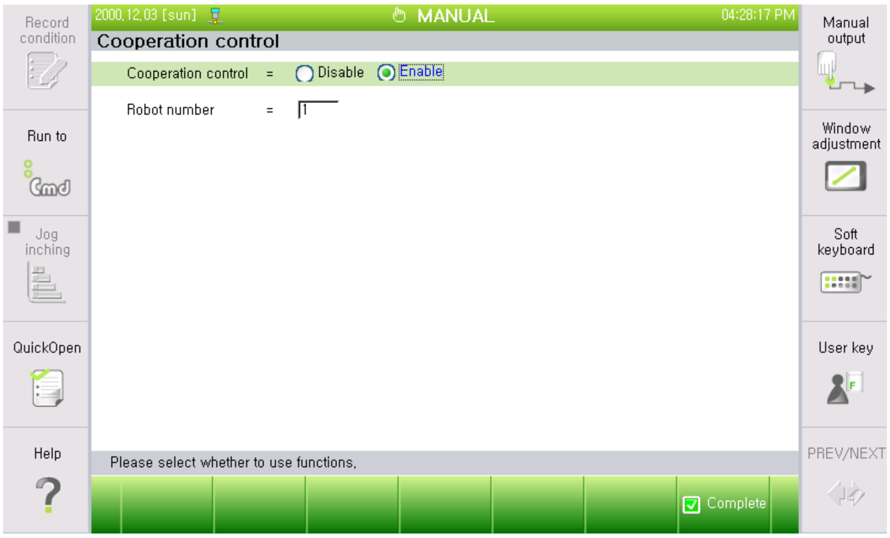
2.1. Setting

2.1.1. Setting HiNet

Set the Cooperation control function to 'Valid' and to a robot number that is not redundant. Up to 4 robots can be connected to HiNet at the same time.

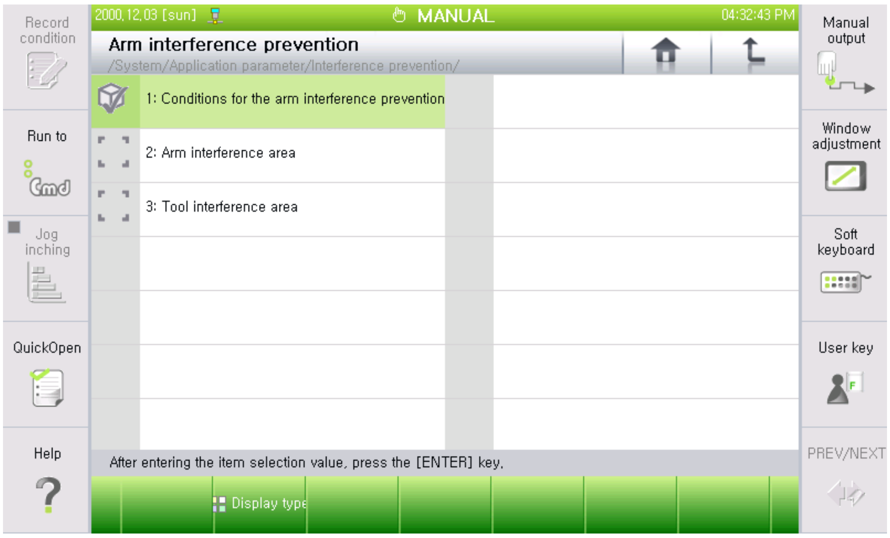


Select 『[F2]: System』 → 『2: Control Parameter』 → 『9: Network』 → 『3: Service』 → 『1: Cooperation control』 to set the robot number and Cooperation control function to 'Enable' as shown below.

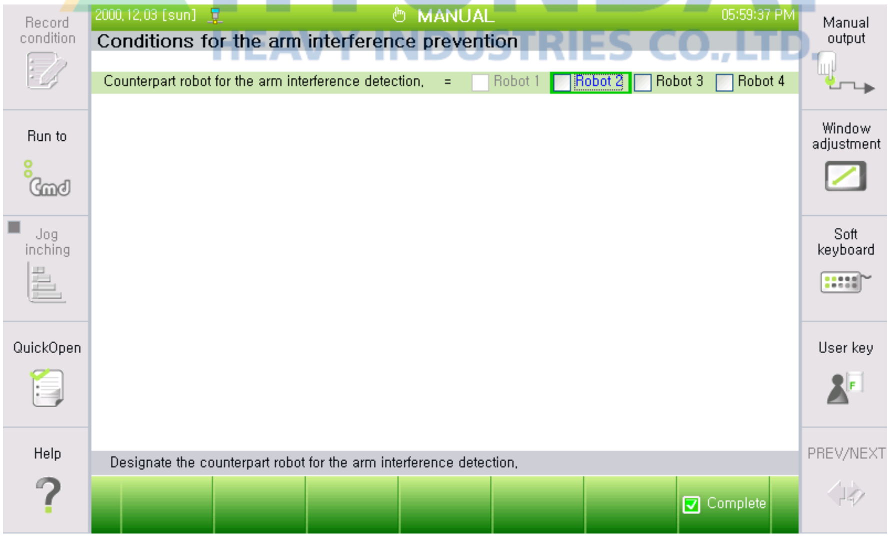


2.1.2. Setting the Prevention of Arm Interference

Select 『[F2]: System』 → 『4: Application parameter』 → 『7: Interference prevention』 → 『2: Arm interference prevention』.



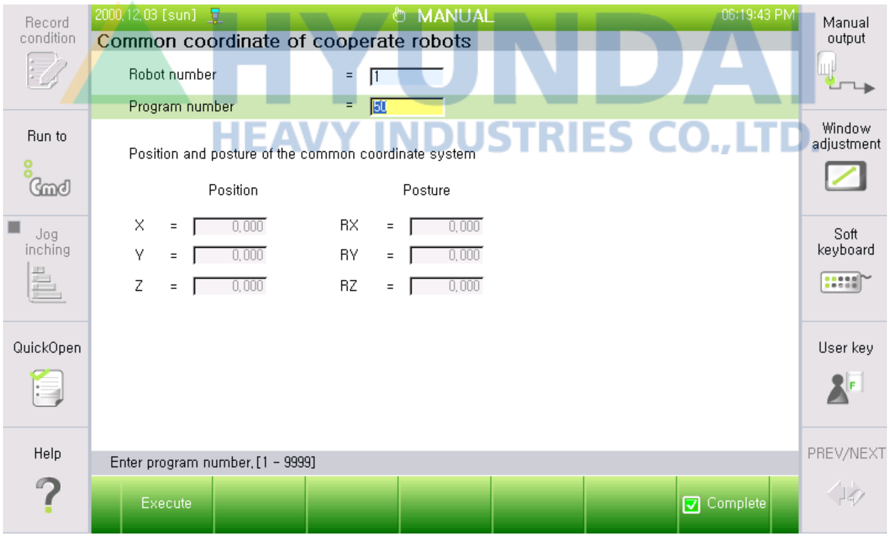
Select 『1: Conditions for arm interference prevention』 and then select 'Counterpart robot for the arm interference detection' to set arm interference prevention to 'Enable'.



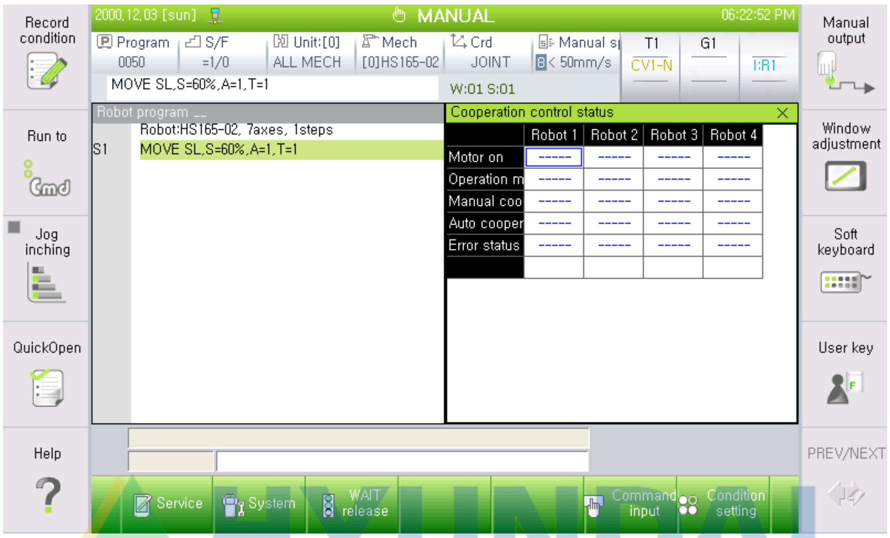
Causes for Possible Errors	Errors may occur in the following cases: When the counterpart robot designated for interference detection by the corresponding robot has set the Cooperation control to 'Null', when the counterpart robot is not connected to HiNet network for Cooperation control, when not setting the counterpart robot's condition of arm interference prevention, and when not setting the counterpart robot's common coordinate system.
Error Message	E0244 Arm interference cannot be detected on robot 0).
Action	Examine the following contents.

Check the following criteria when above errors occur:

(1) Check that the Cooperation control of the counterpart robot is 'Valid' and that the common coordinate system is set. Check the setting of common coordinate system of the counterpart robot's TP under 『[F2]: System』 → 『6: Automatic constant setting』 → 『5: Common coordinate of cooperate robots』.



(2) Check that the corresponding robot is connected to HiNet network. HiNet network status displays the status of Robots 1~4 on the right side of the screen upon selecting 『[F1]: Service』 → 『1: Monitoring』 → 『10: Cooperation control data』 → 『1: Cooperation control status』. At this time, robots displayed as '----' have not been properly connected to the Cooperation control network. If this occurs, reconnect the robot's power to check normal indication. If the problem is not solved after reconnecting the power, reexamine the Cooperation control setting and check for faulty network lines.



2.1.3. Setting the Common Coordinate System

It is necessary to set the common coordinate system for Cooperation control to detect inter-robot arm interference.

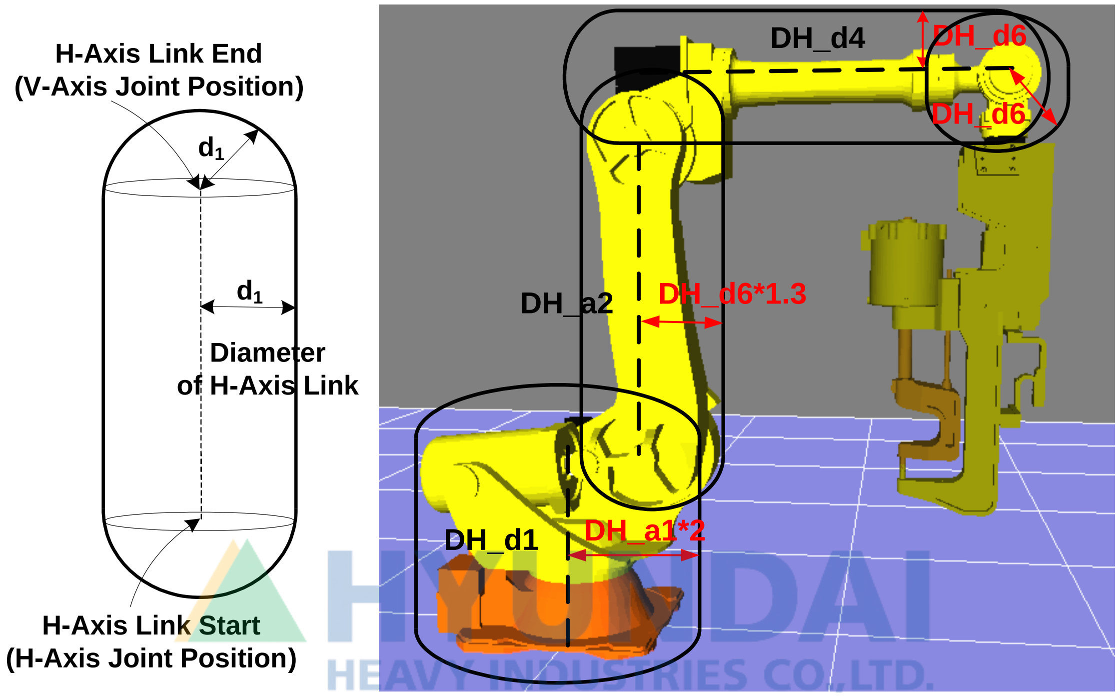
① Before setting the common coordinate system, prepare a sharp tool and complete setting the auto integer.
② After identifying the accurate tool information through auto integer setting, cross the 3 points.
③ For further details, refer to the user's manual on Hi5 Cooperation control.

The common coordinate system needs to be set for both the corresponding and counterpart robots. When the corresponding robot's Cooperation control is null or the common coordinate system is not set, jog and playback will not occur.

Causes for Possible Errors	Errors may occur in the following cases: When the corresponding robot's Cooperation control status is null, or when setting the conditions for detecting arm interference without setting the common coordinate system.
Error Message	E1342 Robot collaborative condition, common coordinate system invalid.
Action	Robot coordination and common coordinate system must be set to use this function.

2.1.4. Setting the Arm Interference area

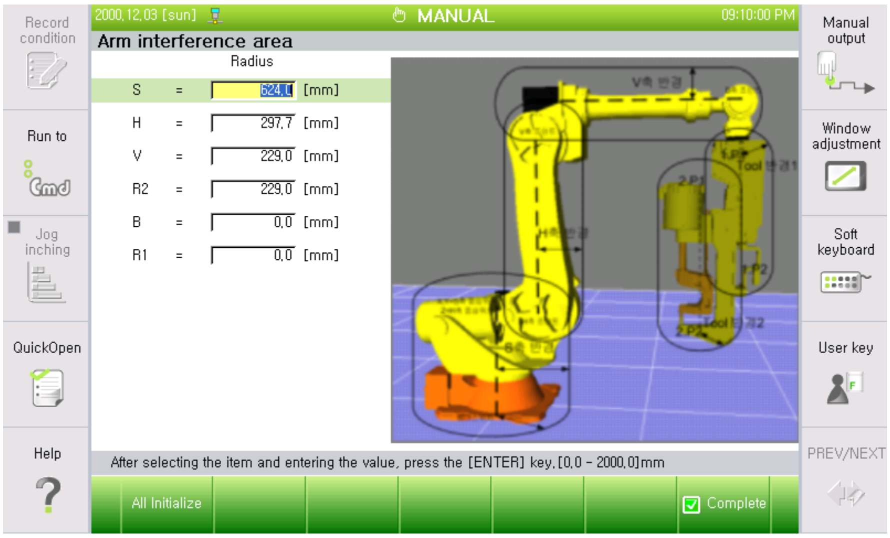
Both sides of the arm Interference area model are comprised of hemi-sphere cylinders. For example, the H-axis can be modeled as shown below by setting the radius from the H-axis joint position to the V-axis joint position.



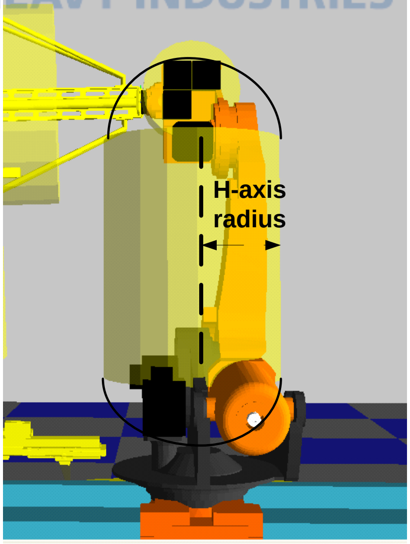
The cylindrical link model for the robot body arm is applicable to S-axis, H-axis, V-axis, and B-axis. The basic radius setting value for each axis has been determined as follows. If additional equipment is mounted on the robot, designate an axis radius higher than the basic value.

- S-axis radius: Set double distance from S-axis rotational center to H-axis joint position
- H-axis radius: Set 1.8 times distance from B-axis rotational center to flange
- V-axis radius: Set distance from B-axis rotational center to flange

Select 『[F2]: System』 → 『4: Application parameter』 → 『7: Interference prevention』 → 『2: Arm interference prevention』 → 『2: Arm interference area』 to view the radius currently set as default. To change the default setting, enter the setting value and press “[F7]: Complete”. To return to the default setting, select “[F1]: ALL Initialize”.



Currently regarding robot arm interference, the setting values for S, H, V-axis can detect all axis.



Take extreme caution when planning to use a value less than the default value.

For example, the H-axis of serial links such as HS165 has an offset to the right of the S-axis center as shown in the Figure above. Since the interference detection field of H-axis is determined based on the segment that connects from the rotational center of S-axis, along the H-axis link and to the rotational center of V-axis as shown above, the radius of H-axis needs to be set to a size that can contain everything from the rotational center of S-axis to the H-axis link.

2.1.5. Setting the Tool Interference Area

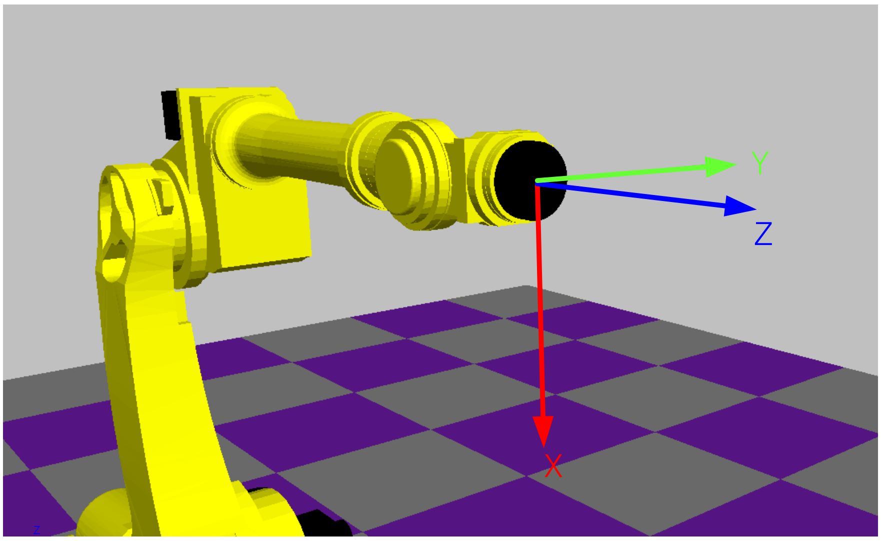


Figure 2.1 Flange Coordinate System

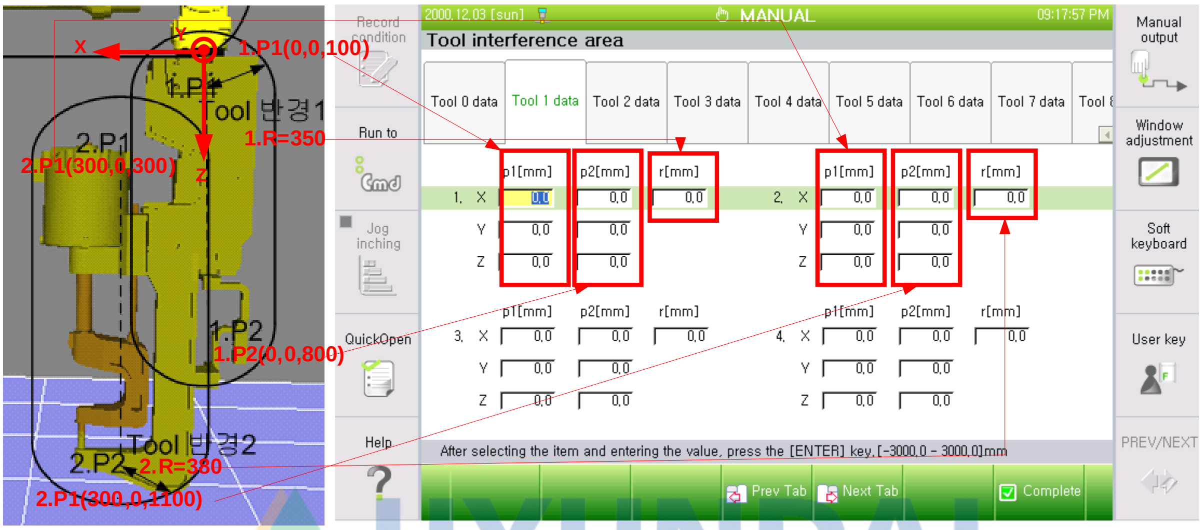
In order to set the tool Interference area for each tool number, use the robot flange coordinate system as the base standard. In the flange coordinate system, when the robot is in the standard position, 'Z' is the outward direction that is vertical to the flange, 'X' is the downward direction, and 'Y' is the left side of the robot.

Each tool number can be set with up to 4 Interference areas. The tool number used in the robot program must be set with the tool Interference area. If this setting is not done, tool interference will not be detected.

(1) Example of servo gun setting

The tool Interference area can be designated by setting the starting point, ending point, and radius for the coordinate of the tool flange. Each tool number can be set with up to 4 Interference areas.

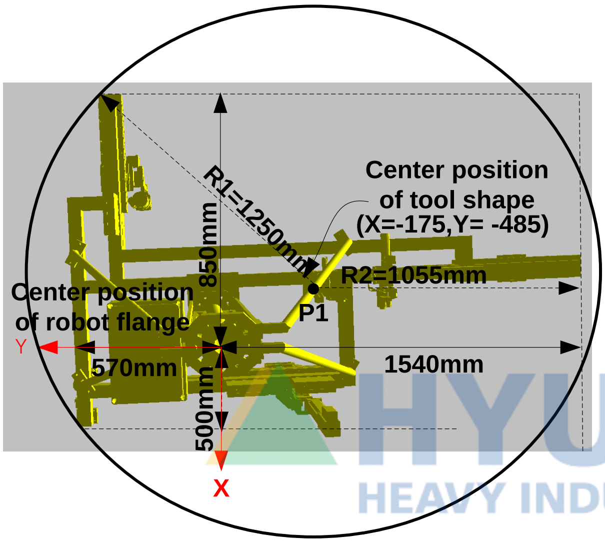
Refer to this Figure for examples on direction and setting of the flange coordinate system.

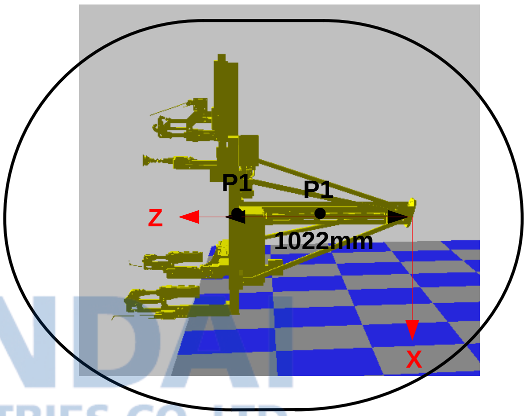


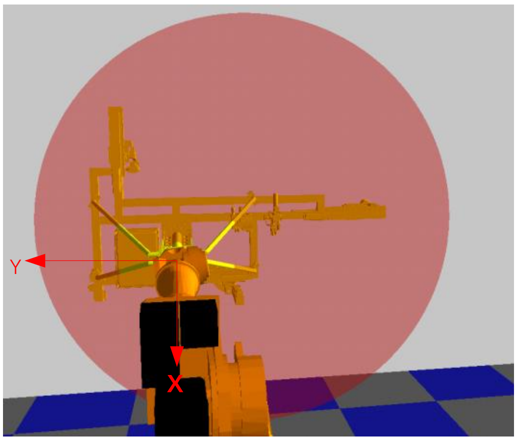
(2) Example of hanger setting

- When setting only 1 tool Interference area

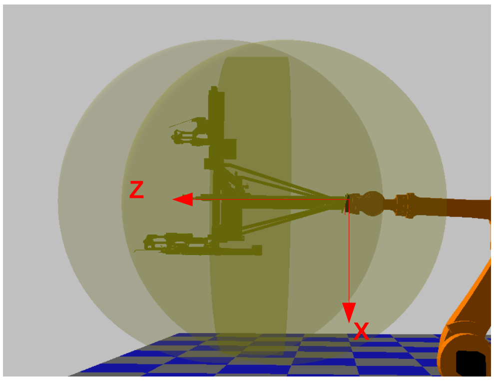
When setting only 1 tool Interference area for tools that are not symmetrical based on the flange center, use the method of setting the maximum distance between the tool shape's center and corner as the radius.
In the example below, the robot coordinate system displays the values of X=-175, Y=-485. As for the radius, R1 is the larger between R1 and R2, so set to 1,300, which is slightly higher than 1,250. Setting the radius to 1,300 sets a hemi-sphere in each side of the cylinder, so respectively set P1=(-175,-485,500), P2=(-175,-485,1000) for 'Z' position.



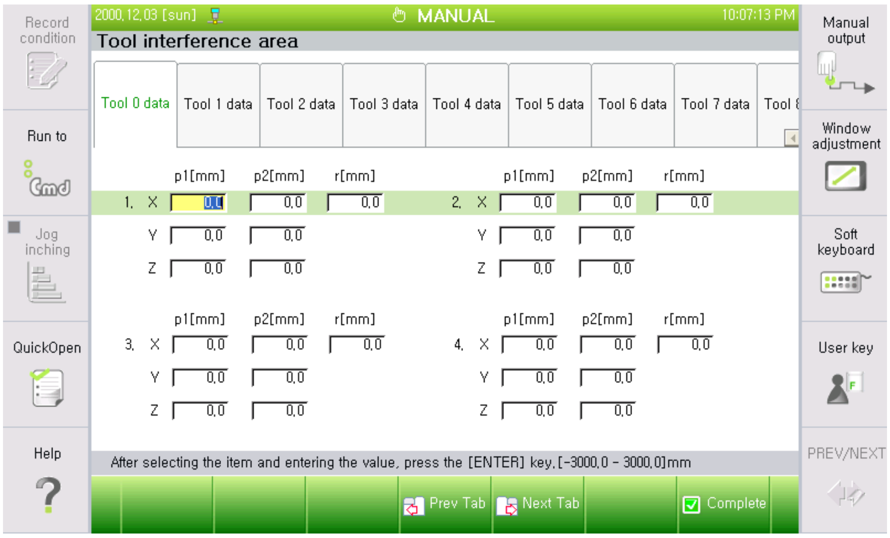




Front view of tool interference field setting

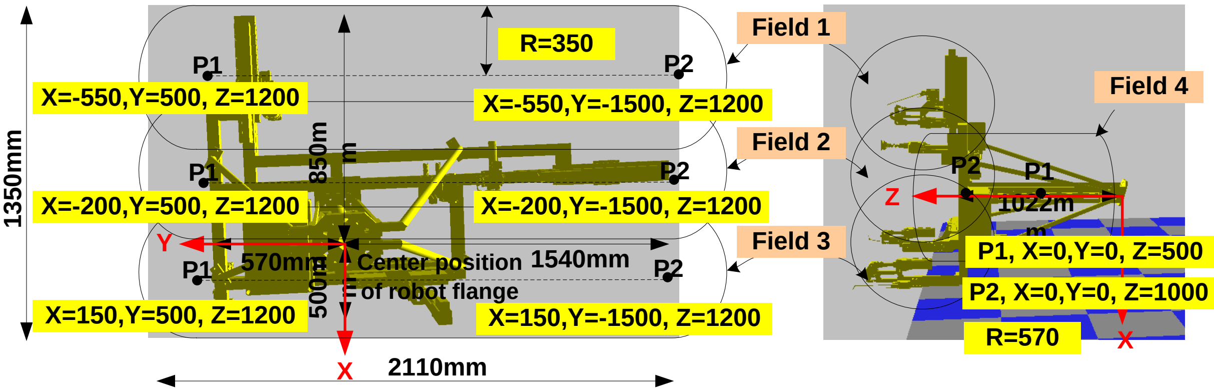


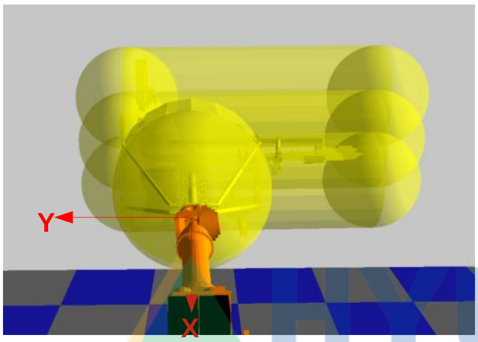
Side view of tool interference field setting

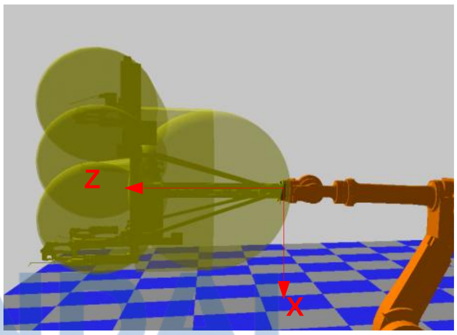


However, it is unavoidable to unnecessarily set a larger value than the tool's actual shape when setting a large radius as above. Thus, several modeling should be conducted when it is necessary to designate detailed tool areas.

- When setting 4 tool Interference areas

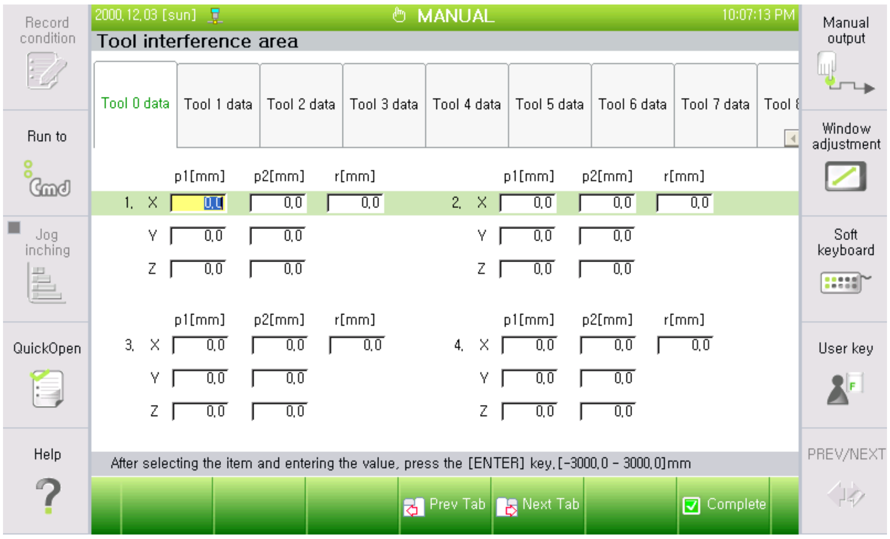






Front view of tool interference field setting **Side view of tool interference field setting**

If the tool is large, as with the hanger, setting the fields in partial divisions can help to prevent setting an excessively large tool Interference area. When dealing with a tool of 2,110mm width and 1,350mm length as below, it is possible to divide the vertical fields into three parts and conduct modeling for 3 cylindrical fields (1~3), each with a respective radius of 350mm. Lastly, setting the offset from the flange to the tool as field 4 enables settings as below.

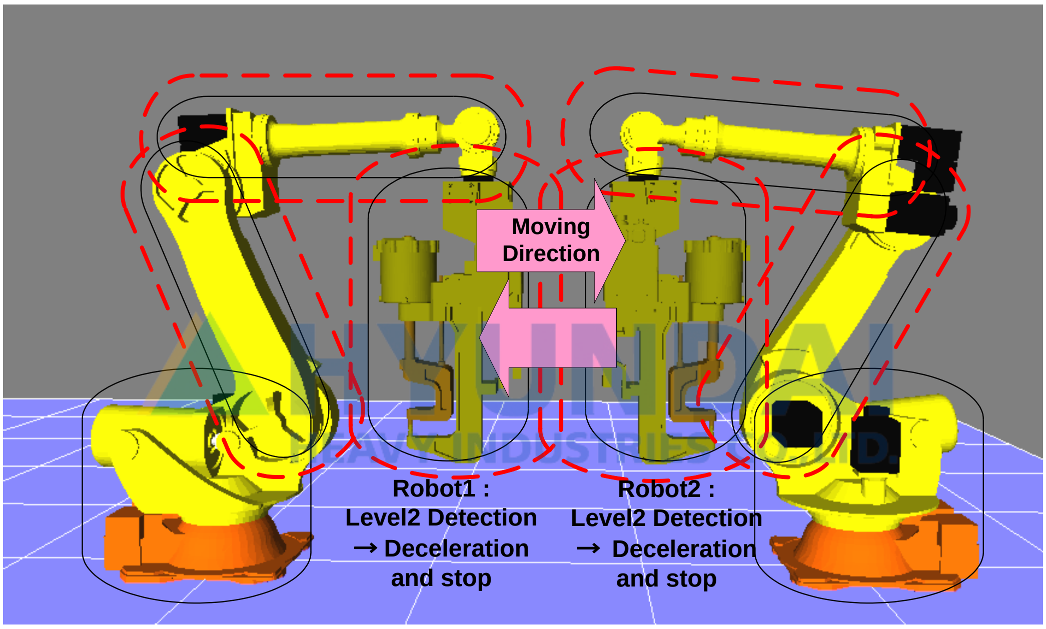


2.2. Detection of Interference

2.2.1. Deceleration to a Stop

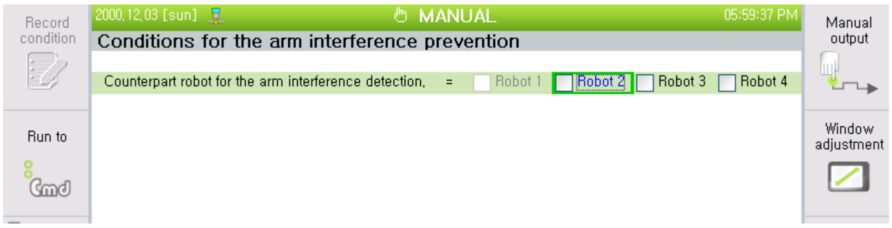
In case of a deceleration to a stop after entering the arm or tool Interference area set by the user, the robot may still collide even after detecting the error due to the deceleration stop distance and robot's inertia. Therefore, it is necessary to expand the detection field while considering for the robot's speed.

The Figure below displays the concept of early-detecting interference by creating interference anticipation fields (Level 2 detection fields), under the premise that the robots are approaching each other. The dotted line refers to the interference anticipation field and the straight line refers to the Interference area set by the user.



The interference anticipation field is automatically set to a distance that also considers for the robot's movement speed and stopping time. The user can set the maximum value as the 'maximum interference anticipation distance'.

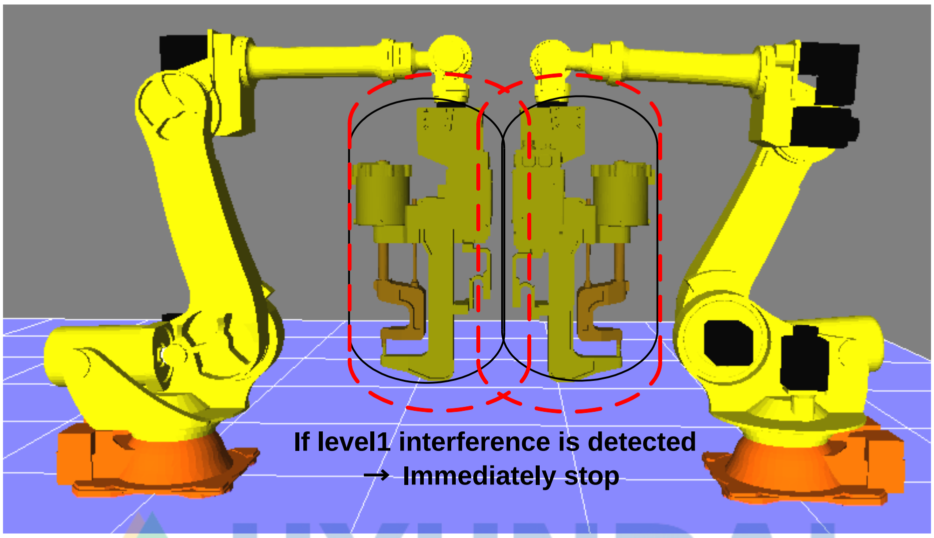
When the robot is moving in high speed, the interference anticipation distance calculated by the controller detects interference by adding this max. distance to the previously designated Interference area. The robot decelerates upon entering the interference anticipation segment, and immediately stops upon entering the Interference area without decelerating. When the robot is moving in low speed and the internally calculated anticipation distance is smaller than the 'maximum interference anticipation distance', the robot will not detect interference even when entering the maximum interference anticipation distance.



Causes for Possible Errors	When the robot enters the interference anticipation field of another robot while in transit, alarms and error messages as shown below occur simultaneously and the robot decelerates to a stop.
Error Message	W0147 Stop as interference between the robot 0) and the arm is expected. E0237 Detection of the interference with the robot 0) arm area
Action	Reexamine the operation program when an alarm message as above is displayed while operating a normal robot program.

2.2.2. Immediate Stop

There are cases where robots inevitably enter the Interference area even when decelerating in the interference anticipation field (Level 2 detection fields) due to the deceleration speed. When directly exceeding the range designated as the Interference area, the robot will immediately stop instead of decelerating to a stop.



Causes for Possible Errors	When entering the arm and tool Interference area
Error Message	E0237 Detection of the interference with the robot 0) arm area
Action	Reexamine the operation program when an alarm message as above is displayed while operating a normal robot program.

2.2.3. In Case of Error during Operation

When two robots are respectively moving from S1 to S2 on top of the drive axis, as shown below, W0147 or E0237 will not occur if the S2 positions of the two robots are further away than the addition of the tool Interference area and maximum interference anticipation distance. This is an example of a normal operation program.

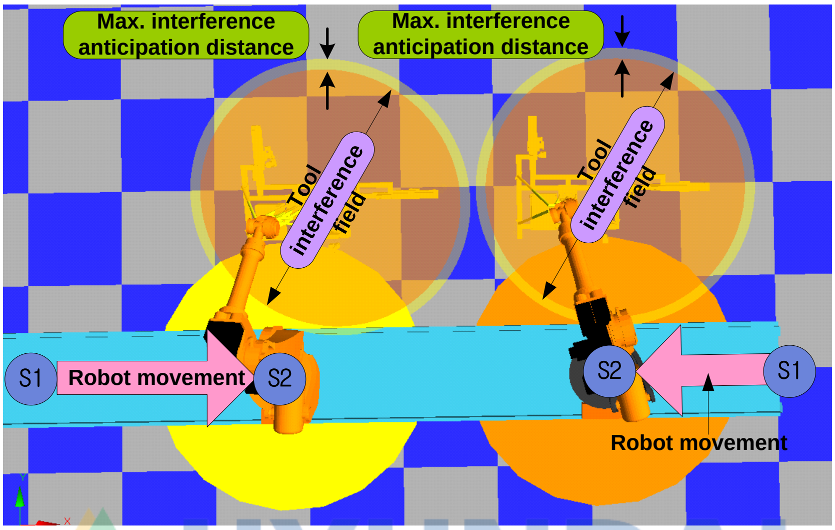


Figure 2.2 Example of Normal Operation Program

The Figure below displays how the tool Interference areas are slightly apart, but S2 is located slightly within the maximum interference anticipation distance. Errors (W0147 or E0237) will not occur when the robot is moving in low speed, but may occur in high speed. As such, errors may or may not occur based on the operating speed and other circumstances. Take caution not to assemble in this fashion.

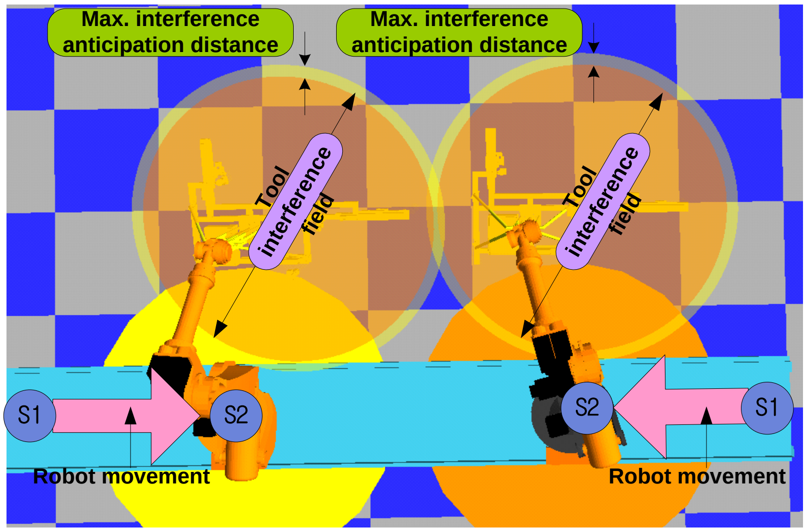


Figure 2.3 Example 1 of Abnormal Program

When S2 is situated as below, where the tool Interference areas are completely crossed, errors (W0147 or E0237) will occur when the robots move towards S2, regardless of their speed.

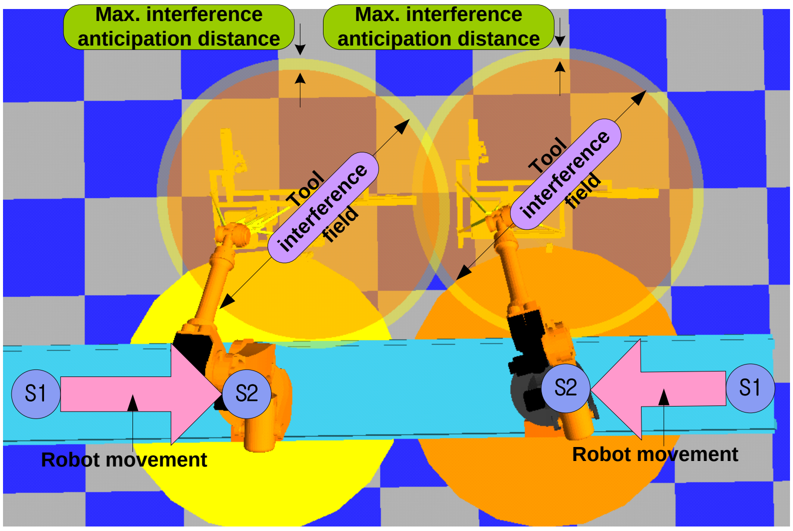


Figure 2.4 Example 2 of Abnormal Program

In the above case, errors can be prevented by decreasing the 'tool Interference area' or 'maximum interference anticipation distance'.

Inter-robot collision may occur when excessively decreasing the tool Interference areas and setting a smaller value than the actual tool.

2.2.4. Process for Dead Lock

A dead lock refers to a condition where two robots have entered each other's Interference area and cannot be moved by either jog or program.
In such cases, 'lift' the interference detection of the interfered robot and use the jog function to exit the Interference area under the user's monitoring.

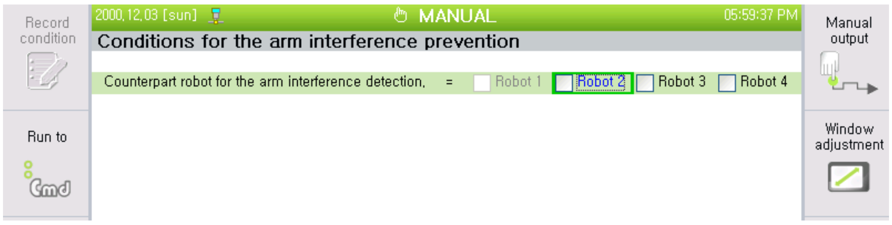


Figure 2.5 Removing Detection of Inter-robot Arm Interference

After exiting the Interference area, check the counterpart robot's number and return.

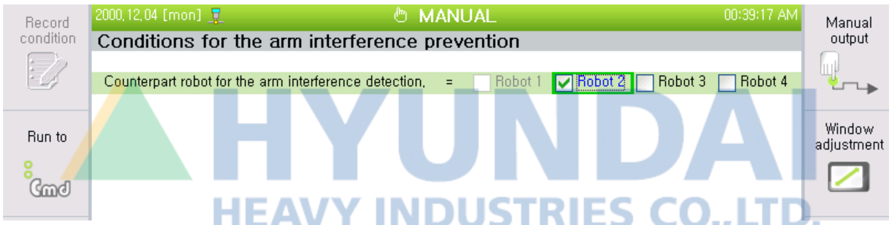


Figure 2.6 Setting Detection of Inter-robot Arm Interference

2.2.5. Process for HiNet Network Errors

Inter-robot arm interference cannot be normally detected if the HiNet network is not operating normally. Therefore, any issues in the HiNet network may result in the following errors.

Causes for Possible Errors	Robot's own HiNet network is severed.
Error Message	E0205　HiNet communication error of system
Action	Check the robot's network cable. Refer to the Cooperation control status monitoring to normalize the robot's Cooperation control status.

Causes for Possible Errors	HiNet network between the robot and counterpart robot designated with interference detection conditions is severed.
Error Message	E0244　Robot 0) Arm interference detection is impossible.
Action	Check the robot's network cable. Refer to the Cooperation control status monitoring to normalize the robot's Cooperation control status.

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