HYUNDAI ROBOTICS

WARNING

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

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Hi5a Controller Function Manual

Cooperation Control

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Printed in Korea - Jun. 2023. 3rd Edition

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1 Overview

1.1. Introduction of robot cooperation function

Robot cooperation function is the function to execute an operation using several robots to complete an operation that would not be possible with one robot.

This function can be applied to the following cases.

- When handling the work object through a cooperation of two robots with a simple hand.
- When handling work object of which the volume exceeds the possible range one robot can handle
- When the master robot is handling the work object and at the same time the slave robot is executing a jigless operation such as arc welding or sealing.

You can synchronize the cooperation work among a maximum of 4 robots.
Each robot can execute an independent operation and a cooperation operation from one program.

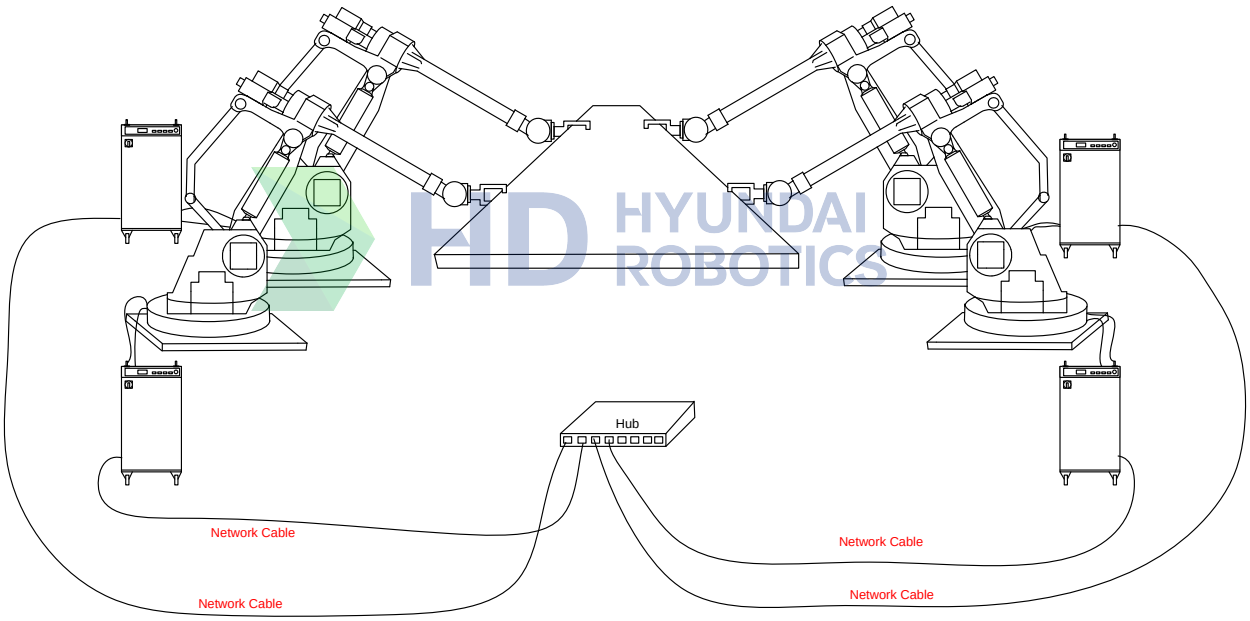

Figure 1.1 Robot cooperation function

1.2. Major function

1.2.1. Major function specification

Table 1-1 Specifications of the cowork control

Major function specification	Remarks
Number of cooperation robots	Maximum four units within a group
Communication method	Exclusive for Ethernet (HiNet™)
Communication speed	100MBPS
Possible number of master robot	1 robot
Possible number of slave robot	3 controllable slave under 1 master
Main axis	Main axis cooperation is possible
HiNet I/O	32 output point per robot
Jigless cooperation	Robot and positioner jigless cooperation support

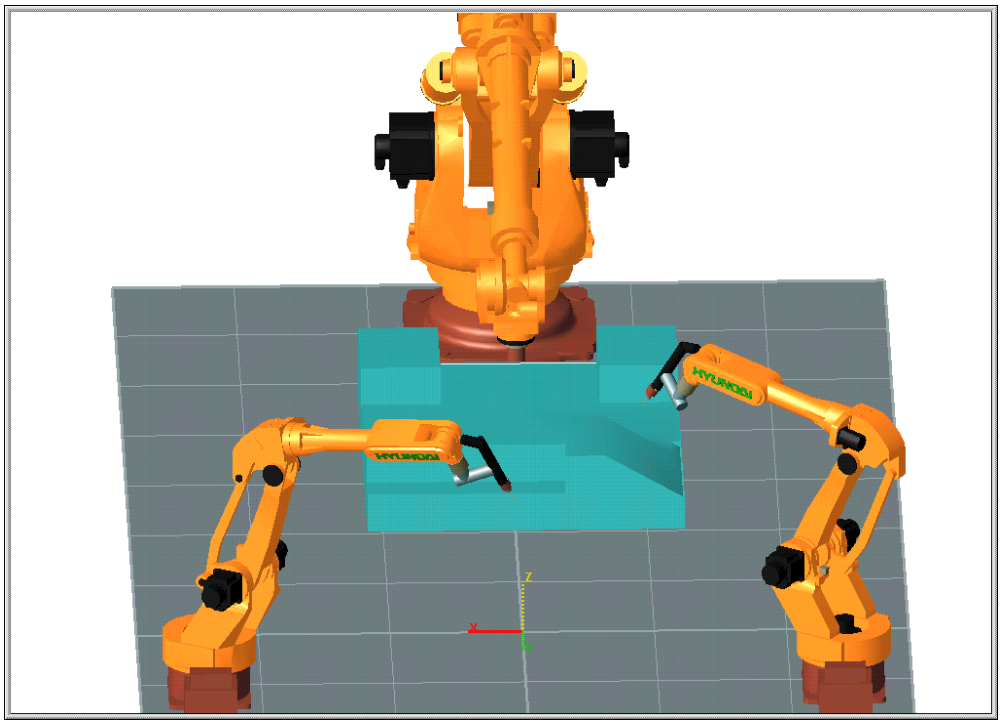

Figure 1.2 Jigless Cooperation

1.2.2. Functional characteristics

- Communications
  With the cowork control function, it is possible to control a maximum of four robots within a group in an interlocked manner through the HiNet (dedicated Ethernet network).

- Setting of a common coordinate system for robots
  This function is to locate the relative positions between robots. The setting of the common coordinate between robots is to be acquired through the teaching of 3 identical points on the work range.

- Manual mode cooperation
  The user can perform teaching in the manual mode easily. After individual robots are set for the master and slave roles, the teaching will be made possible only by operating the master in case of the application of handling, while, in case of jigless operation, the support should be provided in a way that the teaching of the position of the slave is performed on the work object of the master.

- Positioner master support
  Cooperated control can be made possible by setting the positioner of the robot that is set as the master robot as a master. For a positioner, 4 robots can operate in a cooperative manner at the same time.

- Teaching
  Each control unit requires its own independent program. In one program, the part for the robot to operate independently and the other part for it to operate cooperatively can be separated, allowing programming to take place easily and without restriction.

- Playback cooperation
  According to the command (COWORK) for the cooperative operation, counterpart robots are made to stand by, and, when all the cooperative robots are already, the cooperative operation will start.

- HiNet I/O
  This is to provide a function that allows the input and output of signals between robots to occur, without an additional control panel for the interlocking between roots, through the use of an exclusive Ethernet network developed for the cooperative control.

1.3. Operating sequence

This explains the sequence of using the cooperation robot function. Details are as follows.

Robot calibration

For the cowork control, the axis origin points and tool integers of the robots should be set properly.

Refer to the automatic calibration function.

Hardware installation

Connect the hardware necessary for controller communications.

- Connect the network card and the communications cable.

Cooperation control parameter setting

For the network-connected robots, set the applicability of the cowork control, a group number, and robot numbers.

Cooperation robot coordinate setting

Do the calibration operation that notifies the position of cooperation robots.

Teaching

Allocate the function key for cooperation teaching and designate the robot roles of master and slave. Then teach the master robot.

Check operation

Check the cooperation operation in manual mode.

Operate the cooperation robots to step forward at the same time.

Continuous operation

Switch to auto mode. Set the program to head position and press all the operating switches of the controller designated for cooperation robot.

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2 System Setting

2.1. Hardware installation

2.1.1. Emergency stop line connection

When there is an emergency stop during cooperation operation, the corresponding robot is also supposed to stop because it monitors each other through communication. But because the hardware signals have higher priority, the position of the cooperation robots is misaligned. To minimize this misalignment during an emergency stop, make the connections for external emergency stop.

An external emergency stop function for user is prepared in the Hi5 controller. The connection diagram of the external emergency stop is as follows.

When the robot cooperation function is to be used, an additional emergency stop switch needs to be installed at the same time to allow the input of emergency stop to be made into each control unit. It is required to combine the external emergency stop wire connections, prepared for the user, into one single emergency stop system and use it, which will minimize the misalignment in the cooperation position when the emergency stop occurs.

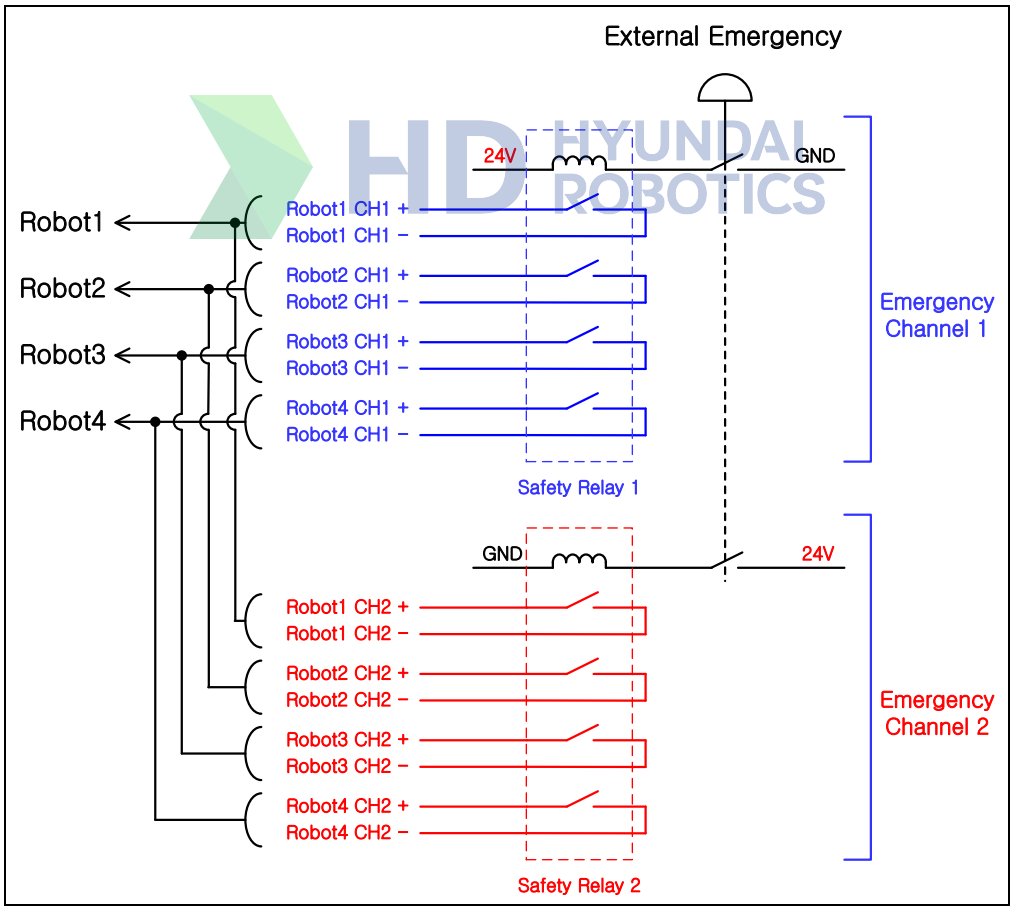


Figure 2.1 Emergency stop connection for cooperation robot

Caution

- There can be a misalignment of relative cooperation position in case of an emergency stop during cooperation.
- When applying the handling function, you must install the floating equipment to absorb the cooperation misalignment (emergency stop error, synchronization error, calibration error, trace error).
- When applying the handling function and installing the floating equipment, it is recommended to install at least 1 for 2 cooperation robots.
- The relay for the external emergency stop should be a safety relay.
  e.g., Omron safety relay, G7S-4A2B

2.1.2. Network composition

Table 2-1 Requirements for the cowork control

Components	Specification
BD511	Main CPU board
UTP cable	Connection with a hub: direct LAN cable Direct connection between two units: cross LAN cable
Network Hub	Specification provided by Hyundai Robotics (Switching hub)

■ Connecting method
The one end of the network UTP cable (Direct) needs to be connected to a socket located at the top among the BD511 board network cable sockets, and the other end needs to be connected to the network hub. In this manner, up to 4 units can be connected to the hub.
If it is required to connect two robots without using the hub, the network UTP cross cable needs to be connected to the socket located at the top of BD511.
If a teach pendant (TP) sharer is used, the cowork control can be made without any LAN cables.

2.1.3. Network connection check

Check for network error in the following cases.

- Initial installation
- When a network error is detected during cooperation control

■ Check points
Check the mode of the network cable connection. A green light should be turned on at the BD511 socket.
Check the cable.
Can use System/Control Parameter/Network/2. Ethernet Status to check the mode of the network.

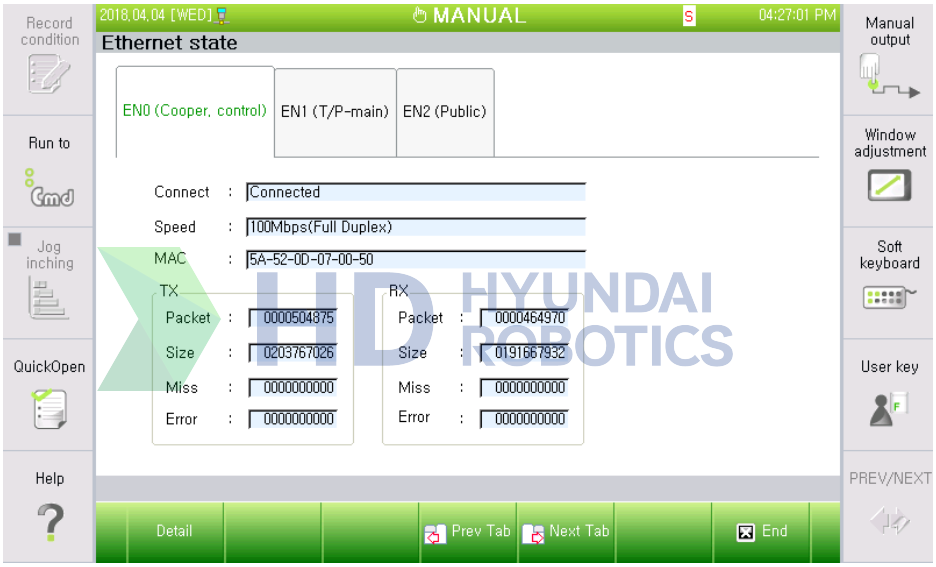


Figure 2.2 Dialog box for identifying Ethernet conditions

Caution

- The HiNet for cooperation control is an exclusive network for controlling the cooperation between robots of Hyundai Robotics .
- The cooperation control network should be configured independently and separately from the general network.

2.2. Controller setting

This sets the communication and robot number etc. for cooperation control of the controller.

(1) Select 『[F2]: System』 → 『2: Control Parameter』 → 『9: Network』 → 『3: Service』.

(2) Select 『1: Cooperation Control』.

(3) Set the parameters of the dialog box. The parameters have the following purposes:

■ Cooperation control function <Disable. Enable>
Select whether to use the cooperation control function.

■ Group number: <1~6>
This designates a number for the group of robots. The cowork control function applies only to the robots that belong to a group. The robots that will be subject to the cowork control should be designated as a group. However, for robots from another group, the HiNet I/O applies commonly.

■ Robot number: <1~4>
This designates a number for a robot. The robot number is a number for recognizing its controller on the network connected through the cooperation control. In case of the Hi5 controller, up to 4 robots can be configured in the cooperation network. Be careful not to allow the robot number not to be duplicated while setting.

Caution

- Only the HiNET communication should be applied for special robots and the robots whose degree of freedom is 6 or lower, the COWORK command can not be used.
- The cooperation control is an optional item. In order to use the control COWORK command, the license key should be registered. While the temporary key can be used for one month, it is required to contact the company if you have any question if you want to use the key for a longer period than that.

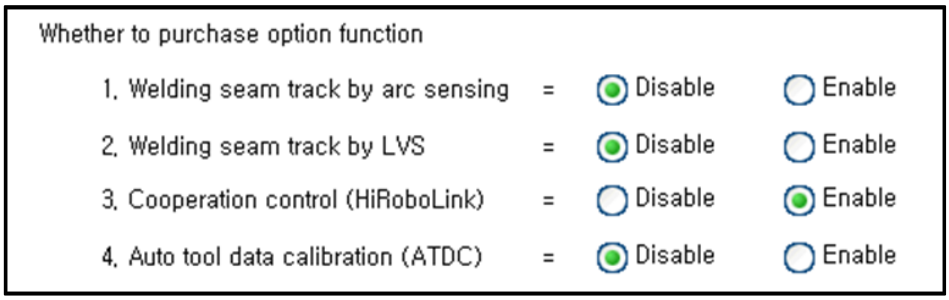


Figure 2.3 Setting of the cowork control (HiRoboLink) license key option

2.3. Common coordinate setting among cooperation robots

2.3.1. Introduction to common coordinate setting

For the cowork control, the correct relative positions of the robots should be identified. The robot controller calculates the position of the end of the tool based on the base coordinate, and the information of the counterpart robot should be registered additionally. The information regarding the positions of the robot is to be made through the setting of the common coordinate.

Set the common coordinate to mutually identify the position of robot 1 and robot 2. (Figure 2.4) It can be set by teaching 3 same points in the area for each robot.

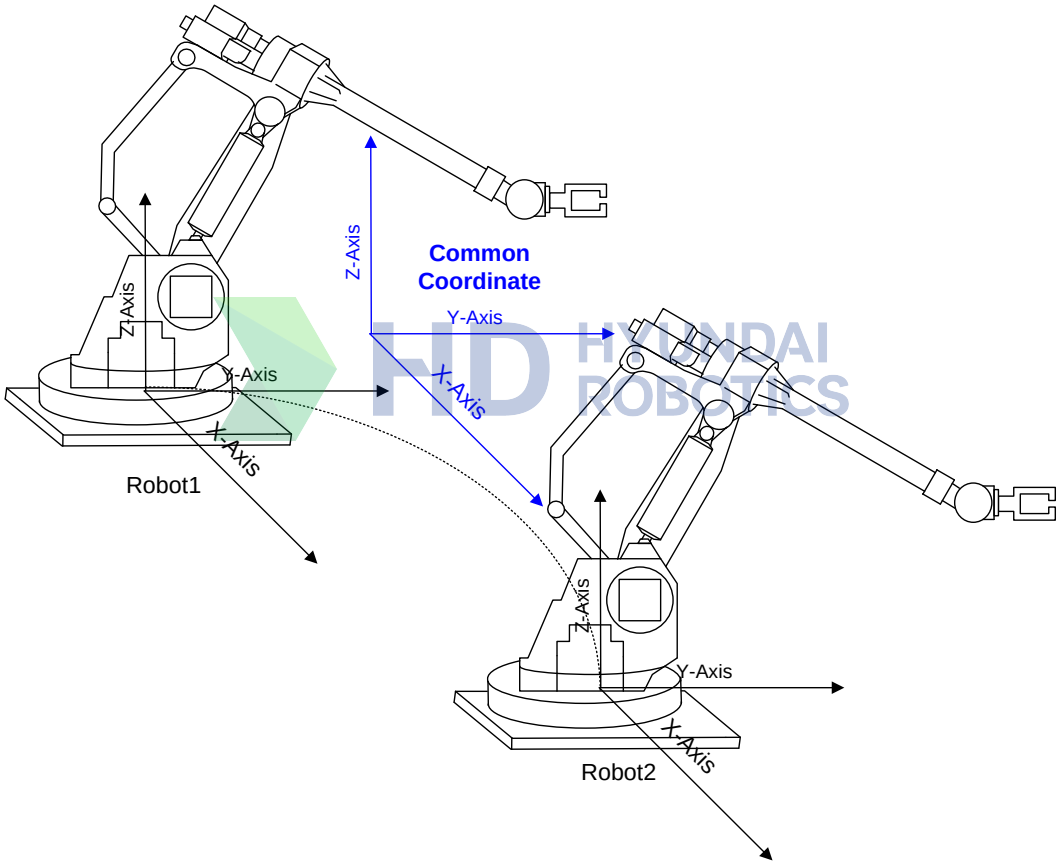


Figure 2.4 Common coordinate setting among cooperation robots

Caution

- Prior to the setting of the common coordinates, the calibration of the robots should be performed first.

2.3.2. Setting common coordinate for 2 or more robots

The common coordinate for the cooperation robot must be set with same points among the robots. Therefore make sure all the robots are pointing to the same point. Therefore if the robots are far spread out, it is impossible to set a common coordinate. For such cases, you can create a separate tool to teach the same points to the robots.

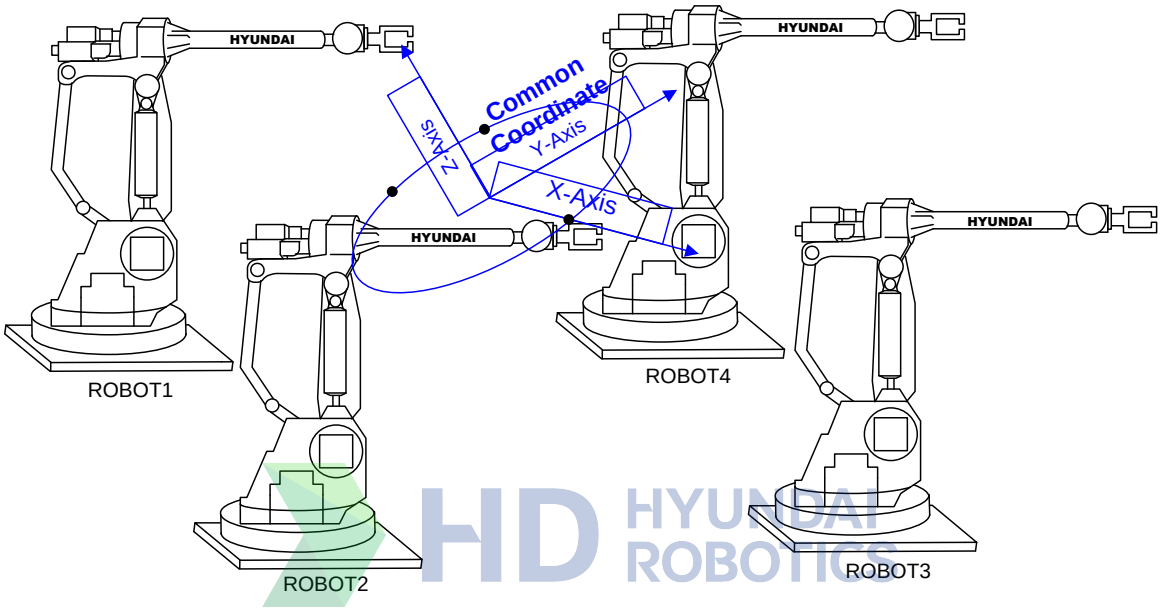


Figure 2.5 Setting common coordinate for 2 or more robots

2.3.3. Traverse axis system

When composing a traverse axis system for cooperation control, the traverse axes with same specification must be installed in parallel as possible.

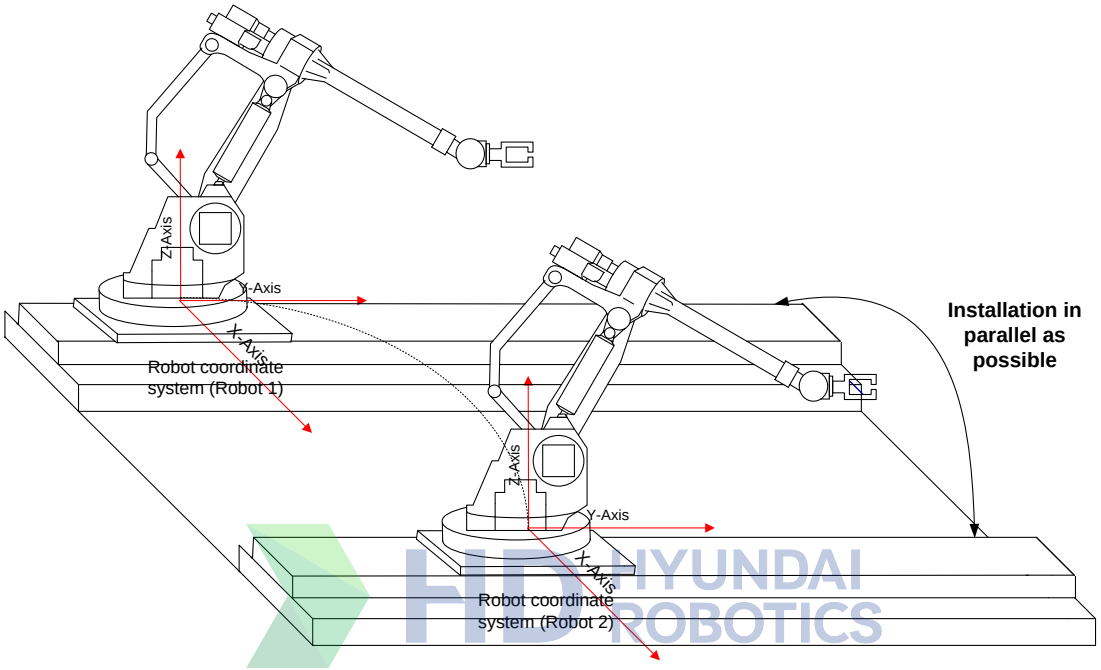


Figure 2.6 Composition of the operating axis system for the cowork control

Caution

- For system with a main axis, set the specification of the traverse axis to ‘arbitrary’ and use it after traverse axis calibration.
- The traverse axes need to be installed in parallel to each other as much as possible.
- If the synchronization error increases as the robot moves along the traverse axis, this can be from inaccurate calibration of traverse axis.
- For details on the traverse axis calibration function, please refer to 『Hi5a Controller operating manual』.
- Traverse axis calibration must be set for both master and slave.

2.3.4. Common coordinate setting

If a common coordinate system is not set, it is not possible to operate the manual cowork jog or to make the cowork control. If a common coordinate system is set, it is recommended to try a cowork jog operation to check whether the system has been set correctly before starting the main operation.
The common coordinate setting is only possible when the accurate position of the cooperation robot tool end is known. Otherwise, a position synchronization error may occur during the cowork control of the robots. Therefore, you should carry out a calibration for the correct setting of the origin points and tools of the robots. The Hi5a controller features an automatic calibration function ("[F2]: System" → "6: Automatic Calibration" → "1: Optimize Axis Origin and Tool Length") for cases where you have no 3-D position meter. If you have a 3-D position meter, you can make a more precise calibration. If you have a 3-D position meter, use the "9: Calibrate Robot and Tool" function. For more details please refer to the『Hi5a Controller operation manual』.

■ Exemplary setting of a common coordinate system for two robots, Robot 1 and Robot 2

① For the controllers of Robot 1 and Robot 2, select a program number for the setting of a common coordinate system.
② By using each jog of Robot 1 and 2, record the 3 points to step 1, 2 and 3 in order to create a triangle, as large as possible. In this case, the identical spatial positions should be recorded. Although interpolation types and speed do not matter, tool numbers should be selected for the tools of which the edge positions are correctly identified.
③ Select 『[F2]: System』 → 『6: Automatic Calibration』→ 『5: Common coordinate of cooperate robots 』 in manual mode.
④ In the program number field, enter the program number for the setting of the common coordinate system.
⑤ Press the 『[F1]: Execute』 key. The results will be displayed in the screen through position and position of the common coordinate from robot base.
Press the 『[F7]: Complete』 key to complete the setting.

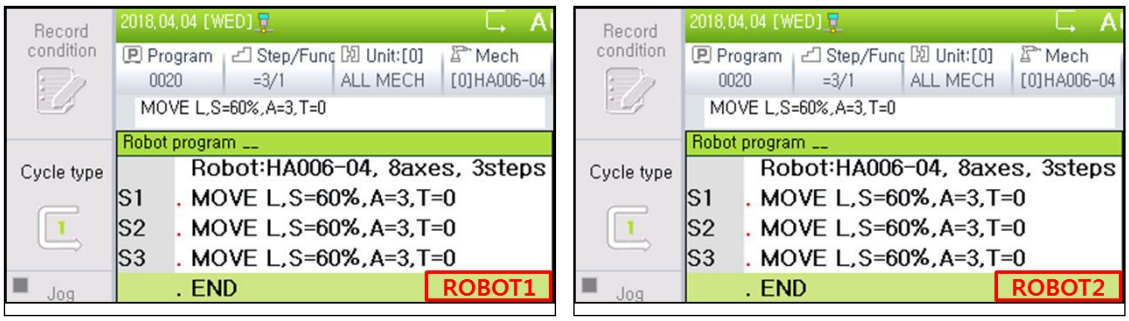


Figure 2.7 Program for setting a common coordinate system for robots

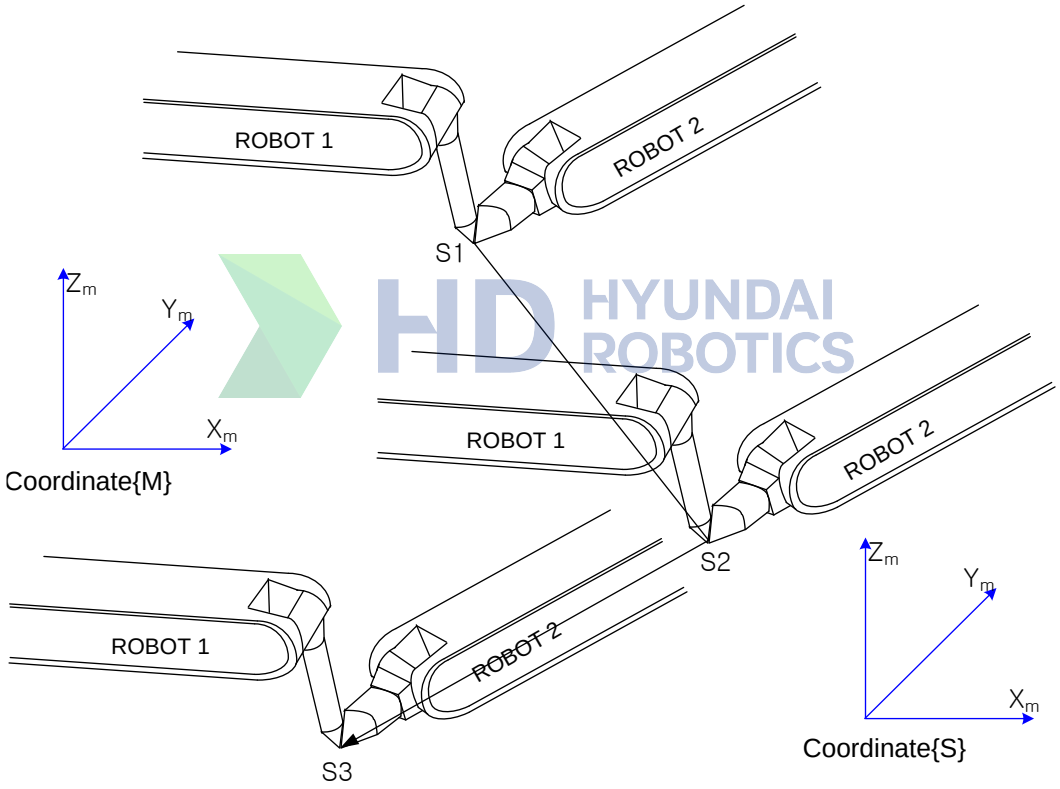


Figure 2.8 Teaching method of common coordinate setting

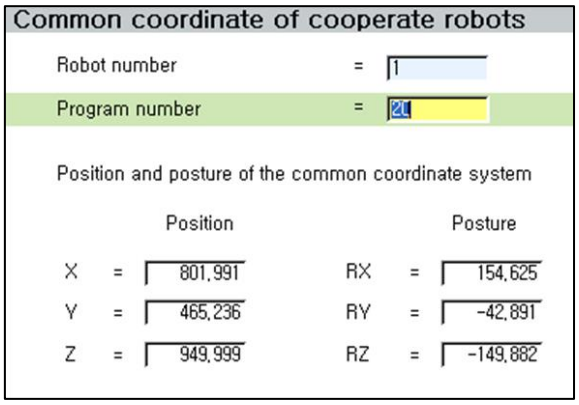


Figure 2.9 Window showing the setting result of the common coordinate system

Caution

- With regard to the tool data values for setting the common coordinate system, enter the correct specifications of the tool or find the tool data value by using the automatic calibration. It is recommended that you record the identical position of the robots for each point.
- Record the points so that the three set points may form a triangle as large as possible. If the distance between two points is short or if the three points form a shape close to a straight line, an error will occur.
- The relationship of the position Rx, Ry and Rz of the common coordinate to the robot coordinate is as follows.

① Rotate its robot (No. 2) coordinate (ref) to X axis direction by γ angle.

② Rotate its robot (No. 2) coordinate (ref) to Y axis direction by β angle.

③ Rotate its robot (No. 2) coordinate (ref) to Z axis direction by α angle.

④ The position in the common coordinate is the position rotated by γ, β and α from the its own robot (No. 2) base coordinate.

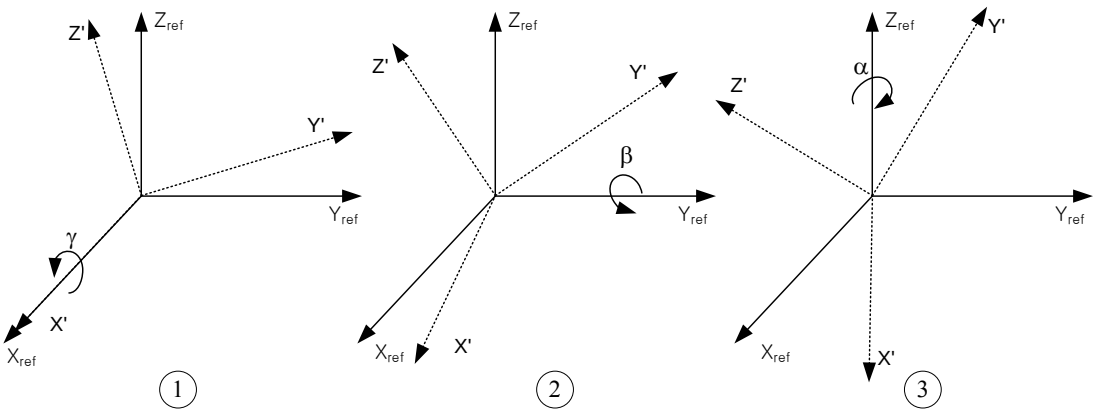


Figure 2.10 Common coordinate position conversion

3

Manual Mode Cooperation Operation

3.1. User key (F-Key) registration

This sets the user key for cooperation control in the manual mode.

(1) While the Shift key is being pushed on the teaching pendant, the User key at the side bar menu needs to be pushed.

Figure 3.1 Window for a user-defined hot key setting

(2) Designate the "Manual Switching of Cowork Mode" item to one of F1 through F7.

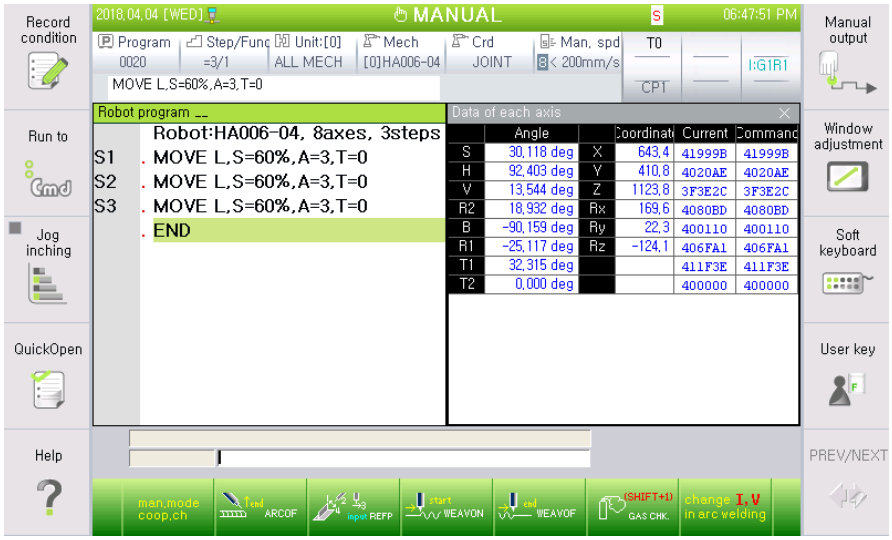


Figure 3.2 Result of user-defined hot key setting

(3) You can switch between manual individual mode and manual cooperation mode by using the allocated user key in manual mode. In the cowork status indicated on the upper right of the window, you can view the group number, robot numbers, and cowork modes.

3.2. Switching between the individual mode and the cowork mode

3.2.1. Mode switching by key operation

The manual switching of the cowork modes can be done by the following method:

① Use of a user-defined hot key
② Use of the R code
③ Use of the hot key, “Shift+6.” The mode changes in the order of individual, master, slave, and CMOV recording.

Details are shown in the table below.

Table 3-1 Function switch by key operation

Key operation	Function switch
User key	Manual individual mode (Indiv) ↔ Manual cooperation mode (MASTER/SLAVE)
SHIFT + User key	Applicable only for SLAVE SLAVE manual cooperation mode ↔ CMOV record mode
R351,0	Manual individual mode
R351,1	Manual cooperation mode, designate master
R351,2	Manual cooperation mode, designate slave
R351,3	CMOV record mode, designate SLAVE jog mode If the previous mode is “slave,” it can be switched to the master mode.

■ Manual mode individual condition

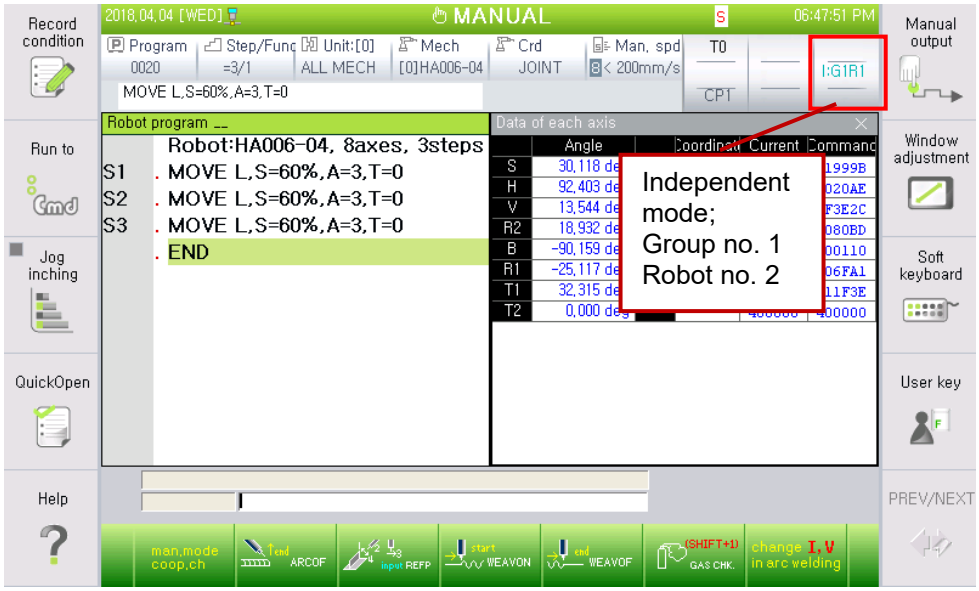


Figure 3.3 Window showing the manual individual mode

In this condition, each robot can be individually controlled with jog.

■ Manual mode cooperation condition (master designation)

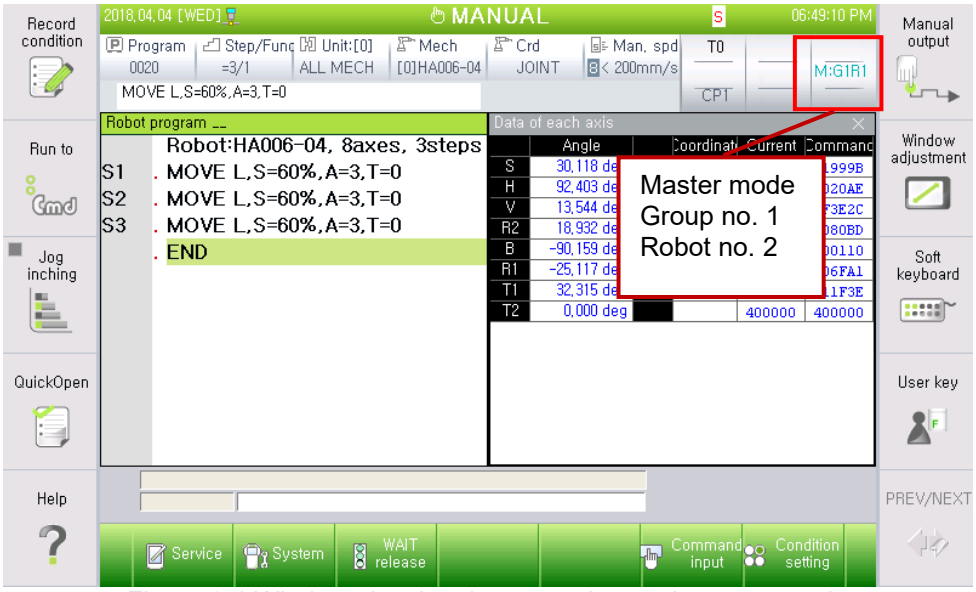


Figure 3.4 Window showing the manual cowork master mode

This mode is to operate in a synchronized manner following the movement of the master while in the mode that the slave is set.

■ Manual mode cooperation condition (slave designation)

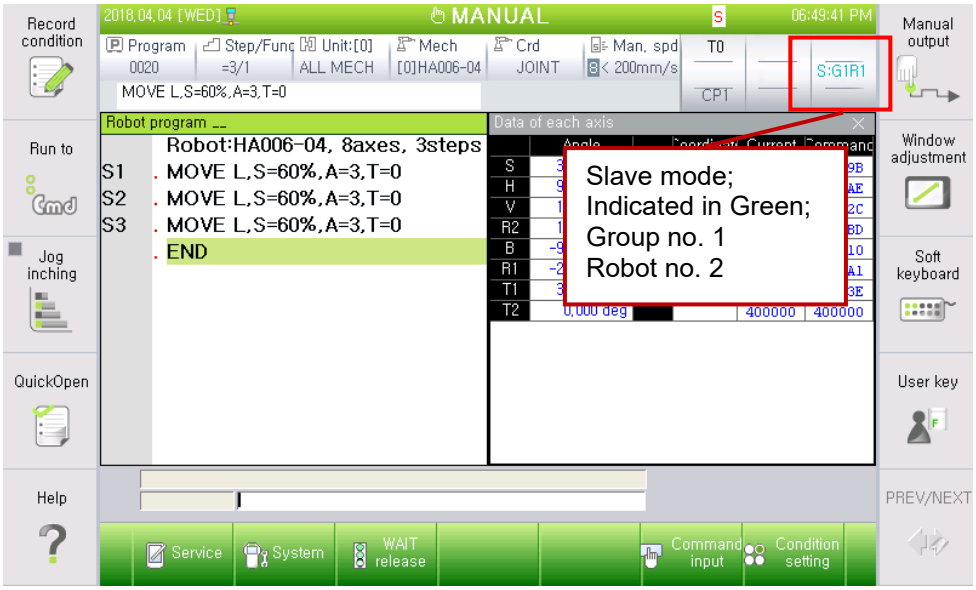


Figure 3.5 Window showing the manual cowork slave mode

This is the condition to designate the slave to follow the movement of the master.

■ CMOV record mode, SLAVE jog mode condition

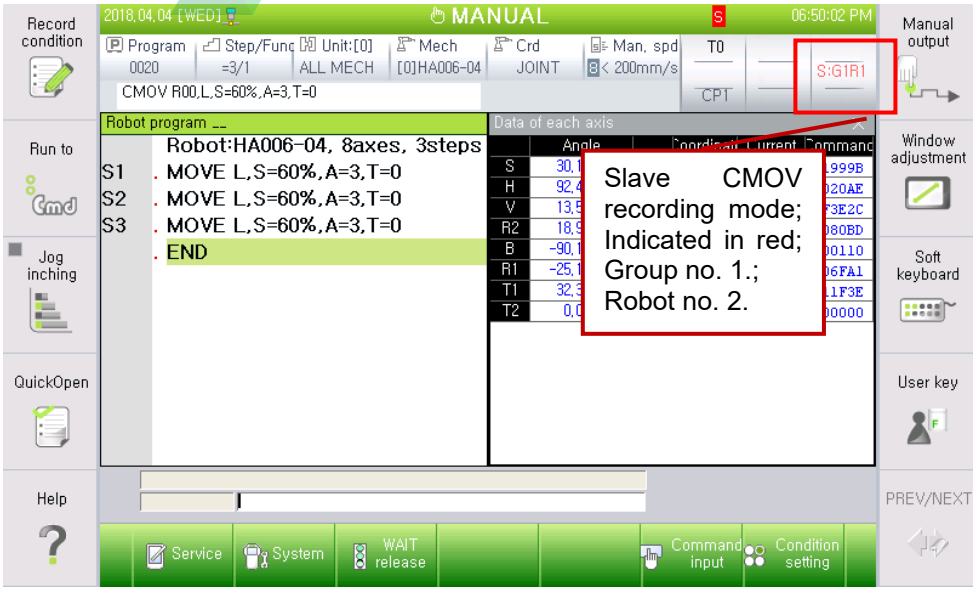


Figure 3.6 Window showing the CMOV recording mode

This is the condition to record CMOV, check the teaching position by moving the step of CMOV command forward/backward and jog control the slave based on the master robot's end effecter coordinate. However, recording a step or moving the robots requires a robot set as the master among the robots is subject to the cowork control.

Caution

- If no common coordinate system is set, it is impossible to switch from the manual individual mode to the cowork master or slave mode.
- In manual cooperation condition switch through R code, the R351,3‘CMOV record condition’ can only be done in ‘manual cooperation condition (slave designation mode)’(R351,2).
- To switch to the CMOV recording mode with the hot key, switch the robot mode to the slave mode first, then use the hot key.

3.3. Manual mode cooperation operation

3.3.1. Setting master and slave robot

Set the robot roles of master and slave using the set User key (or R351). At this time, the role of the robot has nothing to do with the robot number.

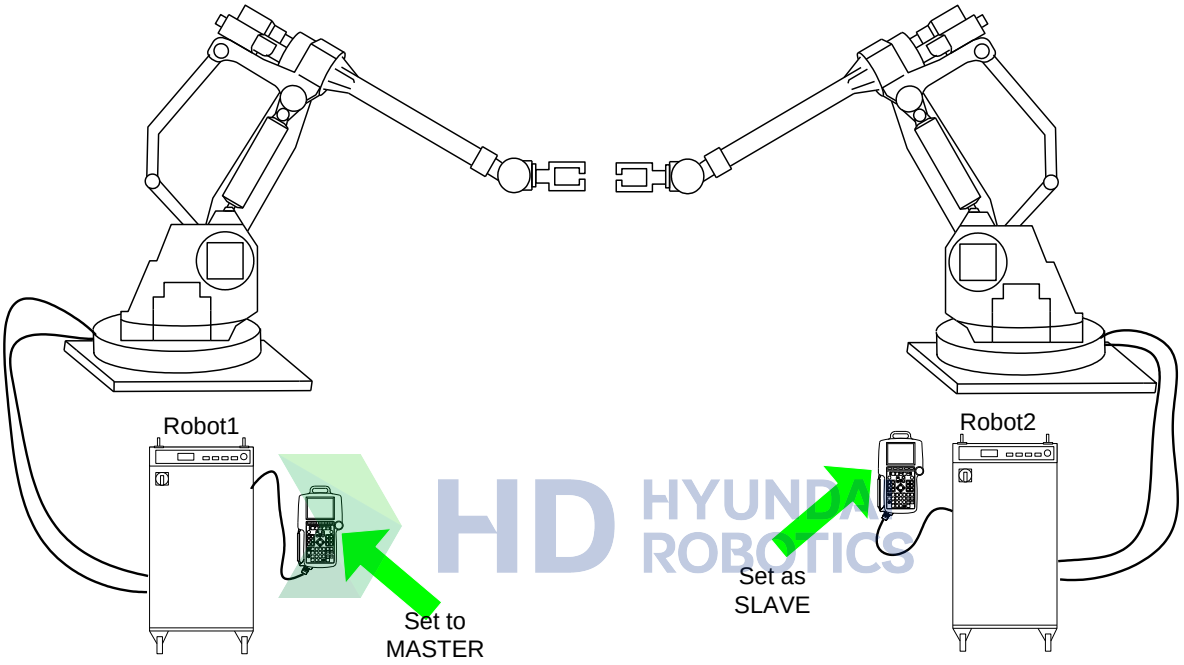


Figure 3.7 Manual mode cooperation operation (Setting master robot and slave robot)

① Check if both master and slave robot are in ‘manual mode’.
② Keep both the master and slave robot in operation ready ON condition.
③ Use the Enable switch of the slave robot and maintain it to operation ready ON condition, and also check if the master robot is in operation ready ON condition.
④ When you control the master robot, the slave robot will follow in a relative position.

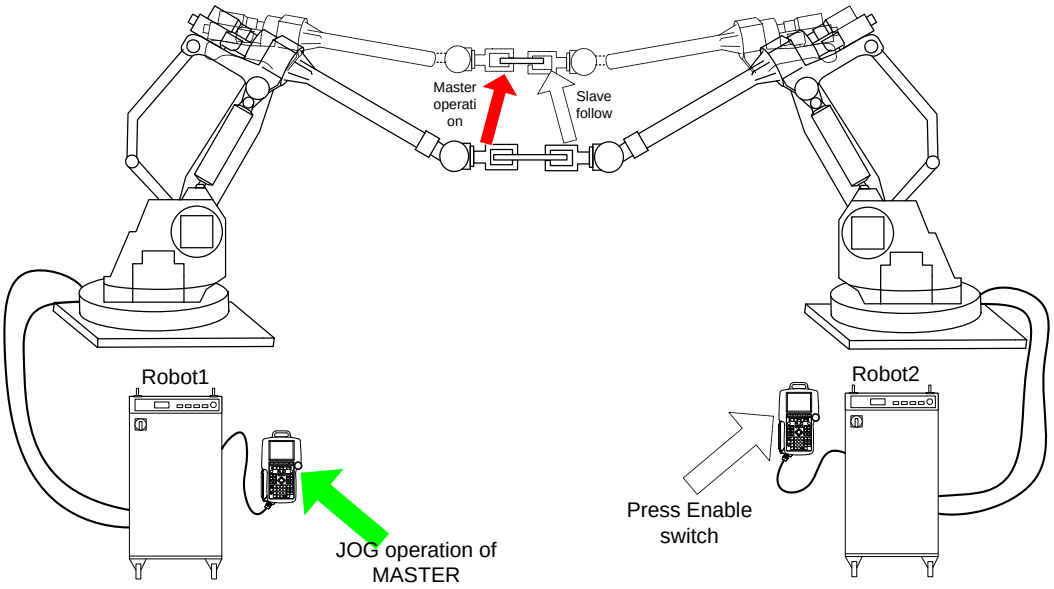


Figure 3.8 Manual mode cooperation operation (Master robot operation / Slave robot follow)

Caution

- Manual collaborative job is not possible in the following cases.

  When operating two or more master robots
  When operating the slave robot
  When the Enable switch for master or slave robot is not pressed
  When the collaborative coordinate among robots is not set
  Broken HiNet communication among the robots

- Jog operation is not possible for the slave robot during manual mode cooperation function. For a jog operation of the slave robots, switch the robot mode to the manual individual mode first.

- When the cooperation control is set to <Disable>, I:R#/S:R#/M:R# will not be displayed on the top part of the screen in manual mode and the setting will not be in effect. Therefore, manual cooperation jog is also not possible.

3.4. Cooperation Traverse Axis Jog

Cooperation traverse axis jog is the same operation as the general cooperation jog. If you operate the master robot on the traverse axis in cooperation jog condition, as shown in Figure 3.9, the slave robot will adjust and move to the relative position of the traverse axis.

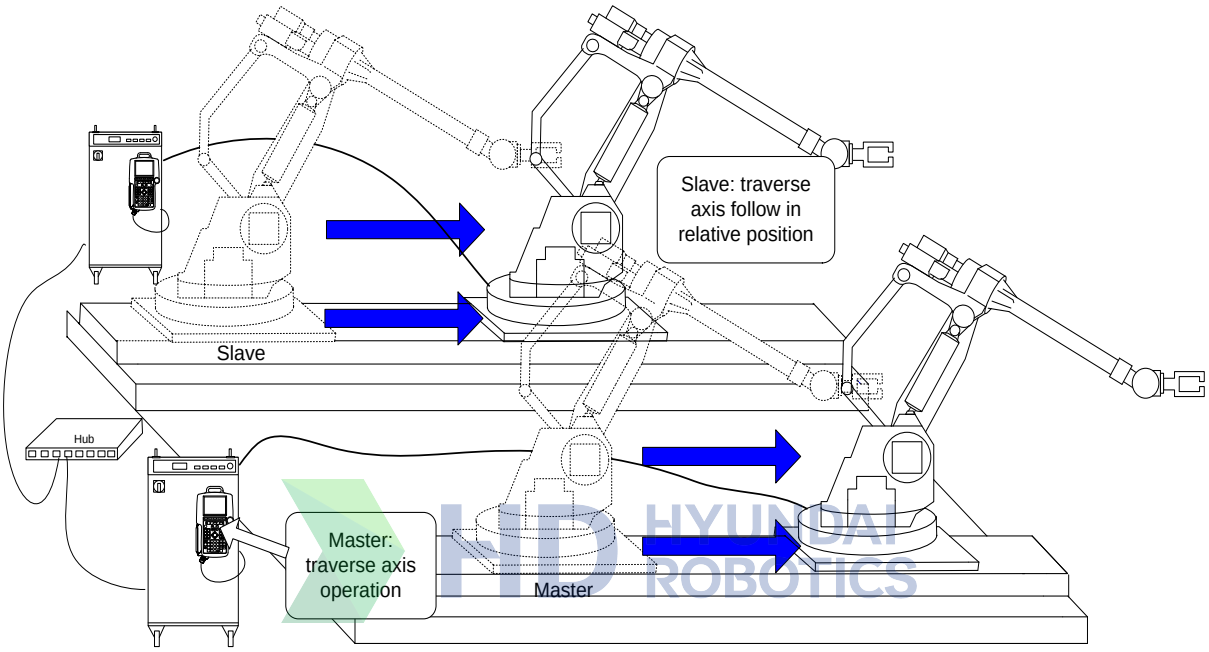


Figure 3.9 Cooperation traverse axis jog

Caution

- The traverse axes of the master and slave robot for cooperation control system must be installed in parallel, as possible.
- Cooperation control traverse axis system only supports one axis.
- In using the cowork driving axis function, you should carry out a calibration of the driving axis first.

3.5. CMOV record mode jog

CMOV record mode is the mode to teach the slave position for jigless cooperation operation.

■ Method for setting the CMOV recording mode

① Select the robot role as Slave
② Switch the manual cowork mode of the master robot to “master.”
③ When the operation is carried out in the orthogonal coordinate jog mode, the orthogonal coordinate jog will take place based on the tool End Effector coordinate of the mater. (Version V40.13-00 or older)

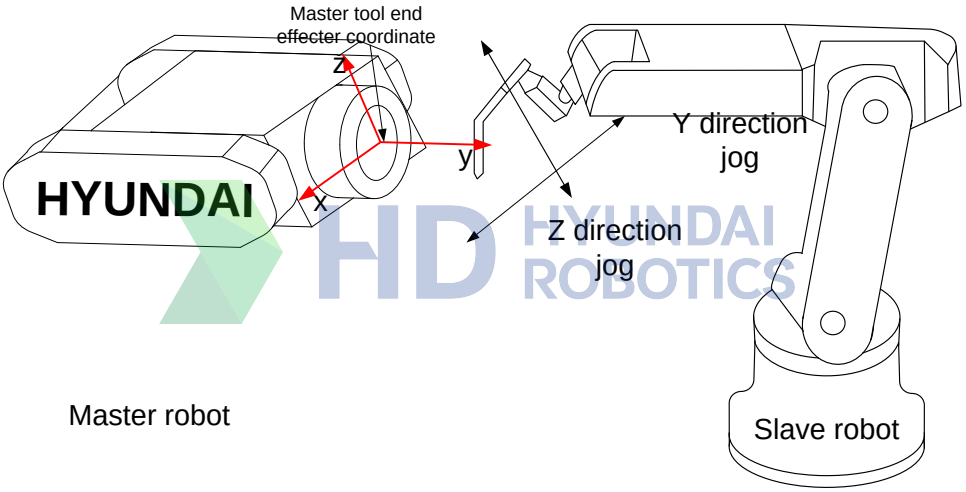


Figure 3.10 CMOV record mode jog

④ Even in the Cartesian coordinate system jog mode, the jog operation is made based on the Cartesian coordinate system of the robots regardless of the master coordinates. (Version V40.13-03 or later)

Caution

- The driving axes of the master and the slave robots that are subject to the cowork control should be parallel to each other as much as possible.
- When the slave is in CMOV record mode, jog operation for master robot in manual cooperation condition is not possible.
- Care should be taken because the jog coordinate system of the CMOV recording mode varies depending on versions.

3.6. Arm interference and soft limit detection among cooperation robots

In the cooperation activity, the slave moves in line with the movement of the maser. At this time, while the user is carrying out the manual operation of the cooperative robot by using the master, if soft limt or arm interference angle error occurs at the slave robot, stopping will occur while the relative position for the cooperation is maintained.

3.6.1. Error detection

When one of the robots stops from an error caused from an arm interference error or soft limit, the robot stops keeping its current position. Even when the error is caused by the slave, the master also stops the operation

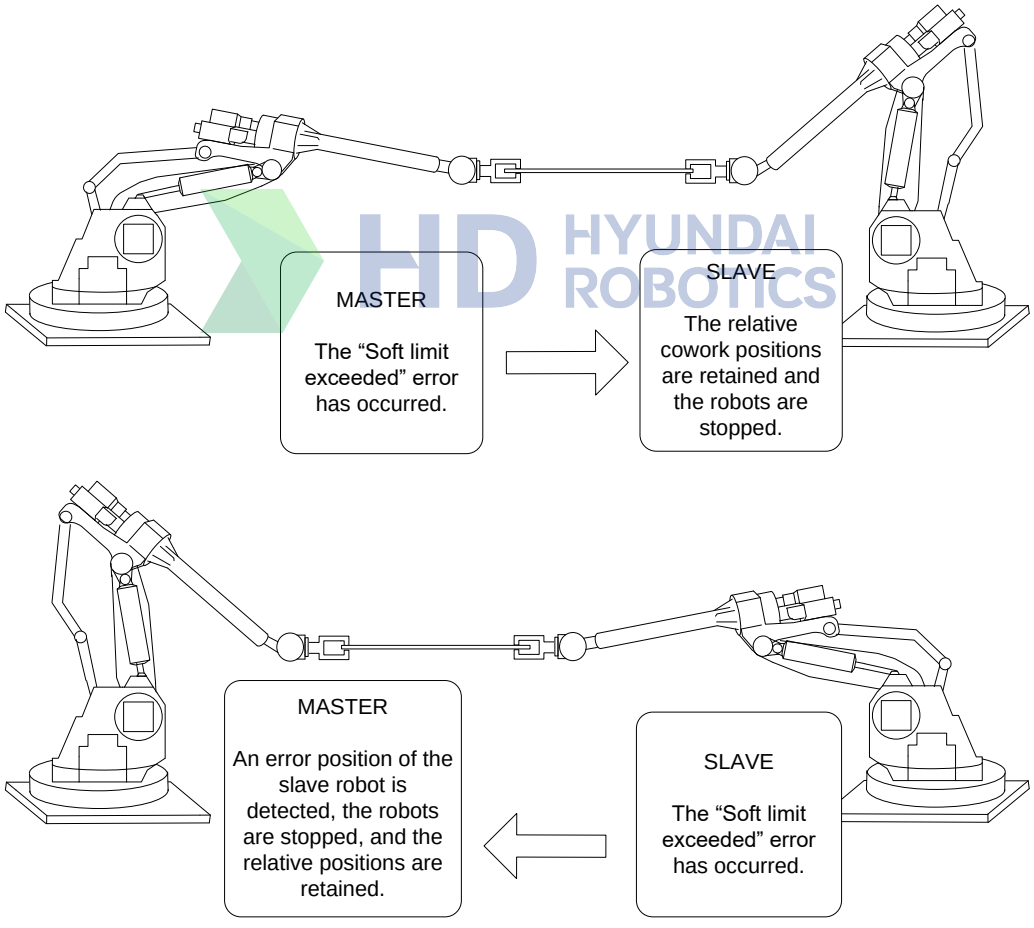


Figure 3.11 Soft limit error detection

3.6.2. Error cancel

Pressing the jog key for the master robot in the nonerror direction will clear the error. After clearing the error, press the jog key again in the nonerror direction to resume operation.

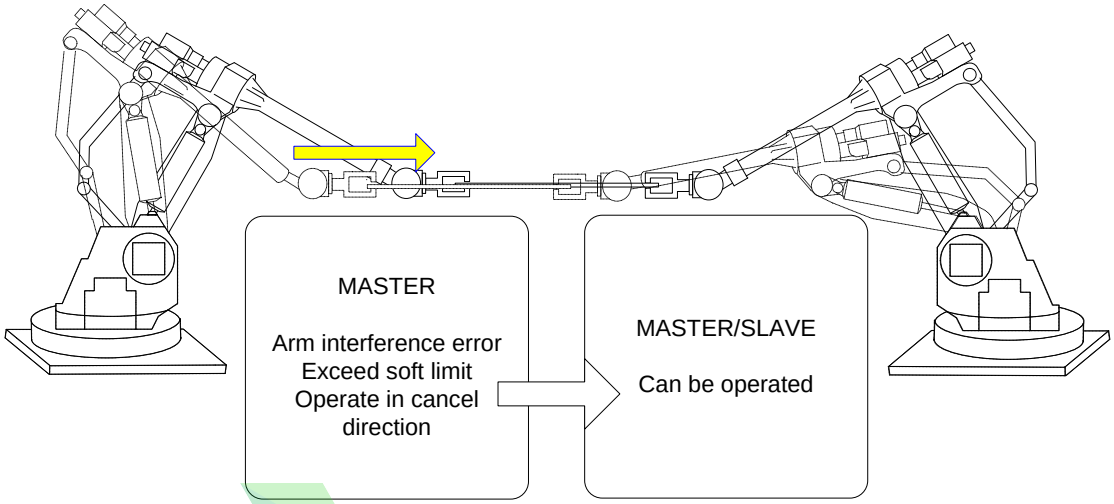


Figure 3.12 Soft limit error cancel

4

Cooperation Operation Teaching

4.1. COWORK function

4.1.1. Function parameter

COWORK function is recorded in the program as a function and indicates the start and end of the cooperation control. This function also designates the master and slave of each robot.

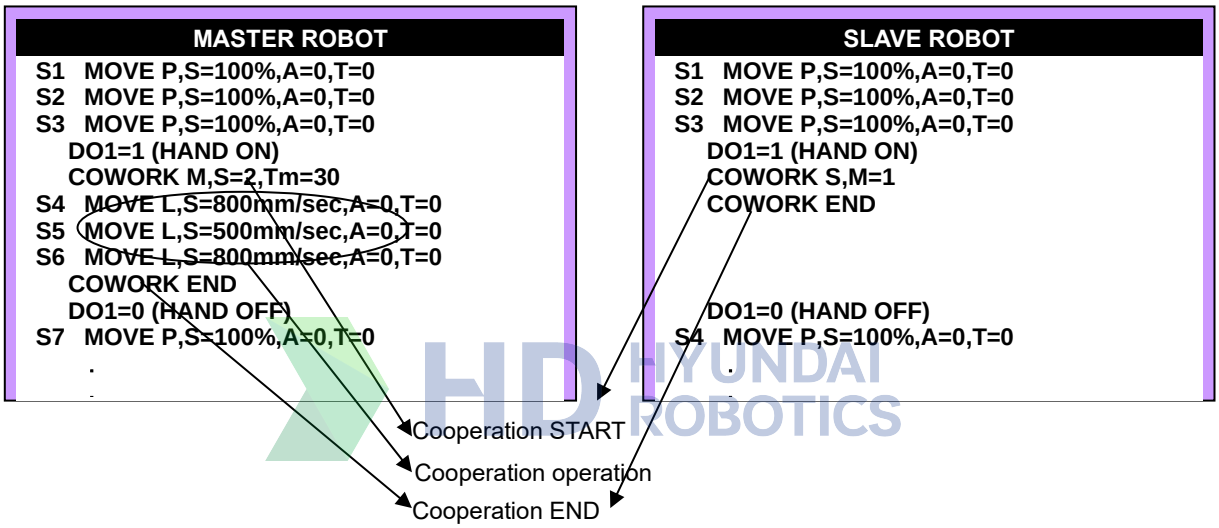
COWORK **{parameter1},{parameter2},{parameter3},{parameter4},{parameter5}** **…** **(Cooperation program)** **…** **COWORK END**	**Start cooperation** **End cooperation**
Parameter1	- Designates own robot role (MASTER/SLAVE) - Designates end of cooperation operation **M**: Designates itself as master **COWORK M,S=…,** **S**: Designates itself as slave **COWORK S,M=…** **END**: End cooperation operation **COWORK END** **WITH:** The position synchronization and the SN number of the robot should match those of the other robots. **COWORK WITH,SN=1**
Parameter2	- The ID number of the manipulator to be designated by the master robot controller as the master. **If it is the master itself: COWORK M, ID=1,S** ID = 0 is the robot manipulator ID = 1 is the positioner group 1 registered as the additional axis (If the positioner group is set as the additional axis at the master)
Parameter3	-Designates other robot number **When designated itself as master : COWORK M,S=2,3,4** Others become the slave and designates the slave robot number (maximum of 3) **When designated itself as slave : COWORK S,M=1** Other robot becomes the master and designates the master robot number
Parameter4	- **Manipulator ID number designated as master from the master robot controller** **if it is the slave itself: COWORK S,M=1,ID=0** ID = 0 is robot manipulator ID = 1 is positioner group 1 registered as additional axis (When the positioner group is set as additional axis to master axis)
Parameter5	-Collaborative corresponding robot standby time (Sec) < 0 ~ 120 > When not designated, it is infinite standby **When designated itself as master : COWORK M,S=2,T=30** Standby time until slave returns to collaborative reference position **When designated itself as slave : COWORK S,M=1,T=30** Standby time until master returns to collaborative reference position

4.1.2. Method of using COWORK function

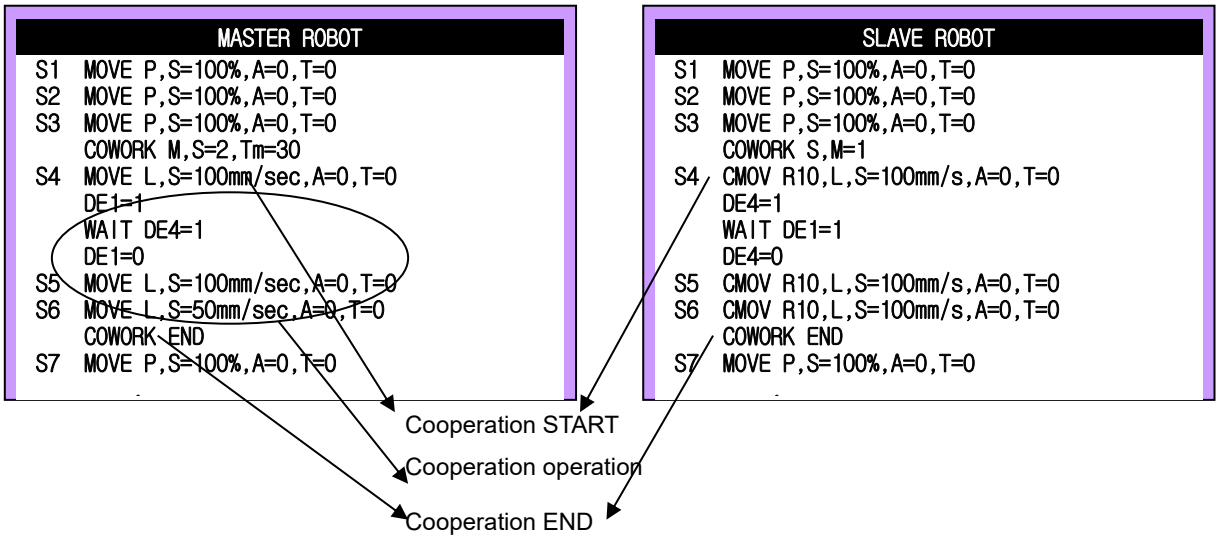
(1) For the master robot, the operating command in the zone between COWORK and COWORK END becomes the collaborative zone command. The slave cannot insert an operating command.

(2) For the slave robots, general move commands cannot be used in the cowork section, but the CMOV (cowork move) commands should be used.

(3) For handling operation, which is for the slave to follow the master robot, the slave moves with the master while keeping a relative position even though the CMOV command is not inserted, as shown in the below example.



(4) You can insert a CMOV command to the slave based on the master end effecter coordinate, and the recording position of CMOV is based on the master tool end effecter coordinate. If it is taught as shown in the following example, the cowork will be carried out in the “COWORK – COWORK END” section. In the cowork section, the slave robot will follow the movement of the master robot that is made along the CMOV route recorded in the master end-effector coordinate system.



Caution

- At the end position of the cooperation operation, a COWORK END command must be inserted.
- For the slave robot, the MOVE command cannot be inserted within the cooperation zone. For the master robot, the CMOV command cannot be inserted.

4.2. Program Teaching and Preparation for Cooperation Handling

(1) You need the same number of operators as the number of cooperation control units. Therefore you need as many operators as the robots. However, with a TP sharer, one operator can make a concurrent control of all the robots.

(2) Check whether the common coordinate of the cooperation robot is set. Designate the manual cowork control mode switching function to a user-defined key.

(3) Move the master and slave robot to the starting position of the cooperation operation and record the starting position based on the reference position.

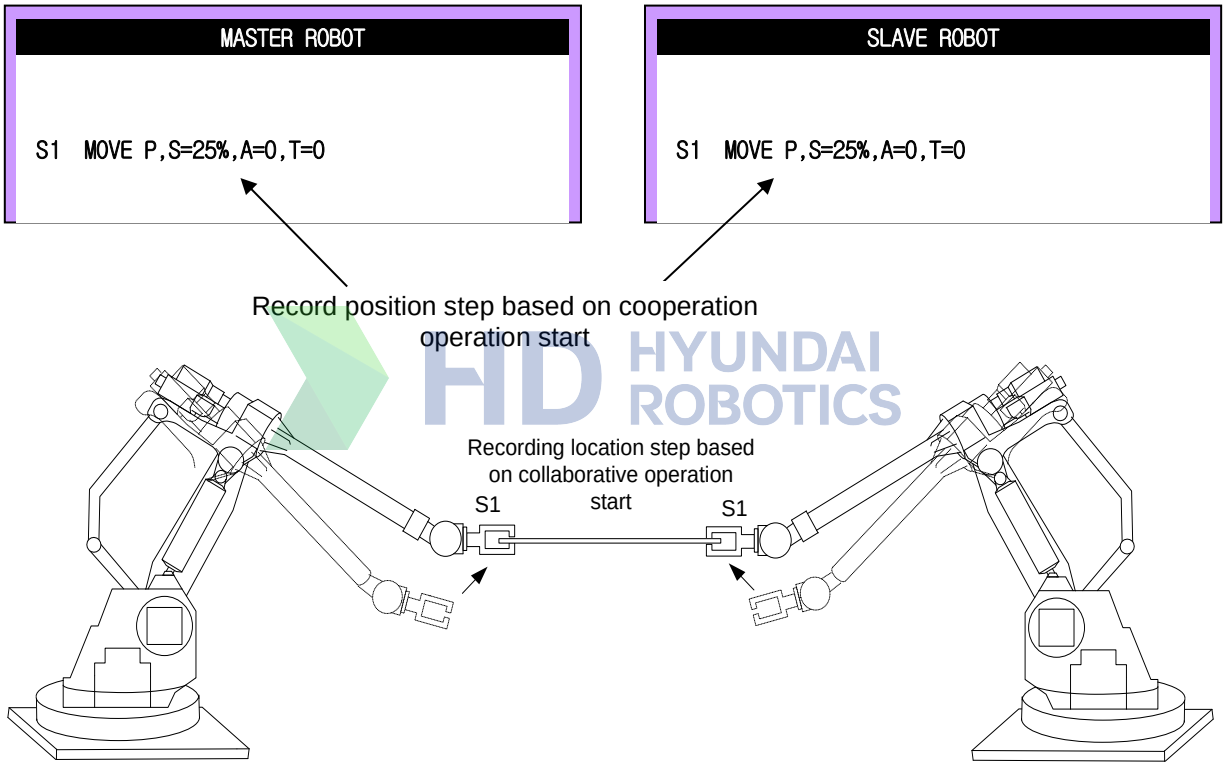
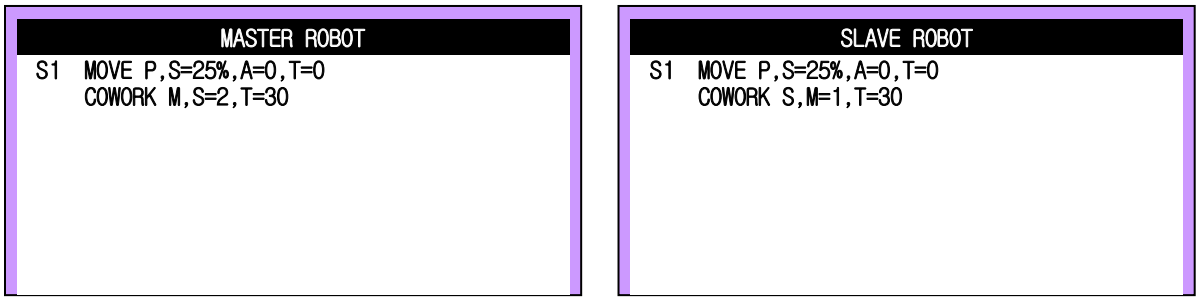


Figure 4.1 Recording position step based on cooperation operation start

(4) Set the mode of the master and the slave robots to the cowork mode with the user-defined function key. The robot roles can be set by entering the R351 code.

(5) Register the COWORK M/S command. COWORK command designates the master/slave recognition and designates the slave/master number. In this case, only one robot should be set as the master within a group, while up to three robots may be set as the slave robots.



(6) Control the master robot with jog. At this time the slave follow the master robot's movement in relative position at the tools end position. During the cowork jog operation, the "Enable" switches of the slave robots should be on. The step is recorded only to the master from record position. It is not recorded in the slave robot controller.

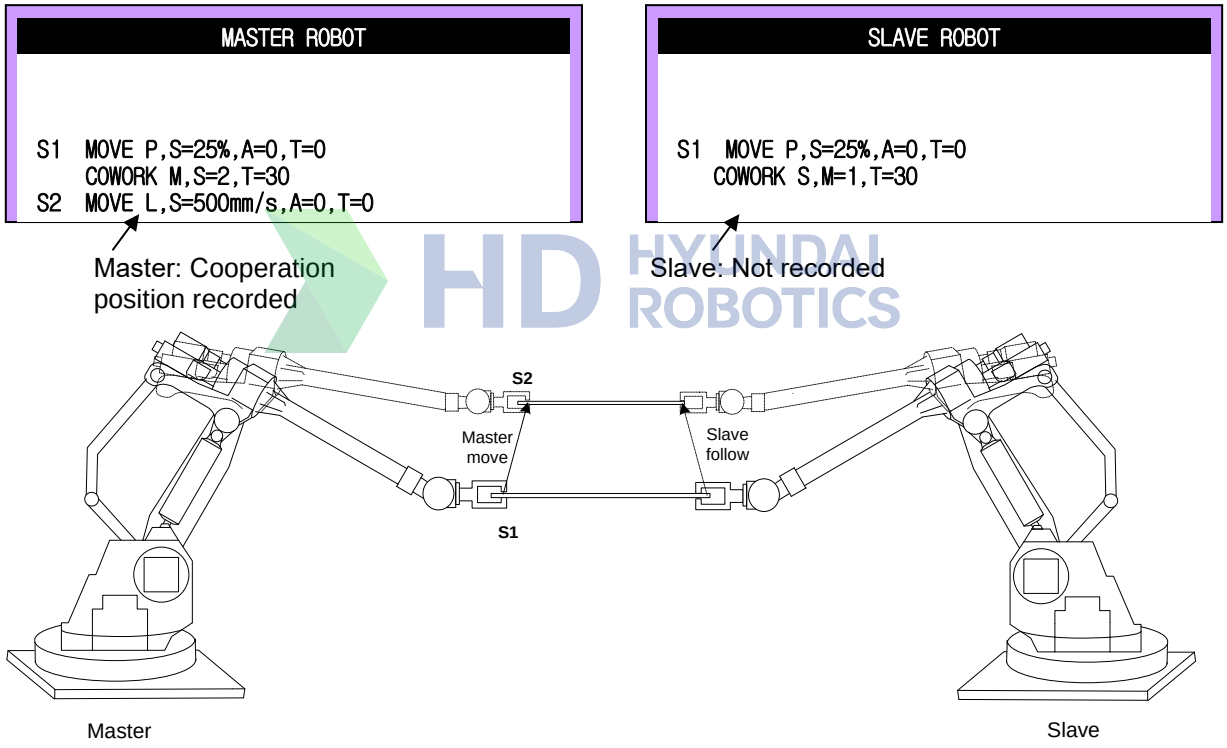
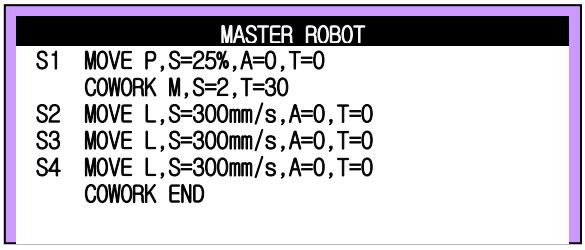
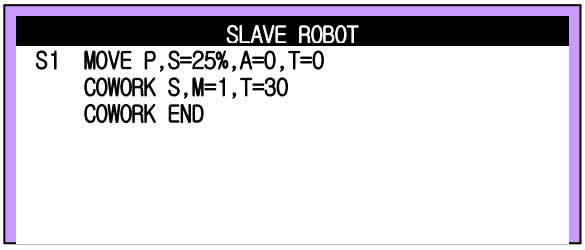


Figure 4.2 Master robot operation

(7) Cooperation operation step is recorded to the master. Set the interpolation type and speed of the master. Use the general move command within the cooperation operation function. (SMOV cannot be used.)

(8) When the cooperation operation is done, the COWORK END command is inserted to the master and slave.





Caution

- Do not set to Enable switch of the slave to OFF during manual cooperation operation. Because the hardware signal is processed prior to the communication speed, a misalignment between the robots can occur. In this case, it can damage the work object or robot hand in severe cases.

4.3. CMOV command

CMOV {parameter1}, {parameter2}, {parameter3}, {parameter4}, {parameter5}	
parameter1	**Manipulator identifier of master robot system** Type: R(#1)(#2) #1 : Master robot system number (1 ~ 4) #2 : Master manipulator identifier of robot system (0: Robot, 1: Positioner Group 1, 2: Positioner Group 2)
parameter2	**Types of interpolation** Designs the slave robot's interpolation method. Only applies to straight line or arc. (L: Linear, C: Circular)
parameter3	**Interpolation speed** Designates the relative speed compared to work object
parameter4	**Accuracy (0~7)**
parameter5	**Tool number (0~31)**

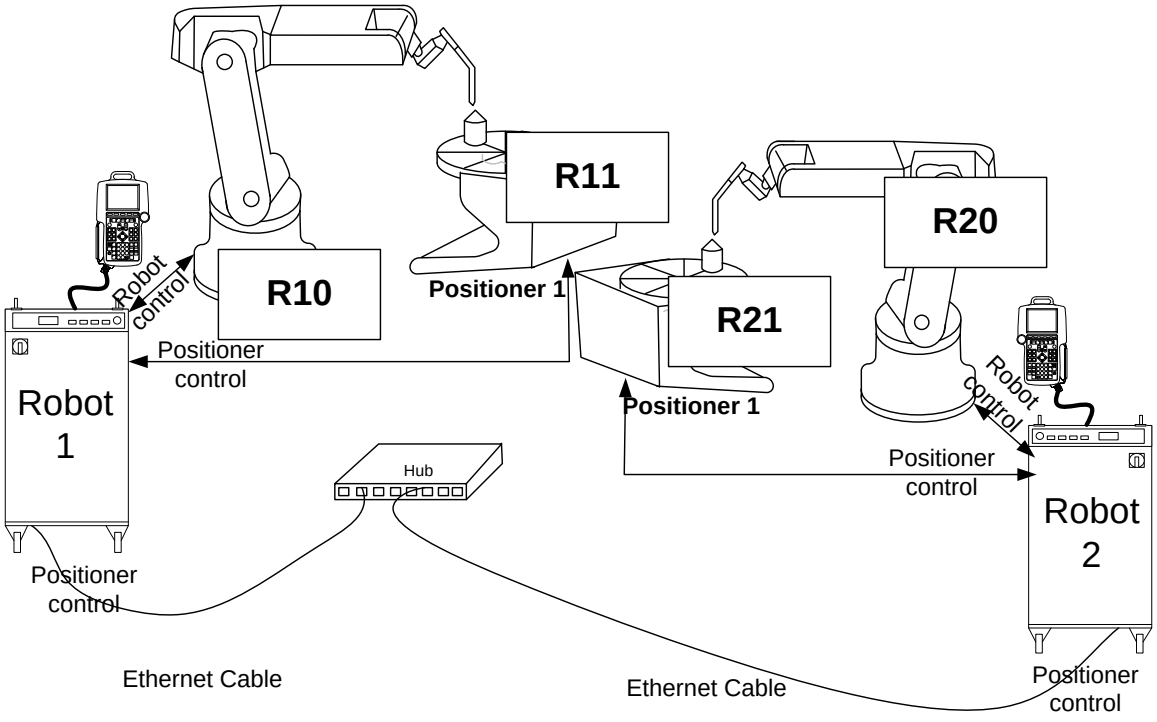


Figure 4.3 Method of distinguishing ID identifier

4.4. Teaching for Arc Welding and Sealing (Jigless Cooperation Control)

(1) Set the manual cowork mode of the master and the slave robots to “individual,” record the steps for the cowork start position, and input the COWORK command for the cowork start position.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
```

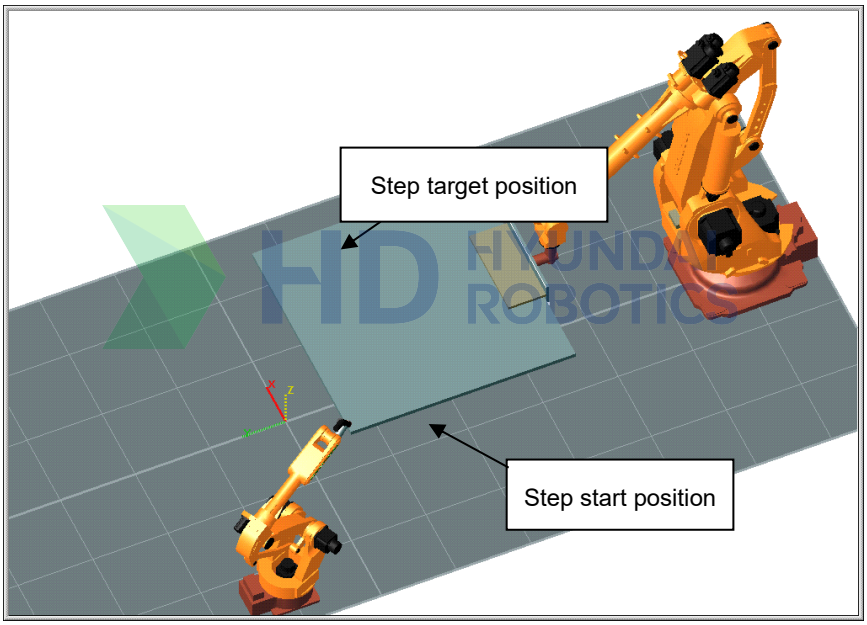


Figure 4.4 Step start and target position

(2) Set the manual cowork modes of the robots to master and slave depending on their roles.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
```

(3) Operate the master with jog operation and the slave will follow. Record the master step in the desired recording position.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
S4   MOVE L,S=100mm/s,A=0,T=0
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
```

(4) The slave needs to be turned into the CMOV record mode by using the Shift+User keys or the R351,3 command. The robot role displayed at the top right of the screen turns from green to red.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
S4   MOVE L,S=100mm/s,A=0,T=0
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
```

(5) Jog operate the slave robot to the target position and press the 'REC' key.

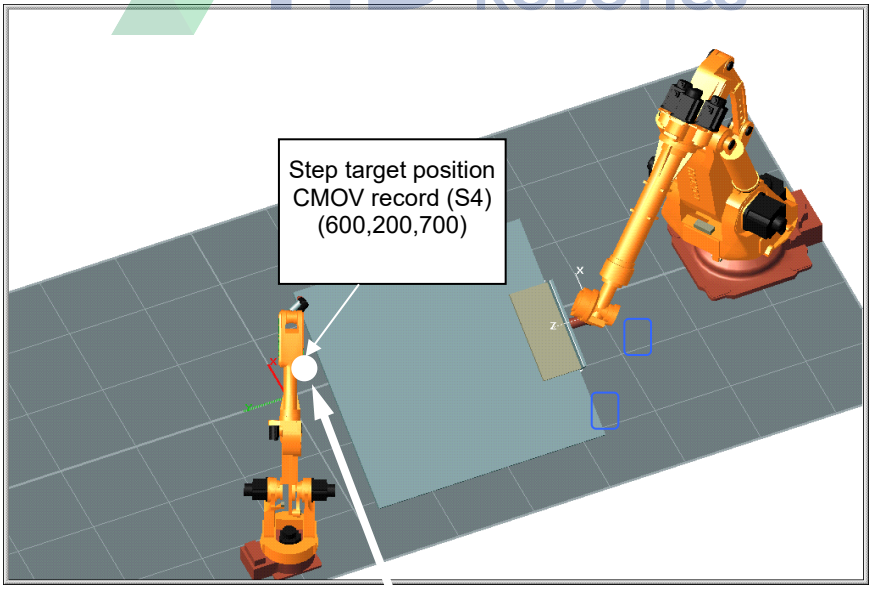


Figure 4.5 Step target position CMOV record

```
MASTER ROBOT
     COWORK M,S=2
S4   MOVE L,S=100mm/s,A=0,T=0
>
```

```
SLAVE ROBOT
     COWORK S.M=1,ID=0
S4   CMOV L,R10,S=100mm/s,A=0,T=0
```

(6) CMOV is recorded to the slave. The recording position of CMOV is based on the master tool end effecter coordinate. Press the QUICK OPEN to check and edit the recorded coordinate position.

(7) The coordinate recorded at this time is to be displayed as 'Master end'.

(8) For example, to synchronize the starting point of step 5 (S5) of master and slave, method of checking whether they arrived with GE or DE parameter is used.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
S4   MOVE L,S=100mm/s,A=0,T=0
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
S4   CMOV L,R10,S=100mm/s,A=0,T=0
S5   CMOV L,R10,S=100mm/s,A=0,T=0
```

(9) But because the moving plan for recording step is executed individually between the master and slave, the time reaching the target position is different. To match the cowork start timing of the "MOVE" position of the master and the "CMOVE" position of the slaves in the cowork section, you may use the mutual interlock method using the HiNet I/O or the "COWORK WITH,SN=1" command. The "COWORK WITH" command will carry out a synchronization move only for the robots with a same SN number. If the command encounters the "COWORK WITH" command for a different SN number, an error will occur.

(10) For example, to synchronize the starting point of step 5 (S5) of master and slave, method of checking whether they arrived with GE, DE parameter is used.

```
MASTER ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK M,S=2
S4   MOVE L,S=100mm/s,A=0,T=0
     WAIT GE5=1
     GE1=1
S5   MOVE L,S=100mm/s,A=0,T=0
```

```
SLAVE ROBOT
S1   MOVE P,S=100%,A=0,T=0
S2   MOVE P,S=100%,A=0,T=0
S3   MOVE P,S=100%,A=0,T=0
     COWORK S.M=1,ID=0
S4   CMOV L,R10,S=100mm/s,A=0,T=0
     GE5=1
     WAIT GE1=1
     GE5=0
S5   CMOV L,R10,S=100mm/s,A=0,T=0
```

※ If the above method is used, the master and slave robot checks each other whether they have arrived at step 4 (S4) and moves to step 5 (S5).

(11) When the cooperation operation is completed, the COWORK END command is inserted to both master and slave to complete the cooperation control teaching.

```
MASTER ROBOT
S1  MOVE P,S=100%,A=0,T=0
S2  MOVE P,S=100%,A=0,T=0
S3  MOVE P,S=100%,A=0,T=0
    COWORK M,S=2
S4  MOVE L,S=100mm/s,A=0,T=0
    WAIT GE5=1
    GE1=1
S5  MOVE L,S=100mm/s,A=0,T=0
    WAIT GE5=0
S6  MOVE L,S=100mm/s,A=0,T=0
    COWORK END
    GE1=0
```

```
SLAVE ROBOT
S1  MOVE P,S=100%,A=0,T=0
S2  MOVE P,S=100%,A=0,T=0
S3  MOVE P,S=100%,A=0,T=0
    COWORK S.M=1,ID=0
S4  CMOV L,R10,S=100mm/s,A=0,T=0
    GE5=1
    WAIT GE1=1
    ARCON
S5  CMOV R10,L,S=50mm/s,A=0,T=0
S6  CMOV R10,L,S=50mm/s,A=0,T=0
    ARCOF
    GE5=0
    COWORK END
```

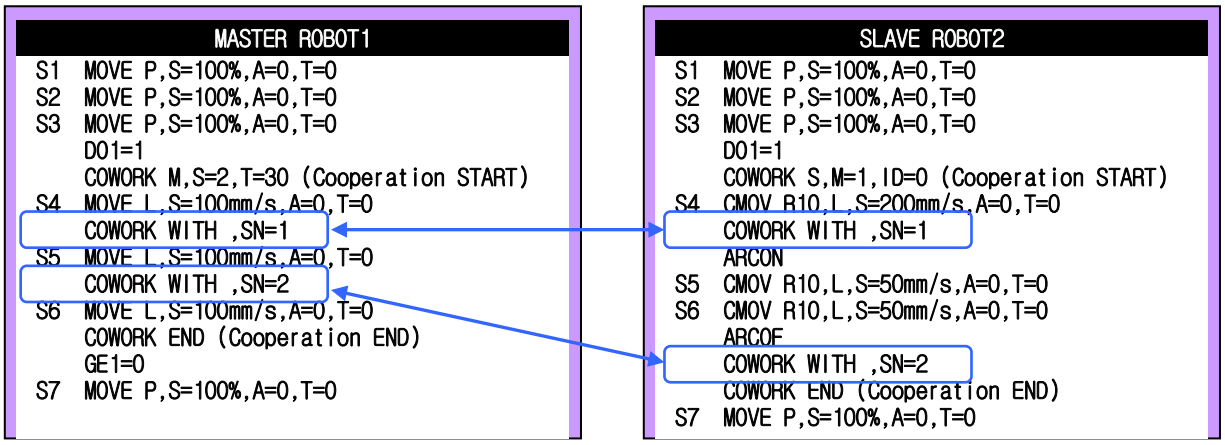
(12) The whole program explained earlier can control the timing such as ⓐ, ⓑ and ⓒ to control the timing of cooperation control, as follows.

```
MASTER ROBOT1
S1  MOVE P,S=100%,A=0,T=0
S2  MOVE P,S=100%,A=0,T=0
S3  MOVE P,S=100%,A=0,T=0
    DO1=1
    COWORK M,S=2,T=30 (Cooperation START)
S4  MOVE L,S=100mm/s,A=0,T=0

    WAIT GE5=1 (wait slave)
    GE1=1
S5  MOVE L,S=100mm/s,A=0,T=0



    WAIT GE5=0 (wait ARCOF of slave)
S6  MOVE L,S=100mm/s,A=0,T=0
    COWORK END (Cooperation END)
    GE1=0
S7  MOVE P,S=100%,A=0,T=0
```

ⓐ ⓑ ⓒ

```
SLAVE ROBOT2
S1  MOVE P,S=100%,A=0,T=0
S2  MOVE P,S=100%,A=0,T=0
S3  MOVE P,S=100%,A=0,T=0
    DO1=1
    COWORK S,M=1,ID=0 (Cooperation START)
S4  CMOV R10,L,S=200mm/s,A=0,T=0
    GE5=1


    WAIT GE1=1 (wait master)
    ARCON
S5  CMOV R10,L,S=50mm/s,A=0,T=0
S6  CMOV R10,L,S=50mm/s,A=0,T=0
    ARCOF
    GE5=0
    COWORK END (Cooperation END)
S7  MOVE P,S=100%,A=0,T=0
```

(13) The COWORK WITH command is to be used to synchronize the positions between the master and slave while the cooperation control (Between COWORK~COWORK END) is in progress. If the COWORK WITH command is met in the middle of the cooperation control, it is required to wait until all the cooperating robots reach the COWORK WITH condition. Therefore, in the older versions of the program, the change can be also made by the following method:



Caution

- To use the weaving operation of CMOV, reference PREF setting must be recorded within cooperation control zone (COWORK~COWORK END).
- CMOV trace seam-tracking function using the laser vision sensor is not supported.
- COWORK WITH command must be used for same number for both master and slave in the cooperation control zone (COWORK~COWORK END).
- For the “COWORK WITH” command fulfilled by the cowork robots, a same SN number should be used.

4.5. CMOV record position check

CMOV step is a useful function to check the teaching position during CMOV record mode using the step forward/backward function. Because CMOV step records position and position of master end effecter coordinate, the tool position of the master must be checked before executing.

(1) Set the master robot (COWORK M) to the master condition for manual cooperation. (R351,1)

(2) Set the slave robot (COWORK S) to CMOV record condition. (R351,3)

(3) Move and stop the master robot to the step position for cooperation.

(4) Select the CMOV step to move and press the step forward key to move the slave to the recording position on master end effecter. For example, if the CMOV record position is the origin (0,0,0) of the master end-effector coordinate system as shown in the following figure, the slave robots will move to the origin regardless of the position of the master robot.

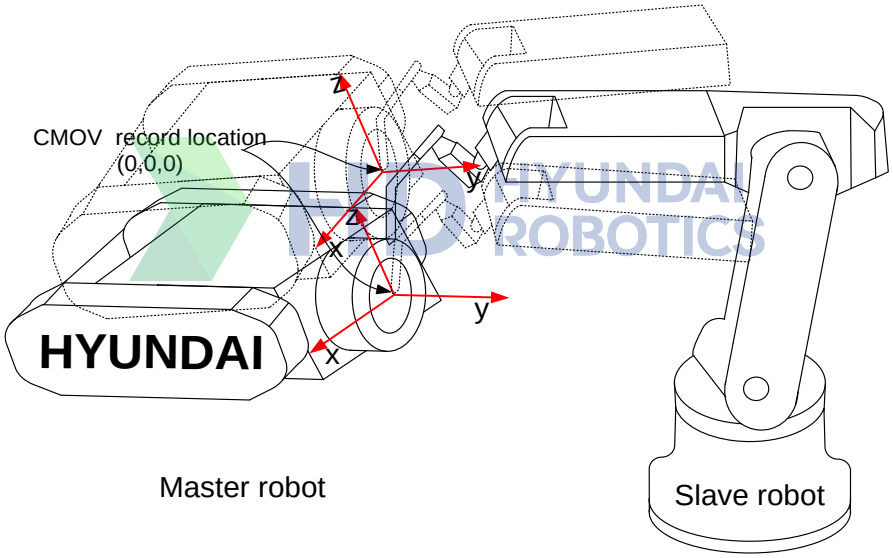


Figure 4.6 CMOV record position check

Caution

- In CMOV record condition (R351,3 condition), it moves to the applicable step position irrelevant of whether the COWORK command is executed or not.
- Master jog cannot be used in CMOV record condition.
- Because real time cooperation operation does not work in CMOV record condition, keep the master stopped and not operate it step forward/backward.
- After changing the master position of the CMOV record, stop the robot. If you move the CMOV step forward it will move the renewed position.

4.6. Positioner master system

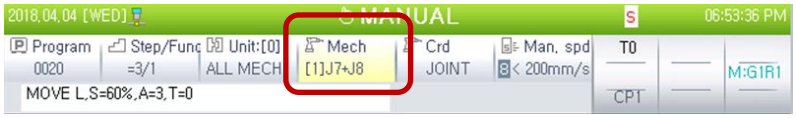
This function allocates the collaborative master to the positioner so that the slave robot can collaborate with the master positioner. The positioner groups 1~2 are supported.

4.6.1. Positioner master jog

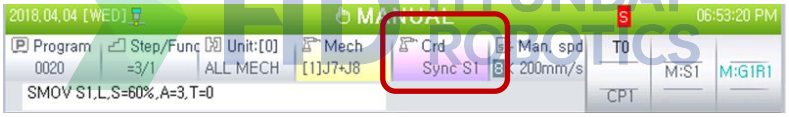
(1) This executes the positioner group setting and positioner calibration for positioner synchronization.

(2) The robot, for which a positioner is set as the master, needs to be set as the manual cooperation master (M:G#R#) by using R351, 1 or the user key.

(3) The 'Mechanism' key needs to be pushed to select the positioner mechanism.



(4) The 'Coordinate' key needs to be pushed to allow Synchronize coordinate S1(or S2) to be selected.



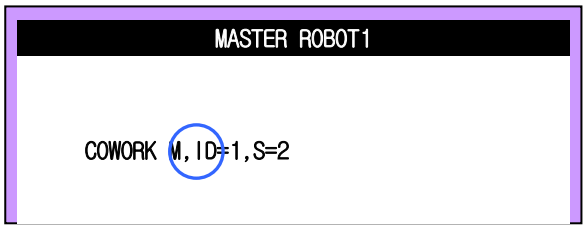
(5) The slave robot needs to be set for the slave role (S:G#R#) by using R351,2.

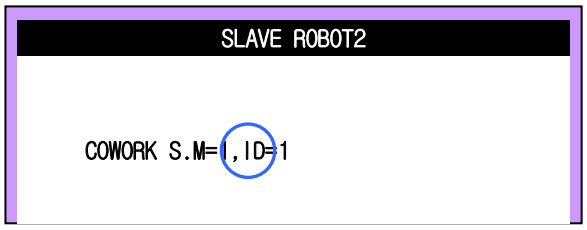
(6) If you execute the positioner synchronized jog operation, the robot 1 and 2 will be synchronized to the positioner.

4.6.2. Positioner master teaching and playback

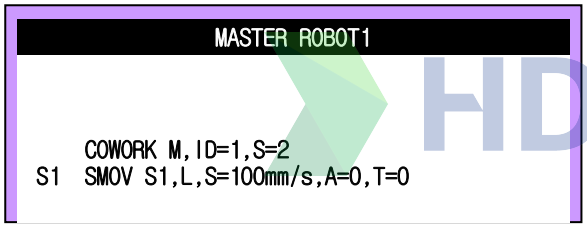
You can teach the master and slave using the COWORK command. Set the ID=1 for the slave to select the master positioner to master.

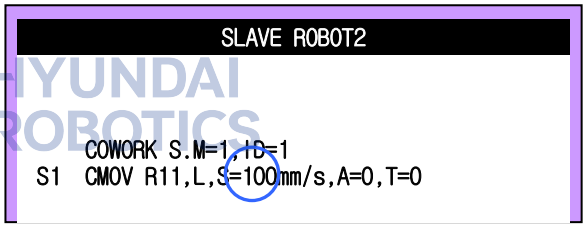
While the positioner is set as the master (Master robot side coordinate ‘Synchronize S1’), the position of the slave needs to be recorded. At this time, this position is recorded based on positioner end effecter coordinate.





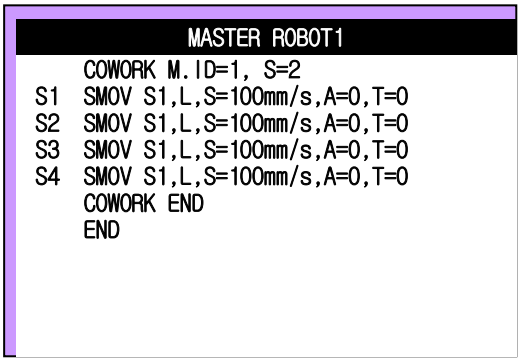
For the master side to collaborate with the positioner, teach SMOV step in the same way as the existing positioner. The slave robot number will be recorded containing the master ID when steps are recorded while the positioner of the master robot is set as master.

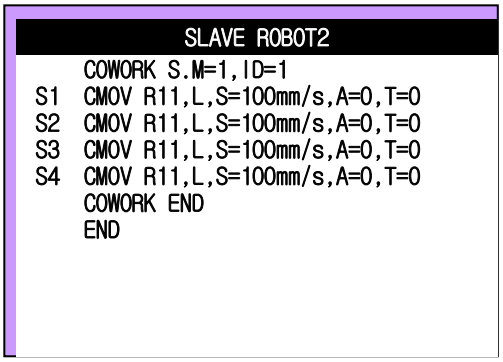




The master is the same as the positioner synchronization function. The slave is recorded in R11.

Teach the master and slave in the above method in (3) and finalize with COWORK END.





Check the operation in manual mode and operate in auto mode.

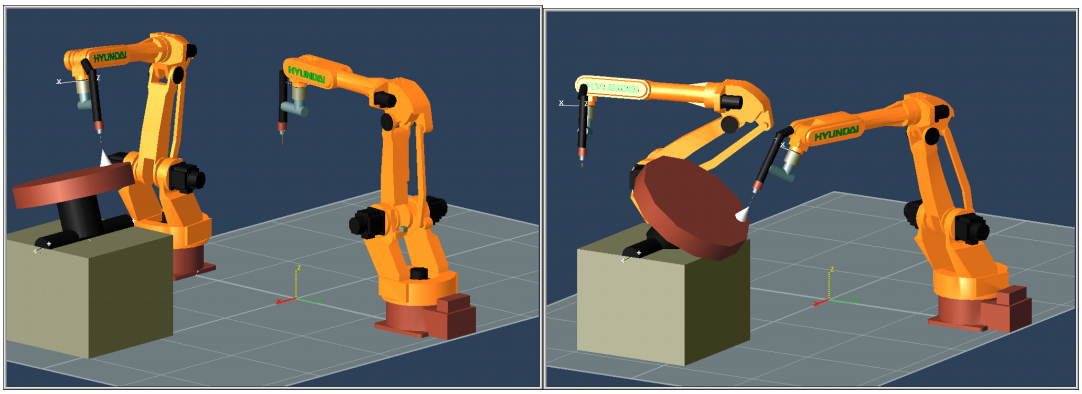


Figure 4.7 Simulation of the synchronized move of the positioners of the robots

Caution

- In the jigless cooperation control, the positioner groups 1~2 are supported. You must select positioner group number 1 or 2 for positioner jog and CMOV.
- If the value set in COWORK S,M=#1, ID=#2 for slave is different from the CMOV R#1#2 value, an error is generated saying 『E1365 CMOV master No. ID is inappropriate.』.

5

Cooperation Operation Playback

5.1. Introduction of Cooperation Playback

Individual operation is the general control method as same as the individual operation method, and the cooperation operation is the COWORK ~ COWORK END part in which the program position of the master decides the slave operation.

(1) Cooperation operation part is the COWORK ~ COWORK END part and the when the COWORK command starts all collaborating robots standby until COWORK is executed.

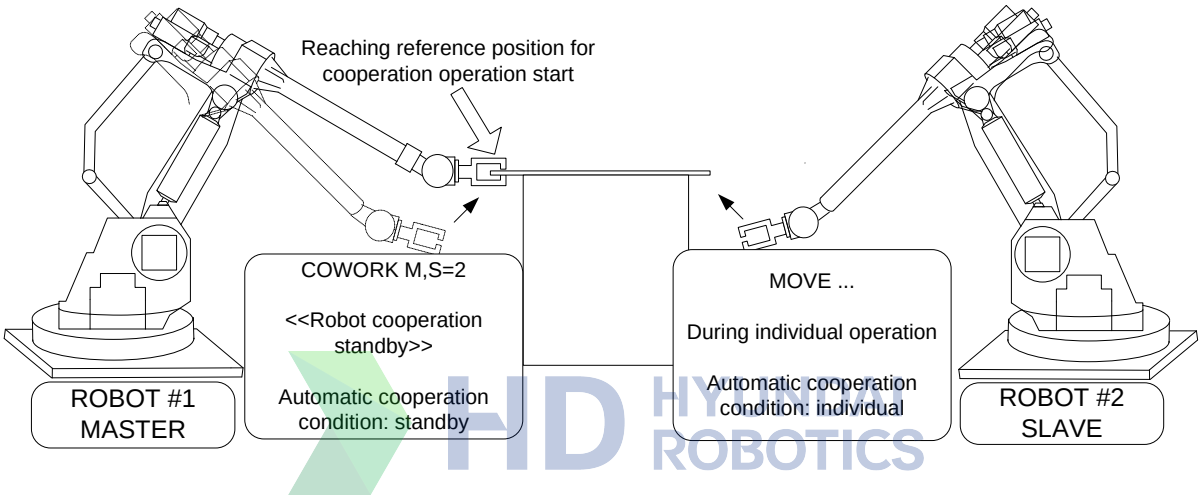


Figure 5.1 Cooperation playback 1

(2) When the collaborating robots are all in COWORK position, the cooperation operation starts.

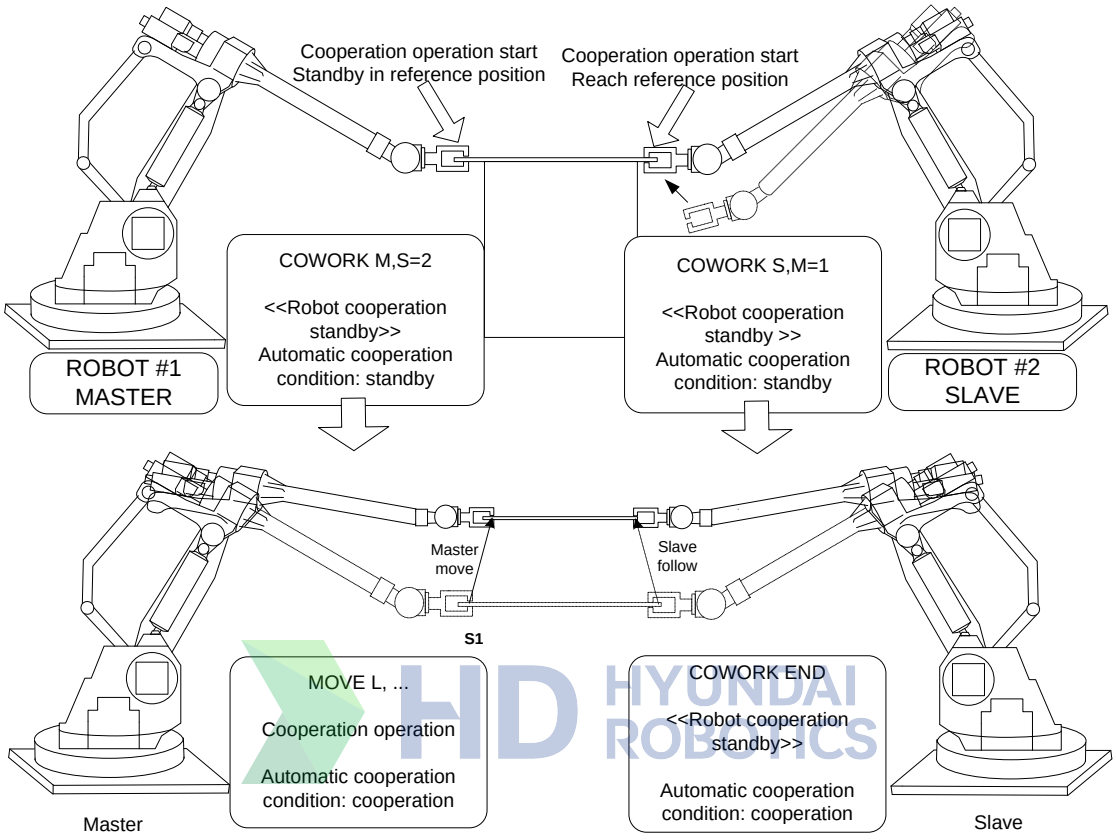


Figure 5.2 Cooperation playback 2

(3) If the collaborative zone operation is completed, master reaches the COWORK END command to end the cooperation condition.

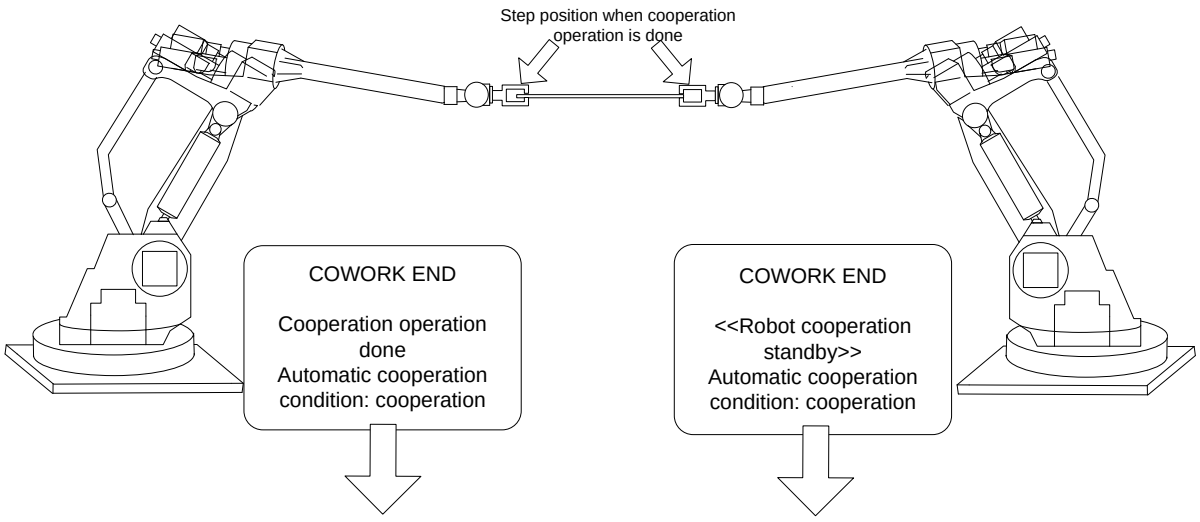


Figure 5.3 Cooperation playback 3

(4) When the cooperation operation is completed, each individual operation is resumed.

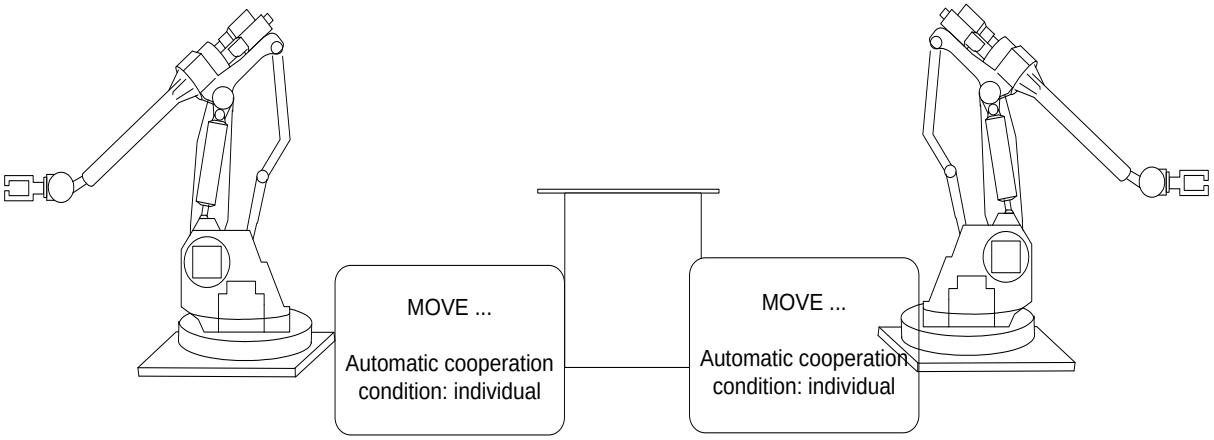


Figure 5.4 Cooperation playback 4

5.2. Program check in manual mode

(1) In the manual mode, the manual cooperation mode needs to be set as I(Indiv.) or M(Master) for the master robot, and it needs to be set as I(Indiv.) or S(Slave) for the slave robot.

(2) The preparation for the operation needs to be on and the 'Step forward' keys on both sides need to be pushed.

(3) To check the synchronized operation of the master and slave, press the step forward key of the slave until the cooperation operation is completed.

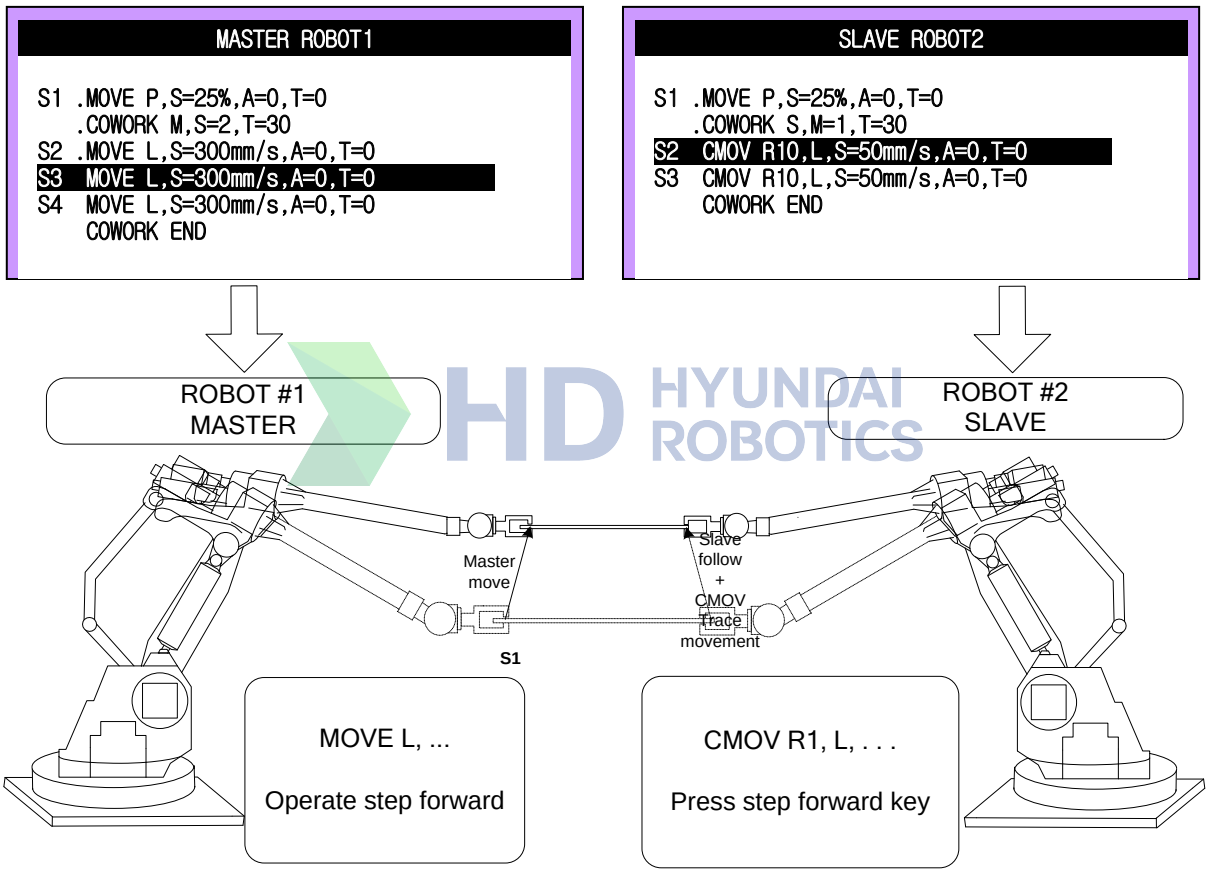


Figure 5.5 Program check in manual mode

Caution

- If a slave robot is in the CMOV recording mode, a manual cowork with the master robot will not be made.
- For step forward/reverse movement, the “carry out function in step forward movement” option should be turned on.
- The master and slave robot check the execution position only when executing the COWORK command, and step position synchronization of master and slave is not done in other work zones. Therefore, the relative position checked with step forward/backward function can change during auto mode playback.
- In order to synchronize the positions of the two robots, the COWORK WITH,SN=1 command needs to be used.

5.3. Playback in auto mode

(1) Switch all collaborating robots to auto mode.

(2) Check if the operation ready condition is ON for all the collaborating robots.

(3) Start the program from the beginning.

(4) Operate all the collaborating robots.
(The operating sequence of master and slave can be either way.)

Caution

- Do not execute the COWORK M (or COWORK S) in any arbitrary position that is not the reference position for cooperation playback. You must calculate the relative position of master and slave in COWORK M (COWORK S) position and always operate it in the collaborative reference position.

- Set the collaborative standby time appropriately. An error will be generated if one of the master or slave arrives to the collaborative reference position and the other does not within the ‘collaborative standby time’. Set the collaborative standby time to 0 to make it standby infinitely.

5.4. Cooperation Playback Stop/Restart

If the user enters the stop command (external stop, internal stop) during cooperation operation, all the robots in cooperation stop.

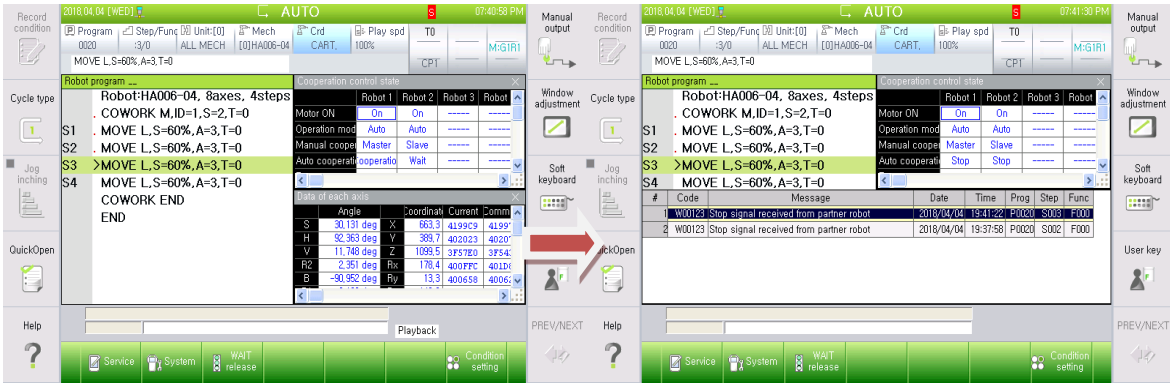


Figure 5.6 Warning message output for a stopped cowork robot

After stopping during cooperation operation, changing the step number and restarting the robot is only possible if the cooperation playback condition is disabled. In this case, the system requires the user to enter the R353 code as a warning.

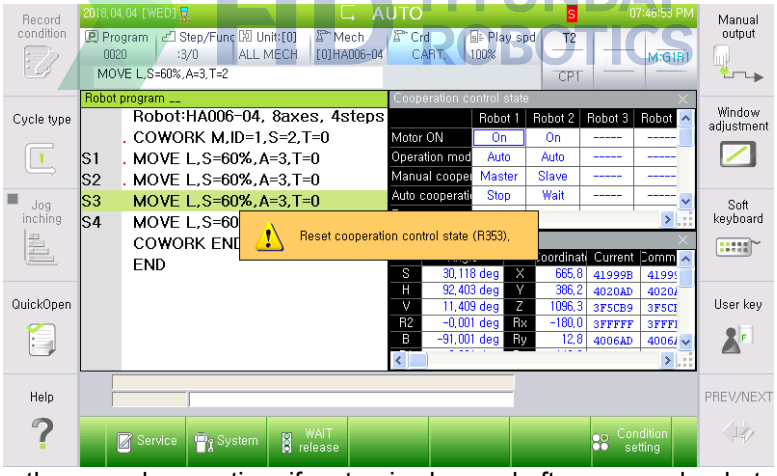
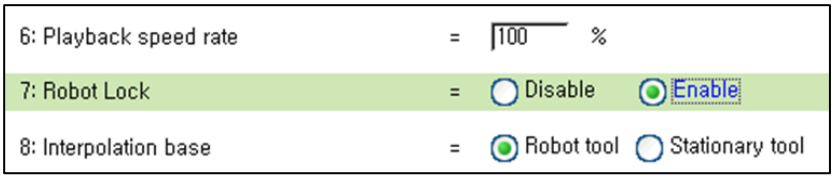


Figure 5.7 During the cowork operation, if a step is changed after a cowork robot stops, a warning message will be issued.

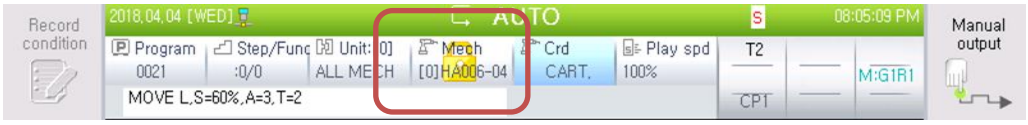
When you enter the reset command (R353) for cooperation control condition, the operation resumes with the cooperation condition canceled. To operate with the cooperation condition maintained, designate the stop step number and execute the operation.

5.5. Robot Lock Function(Robot Lock Playback)

Set the 『[F7]: Condition setting』 → 『5: Robot Lock』 to <Enable>.



When the Robot Lock option is selected, the Mechanism window on the top of the screen will show a lock icon.



If you set the robot lock playback to <Enable> for the master robot and execute playback, the slave will execute cooperation operation and the master robot will not operate. The axis data monitoring changes.

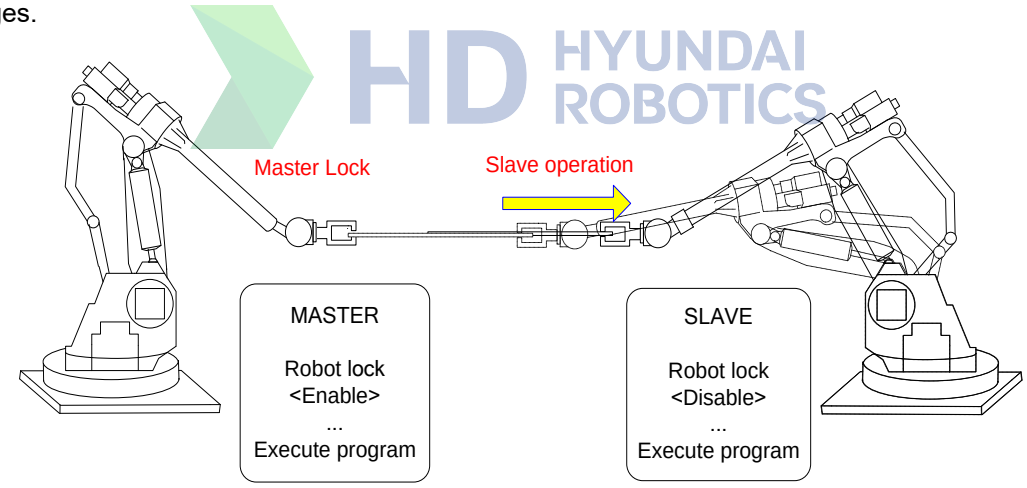


Figure 5.8 Robot lock function (Master Lock)

If you set the robot lock playback to <Enable> for the slave robot and <Disable> for the master robot, the master robot will operate normally and the slave robot will stay stopped with only monitoring data moving.

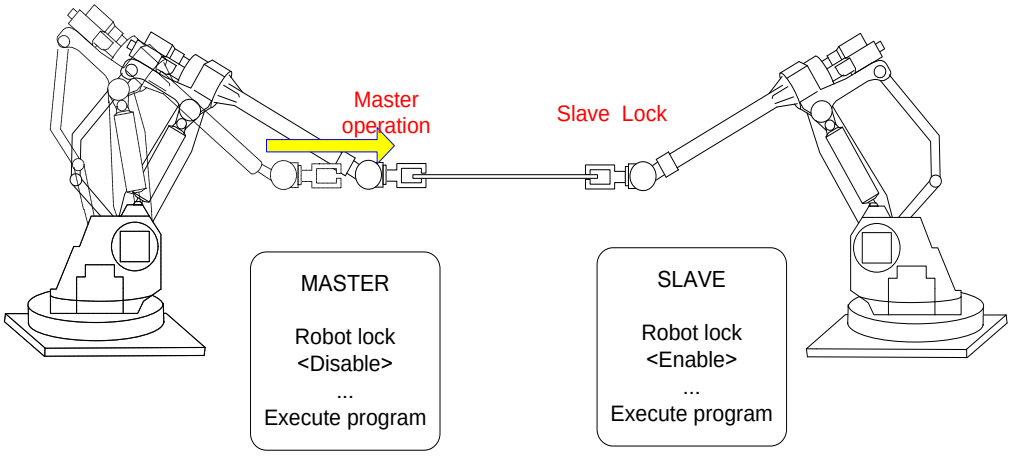


Figure 5.9 Robot lock function (Slave Lock)

If you set the robot lock playback to <Enable> for both master and slave, both will execute the program while stopped.

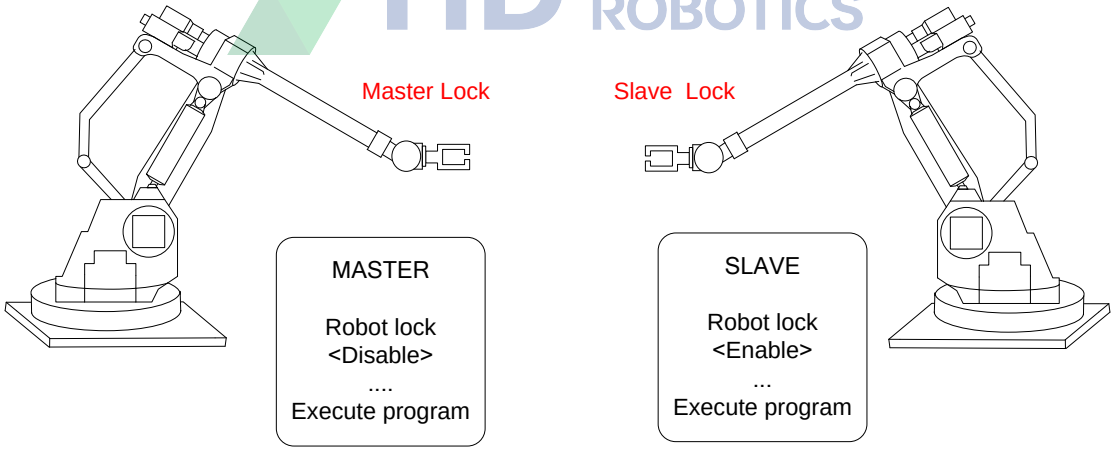


Figure 5.10 Robot lock function (Master, Slave Lock)

Caution

- Set a proper cowork standby time.
- Because the robot that has been set to <Enable> with robot lock playback function does not move, move the robot to a position where it will not interfere with other robot and then execute the program.
- If you change the robot lock playback back to <Disable>, the position of the robot and the position of the step will not correspond. Therefore you must execute the program from the start.

6

HiNet I/O Function

6.1. Overview of the HiNet I/O

The HiNet I/O enables I/O sharing by using a network dedicated to the cowork control. Each controller monitors the signal between cooperation robots and allocates the shared signals to I/O so that they can be freely flow. The output size that can be used by each controller is 4 bytes, and each controller can receive 124 bytes in addition to the output size. Unlike the cowork control, the HiNet I/O enables the transmission and reception of signals for a maximum of 12 robots belonging to different groups that are connected to the HiNet network.

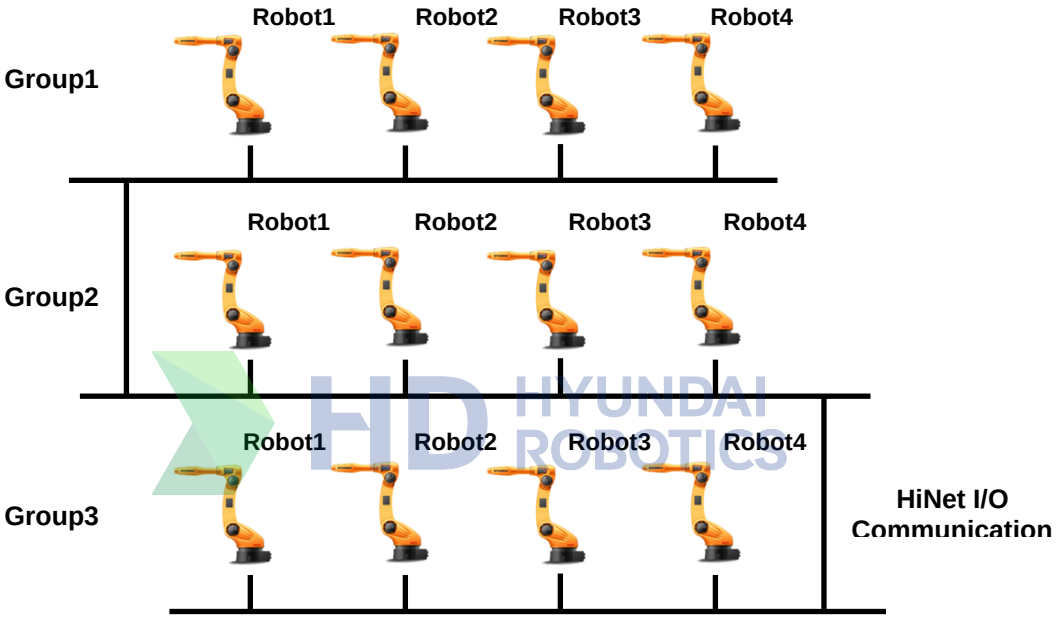


Figure 6.1 Structure of HiNet groups

Because this function can not only be used to detect the I/O signal by using the robot language (HR-BASIC) but also be used as a parameter, there are various applied methods to meet the various needs of the user.

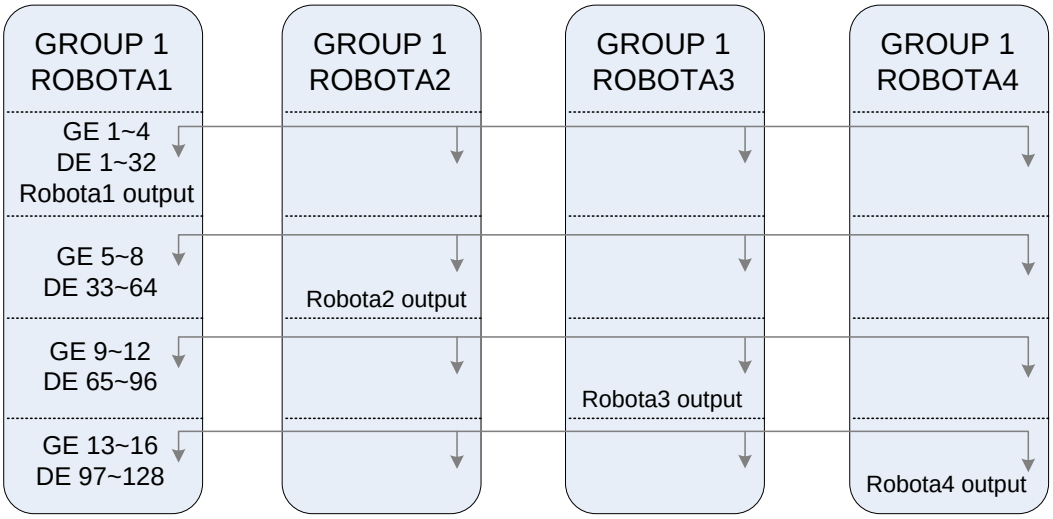


Figure 6.2 Example of the use of the HiNet I/O (Group 1 – Four robots)

The DE is a signal in the bit unit. The GE is a bundle of eight DE signals in the byte unit. Therefore, signals can be inputted/outputted in the 0–255 range.

The range of the GE signal output of the individual robot controllers belonging to a cowork control group number is as follows:

- Min. GE = { (G#-1)X4 + (R#-1) }X4 + 1
- Max. GE = { (G#-1)X4 + (R#-1) }X4 + 4

Table 6-1 I/O Zone by robot number

GE [byte]	G1 R1	G1 R2	G1 R3	G1 R4	G2 R1	G2 R2	G2 R3	G2 R4	...
1~4	Out	In	In	In	In	In	In	In	…
5~8	In	Out	In	In	In	In	In	In	…
9~12	In	In	Out	In	In	In	In	In	…
13~16	In	In	In	Out	In	In	In	In	…
17~20	In	In	In	In	Out	In	In	In	…
21~24	In	In	In	In	In	Out	In	In	…
25~28	In	In	In	In	In	In	Out	In	…
29~32	In	In	In	In	In	In	In	Out	…
…	…	…	…	…	...	…	…	…	…

6.2. HiNet I/O Command

6.2.1. DE command

DE command inputs and outputs the self area in 1 bit unit to the HiNet I/O function.

DE[{Script}]={parameter}	
Script	■ I/O output signal designation (1~1024) ■ 1~1024: Select applicable I/O bit
parameter	■ On/Off setting ■ 1 : On ■ 0 : Off

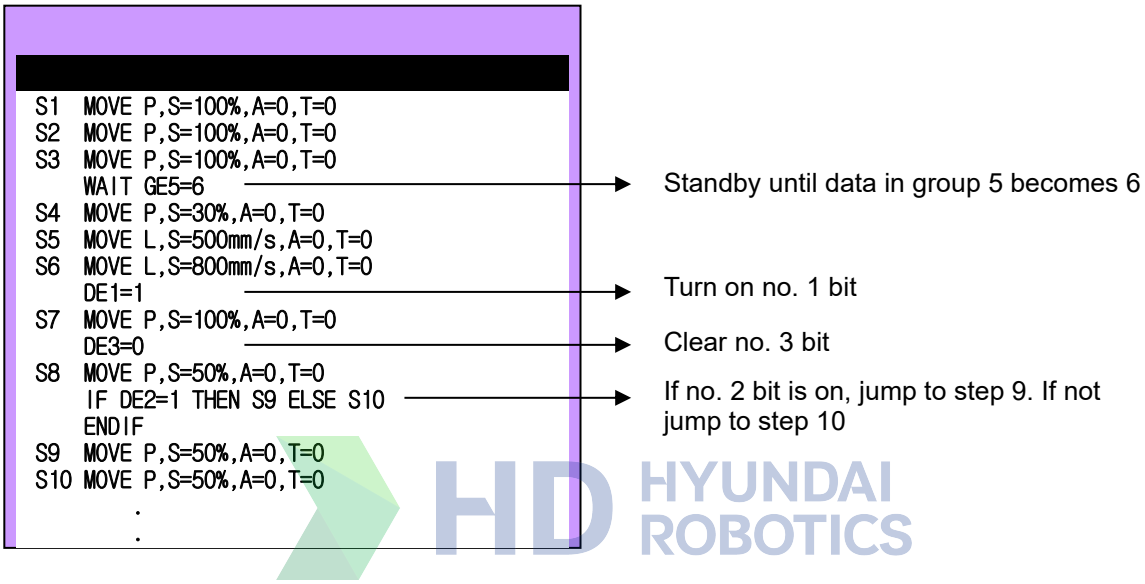
6.2.2. GE command

GE command inputs and outputs the self area in 1 byte unit to the HiNet I/O function. 128 bit is allocated for HiNet shared I/O area and it is possible to output self area in 32 bit units.

GE[{Script}]={parameter}	
Script	■ I/O signal group designation (1~128) ■ 1~128: Select applicable I/O group
parameter	■ It designates 1byte of I/O signal (0~255)

6.3. Application example

The following is a simple applied example to help you better understand the application of robot language. Because DE and GE can also be used as a parameter, it has an advantage in terms of flexibility of application.



7

Cowork-controlled arc welding

7.1. Description of arc sensing information data

7.1.1. Drawing arc sensing wave form

The conditions of arc welding may be set by clicking the “[QuickOpen]” key under the ARCON command. In the case of a system for which cowork control is set, the “cowork control condition” setting items will be displayed in the welding condition dialog box as shown in the figure.

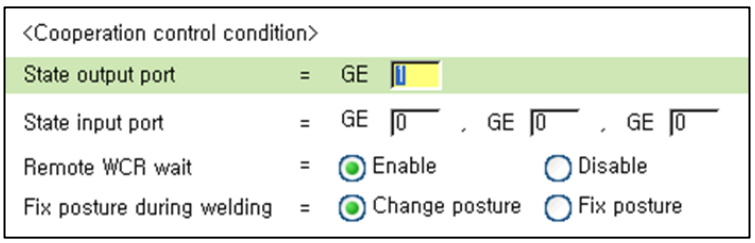


Figure 7.1 Cowork control condition items in the welding condition dialog box

- State output port: Set the GE port from which arc welding signals will be outputted for a cowork-controlled arc welding.
- State input port: Set the GE port to which arc welding signals will be inputted for a cowork-controlled arc welding. The arc welding signals can be inputted from a maximum of three cowork robots.
- Remote WCR: Set whether to check the welding current relay (WCR) of the cowork robots while checking the WCR signal input for the arc welding process.
- If 0 is set for a port, the input and output ports set for 0 will not be used.
- Details of the GE signal by bit

  Bit 0(ArcOn): To be set as ‘1’ when the torch is on as the ARCON command is executed.
  Bit 2(WCR): To be set as ‘1’ when there is an input of WCR of the robot as set.
  Bit 3(Retry): To be set as ‘1’ until retry ends while the retry function is being performed.
  Bit 4(Overlap): To be set as ‘1’ until overlapping ends while the restart function is being carried out.
  Bit 5(Dry Run): In the dry run in which the robot moves without making an actual welding, the bit will be set at 1.
  Bit 6(ArcSt): To be set as ‘1’ until the main moving operation is handled after the arc is turned on. The retry state is included.

- Position fixation during welding: This function prevents rapid changes in the position of the slave robots during cowork-controlled welding. When this function is enabled, the position of the torch will be fixed, and only the TCP position will change.

Caution

- Cowork robots of different robot numbers will have different port numbers that can be set as I/O ports. Refer to Table 7-1, “I/O Area by Robot Number.”
- Cowork control cannot be made in the welding section of a dry run (welding simulation) because remote WCR signals will not be transmitted. Therefore, disable this setting for a dry run.
- Welding with a disabled remote WCR signal may lead to a wrong synchronization in the welding section.

7.2. Operation

As shown below, if two robots are performing welding for one positioner at the same time, the cooperation control arc function will be used. In this situation, if the two robots do not carry out welding simultaneously, defective welding could be caused.

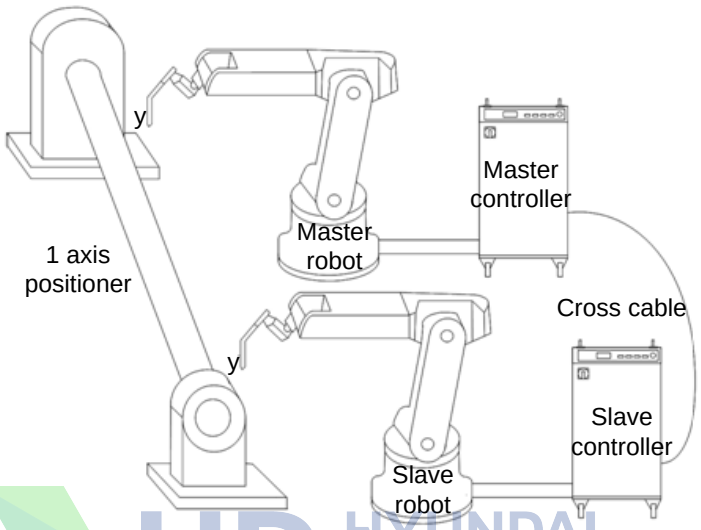


Figure 7.2 Conceptual diagram of cooperative controlled arc welding function

The following is an example of the actual application:

(1) In case the master robot number is 1 and the slave robot number is 2, the master side controller setting can be done as follows.

- State output port: GE4 (Select one among 1~4)
- State input port: GE8 (Match with slave size state output port)

(2) Slave side controller setting can be done as follows.

- State output port: GE8 (Select one among 5~8)
- State input port: GE4 (Match with master side state output port)
- Enable the remote WCR signal.

(3) In the automatic mode, make two robots fulfill the ARCON command simultaneously under the cowork control.

(4) If the two robots succeed in simultaneous arc ignition, the positioners and the robots will carry out welding while moving.

(5) If one robot fails the arc ignition, the other robot will stop arc and both robots will execute the retry function simultaneously. When two robots succeed the arc ignition simultaneously, two robots will move normally.

(6) If one of the two robots stops the arc welding due to stoppage or an error during the welding work, the other robot will also cease the arc welding work. When started again after the cause of the error is removed, the two robots will perform the overlap function together before enter the stage of performing the main welding work again.

(7) When only arc welding work on one side is finished normally during welding work by ARCOF, arc welding work on the other side will not be influenced by this.

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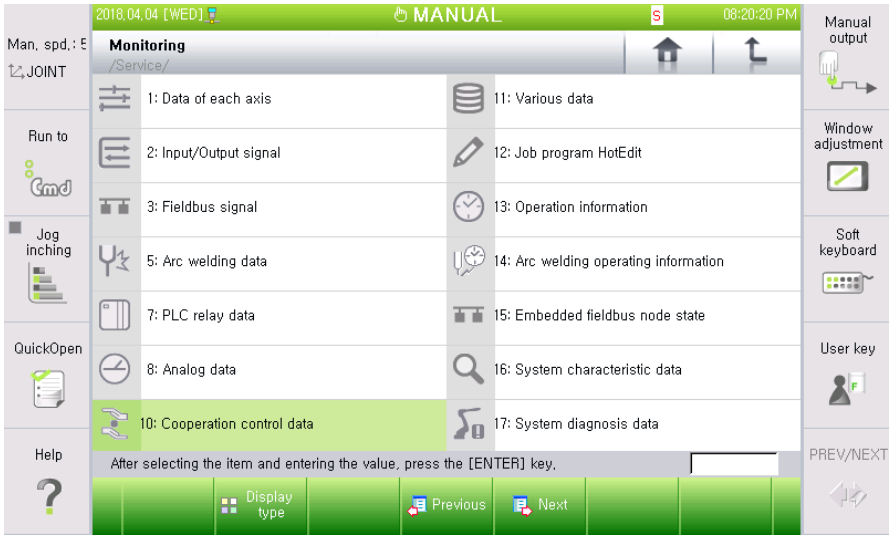
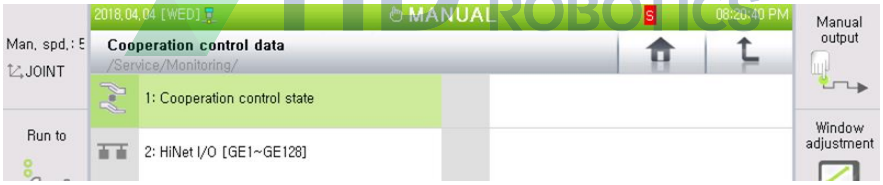
8 Service Function

8.1. Cooperation control condition monitor

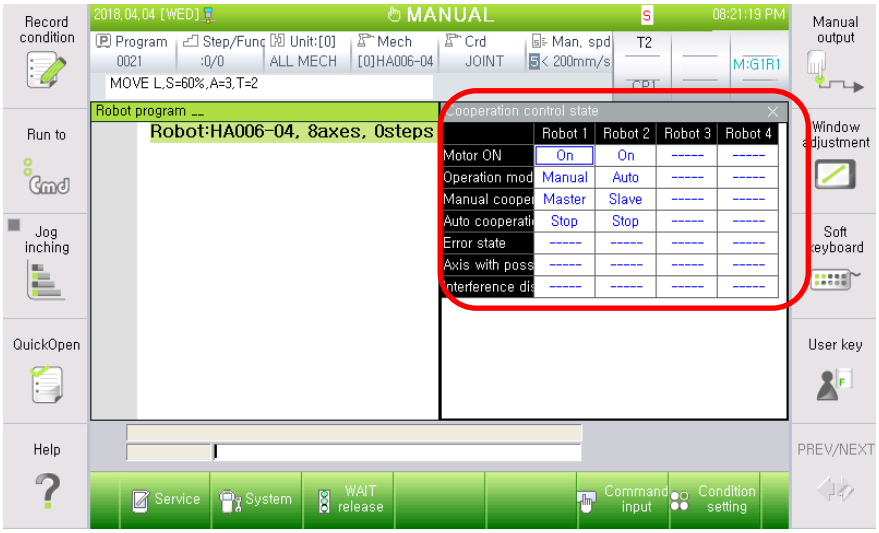
(1) Select 『[F1]: Service』 → 『1: Monitoring』 → 『10: Cooperation control data 』



(2) Select 『1: Cooperation control status』.



(3) Cooperation control condition will be displayed as follows.



(4) Each condition of monitoring function has different meanings as follows.

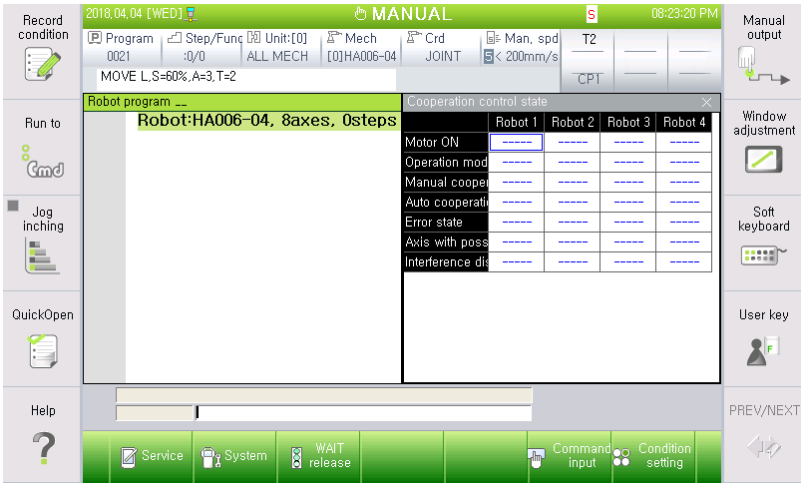
- Motor ON: This shows whether each robot is ready for operation. (ON/OFF)
- Operation mode: This shows whether each robot is set to manual or auto mode. (Manual/Auto)
- Manual cooperation: This shows the cooperation condition of each robot in manual mode.
  Individual: Individual jog condition
  Master: Cooperation jog condition, designated as master
  Slave: Cooperation jog condition, designated as slave

- Auto cooperation: This shows the cooperation condition during robot playback.
  Stop : Robot is not in operation
  Indiv. : Individual robot playback
  Wait : Standby for collaborating robots to be in position for COWORK command
  Cowork : Playback during cooperation

- Error: This shows the recent error condition of each robot and it is cleared when operation starts.
- Axis subject to interference: This means the axis of a robot that is closest to another cowork robot.
- Interference distance (mm): Distance between axes subject to interference

Caution

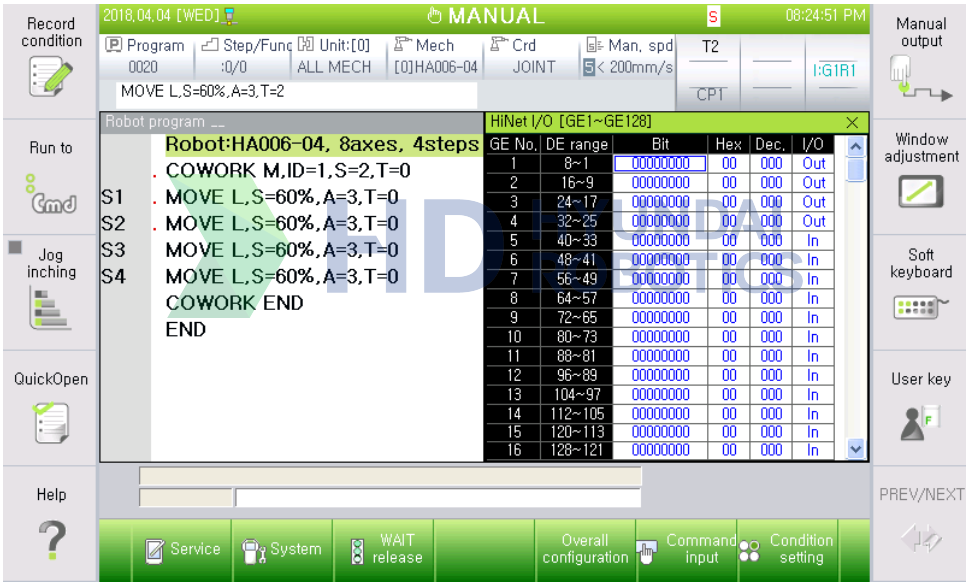
- If the cooperation control is set to <Disable> in cooperation control, the monitoring information will not be displayed.



8.2. HiNet I/O monitor

(1) Select 『[F1]: Service』 → 『1: Monitoring』 → 『10: Cooperation control data』

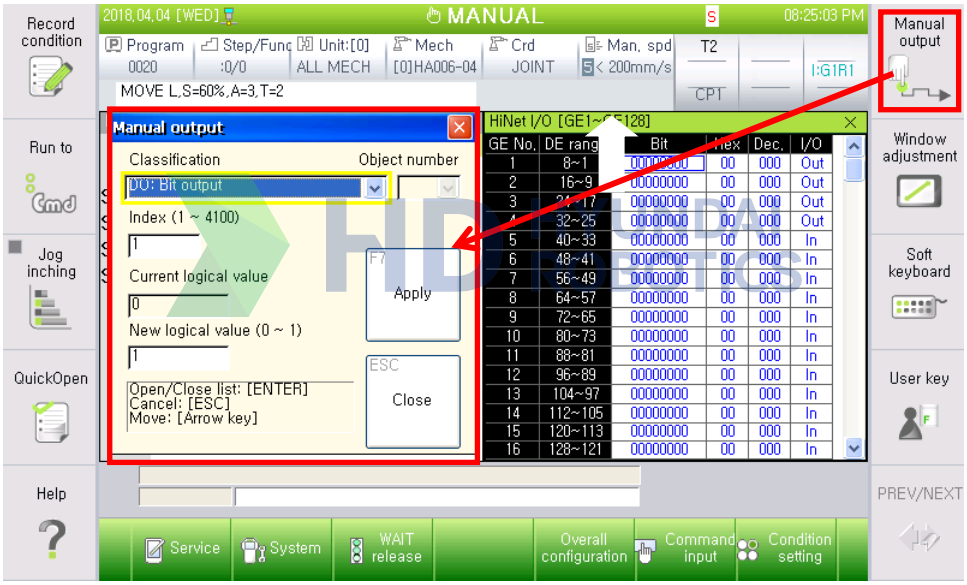
(2) This displays the overall range of the HiNet I/O on the screen. The Input/Output information is displayed on the most right column. When each signal is on, it is displayed in binary, hexadecimal and decimal numbers.



8.3. Manual output function

You can manually send out the HiNet I/O signal for cooperation control.

- In the manual mode, clicking the “[Manual Output]” button on the upper right part of the TP window will show the “Manual Output” dialog box.
- Among the category items, select a DE/GE HiNet I/O item to be used for the output.
- Under the robot number, input the DE/GE number for the output in the index item.
- In the case of DE, select either 0 or 1 to be outputted, and click the “Apply” button.
- In the case of GE, select from 0 to 255 bytes to be outputted, and click the “Apply” button.
- Check that the current value item has been changed to match the new value item.



8.4. R code

This is the R code used in cooperation control.

Table 8-1 R code used in cooperation control

Operation	#1	#2	Content
R351,#1	Robot role		Robot role 0 = Indiv
			1 = Master
			2 = Slave
			3= CMOV record mode
R353			Cooperation playback condition clear

9 Error Code

9.1. Warning

■ Code	W0016 Improper use of GE or DE signal No
■ Cause	The specified values for GE or DE variable are incorrect. The values are out of range.
■ Action	It is different from coworking robot number. - GE: Min.=(robot#-1)*4+1, Max.=(robot#-1)*4+4 - DE: Min.=(robot#-1)*32+1, Max.=(robot#-1)*32+32

■ Code	W0123 Stop input from partner robot
■ Cause	During the cowork control, a stop command has been inputted from a cowork robot. In this case, the above message is output, and the robot stops.
■ Action	Start running a master to resume a program after starting the robot on the part of slave.

■ Code	W0124 Slave is Impossible to jog
■ Cause	It is set as salve in the condition of manual cowork control. The robot set as slave is impossible to operate separately.
■ Action	To operate each robot manually, change the manual cowork mode to “individual.” The manual cowork mode can be changed by a user-defined hot key or the R351 code.

■ Code	W0131 Jog Prohibited - Master overlapped
■ Cause	Among robots connected to HiNet are more than two robots set as Master in their manual cowork.
■ Action	Only one Master for manual cowork is possible to set. Change the setting.

■ Code W0132 Jog Prohibited - No slave selected

■ Cause Jog operation is attempted for Master robot without setting the Slave robot to be available to cowork.

■ Action Check if Slave robot is selected, and get it ready to be available to cowork before operating(Jog Off/Enabling Switch On).

■ Code W0133 Slave jog status are changed-Stop

■ Cause A robot changed its manual cowork is detected among the coworking Slave robots Master during cowork jog operation with robot.

■ Action Double check the cowork condition of Slave before operating.

■ Code W0134 Master Tool Coord. isn't selected

■ Cause It occurs when attempting to operate jog for Slave robot in a CMOV recording mode(R351,3). Master robot is not specified.
Or it may occur when using forwarding function of CMOV step. The currently set number of Master is different from the recorded Master number in CMOV.

■ Action Set a correct master robot for manual cowork Master.

9.2. System Error

■ Code	E00200 (axis 0) Speed over while cooperating
■ Cause	An instruction in excesses of robot maximum speed is input during cowork operation.
■ Action	Change the robot posture, cowork record position, or lower the record speed in a standard position of Slave which has the cowork operation.

■ Code	E00201 Start time mismatch
■ Cause	There is an error in receiving/sending signals between cowork robots. Playback modes do not match each other.
■ Action	Check the communication condition. Match the playback modes of the cowork robots, and resume the cowork.

■ Code	E00203 Partner robot is Emergency
■ Cause	Partner robot motor is OFF during cowork operation. It turns motor OFF to stop.
■ Action	Take necessary actions to the cause of partner robot. Turn motor ON and re-start it.

■ Code	E00204 Error in robot cowork control communications
■ Cause	During the playback of the cowork jog, an error occurred in the communications with a cowork robot.
■ Action	Check on the connection of the cowork control communications cables and connectors.

■ Code	E00205 HiNet is not working
■ Cause	Hinet communication for cowork is not working.
■ Action	Check on the connection of the cowork control communications cables and connectors.

■ Code	E00227 Seq. error of Cooperative control
■ Cause	There is a difference in instruction sequence between master robot and slave robot during cowork control.
■ Action	Check on the connection of the cowork control communications cables and connectors.

9.3. Operation Error

■ Code	E01340 Disable condition for co-work run (WD, common coordinate)
■ Cause	Controller is inadequately set to execute COWORK instruction.
■ Action	Check if communication is normal, if partner's common coordinate system is set, and if the manual coworking is identical with COWORK robot's role.

■ Code	E01341 Cooperation wait time is over
■ Cause	The standby time set in the COWORK command during which the cowork robots wait to fulfill the command has elapsed.
■ Action	Set the standby time taking the reaching time for all coworking robot to the position into account. Setting the standby time at "0" will make all the robots wait until they are ready for the cowork.

■ Code	E01342 Invalided COWORK or common coordi.
■ Cause	COWORK instructions cannot be executed because robot coworking is disable or common coordinate system is not set.
■ Action	In the "System\Control\Parameter\Network\Service\Cowork Control" dialog box, enable the cowork control function and set a common coordinate system.

■ Code	E01343 COWORK execution mismatch
■ Cause	COWORK instructions are executed repeatedly, or program END is executed without COWORK END
■ Action	Program to make COWORK instruction and COWORK END instruction in pairs. To give the COWORK command again after changing the step, reset the cowork control modes.

■ Code	E01344 COWORK Para.(M/S,robot No.) error
■ Cause	Partner robot's number is incorrectly set, indicating my robot's number in COWORK instruction.
■ Action	Change the robot number of the COWORK command to the robot number of the cowork robot.

■ Code E01345 The slave already executed COWORK.

■ Cause Slave robot's cowork is already working in the position of COWORK END, or stopping

■ Action For normal coworking of Master & Slave, do not change step artificially.

■ Code E01355 Partner robot is error stopped

■ Cause A cowork robot has been stopped and cannot make cowork. The system will be stopped because cowork cannot be made.

■ Action Check if the operation mode is identical between robots. Restart Slave first before restarting Master if restarting after stop during cowork.

■ Code E01356 Duplicated robot number is set

■ Cause Overlapping robot number makes it impossible to control COWORK.

■ Action Check the robot number connected to Hinet to change the overlapping robot number, and apply power again.

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