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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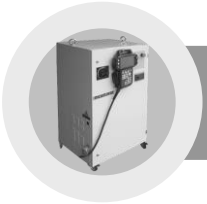

Hi5 Controller Function Manual

Cooperation Control

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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.

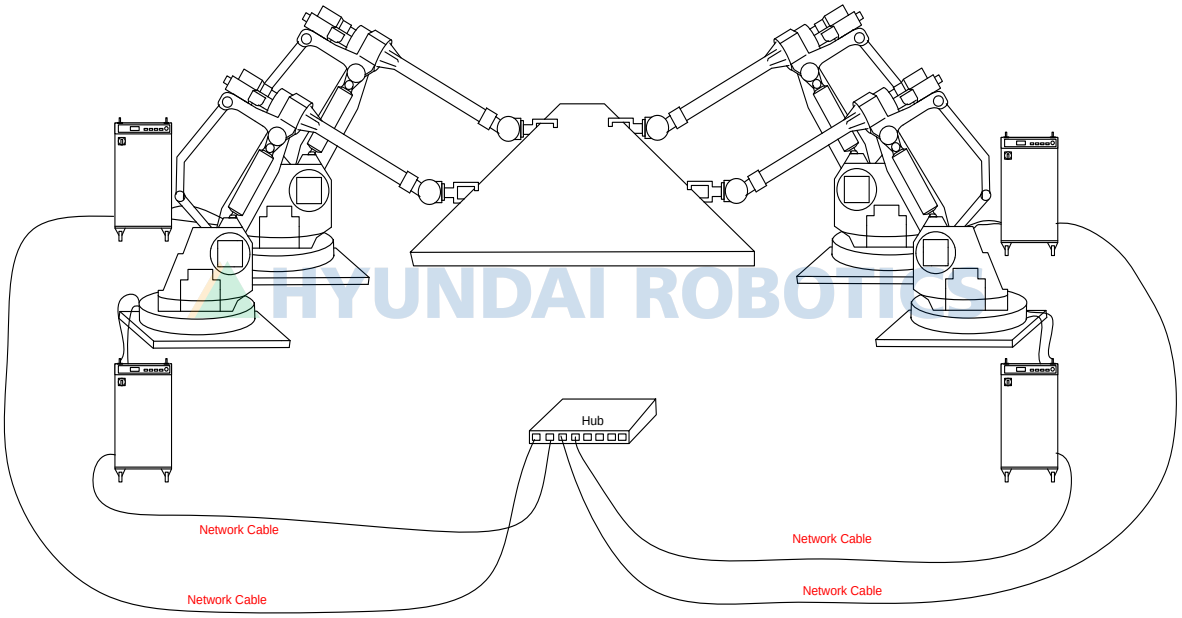

Figure 1.1 Robot cooperation function

1.2. Major function

1.2.1. Major function specification

Table 1-1 Major function specification

Major function specification	Remarks
Number of cooperation robots	Maximum of 4
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

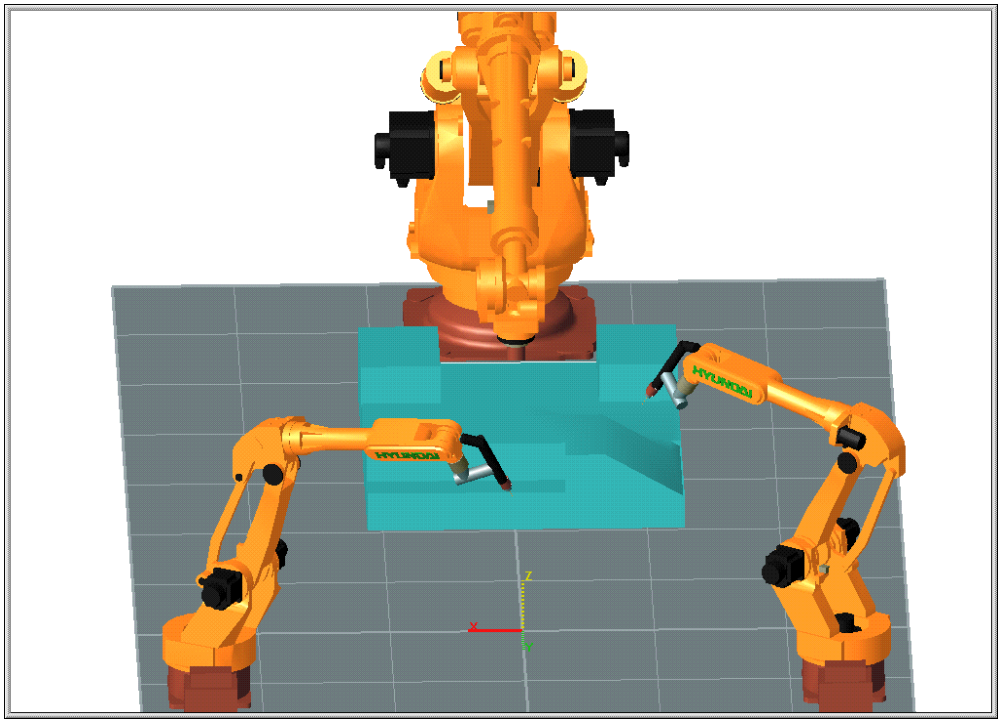

Figure 1.2 Jigless cooperation

1.2.2. Functional characteristics

- Communications
  The cooperation control function can control up to 4 robots in an interlocked manner through HiNet (Exclusive Ethernet).

- Easy setting of the common coordinate between 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
Set the axis and tool constants correctly for collaborative control.
- Refer to automatic constants setting function.

Hardware installation
Connect the hardware necessary for controller communications.
- Connect the network card and the communications cable.

Cooperation control parameter setting
Set the whether to apply cooperation control and set each robot number for the robots connected to the network

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.

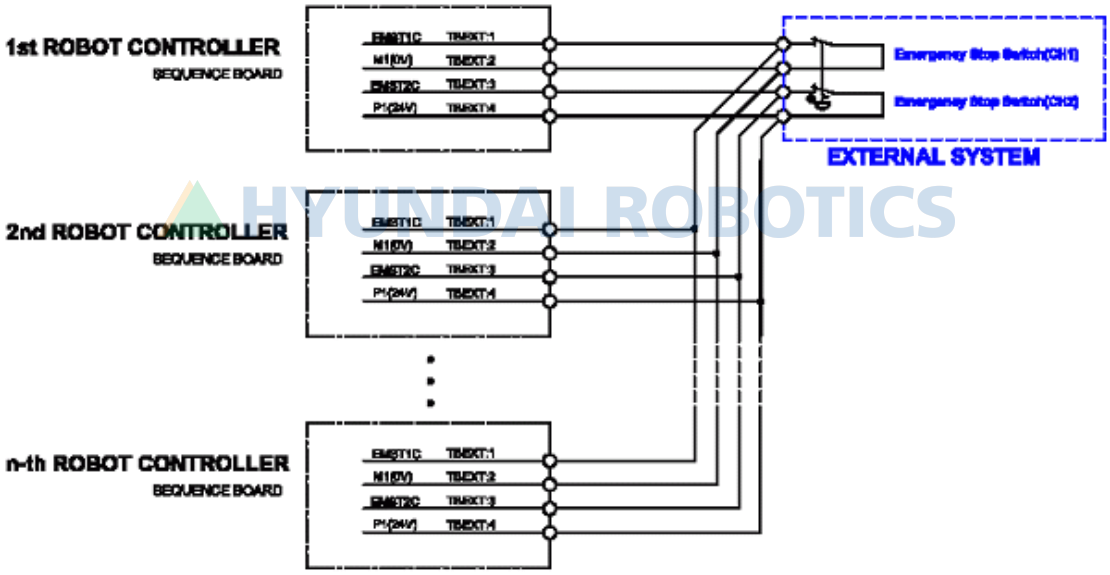


Figure 2.1 Emergency stop connection for cooperation robot

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.

2.1.2. Network composition

(1) Requirements

Components	Specification
BD510	Main CPU board
UTP cable	-
Network Hub	Specification provided by Hyundai Robotics (Switching hub)

(2) Connecting method

- The one end of the network UTP cable (Direct) needs to be connected to a socket located at the top among the BD510 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 BD510.

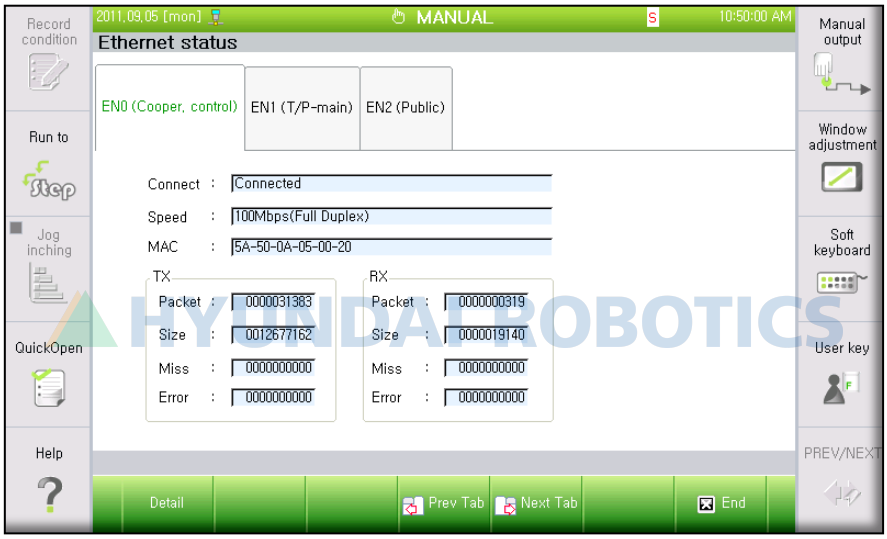
2.1.3. Network connection check

(1) Check for network error in the following cases.

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

(2) Check points

- Check the mode of the network cable connection. A green light should be turned on at the BD510 socket.
- Check the cable.
- Can use『[F2]: System』 → 『2: Control Parameter』 → 『9: Network』 → 『2: Ethernet status』 to check the mode of the network.



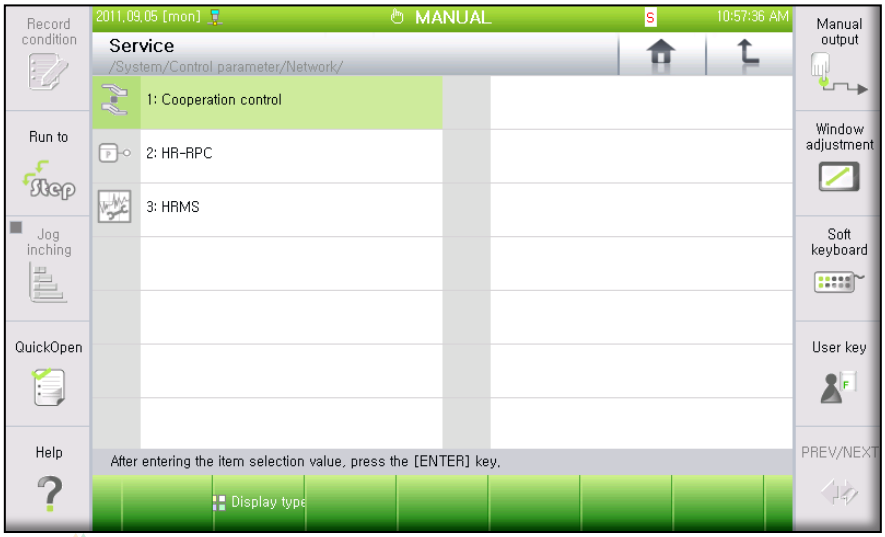
Caution

- 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.

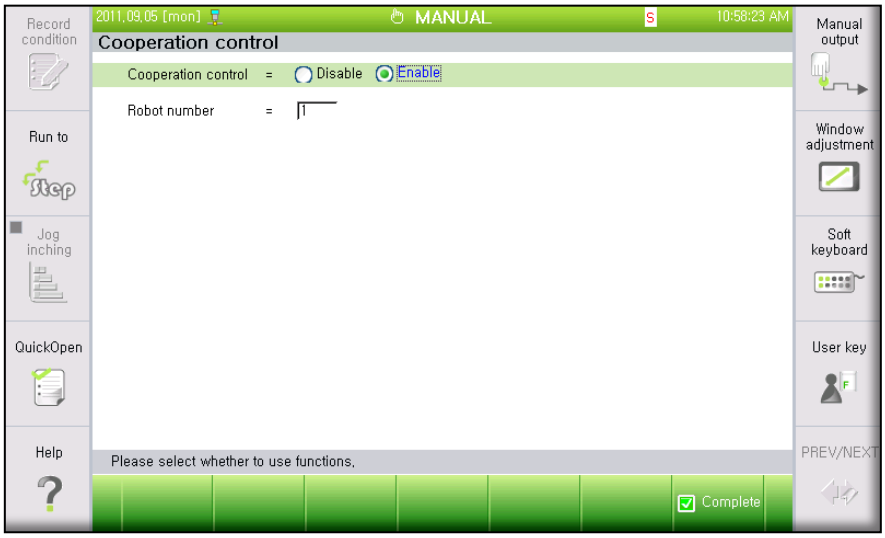
2.2. Controller setting

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』 in the manual mode.



(2) Select 『1: Cooperation Control』.



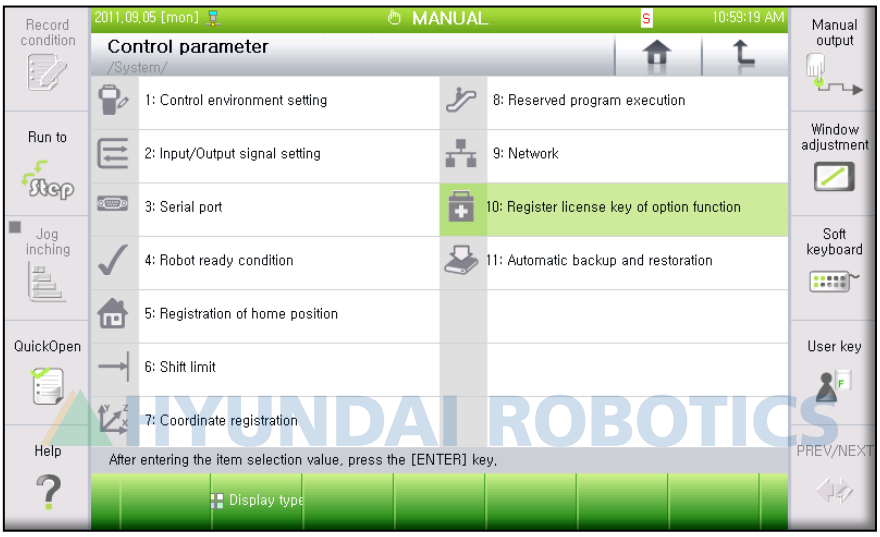
(3) The above parameter is to be used for the following purpose.

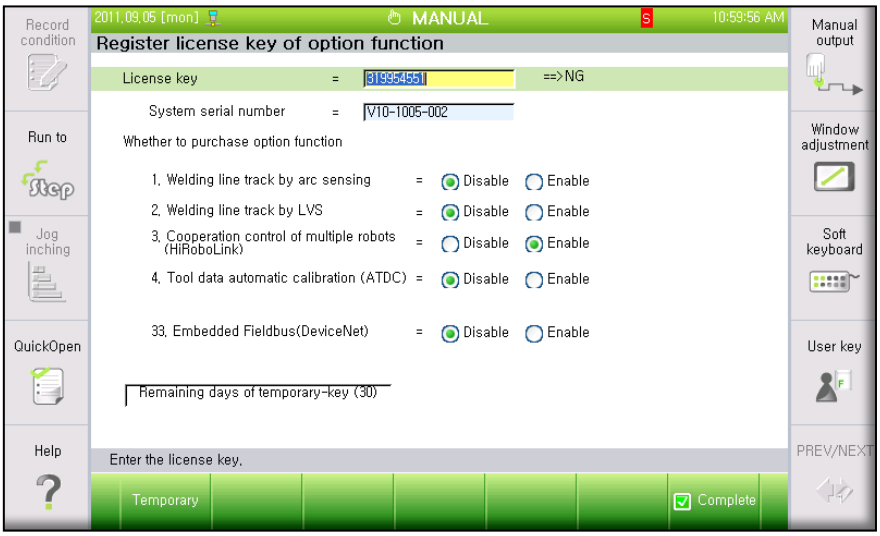
- Cooperation control function <Disable. Enable>: Select whether to use the cooperation control function.
- Robot number: Set the robot number. <1~4>
  The robot number is a number for recognizing its controller on the network connected through the cooperation control. In case of the Hi5 controller, 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

- When it comes to the cooperation control functional, 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. (『[F2]: System』 → 『2: Control Parameter』 → 『10: Register license key of option function』)





2.3. Common coordinate setting among cooperation robots

2.3.1. Introduction to common coordinate setting

For cooperation operation, the installed position among robots must be accurately known. 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 2.2) It can be set by teaching 3 same points in the area for each robot.

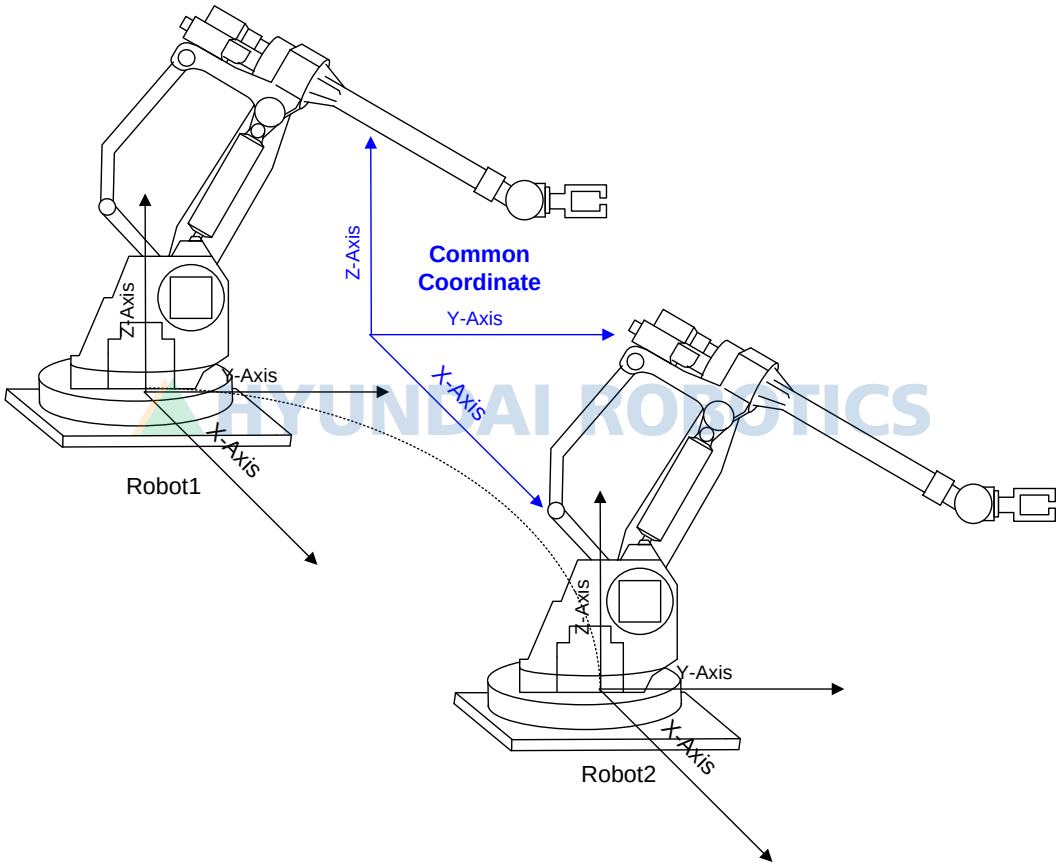


Figure 2.2 Common coordinate setting among cooperation robots

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.

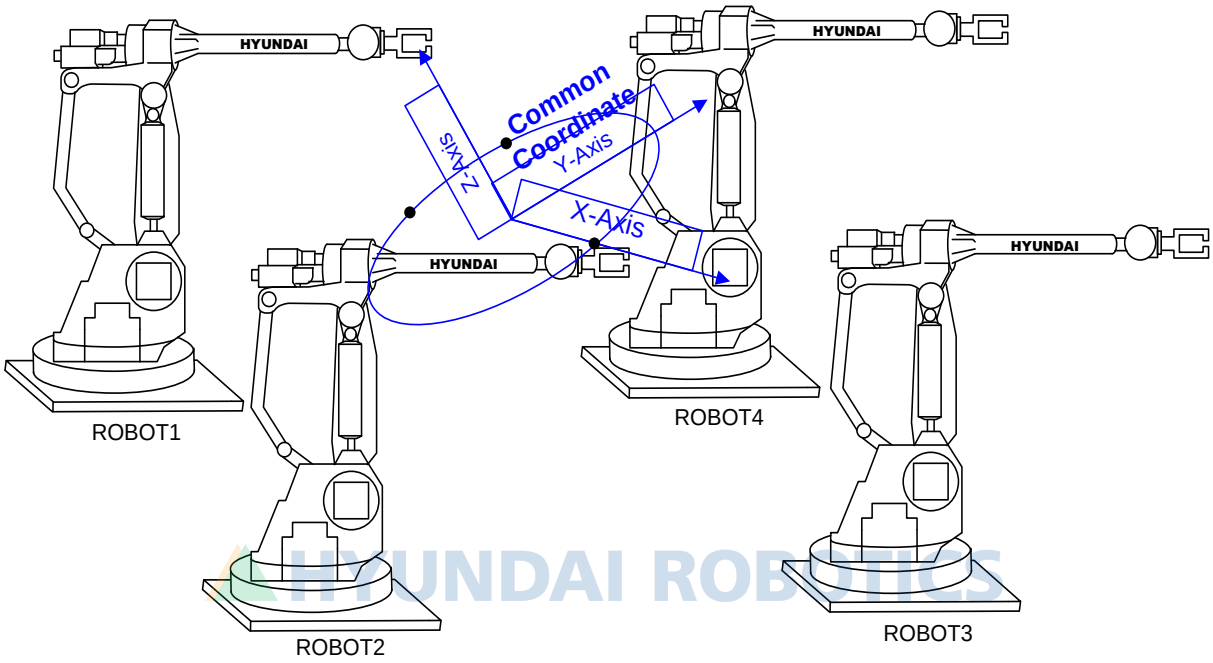


Figure 2.3 Setting common coordinate for 2 or more robots

Caution

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

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.

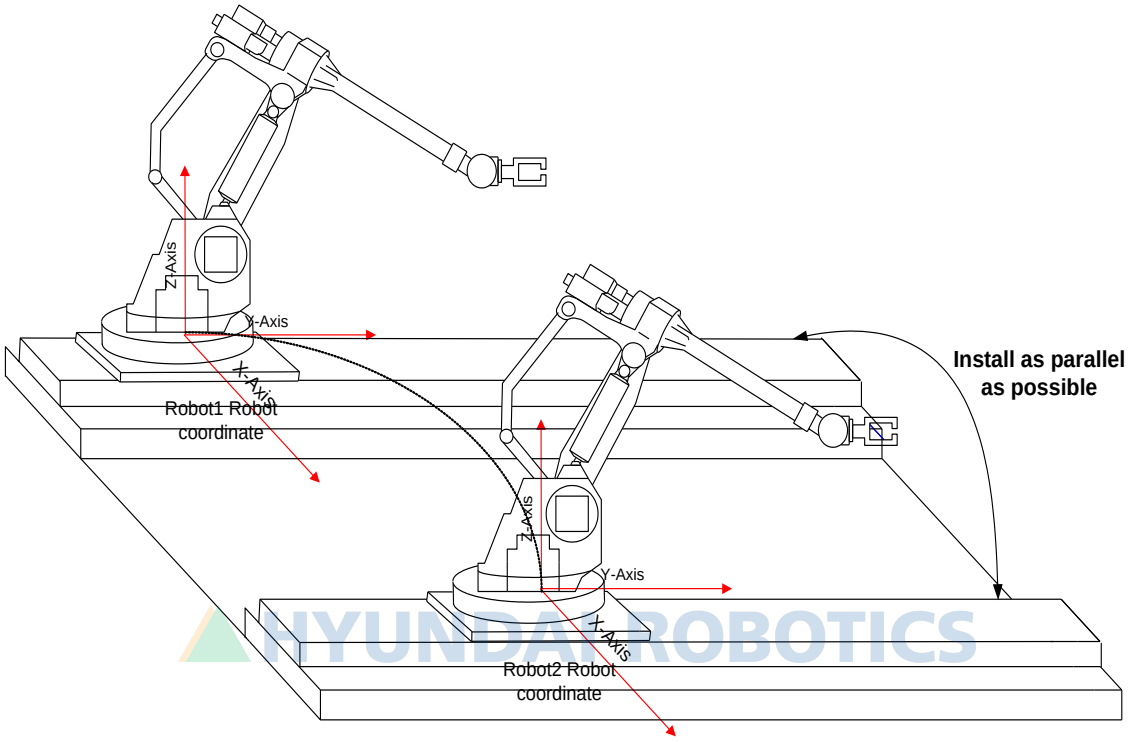


Figure 2.4 Measures to be taken when the external emergency stop for P-Com input is not used

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 『Hi5 Controller operating manual』.
- Traverse axis calibration must be set for both master and slave.

2.3.4. Common coordinate setting

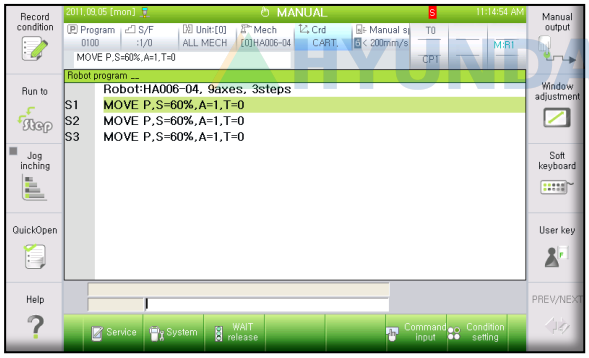
The common coordinate setting is only possible when the accurate position of the cooperation robot tool end is known. At this time, the robot calibration must be done. If there is not a 3-dimensional positioner available, the Hi5 controller provides the auto constant setting function that calibrates the axis constant and the tool length (『[F2]: System』 → 『6: Auto Constant Setting』 → 『1: Optimize Axis Constant And Tool Length』). If a 3-dimensional positioner is available, correct calibration based on kinematics will be possible. Use 『9: Calibrate Robots And Tools.
For more details please refer to the『Hi5 Controller operation manual』. Set the common coordinate after setting the most delicate automatic constant.

The common coordinate setting is explained in an environment involving two robots, Robot 1 and Robot 2.

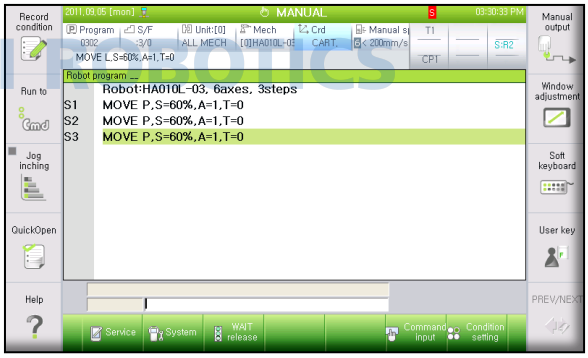
- Teaching method

  ① Select the program to record in the applicable controller for Robot 1 and 2.
  Ex) When registering the cooperation coordinate system programs of both robots 1 and 2 to 100

  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.



Robot1



Robot2

At this time the record position is to be recorded at the same location in the space, and, when it comes to the tool number, the tool that was used when setting the common coordinate needs to be used, independently the interpolation method and the speed.

Caution

- For the tool data for common coordinate setting, enter the accurate tool specification or calculate the tool data through automatic constant setting.
- It is recommended that the robot position of each point is recorded in the same way.
- Records should be kept by carrying out the teaching in a way that the 3 set points create a big triangle as much as possible. If the distance among the points is close, or if the 3 points are forming a straight line, an error will occur.
- If the common coordinate is not set, the manual cooperation jog operation or the cooperation replay will be made impossible.
- It is recommendable to carry out the work in a full scale after checking, through the cooperation jog operation, whether the common coordinate setting among the cooperation robots are carried out correctly.

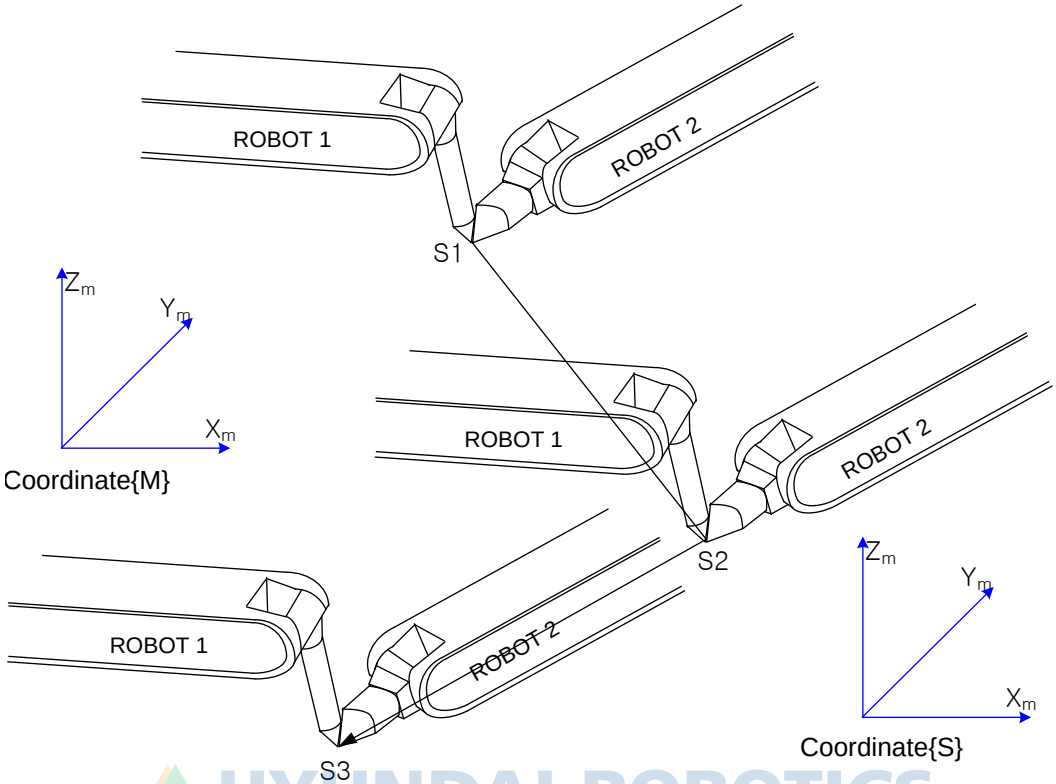
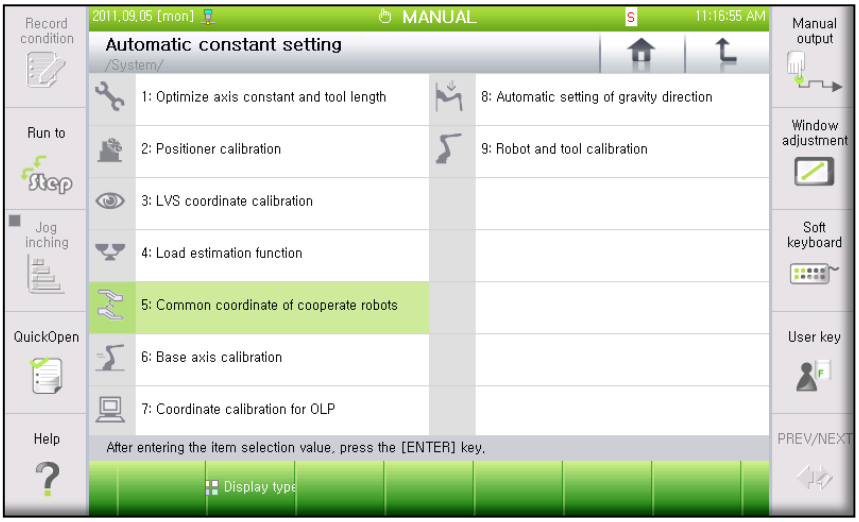


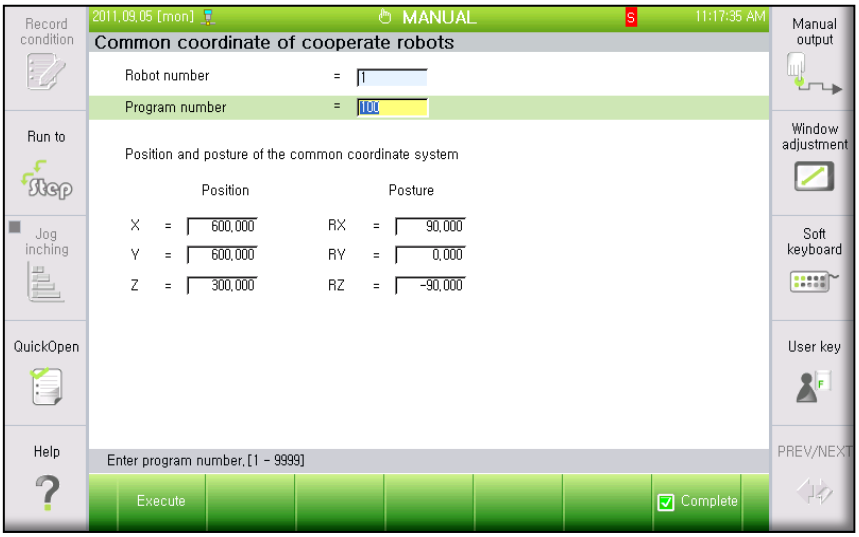
Figure 2.5 Teaching method of common coordinate setting

③ Execute the cooperation coordinate setting for each robot (robot 1 and 2).

④ Select 『[F2]: System』 → 『6: Automatic constant setting』 in manual mode.



⑤ Select 『5: Common coordinate of cooperate robots』.



※ The meaning of the above parameter is as follows.

- Robot number: The robot number set in cooperation control parameter.
- Program number: The program number for cooperation robot coordinate registration

⑥ Press the 『[F1]: Execute』 key. The results will be displayed in the screen through position and position of the common coordinate from robot base. Relative positions are in X, Y, Z and relative positions are in Rx, Ry, Rz.

⑦ Press the 『[F7]: Complete』 key to complete the setting.

2.3.5. Common coordinate check

When the common coordinate of the cooperation robot is set, you can always check the setting from the screen of 『Common coordinate of cooperation robot』.

Caution

- Checking is possible only when the cooperation control is in the <Enable> mode.
- 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.

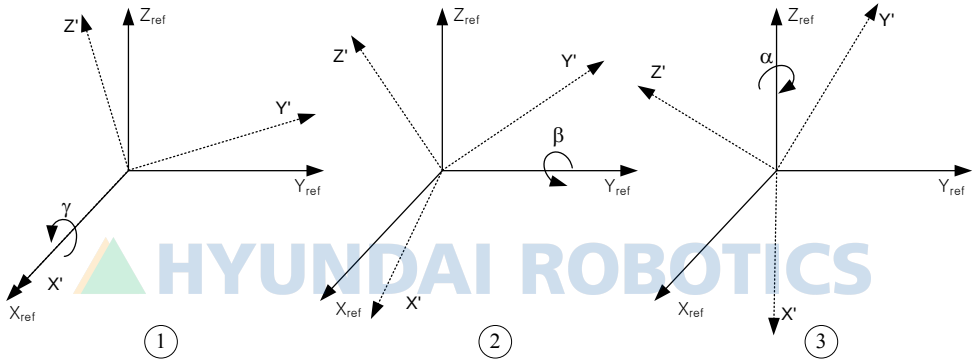


Figure 2.6 Common coordinate position conversion

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.

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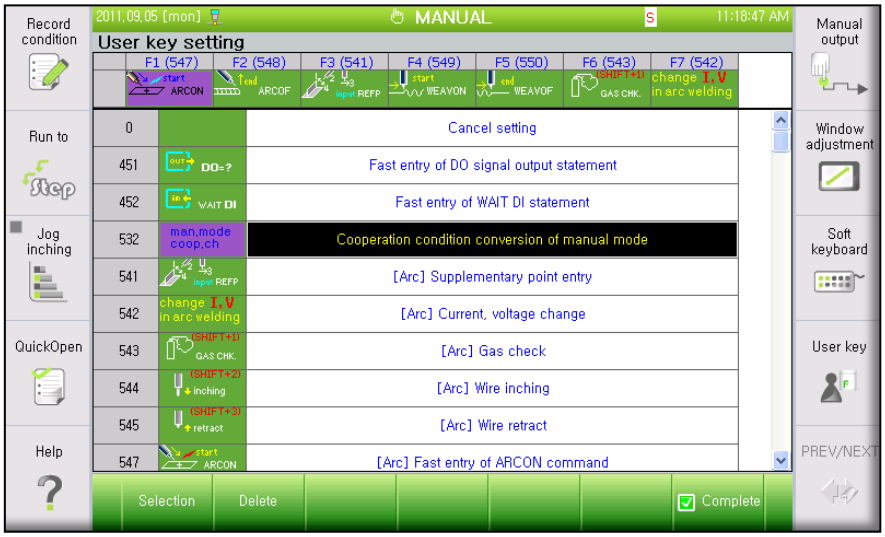
3

Manual Mode Cooperation Operation

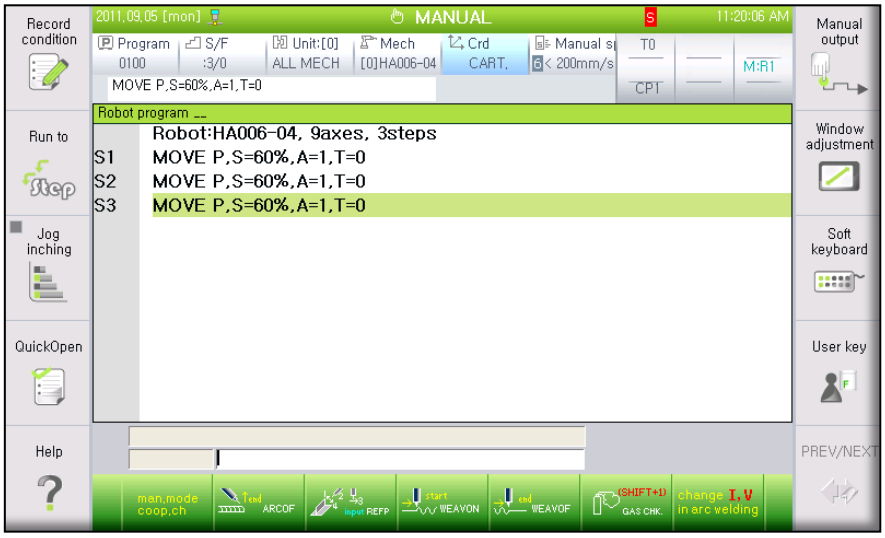
3.1. User key (F-Key) registration

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.



(2) The 『Cooperation condition conversion of manual mode』 item needs to be assigned to one of F1~F7 keys. The F7 key needs to be used to complete the process.



(3) You can switch between manual individual mode and manual cooperation mode by using the allocated F key in manual mode. The manual cooperation mode displayed on the left top changes to the cooperation mode (Master/Slave ↔ Indivisual).

3.2. Individual/Cooperation Switch

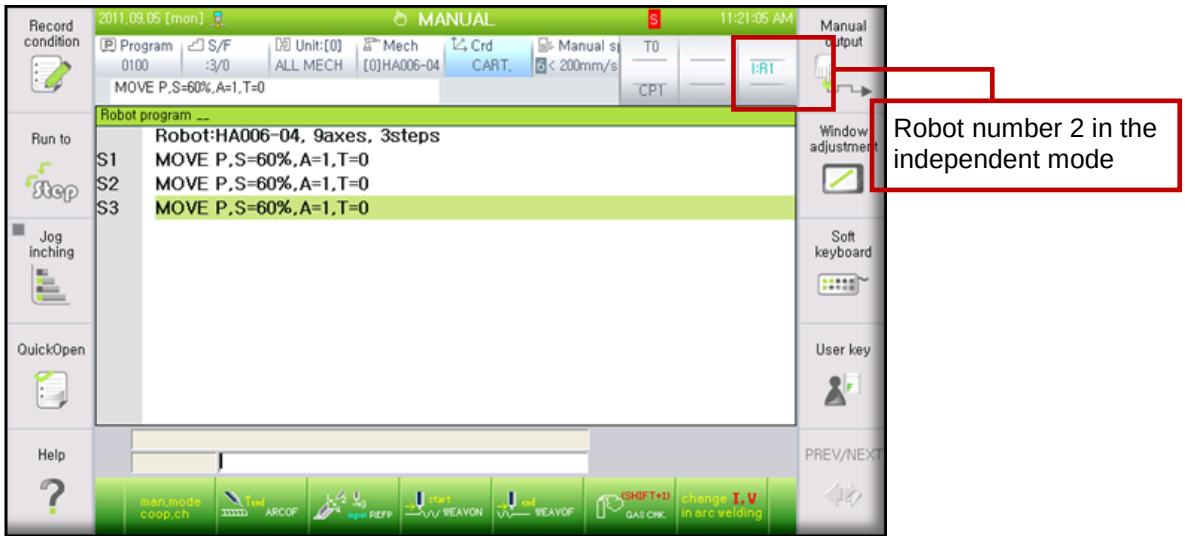
- Function switch by key operation

  There are two ways to switch the cooperation control operation in manual mode; method using the allocated key or method using the R code. Details are shown in the table below.

Table 3-1 Function switch by key operation

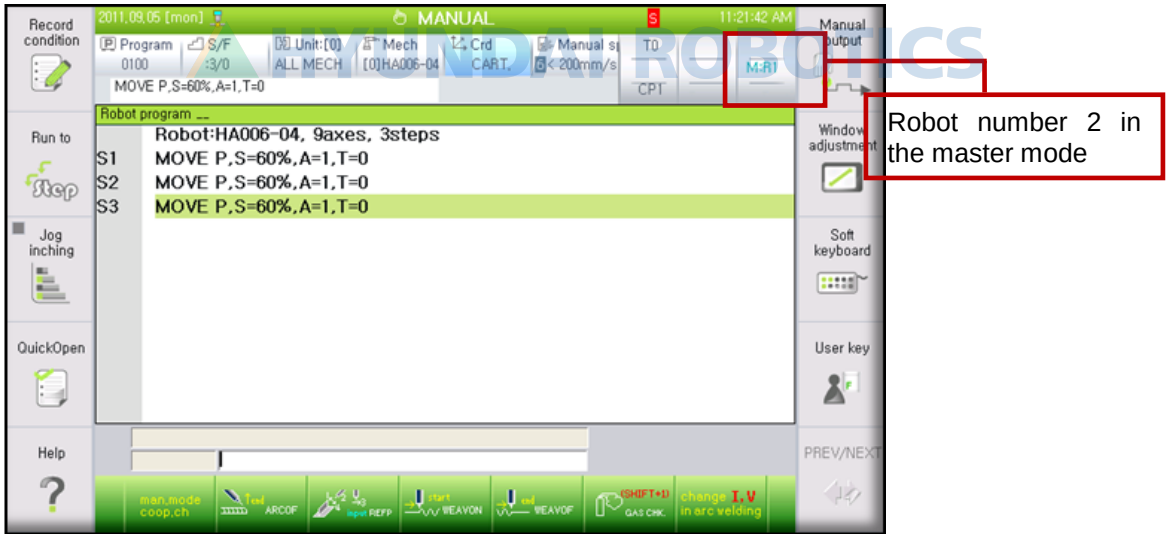
Key operation	Function switch
User key	Manual individual mode (Indi visual) ↔ Manual cooperation mode (MASTER/SLAVE)
SHIFT + User key	Applicable only for SLAVE SLAVE manual cooperation mode ↔ CMOV record mode
R351,0	Manual individual mode
R351,1	Manual cooperation mode, designate master
R351,2	Manual cooperation mode, designate slave
R351,3	CMOV record mode, designate SLAVE jog mode

■ Manual mode individual condition



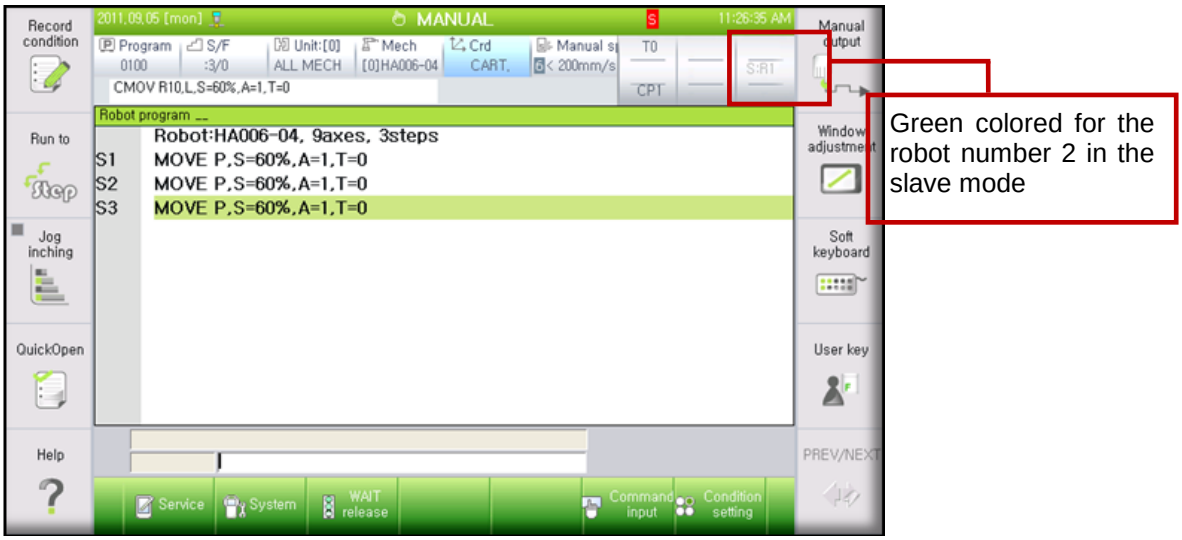
In this condition, each robot can be individually controlled with jog.

■ Manual mode cooperation condition (master designation)



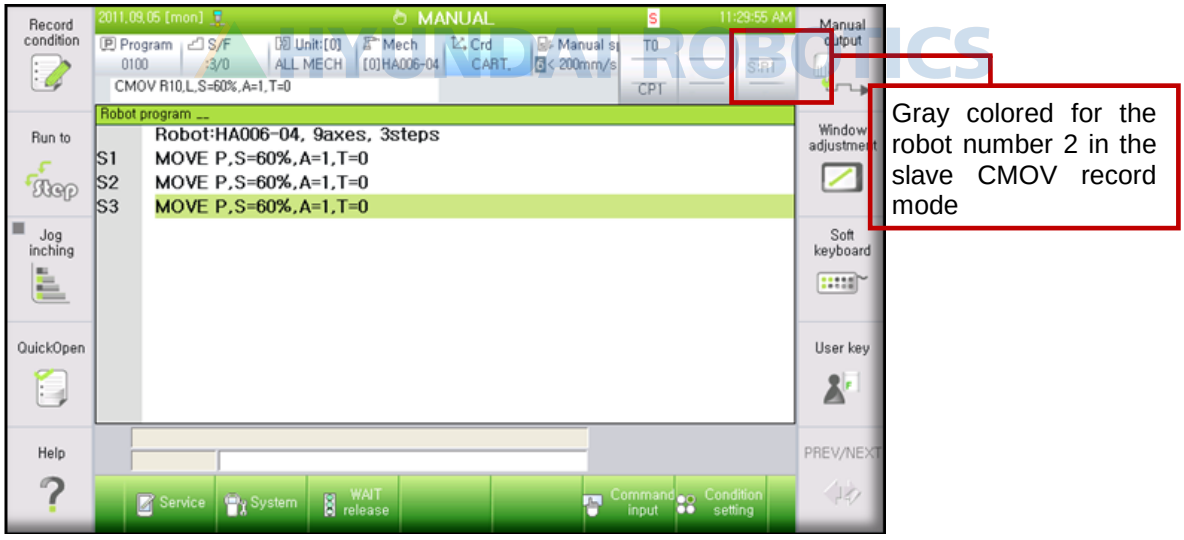
This mode is to operate in a synchronized manner following the movement of the master while in the mode that the slave is set.

- Manual mode cooperation condition (slave designation)



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

- CMOV record mode, SLAVE jog mode condition



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.

Caution

- When the common coordinate is not set, it is impossible to switch the cooperation role between master and slave in the individual condition.
- 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 change the 'CMOV record condition' using the allocated F key, first change the robot role to slave using the F key and then use the SHIFT+F key to change the condition.

3.3. Manual mode cooperation operation

- Setting master and slave robot
  Set the robot roles of master and slave using the set User key (or R351, R352 code). At this time, the role of the robot has nothing to do with the robot number.

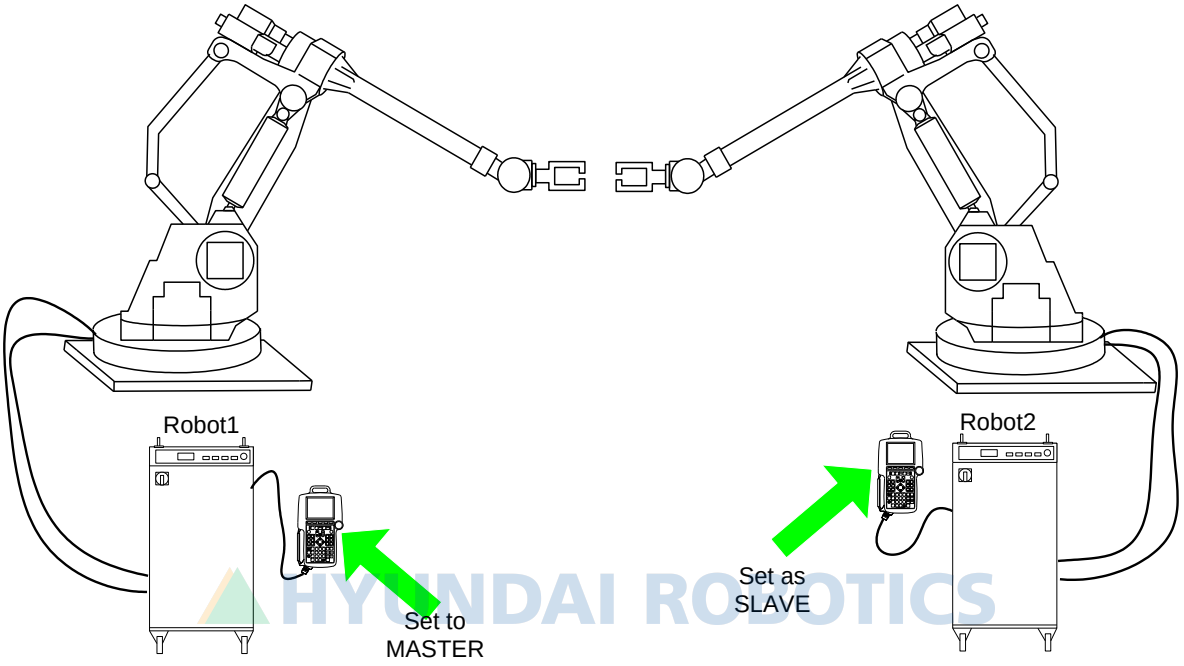


Figure 3.1 Manual mode cooperation operation (Setting master robot and slave robot)

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.

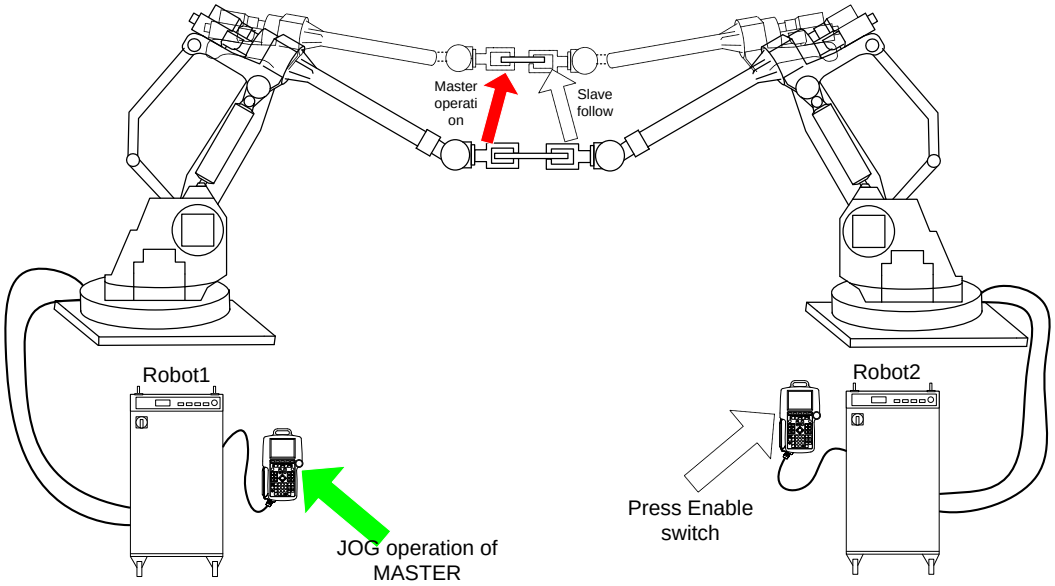


Figure 3.2 Manual mode cooperation operation (Master robot operation / Slave robot follow)

Caution

- Manual collaborative job is not possible in the following cases.
  ① When operating two or more master robots
  ② When operating the slave robot
  ③ When the Enable switch for master or slave robot is not pressed
  ④ When the collaborative coordinate among robots is not set

- Jog operation is not possible for the slave robot during manual mode cooperation function. For jog function of the slave robot, you must change the robot role to individual.

- 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 3.5, the slave robot will adjust and move to the relative position of the traverse axis.

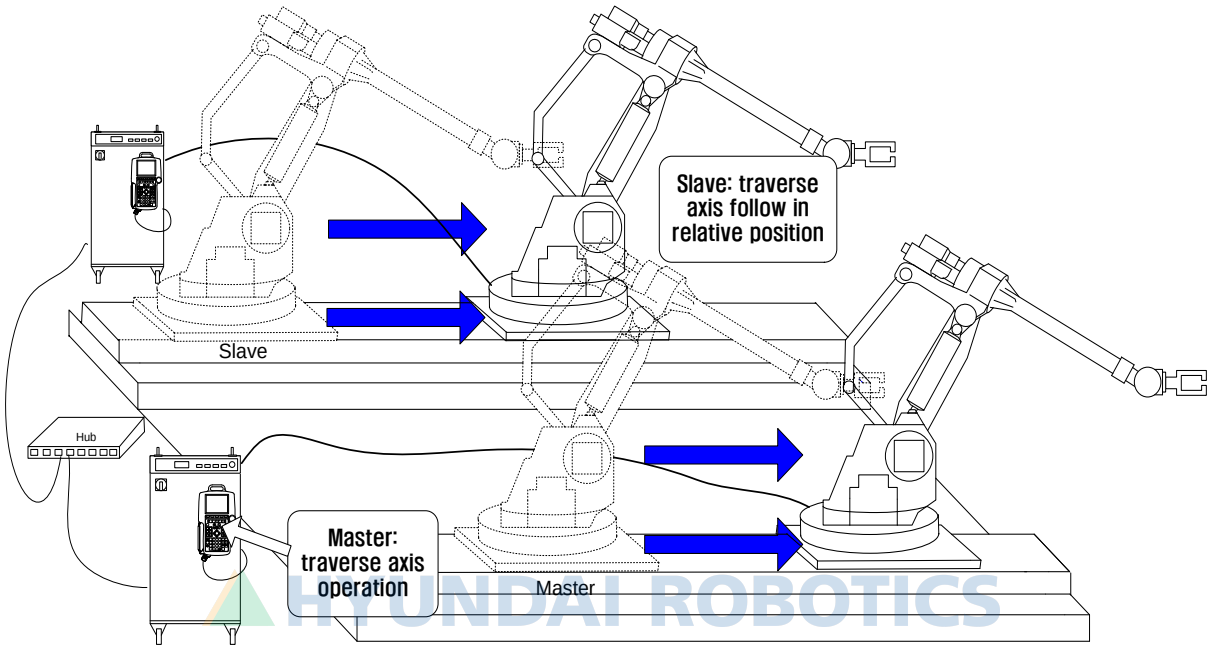


Figure 3.3 Cooperation traverse axis jog

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.
- For cooperation traverse axis function, the main axis calibration function must be used prior to the operation.

3.5. CMOV record mode jog (SLAVE)

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

(2) Select the robot role as Slave to set the CMOV record mode.
(After entering the R 351,2 code, allocate the cooperation condition switch F key and use the SHIFT+F key to change the robot role. S:R2 will be displayed with the robot role and number on the top right side of the screen.)

(3) Set the master robot to manual cooperation condition. (R351,1)

(4) 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.

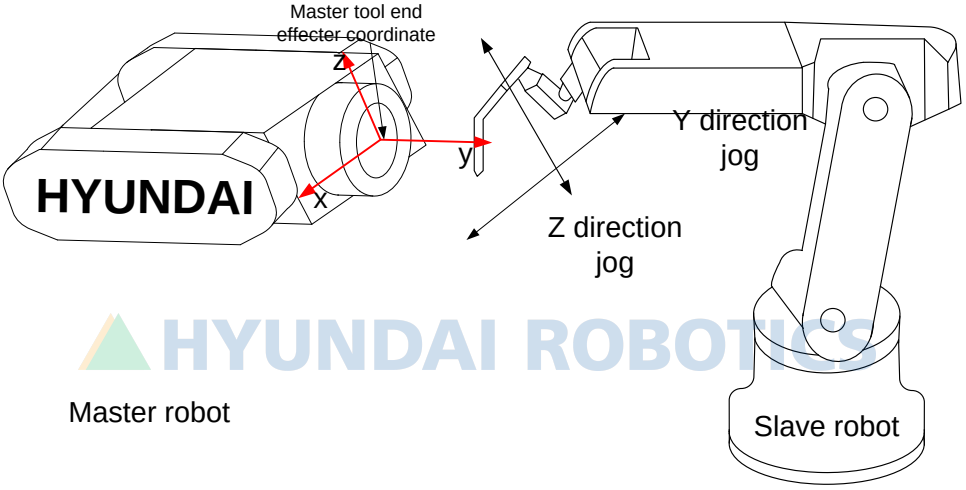


Figure 3.4 CMOV record mode jog

Caution

- When the slave is in CMOV record mode, jog operation for master robot in manual cooperation condition is not possible.

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.

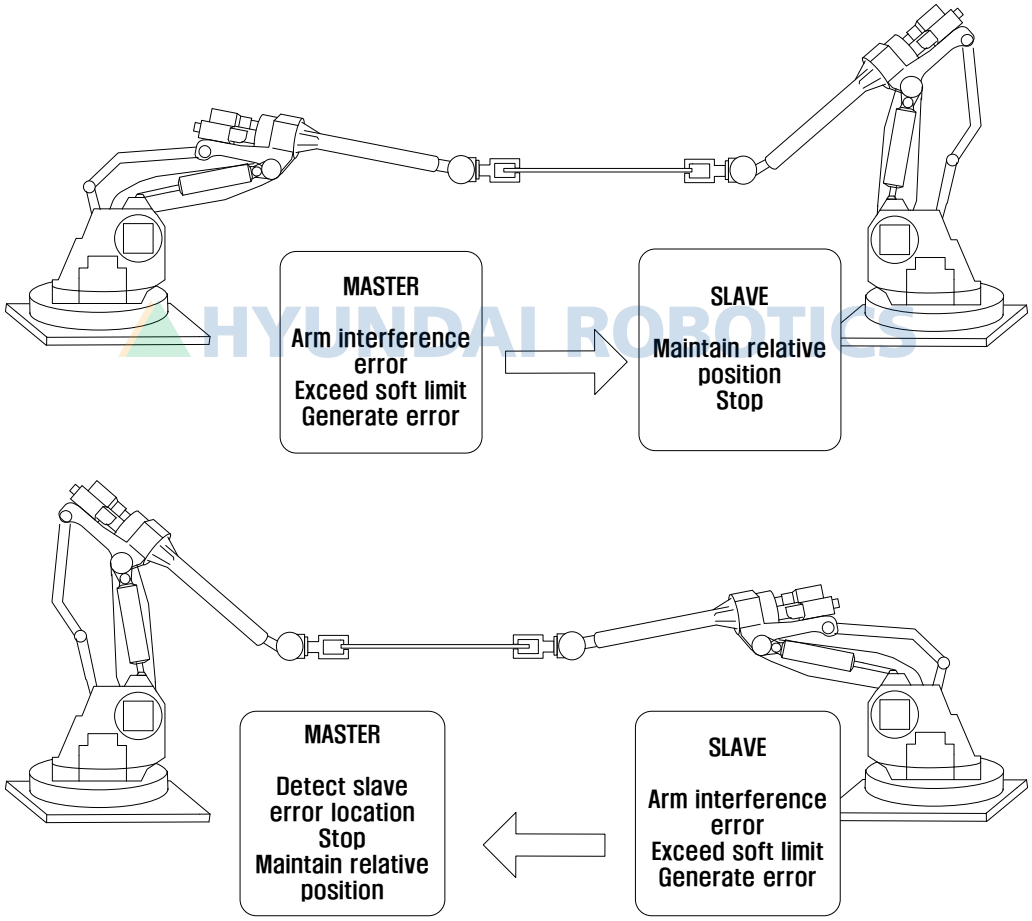


Figure 3.5 Error detection

3.6.2. Error cancel

To cancel the error, you can press the operating key of the master robot to the direction where it does not generate an error. And when you press the operating key to the direction where it does not generate an error one more time, you can proceed the operation.

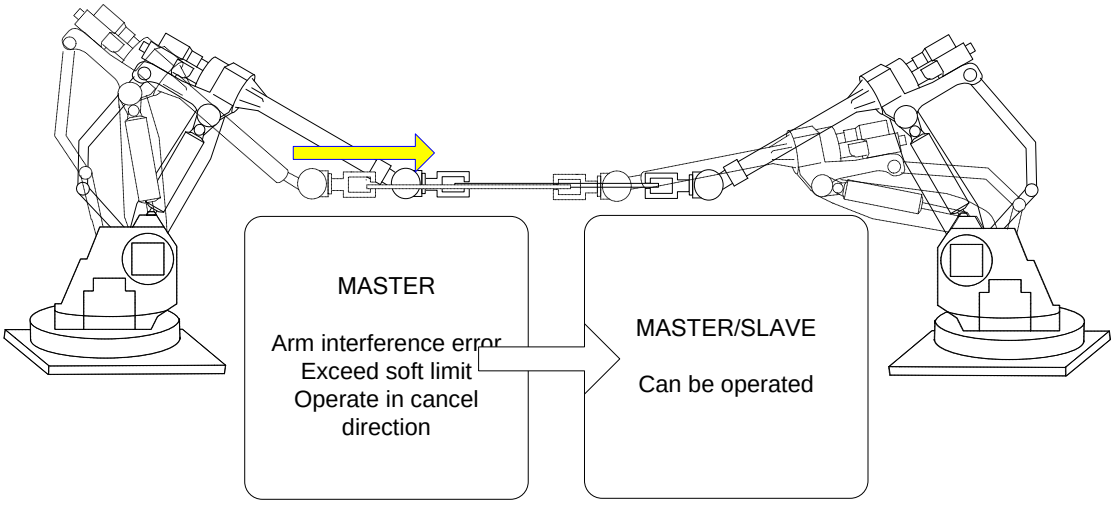


Figure 3.6 Error cancel

HYUNDAI ROBOTICS

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.

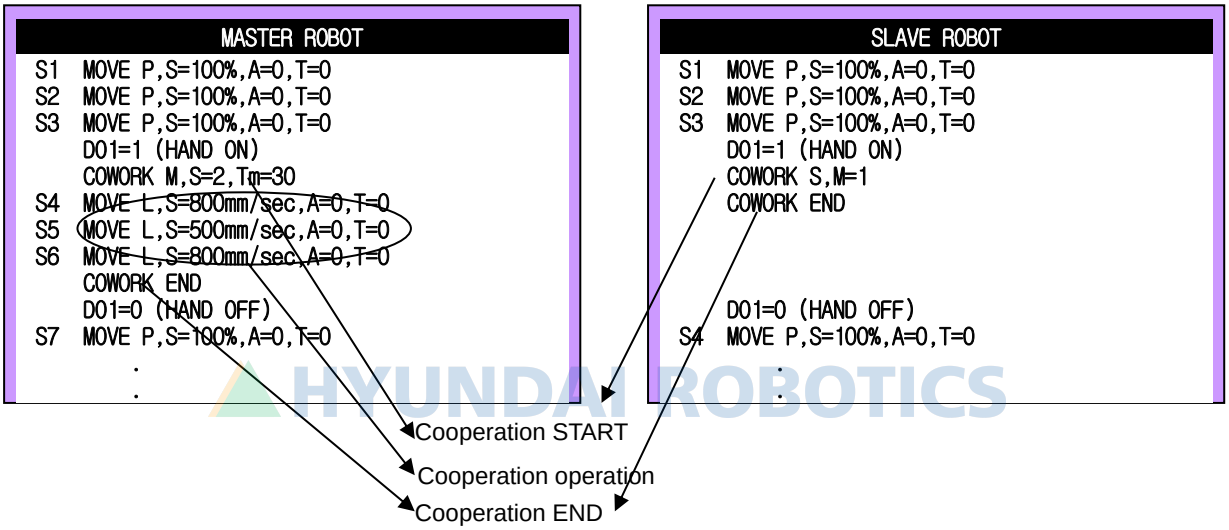
COWORK {parameter1},{parameter2},{parameter3},{parameter4},{parameter5} **…** **(Cooperation program)** **…** **COWORK END**	**Start cooperation** **End cooperation**
parameter1	. Designates own robot role (MASTER/SLAVE) . Designates end of cooperation operation **M**: Designates itself as master **COWORK M,S=…**, **S**: Designates itself as slave **COWORK S,M=…** **END** : End cooperation operation **COWORK END**
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

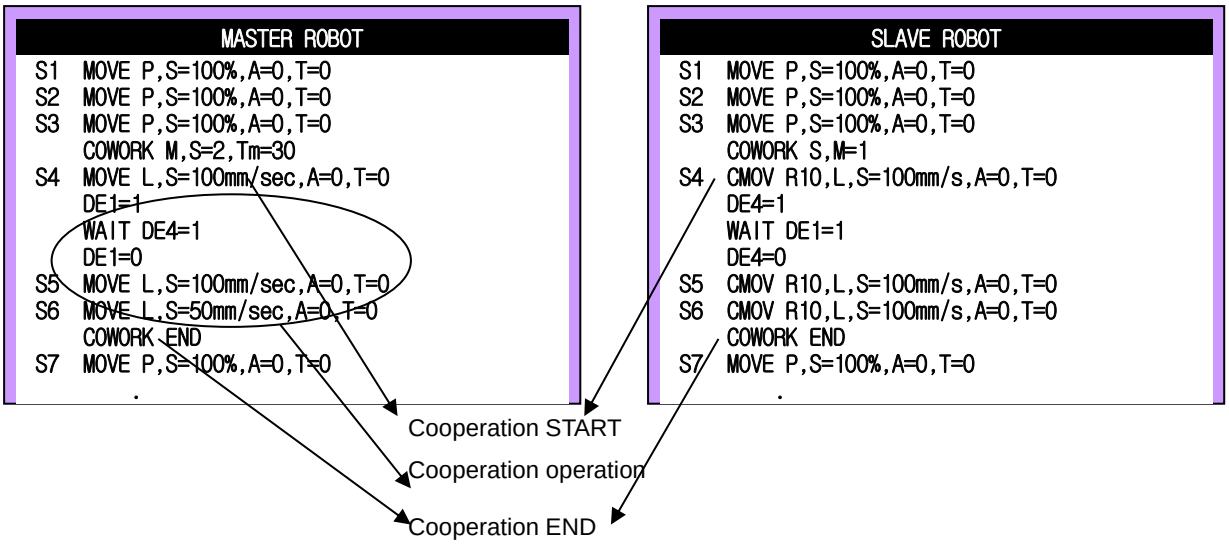
(1) For the master robot, the operating command in the zone between COWORK and COWORK END becomes the collaborative zone command. The slave cannot insert an operating command.

(2) The slave cannot use the general move command and must use the CMOV command which is the COWORK MOVE command.

(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 taught as shown in the below example, the cooperation operation is done in the COWORK~COWORK END zone. In this operation, the slave follows the master robot on the CMOV trace recorded in the master end effecter coordinate. (Jigless cooperation control is an option.)



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.

(2) Check whether the common coordinate of the cooperation robot is set. Allocate the f key necessary for cooperation control.

(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.

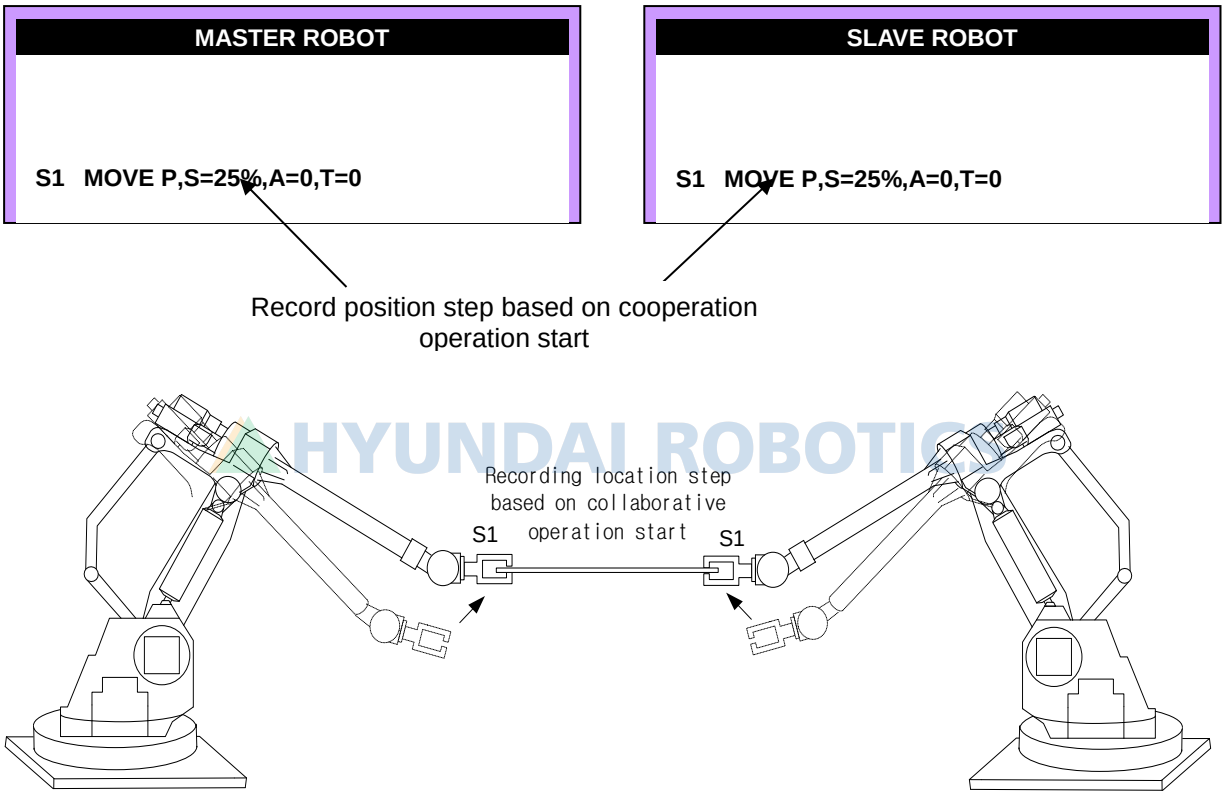


Figure 4.1 Recording position step based on cooperation operation start

(4) Set the master and slave robot to cooperation status using the f key. The robot roles can be set by entering the R351 code.

(5) Check if the master robot is set to master and slave robot to slave and also check whether the operation ready is ON. Set it to jog on for master and jog off for slave.

(6) Register the COWORK M/S command and record the step. COWORK command designates the master/slave recognition and designates the slave/master number.

MASTER ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK M,S=2,T=30
```

SLAVE ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK S,M=1,T=30
```

(7) 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. At this time, the Enable switch must be pressed for the slave. The step is recorded only to the master from record position. It is not recorded in the slave robot controller.

MASTER ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK M,S=2,T=30
S2   MOVE L,S=500mm/s,A=0,T=0
```

Master: Cooperation position recorded

SLAVE ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK S,M=1,T=30
```

Slave: Not recorded

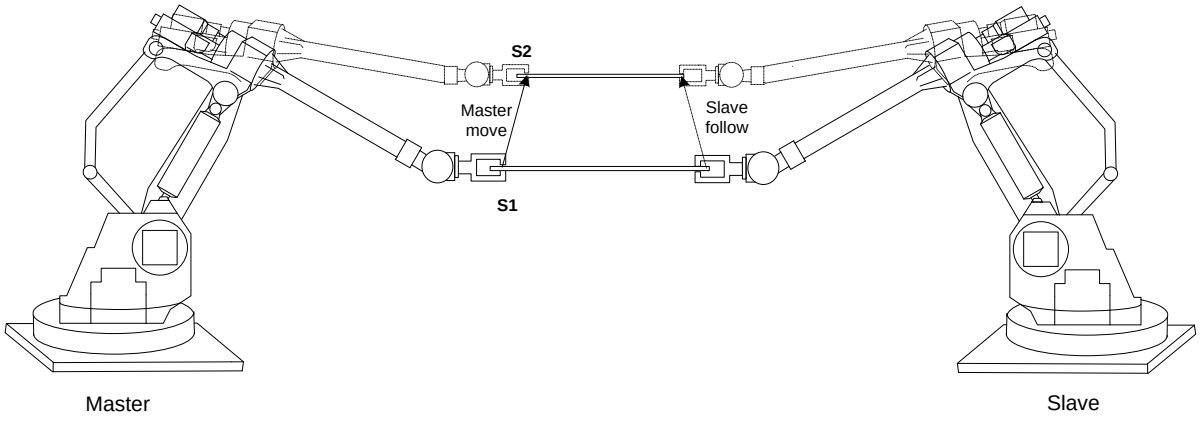


Figure 4.2 Master robot operation

(8) 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.)

MASTER ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK M,S=2,T=30
S2   MOVE L,S=300mm/sec,A=0,T=0
S3   MOVE L,S=300mm/sec,A=0,T=0
S4   MOVE L,S=300mm/sec,A=0,T=0
```

SLAVE ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK S,M=1,T=30
```

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

MASTER ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK M,S=2,T=30
S2   MOVE L,S=300mm/sec,A=0,T=0
S3   MOVE L,S=300mm/sec,A=0,T=0
S4   MOVE L,S=300mm/sec,A=0,T=0
     COWORK END
```

SLAVE ROBOT

```
S1   MOVE P,S=25%,A=0,T=0
     COWORK S,M=1,T=30
     COWORK END
```


Caution

- Manual cooperation robot role and COWORK robot role must be the same. For example, if the manual cooperation condition is set to set to slave, COWORK M cannot be executed.
- 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 system 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	.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 (0~3)
parameter5	.Tool number (0~7)

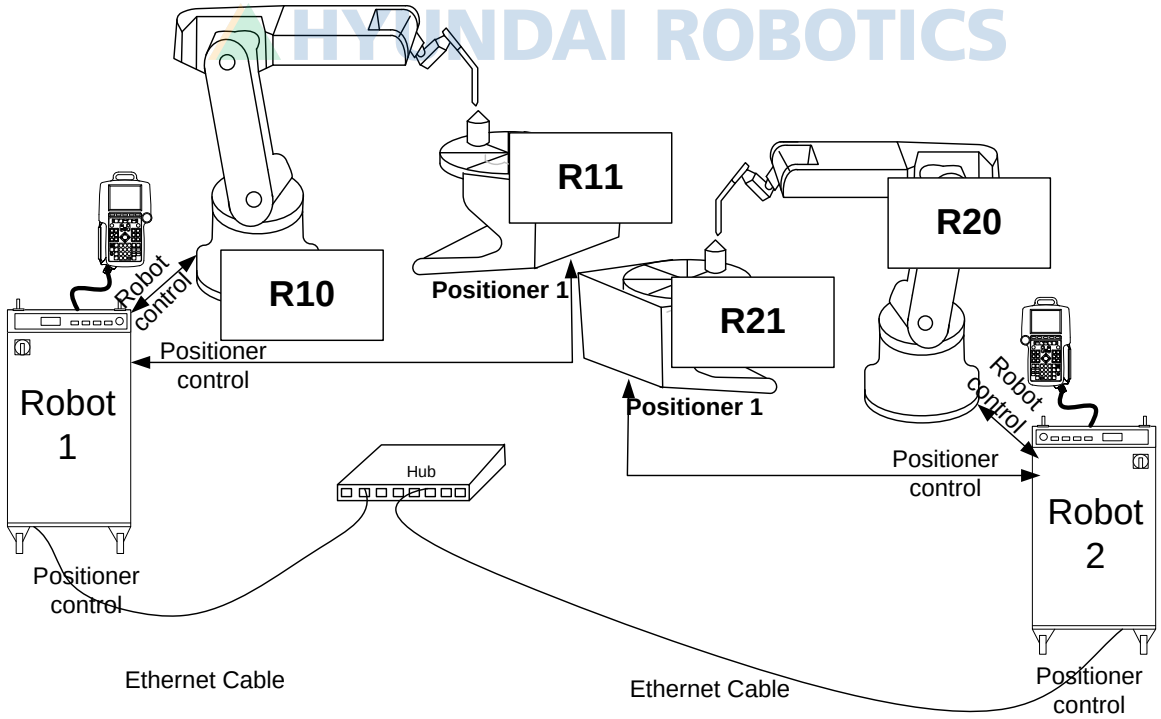


Figure 4.3 Method of distinguishing ID identifier

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

(1) After setting the manual cooperation robot role of master and slave to 'individual', teach the COWORK start step for the individual step and insert the COWORK command.

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

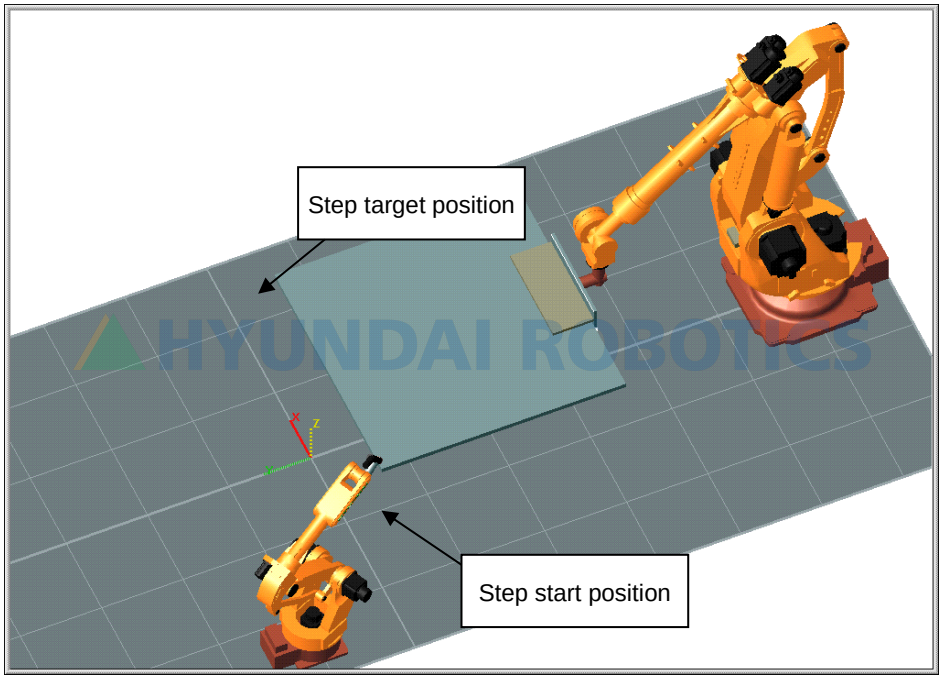


Figure 4.4 Step start and target position

(2) Change the role of master and slave to its role in manual cooperation condition.

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
>R351,1

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
>R351,2

(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 grey.

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



>R351.3
```


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

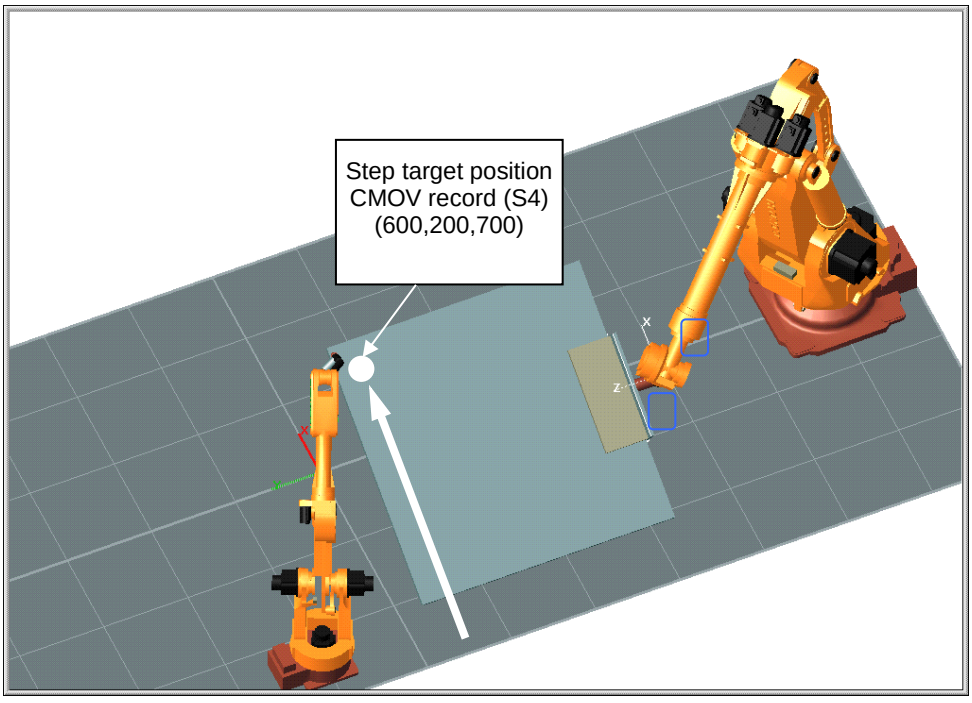
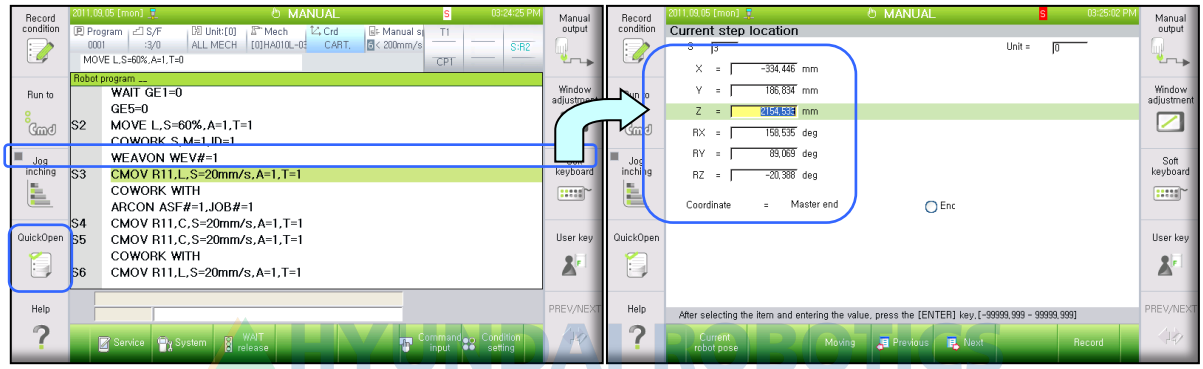


Figure 4.5 Step target position CMOV record

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 >

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.



The coordinate recorded at this time is to be displayed as ‘Master end’.

(6) Multiple CMOV steps can be recorded by moving the slave while applying the same manner.

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

(7) But because the moving plan for recording step is executed individually between the master and slave, the time reaching the target position is different. Therefore, in order to align the timing of master MOVE position and slave CMOV start position in the collaborative zone, mutual interlock method is used with HiNet I/O.

(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
    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).

(9) 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/sec,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/sec,A=0,T=0
S6  CMOV R10,L,S=50mm/sec,A=0,T=0
    ARCOF
    GE5=0
    COWORK END
```


The whole program explained above can control the timing such as ⓐ, ⓑ and ⓒ to control the timing of cooperation control, as shown below.

```
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/sec,A=0,T=0



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

ⓐ

ⓑ

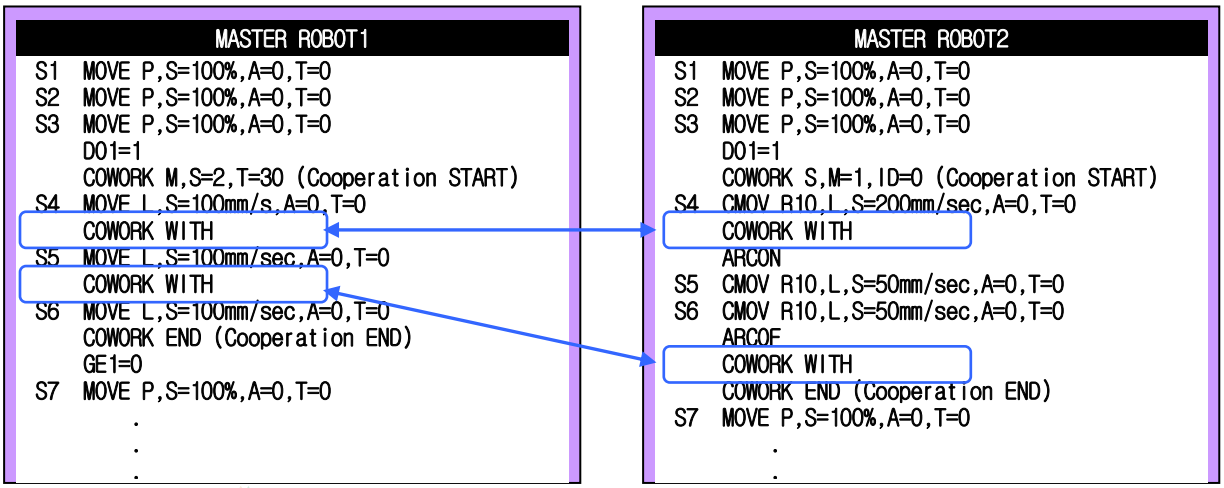
ⓒ

```
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/sec,A=0,T=0
    GE5=1



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

※ Programming method using COWORK WITH command

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. Accordingly, the above program can be changed according to the following method.



You can easily synchronize the starting position of cooperation between master and slave by using the COWORK WITH command as shown above.

※ Reference

- Mutual interlock in cooperation control using HiNet can be composed in different ways from the above method.
- You can check the CMOV record position of slave according to the master position by using the step forward/backward function.
- For the contents on HiNet I/O, please refer to chapter 6.

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).

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 recording position is at the zero point of master end effecter coordinate (0,0,0), the master CMOV step position will move the zero point of master end effecter coordinate irrelevant of whether the master robot is in the solid line or dotted line.

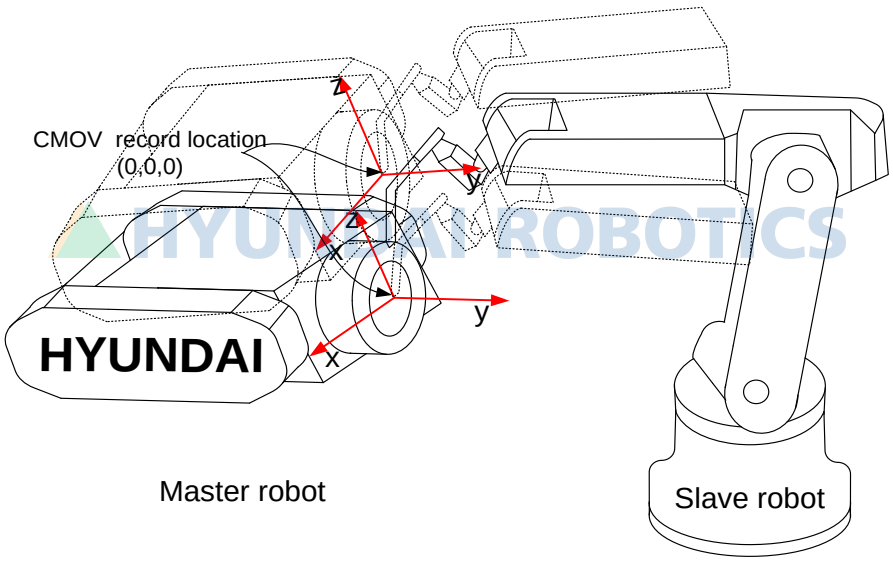


Figure 4.6 CMOV record position check

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

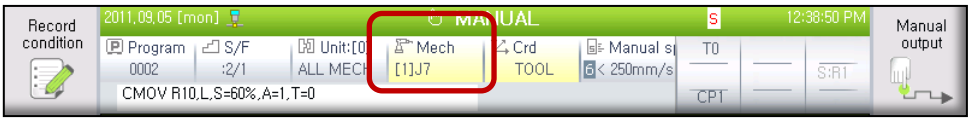
This function allocates the collaborative master to the positioner so that the slave robot can collaborate with the master positioner. The positioner groups 1~2 are supported.

4.6.1. Positioner master jog

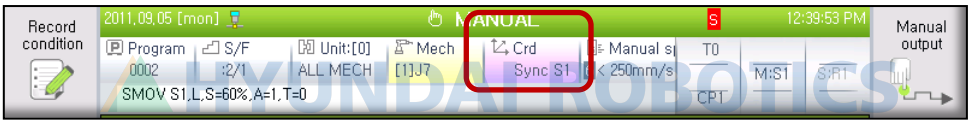
(1) This executes the positioner group setting and positioner calibration for positioner synchronization.

(2) The robot, for which a positioner is set as the master, needs to be set as the manual cooperation master (M: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 S1(or S2) to be selected.



(5) The slave robot needs to be set for the slave role (S: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

(1) 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.

(2) 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.

Master robot

```
MASTER ROBOT1

COWORK M,ID=1,S=2
```

Slave robot

```
SLAVE ROBOT2

COWORK S.M=1,ID=1
```

(3) For the master side to collaborate with the positioner, teach SMOV step in the same way as the existing positioner. If the step is recorded for the slave when the master positioner is set to master (Master robot side coordinate 'Synchronize S1'), the robot number reflecting the master ID is recorded.

Master robot

```
MASTER ROBOT1

   COWORK M,ID=1,S=2
S1 SMOV S1,L,S=100mm/s,A=0,T=0
```

Slave robot

```
SLAVE ROBOT2

   COWORK S.M=1,ID=1
S1 CMOV R11,L,S=100mm/s,A=0,T=0
```

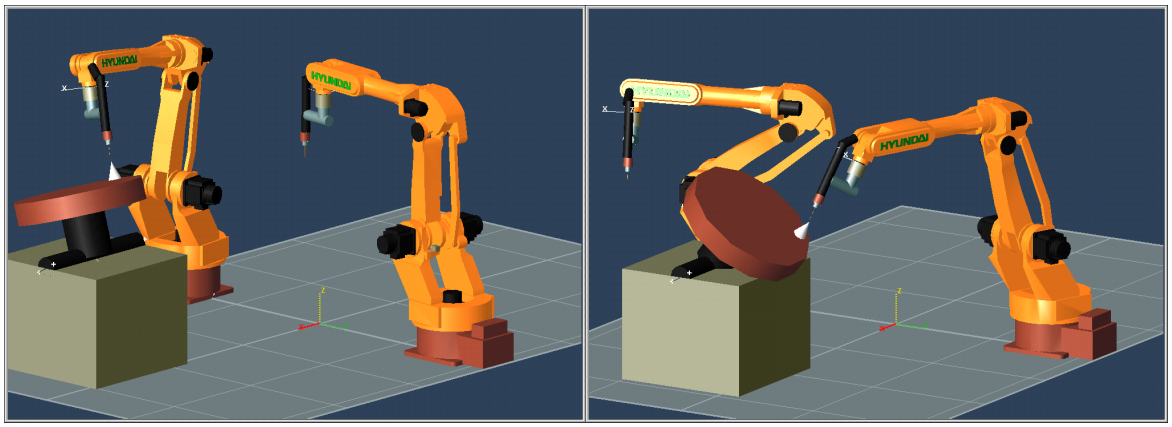
The master is the same as the positioner synchronization function. The slave is recorded in R11.

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

```
MASTER ROBOT1
   COWORK M.ID=1, S=2
S1 SMOV S1,L,S=100mm/s,A=0,T=0
S2 SMOV S1,L,S=100mm/s,A=0,T=0
S3 SMOV S1,L,S=100mm/s,A=0,T=0
S4 SMOV S1,L,S=100mm/s,A=0,T=0
   COWORK END
   END
```

```
SLAVE ROBOT2
   COWORK S.M=1,ID=1
S1 CMOV R11,L,S=100mm/s,A=0,T=0
S2 CMOV R11,L,S=100mm/s,A=0,T=0
S3 CMOV R11,L,S=100mm/s,A=0,T=0
S4 CMOV R11,L,S=100mm/s,A=0,T=0
   COWORK END
   END
```

(5) Check the operation in manual mode and operate in auto mode.



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.』.

HYUNDAI ROBOTICS

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.

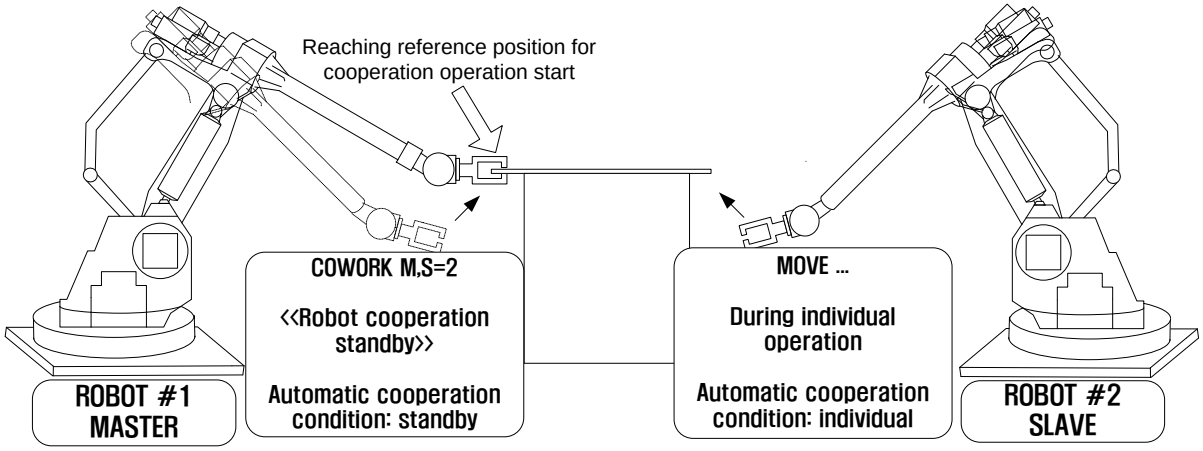


Figure 5.1 Cooperation playback 1

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

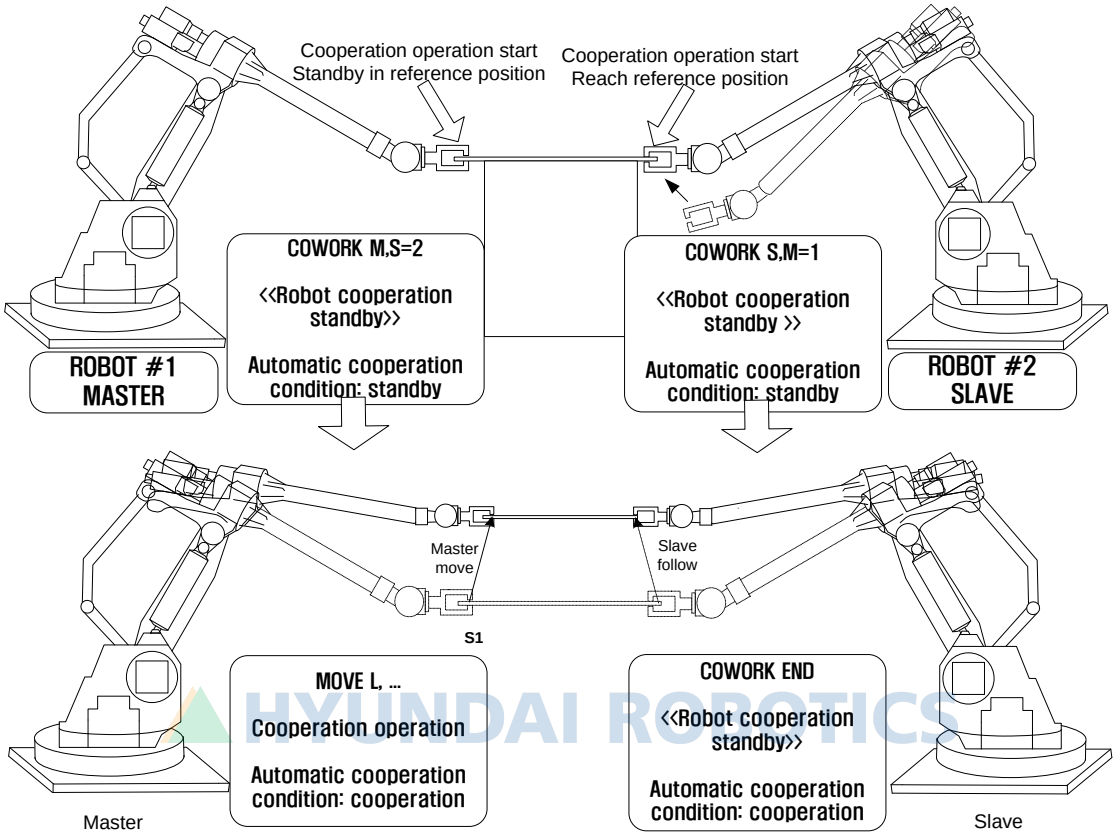


Figure 5.2 Cooperation playback 2

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

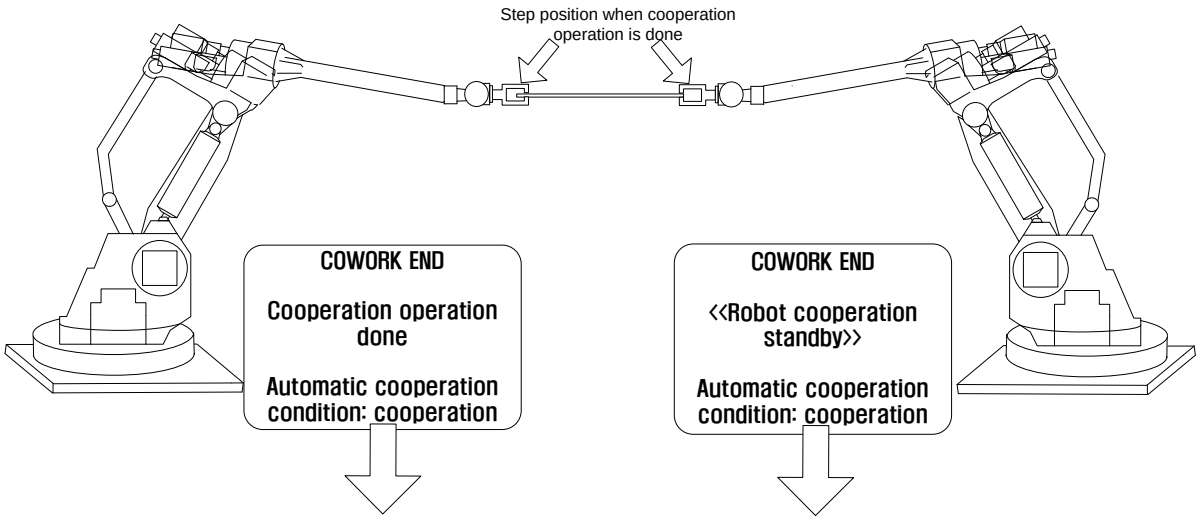


Figure 5.3 Cooperation playback3

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

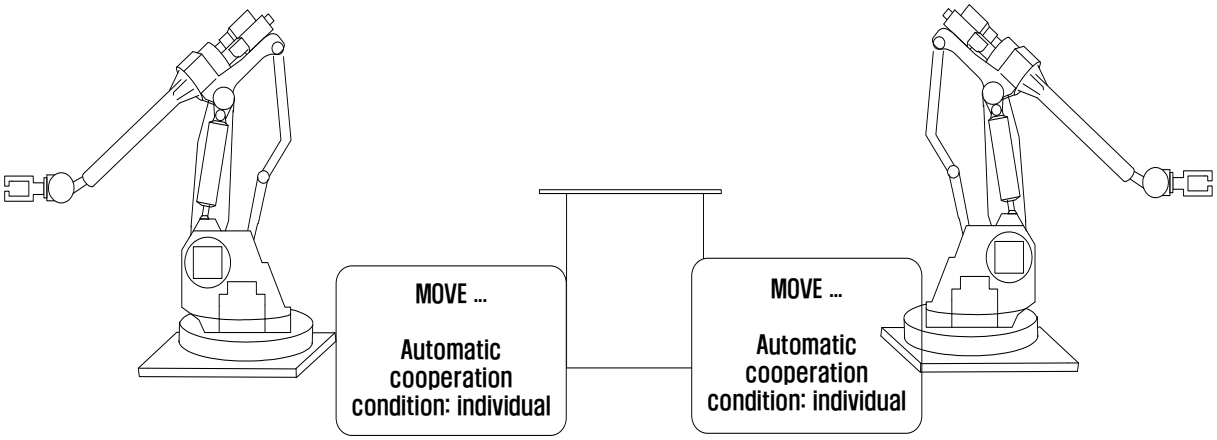


Figure 5.4 Cooperation playback 4

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.

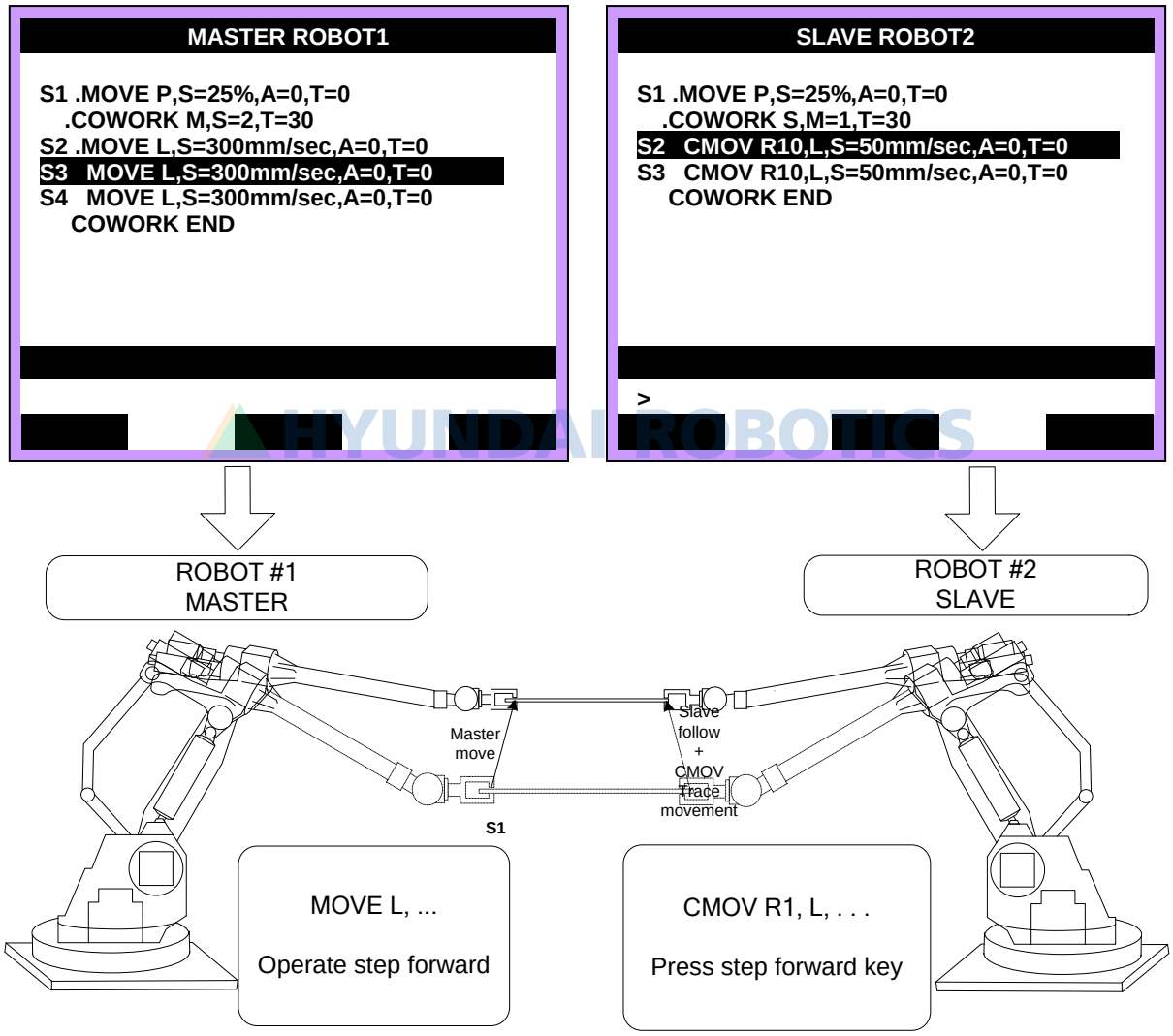


Figure 5.5 Program check in manual mode

Caution

- If you set the slave to CMOV record mode (R351,3), cooperation operation in manual mode with the master will not work. Always set to I (Indiv., R351,0) or S (Slave, R351, 2).
- If you release the 『Step forward』 key during cooperation operation, the robot will stop and 『Stop request of opponent robot』 message will be displayed. To restart at this time, move forward the slave side first then the master side.
- If you do not set the master and slave to 'manual', an error saying "Cooperation operation start error" will be generated and the playback will not start.
- When executing step forward/backward, the condition must be set to 『Function during step fwd/bwd = 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 specific positions of the two robots, the COWORK WITH 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.)

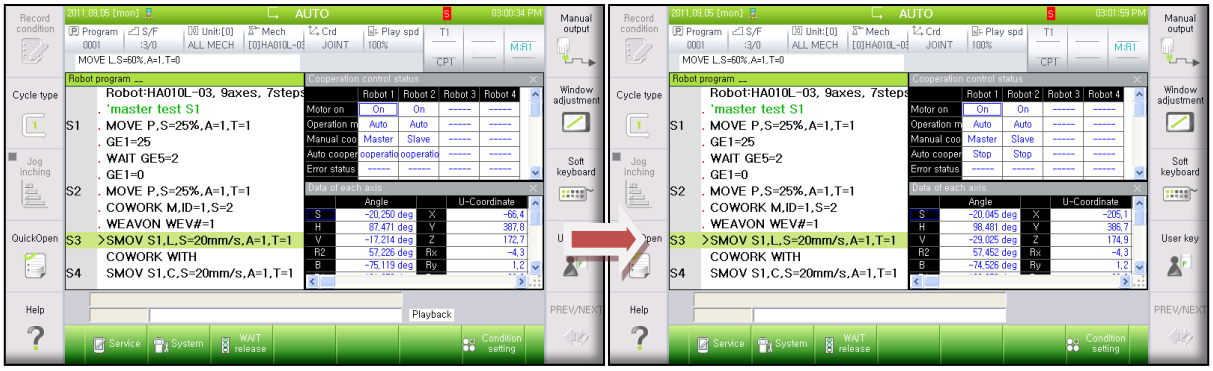
Caution

- 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.

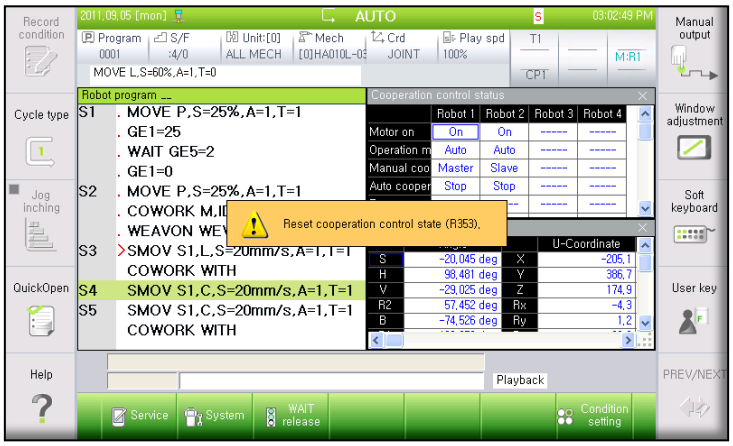
5.4. Cooperation Playback Stop/Restart

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



(2) When restarted after being stopped, the slave robots need to be started first before the master robots are restarted. An error will be generated is the slave robot is not in collaborative standby condition.

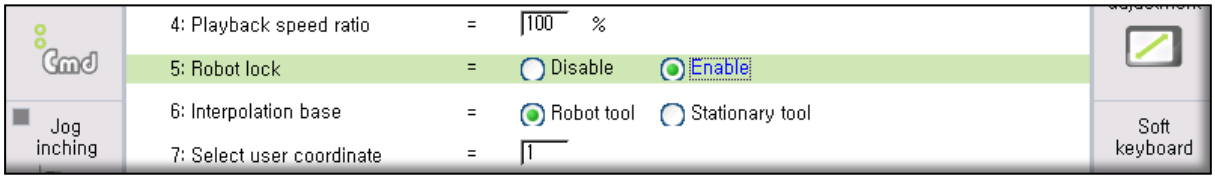
(3) After stopping during cooperation operation, changing the step number and restarting the robot is only possible if the cooperation playback condition is disabled. In this case, the system requires the user to enter the R353 code as a warning.



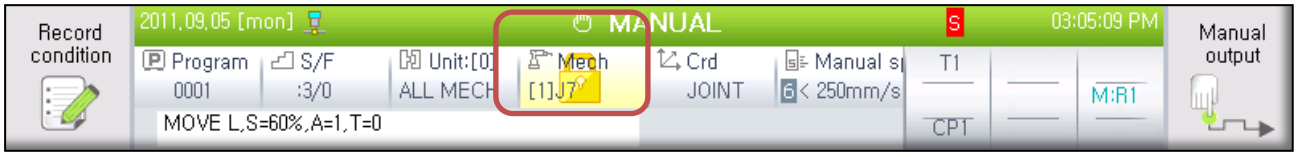
(4) When you enter the reset command (R353) for cooperation control condition, the operation resumes with the cooperation condition canceled. To operate with the cooperation condition maintained, designate the stop step number and execute the operation.

5.5. Robot Lock Function(Robot Lock Playback)

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



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



(3) 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.

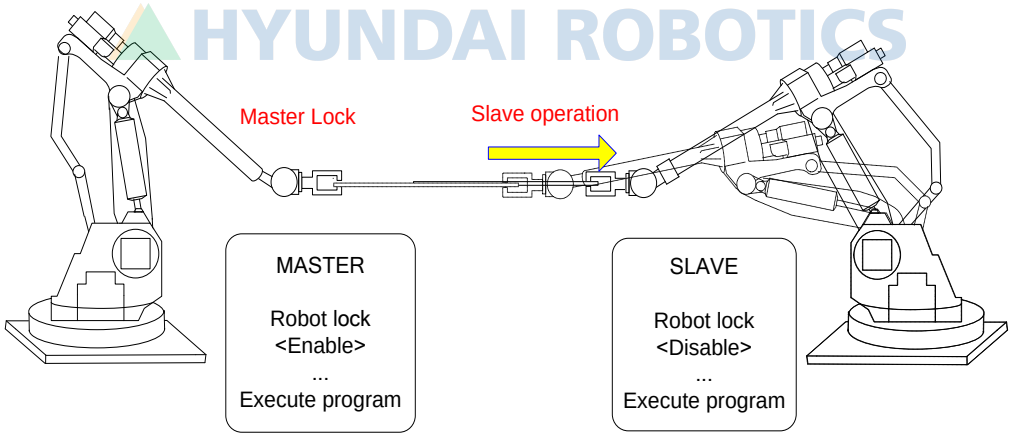


Figure 5.6 Robot lock function (Master Lock)

(4) 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.

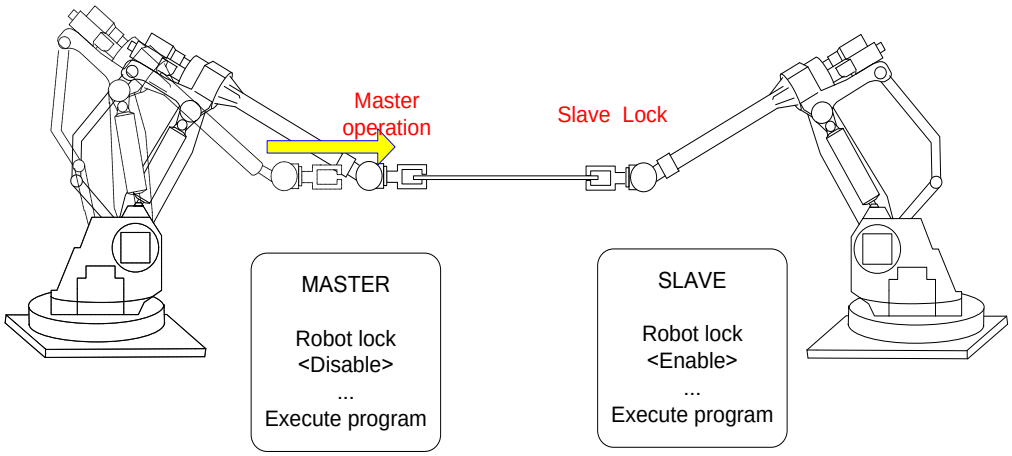


Figure 5.7 Robot lock function (Slave Lock)

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

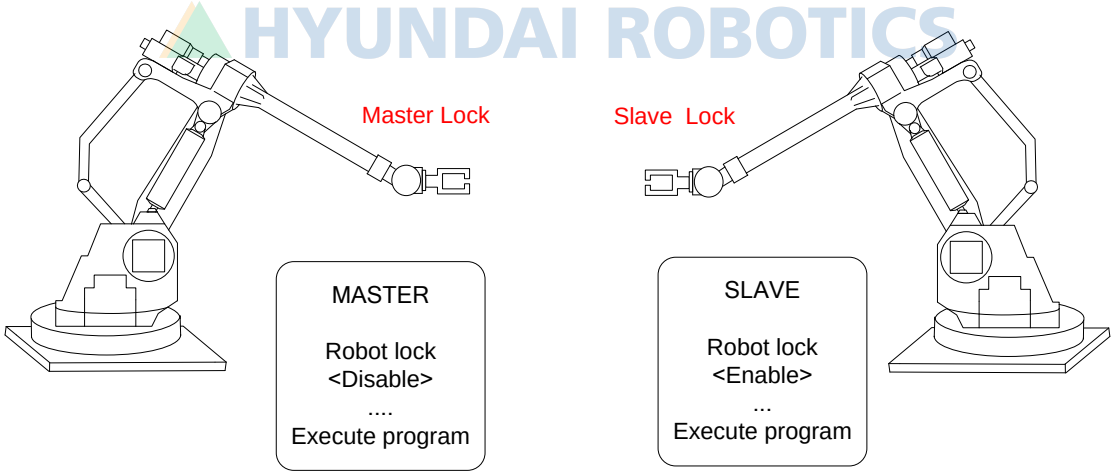


Figure 5.8 Robot lock function (Master, Slave Lock)

Caution

- 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

This function shares the I/O through the HiNet connected to the collaborative network. 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 each controller can use is 4 bytes.

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.

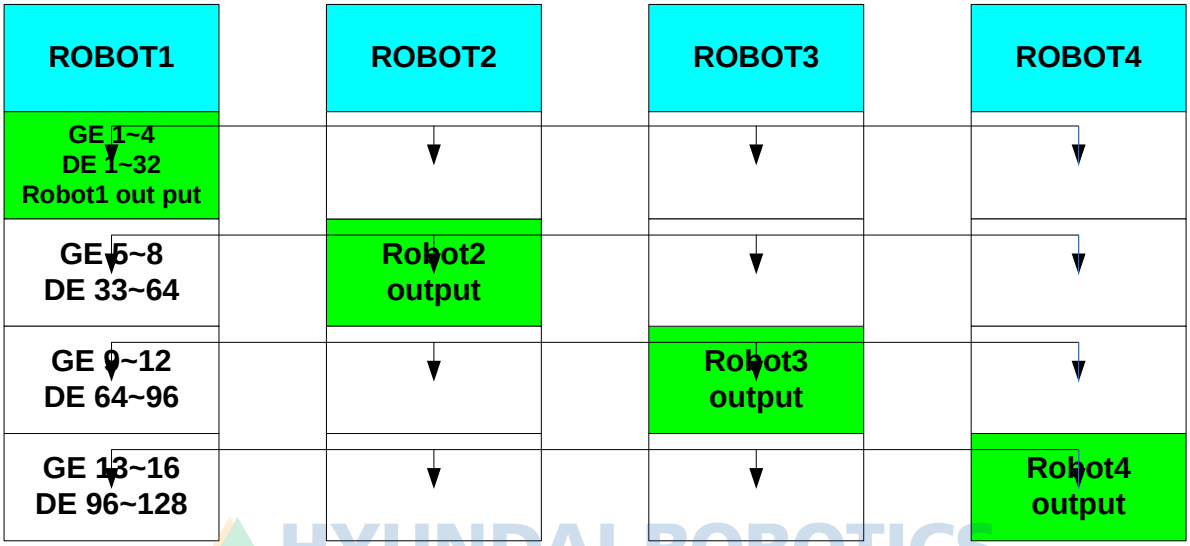


Figure 6.1 HiNet I/O

Table 6-1 I/O Zone by robot number

Robot no.	GE (OUT)	GE (IN)	DE (OUT)	DE (IN)
	Output allocated zone	Input allocated zone	Output allocated zone	Input allocated zone
Robot 1	1~4	5~16	1~32	33~128
Robot 2	5~8	1~4, 9~16	33~64	1~32, 65~128
Robot 3	9~12	1~9, 13~16	65~96	1~64, 97~128
Robot 4	13~16	1~12	97~128	1~96

6.1. 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 (1~128) 0 : Select all I/O bit 1~128 : Select applicable I/O bit
parameter	. On/Off setting 1 : On 0 : Off

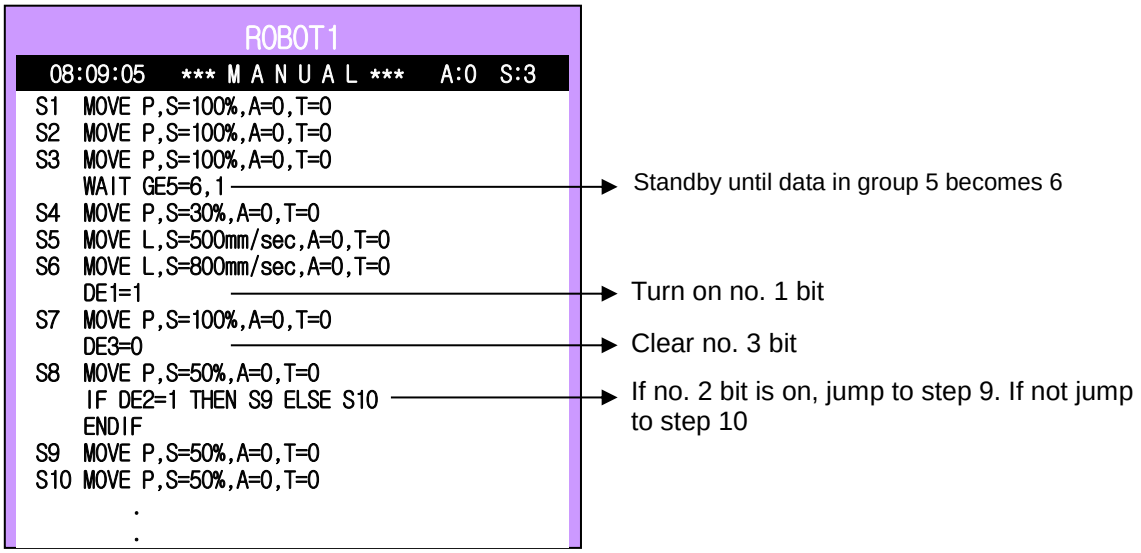
6.2. GE command

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 (1~32) 0 : Select all I/O group 1~32 : Select applicable I/O group
parameter	. It designates 1byte of I/O signal.(0~255)

6.3. Application example

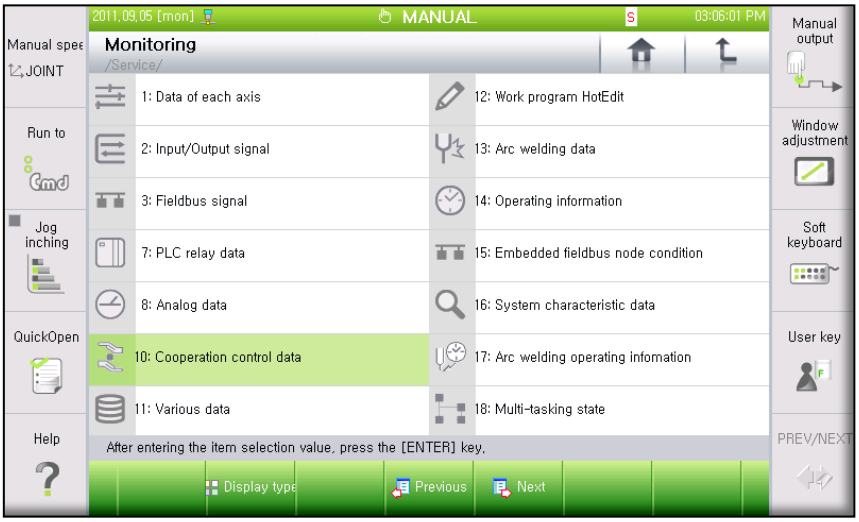
The following is a simple applied example to help you better understand the application of robot language. Because DE and GE can also be used as a parameter, it has an advantage in terms of flexibility of application.



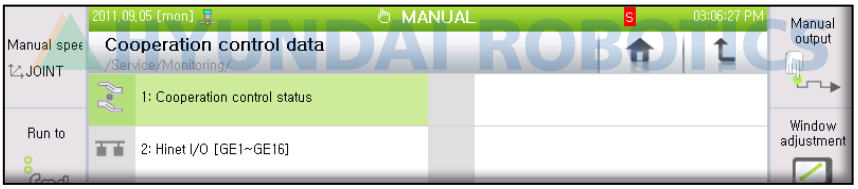
7
Service Function

7.1. Cooperation control condition monitor

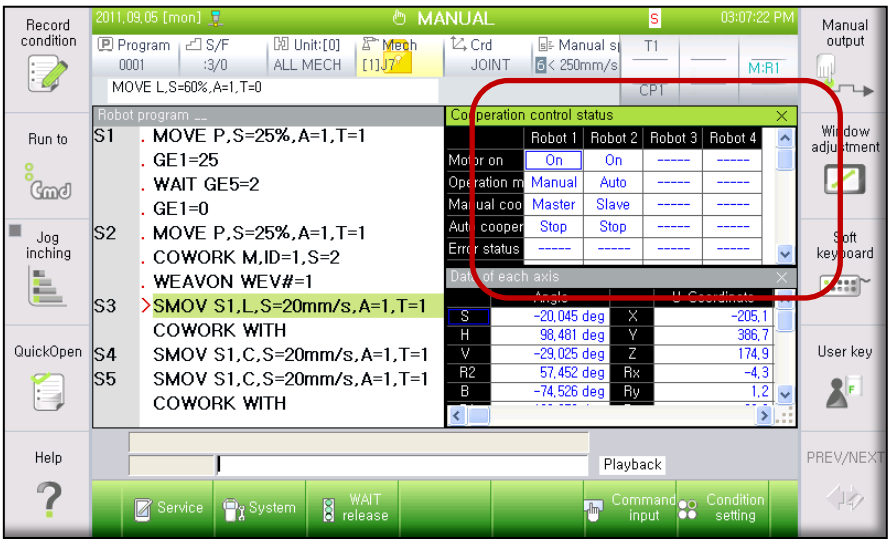
(1) Select 『[F1]: Service』 → 『1: Monitoring』 → 『10: Cooperation control data』.



(2) 『11: 협조제어 데이터』를 선택합니다.



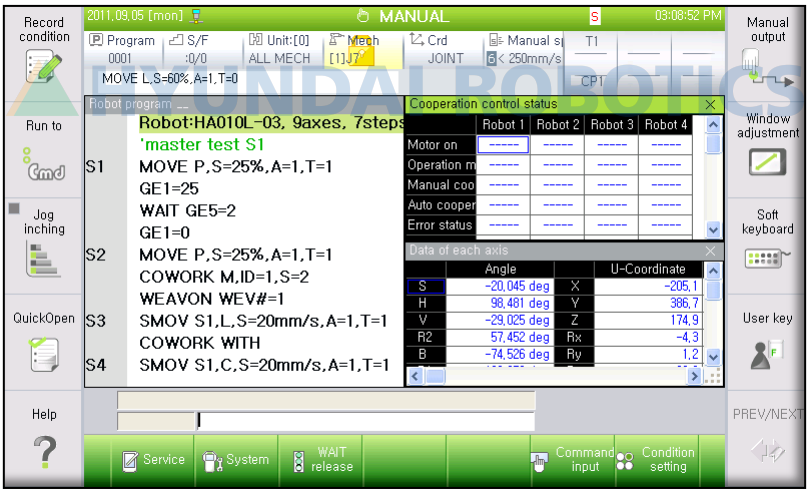
(3) Cooperation control condition will be displayed as follows.



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

- Motor ON : This shows whether each robot is ready for operation. (ON/OFF)
- Man./Auto : 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.
  Indiv. : 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.

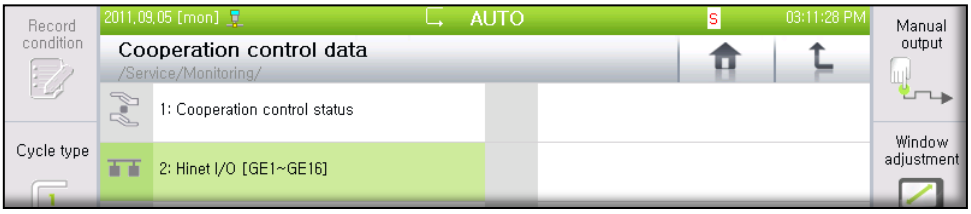
Caution



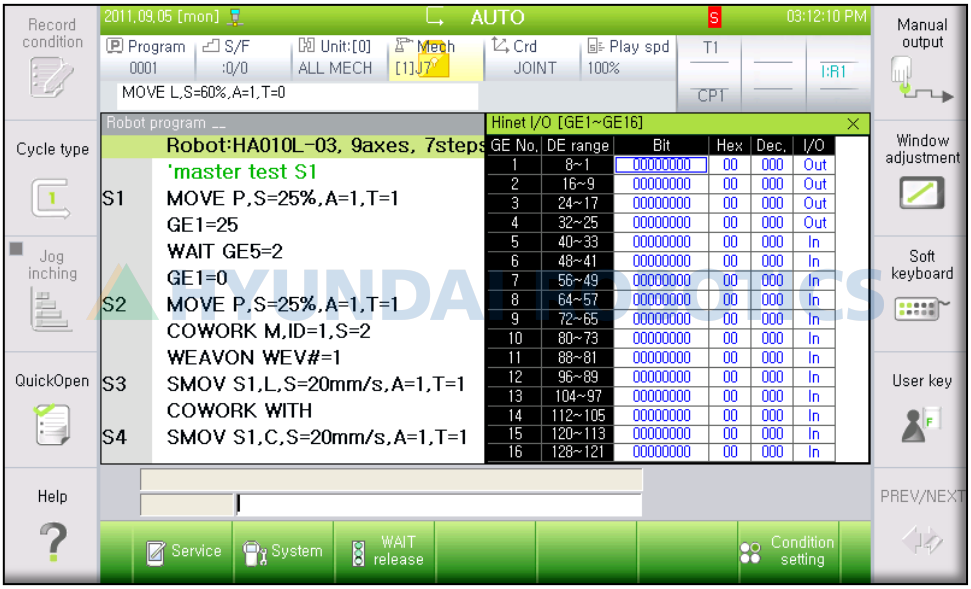
- If the cooperation control is set to <Disable> in cooperation control, the monitoring information will not be displayed.

7.2. HiNet I/O monitor

(1) Select 『[F1]: Service』 → 『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.



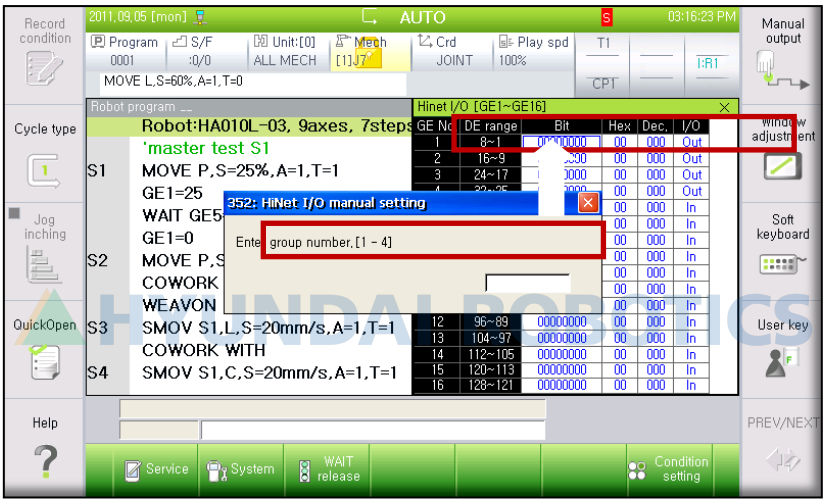
7.3. Manual output function (R352)

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

Operation	Output signal
R352, group no. (1~32), output signal (1~128)	Output signal corresponding to group no. Ex) R352,14,255

Ex) R352,1, 255

First its own robot number has to be able to output GE1. From GE1 to GE4 is the output allocation area for robot 4. It is impossible to set other range than that.



7.4. R code

This is the R code used in cooperation control.

Table 7-1 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
R352,#1,#2	Group no.	Output value	Manual output of group no.
R353			Cooperation playback condition clear

8
Error Code

8.1. 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:
  Stop instruction is received from the partner robot during cowork control operation. 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 individually in a manual mode, change the condition of manual cowork. To change the condition of manual cowork, users need to use F key or 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..

8.2. System Error

- Code:
  E0200 (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:
  E0201 Start time mismatch
- Cause:
  There is an error in receiving/sending signals between cowork robots. It was playback in different modes.
- Action:
  Check the communication condition. Match the modes between cowork robot before operating.

- Code:
  E0203 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:
  E0204 Rbt#1 Communication is not working
- Cause:
  Communication with the corresponding robot is disconnected during cowork, jog, and play.
- Action:
  Check if the connection between communication line and communication card is good. Error can be detected by Hint diagnostic.

- Code:
  E0205 HiNet is not working
- Cause:
  Hinet communication for cowork is not working.
- Action:
  Check if connection between communication line and communication card. Error can be detected by Hinet diagnostic.

- Code:
  E0227 Seq. error of Cooperative control
- Cause:
  There is a difference in instruction sequence between master robot and slave robot during cowork control.
- Action:
  Check the connection of network for cowork control. Check if slave is executing power saving function. Set the power saving function of slave robot as Disable.

8.3. Operation Error

- Code:
  E1340 Disable condition for co-work run
- 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:
  E1341 Cooperation wait time is over
- Cause:
  All the coworking robots are not ready to cowork for the set standby time after meeting with COWORK instruction.
- Action:
  Set the standby time taking the reaching time for all coworking robot to the position into account. If 0 is set, it would continue to standby until all robot could reach.

- Code:
  E1342 Invalided COWORK or common coordi.
- Cause:
  COWORK instructions cannot be executed because robot coworking is disable or common coordinate system is not set.
- Action:
  Set the common coordinate system after setting <enable> in a system setting/control parameter/cowork control parameter.

- Code:
  E1343 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. Double execution by step change is prohibited.

- Code:
  E1344 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 it because the robot's number corresponding to COWORK M(S),S(M)=robot number cannot be set to my robot.

- Code:
  E1345 The slave already executed COWORK.
- Cause:
  Slave robot's cowork is already working in the position of COWORK END, or it stops.
- Action:
  For normal coworking of Master & Slave, do not change step artificially.

- Code:
  E1347 Coord. system not supporting shift.
- Cause:
  Base / Robot / Tool / User coordinate shift is addable to Base / Robot / Encoder / User coordinate system pose, and other shift calculation in coordinate system is not allowed.
- Action:
  Check the coordinate system of pose or shift variable/constant, and convert it to the allowable coordinate system. [QuickOpen]

- Code:
  E1355 Partner robot is error stopped
- Cause:
  Partner robot stops during Cowork so that it is impossible to cowork any longer. It stops because cowork is impossible.
- Action:
  Check if the operation mode is identical between robots. Restart Slave first before restarting Master if restarting after stop during cowork.

- Code:
  E1356 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.

- Code:
  E1360 ROBOT.C00 file is damaged.
- Cause:
  ROBOT.C00 file structure is damaged.
- Action:
  Initialize the memory with a support of our A/S staff.
  TEL : 053-670-7115
  E-Mail : robotas@hyundai-robotics.co.kr

- Code:
  E1361 ROBOT.C01 file is damaged.
- Cause:
  ROBOT.C01 file structure is damaged.
- Action:
  Initialize the memory with a support of our A/S staff.
  TEL : 053-670-7115
  E-Mail : robotas@hyundai-robotics.co.kr

- Code:
  E1362 ROBOT.C00 file is read only.
- Cause:
  Impossible to record a data in ROBOT.C00 file.
- Action:
  Change the property of ROBOT.C00 file.

- Code:
  E1363 ROBOT.C01 file is read only.
- Cause:
  Impossible to record a data in ROBOT.C01file.
- Action:
  Change the protect of ROBOT.C01 file.

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