WARNING

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

HD HYUNDAI ROBOTICS

Hi5a Controller Function Manual

Sensor Based Force Ctrl

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Contents

List of Figures

List of Tables

HD HYUNDAI ROBOTICS

1

Overview of Functions

1.1. Introduction

Force Ctrl uses the force sensor for real-time reaction to the surrounding environment of the robot. This technology enables robot position control and flexible motion by keeping certain contact to the external area in accordance with the settings. This function can improve the operation efficiency for automated assembly and machining areas.

1.2. Summary

- A force sensor is used to control the robot to keep the defined contact force.
- Tool information is obtained by estimating the load with the sensors or it can even be manually specified.
- The monitoring window of robot T/B can be used to monitor the force sensor.
- Force Ctrl is applicable to the assembly and machining.
- Software version: Main V40.05-00 or later, DSP SV6.11 or later

2

Methods of Using

2.1. Summary

- Installation of force sensor
- Force control configuration setting
  ([System]-[Application Parameter]-[Force Control]-[Configuration Setting])
- Sensor-based load estimation for the tool data
  ([System]-[Application Parameter]-[Force Control]-[Force Control Tool Data])
- Job program development using the force control commands
- Execution of force-sensor data monitoring window

2.2. Installation of force sensor

This section covers general issues regardless of the sensor type. For more details on the installation of individual sensors, refer to the appendix.

① Set the axis R1 and R2 of robot to 0 deg. Then, install the sensor on the robot.
② Connect the sensor and the robot controller using the communication cable.
③ Connect the power to the sensor and the communication module.
④ Set suitable communication environment for the sensor.

A. Ethernet communication-based sensor (e.g., 6-axis sensor from ATI)
In the TP, set the IP of EN2 (common) as shown in Fig. 1. Enter a number between 2 and 255 in the last section of the IP address.
(『[F2]: System』 → 『2: Control Parameter』 → 『9: Network』 → 『1: Configuration』)

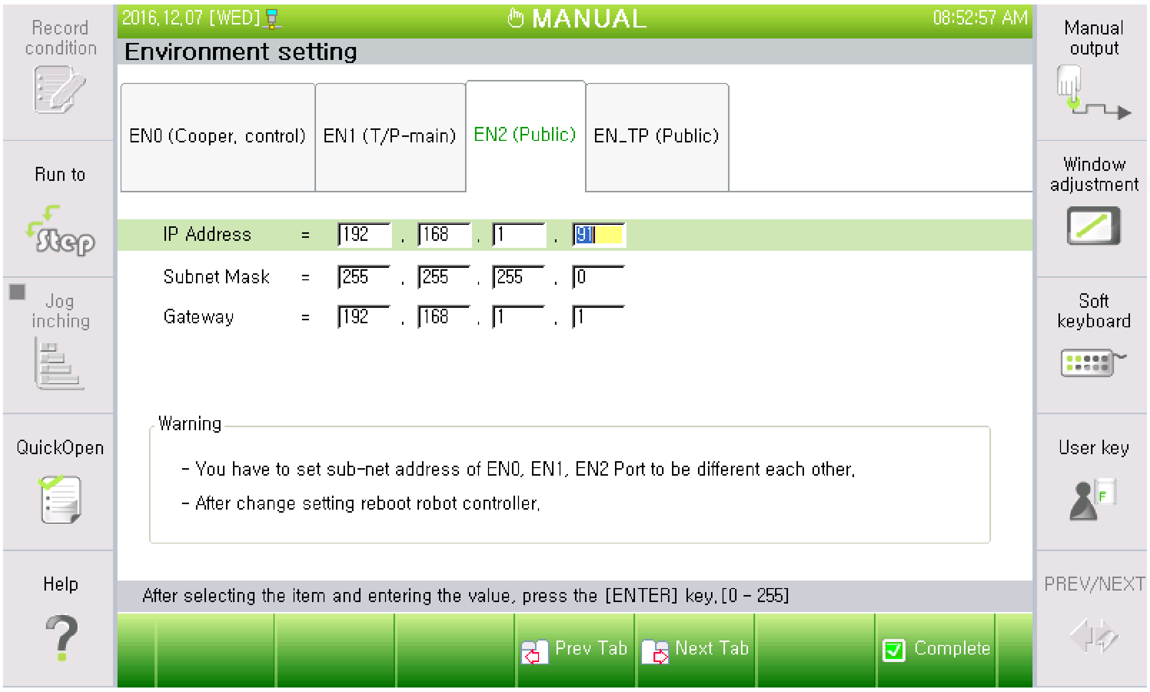

Figure 2.1 Controller network configuration

B. Serial communication based sensor (e.g., a load cell from Burster)
Select a serial port for the controller in the following path. Then, set the communication environment.
(『[F2]: System』 → 『2: Control Parameter』 → 『3: Serial Port』)
To install, check first the communication setting of the sensor module. For the communication settings of the sensor module, check the appendix.

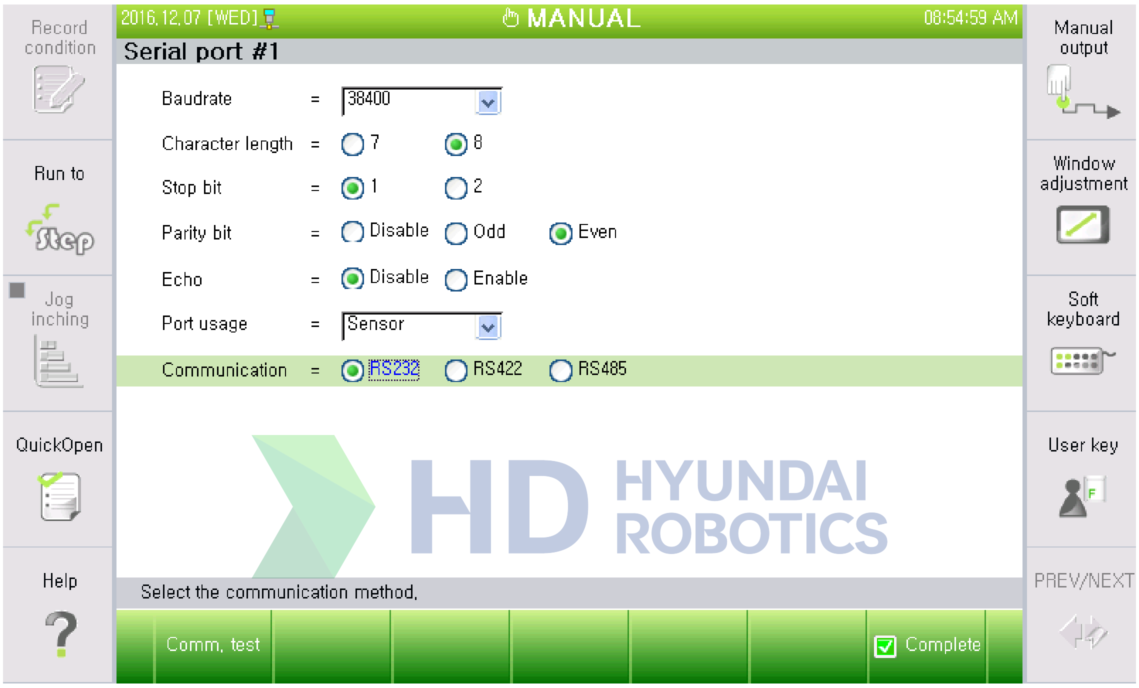

Figure 2.2 Serial port configuration

2.3. Configuration setting

Set the configuration before using the force control function.
(『[F2]: System』 → 『4: Application Parameter』 → 『14: Force Control』 → 『1: Configuration Setting』)

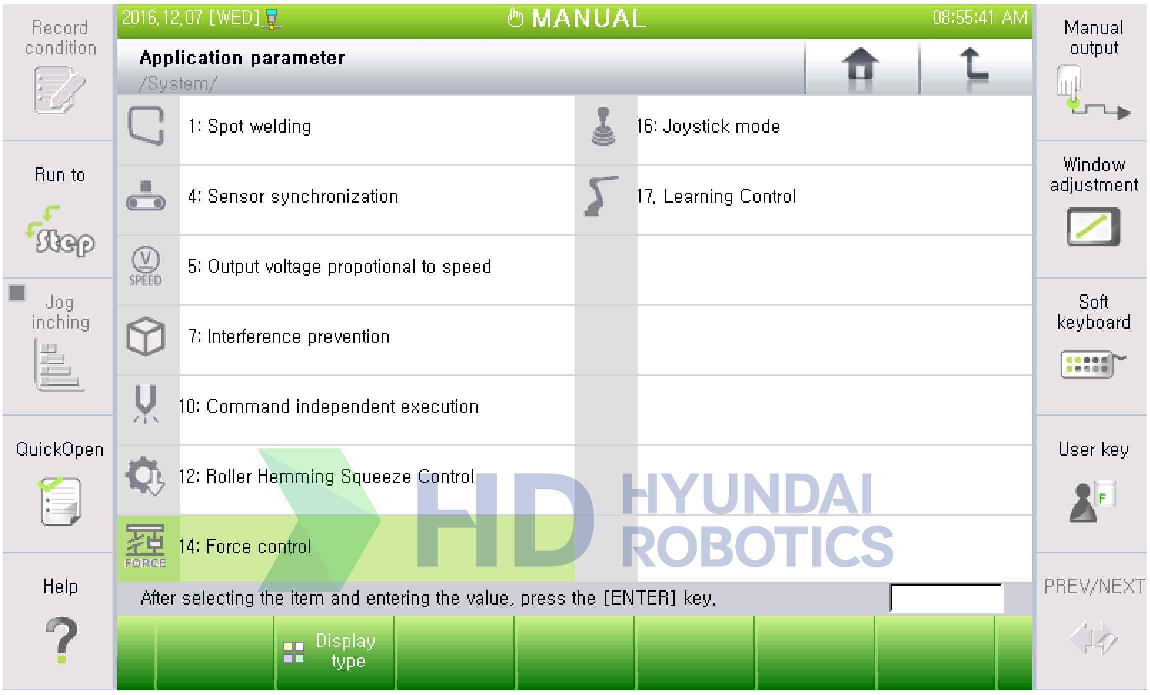

Figure 2.3 Force control menu

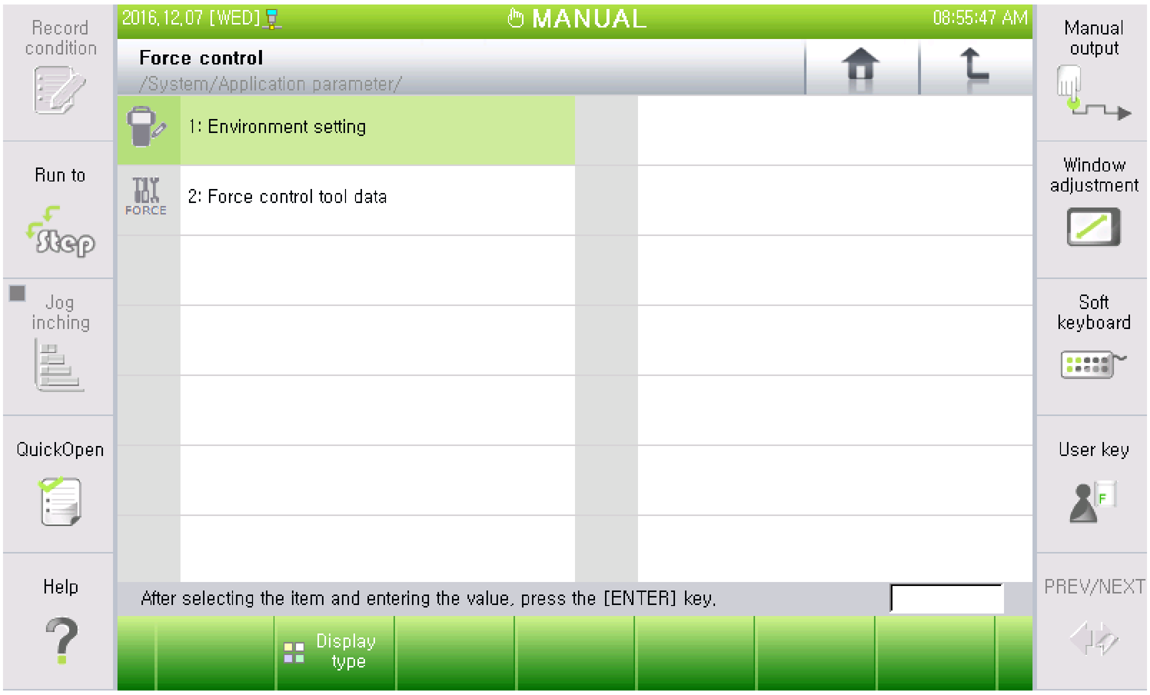

Figure 2.4 Configuration setting menu

① Enable the force control function. Then, it will be possible to use the force control and monitor the force sensor data.

② Set the sensor type. If you want to use a sensor other than registered ones, contact us. The setting is then finished and you can use the force control function.

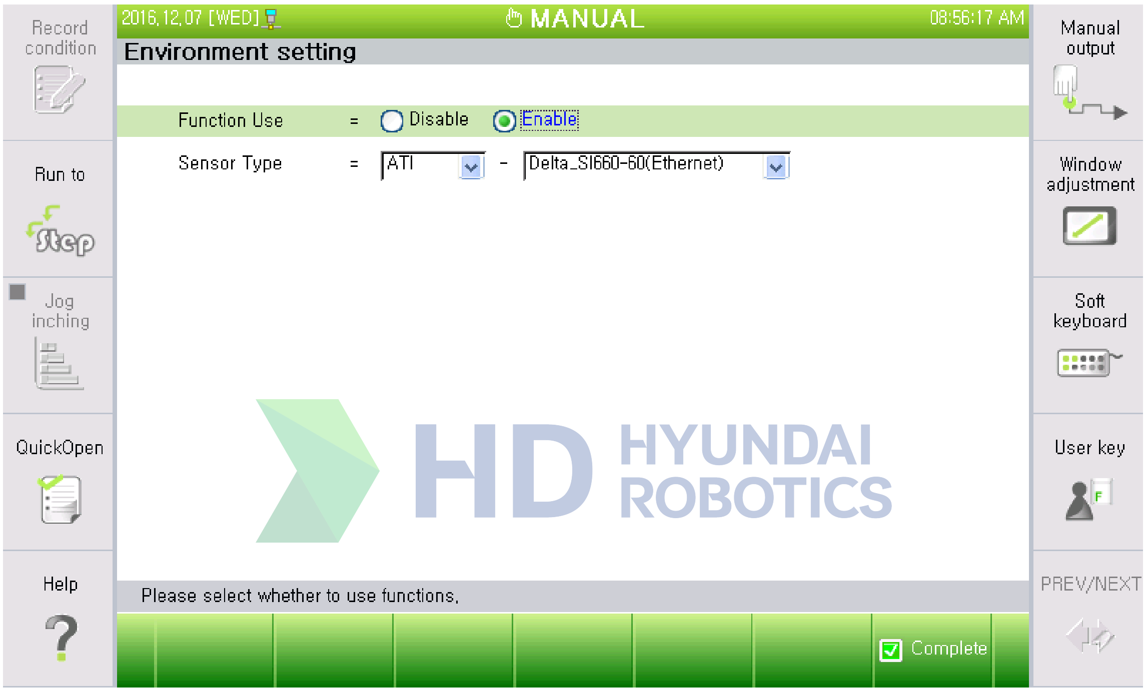

Figure 2.5 Configuration setting screen

2.4. Force-control tool data input

The force control tool is an operation tool installed on the sensor, and the force-control tool data includes the weight and its center. Support for the force control tool data and sensor-based load estimation depends on the type of sensor, and the menu is only displayed if a compatible sensor has been set.

2.4.1. Force-control tool data

If you use a sensor that supports this function, the items would be as shown in Fig. 7. You would be required to enter the force-control tool data for accurate force control.
(『[F2]: System』 → 『4: Application Parameter』 → 『14: Force Control』 → 『2: Force-Control Tool Data』)

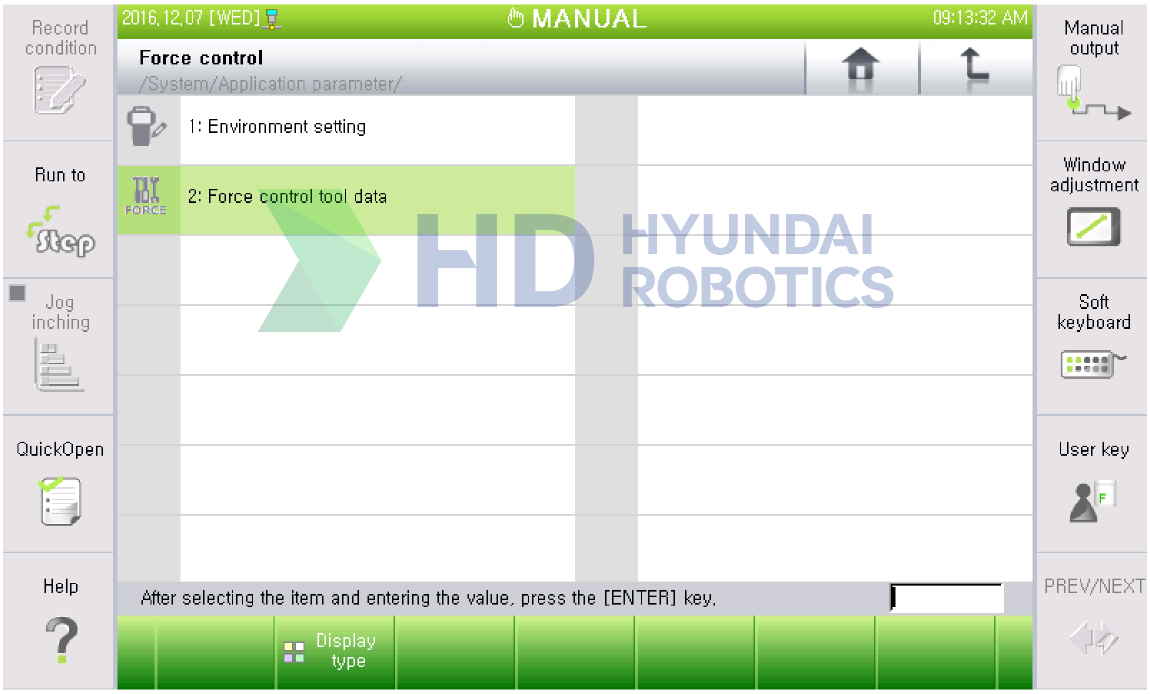

Figure 2.6 Force-control tool data menu

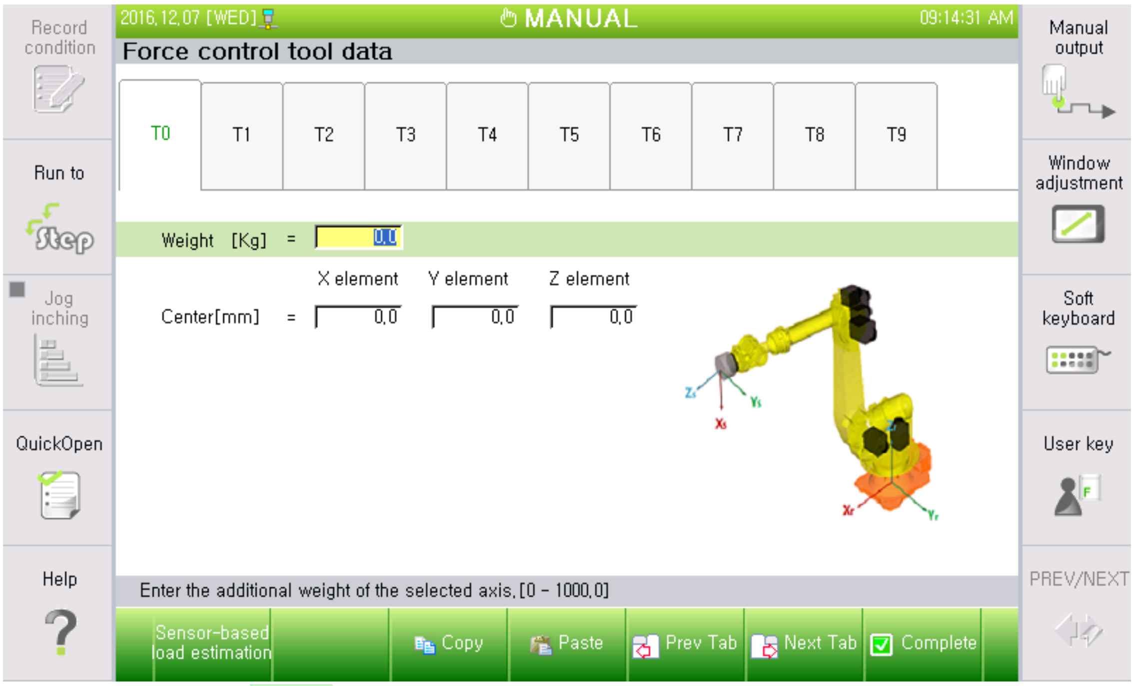

Figure 2.7 Force-control tool data screen

If you know the exact weight and center of the force-control tool data, you can directly input them. Input the position of the center based on the coordinate system of the end of the robot attached in the TP. If you do not have exact information on the force control tool, enter it using the sensor-based load estimation function. Up to 32 tool data can be saved, and existing tool data can be copied and pasted into other tool numbers.

2.4.2. Sensor-based load estimation

It is used to estimate the weight and center of the force control tool with the force sensor, which is unlike the existing one. If a sensor that does not use the force-control tool data is set, the force-control tool data would not be shown. Therefore, sensor-based load estimation would not available. The sensor-based load estimation can be executed in the following order.
(Press 『[F1]: Sensor-Based Load Estimation』 at the bottom of force-control tool data screen.)

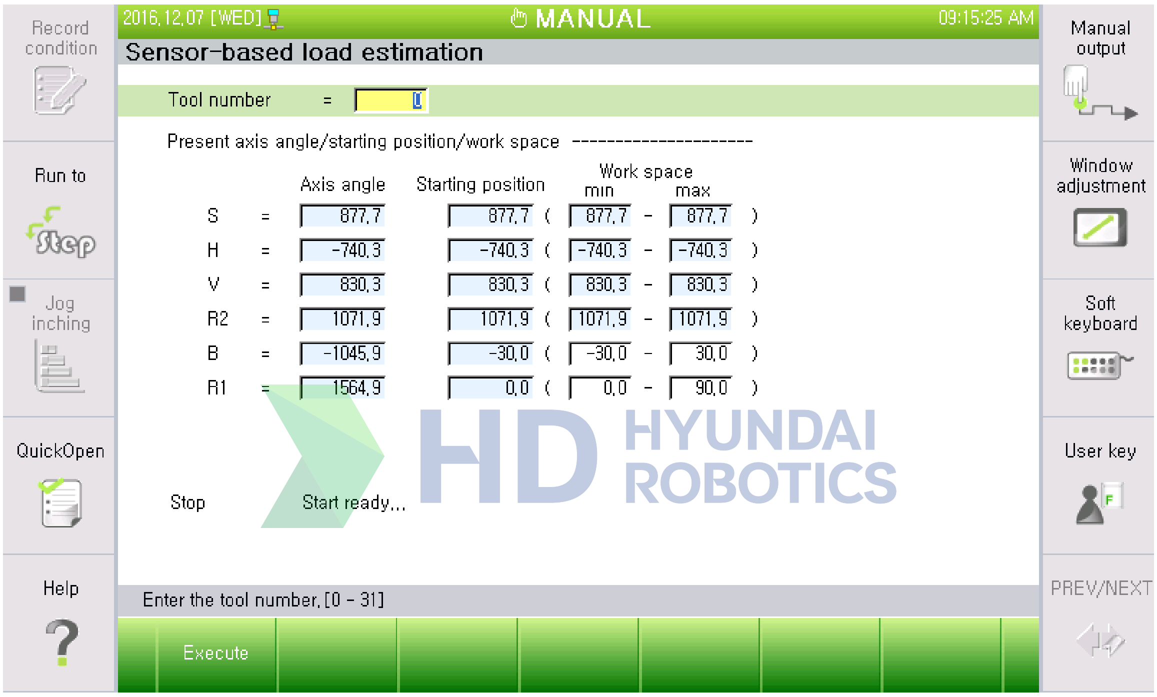

Figure 2.8 Sensor-based load estimation setting screen

① Enter a tool number to reflect the result of the load estimation.
② Enter the working area of axis B and R1. Only axis B and R1 operate for the load estimation so do not enter the working area for other axes.
Make sure that the robot does not interfere with any object within its periphery when setting it.
③ Turn on the motor using the [ENABLE] switch and then press 『[F1]: Execution』 key to perform the load estimation.
④ The result value is output after the load estimation is finished.
⑤ Press the 『[F7]: Exit』 key to set whether or not it should be reflected.
⑥ Check if the result is reflected to the set force-control tool number.

Note: The tool data and load estimation of the robot parameter handles any object attached to the robot flange as the tool data. Remember that the tool data / sensor-based load estimation exclusive for the operation tool attached to the sensor is different from the existing tool data / load estimation.

2.5. Description of Commands

2.5.1. ForceCtrl

Description	Sets factors for the force control function and turns it on/off		
Input	『[F6]: Enter Command』 → 『[F1]: Motion, I/O』 → 『Force Ctrl』		
Syntax	Force Ctrl ON, CRD=_,_,T=_,BC=_ Force Ctrl OFF		
Parameters	CRD	Reference coordinate system	▪ Reference coordinate system for the robot motion under force control (0: Base, 1: Robot, 2: Tool, 3: U, 4: Un) ▪ The No. 2 tool is the tool number of the robot based on the currently active one. ▪ The user coordinate system of No. 3 is based on the currently active one. ▪ Select No.4 to enter the user coordinate system number on the right side.
	T	Force-control tool number	▪ Select a force-control tool number to which the tool data is saved. (0-31) ▪ It is different from the tool number of the robot.
	BC	Bias clear	▪ Initialize the initial value of sensor to 0. (0: Disable, 1: Enable) ▪ Set BC to 1 only if the tool does not come contact with any external object.

2.5.2. FCset

<table>
<tr><td>Description</td><td colspan="3">Setting of factors required to execute the force control function</td></tr>
<tr><td>Input</td><td colspan="3">『[F6]: Enter Command』 → 『[F1]: Motion, I/O』 → 『FCset』</td></tr>
<tr><td>Syntax</td><td colspan="3">FCset Fd, X=_,Y=_,Z=_, Rx=_, Ry=_, Rz=_
FCset Dmp, Dt=_, Dr=_
FCset FLT, Ff=_, Bf=_, St=_, Ft=_, Sr=_, Fr=_</td></tr>
<tr><td rowspan="13">Parameters</td><td>Fd</td><td colspan="2">▪ Set the size of contact force and direction of contact to maintain
▪ Reference coordinate system: Coordinate system set with the Force Ctrl command (CRD)
▪ Unit: X, Y, Z → [N], Rx, Ry, Rz → [Nm]
▪ Size: X, Y, Z → -5,000–5,000[N], Rx, Ry, Rz → -1,400–1,400 [Nm]
(Set a value within the measurement range of the sensor.)
Ex.) X=-100: To maintain the force of 100 N in the -X direction of reference coordinate system</td></tr>
<tr><td rowspan="3">Dmp</td><td colspan="2">▪ Setting of smoothness of robot
▪ Size: 1–10 (smaller value means faster and more flexible motion)</td></tr>
<tr><td>Dt</td><td>Setting of translation (X, Y, Z) direction value</td></tr>
<tr><td>Dr</td><td>Setting of rotation (Rx, Ry, Rz) direction value</td></tr>
<tr><td rowspan="7">FLT</td><td colspan="2">▪ Setting of filter for force control</td></tr>
<tr><td>Ff</td><td>Cut-off frequency [Hz] of force data filter</td></tr>
<tr><td>Bf</td><td>Cut-off frequency [Hz] of bypass filter</td></tr>
<tr><td>St</td><td rowspan="2">Variable scale for the translation motion [N]
(Default: 0)</td></tr>
<tr><td>Ft</td></tr>
<tr><td>Sr</td><td rowspan="2">Variable scale for the rotation motion [Nm]
(Default: 0)</td></tr>
<tr><td>Fr</td></tr>
</table>

2.5.3. LIMIT

Description	Function to set max. operation area and robot speed	
Input	『[F6]: Enter Command』 → 『[F1]: Motion, I/O』 → 『LIMIT』	
Syntax	LIMIT POS, +X=_,-X=_,+Y=_,-Y=_,+Z=_,-Z=_ LIMIT VEL, X=_,Y=_,Z=_,RX=_,RY=_,RZ=_	
Parameter	POS	▪ Setting of robot operation area under force control, based on the starting position of the force control [mm] ▪ Reference coordinate system: Robot coordinate system
	VEL	▪ Setting of max. robot operation speed under force control [mm/s], [deg/s] ▪ Reference coordinate system: Coordinate system set using the Force Ctrl command (CRD).
Example	LIMIT POS,+X=500,-X=200,+Y=0,-Y=150,+Z=300,-Z=300 LIMIT VEL, X=200,Y=200,Z=200,RX=100,RY=100,RZ=100 ForceCtrl ON DELAY 10.0 ForceCtrl OFF	
Note	▪ The LIMIT command can be repetitively used between the Force Ctrl ON and Force Ctrl OFF, but the LIMIT POS is used to reset the operation area based on the **robot position with Force Ctrl ON**. ▪ The LIMIT POS and the LIMIT VEL must be set based on the robot coordinate system, while the coordinate system (CRD) must be set with the Force Ctrl command. ▪ Setting the LIMIT VEL to 0 means unforced control toward that direction. ▪ The LIMIT VEL can be used to limit the speed to control the flexibility of the robot by direction. Low speed reduces the flexibility, which is similar to increasing the Dmp. Therefore, set the Dmp for the direction that requires the fastest response, and control the remaining directions using the LIMIT VEL.	

2.5.4. _F*

Description	Current force sensor data A read-only variable	
Input	To enter a conditional statement → 『[F1]: Variable』 → 『[F6]: System』 → 『F*』 → . → 『[F1]–[F6]』	
Variable type	_F*.X	X-directional force on the reference coordinate system [N]
	_F*.Y	Y-directional force on the reference coordinate system [N]
	_F*.Z	Z-directional force on the reference coordinate system [N]
	_F*.Rx	X-directional torque of the reference coordinate system [Nm]
	_F*.Ry	Y-directional torque of the reference coordinate system [Nm]
	_F*.Rz	Z-directional torque of the reference coordinate system [Nm]
Example	WAIT _F*.X>=500	Wait until the X-directional force exceeds 500 N.
	MOVE L,S=3mm/s,A=1,T=0 UNTIL _F*.Y>=20	MOVE execution stops when the Y-direction force exceeds 20 N.
	IF _F*.Rz>=-10.0 THEN 3 ELSE 5	If the Z-directional torque is bigger or smaller than -10 Nm, move to line No.3 or line No.5, respectively.
Note	▪ The reference coordinate system of _F* is the coordinate system (CRD) set when entering the Force Ctrl command.	

2.5.5. P*

Description	Pose variable to obtain the current position of the robot A read-only variable	
Input	Position in all directions	To enter a conditional statement → 『[F1]: Variable』 → 『[F2]: Pose』 → 『P*』
	Position in individual directions	To enter a conditional statement → 『[F1]: Variable』 → 『[F2]: Pose』 → 『P*』 → . → 『R5: PREV/NEXT』 → 『[F1]-[F6]』
Configuration	With items No.8 and 9 of 『[F2]: System』 → 『1: User Interface』, select the coordinate system and value of P*.	
	P* coordinate system	Set the reference coordinate system to obtain the position of the robot.
	P* selection	Specify whether to obtain the position of the robot as a command or its current value.
Variable type	P*	Position of the reference coordinate system in all directions [mm]
	P*.X	X-directional position of the reference coordinate system [mm]
	P*.Y	Y-directional position of the reference coordinate system [mm]
	P*.Z	Z-directional position of the reference coordinate system [mm]
	P*.RX	RX-directional position of the reference coordinate system [deg]
	P*.RY	RY-directional position of the reference coordinate system [deg]
	P*.RZ	RZ-directional position of the reference coordinate system [deg]
Example	WAIT (P1.Z-P*.Z)<=0.1	Wait until the difference between the Z-directional position of set P1 and the current one of the robot becomes less than 0.1.
	IF P*.RX<P2.RX AND P*.RY<P2.RY THEN 9	If the RX-directional robot position and RY-directional one are smaller than the P2 value, move to line No. 9. Move to the next line if the condition has not been met.
Note	▪ For the P*, set the P* coordinate system and P* selection in 『[F2]: System』 → 『1: User Interface』. ▪ Set the current value to the P* selection to obtain the current position of the robot	

2.6. Program examples

Refer to the following program examples to develop suitable JOB programs.

2.6.1. Example of part assembly

This example can be used as reference to assemble parts using the force control function. Modify the parameters and conditional statement according to your conditions.

```
로봇 프로그램 __
    Robot:HS165-11, 6axes, 1steps
S1  MOVE L,P1,S=50mm/s,A=1,T=0
    LIMIT POS,+X=40,-X=5,+Y=5,-Y=5,+Z=5,-Z=5
    LIMIT VEL,X=5,Y=3,Z=3,RX=1,RY=1,RZ=1
    FCset Fd,X=10,Y=0,Z=0,Rx=0,Ry=0,Rz=0
    FCset Dmp,Dt=5,Dr=5
    FCset FLT,Ff=40,Bf=300,St=0,Ft=0,Sr=0,Fr=0
    ForceCtrl ON,CRD=1,T=0,BC=1
    WAIT (P2.X-P*.X)<=0,40,5
  5 ForceCtrl OFF
    END
```

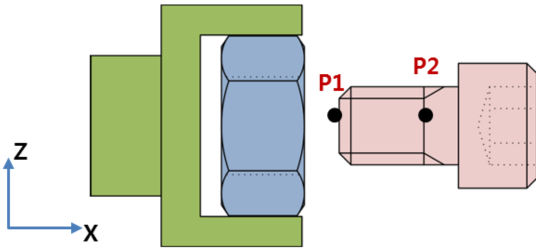

Figure 2.9 Example of part assembly program

Table 2-1 Example of part assembly program

Robot motion	▪ Moves to the position P1 saved in S1 and then starts the force control. ▪ Once the force control starts, it starts to move P2 in order to reach the force set in the X direction of the robot coordinate system. ▪ When the robot reaches P2, it determines that the assembly is over, so its exits the program.
Max. operation area (LIMIT POS)	▪ Sets the force control range based on the robot coordinate system. ▪ X=-5~40 [mm], Y=-5~5 [mm], Z=-5~5 [mm]
Max. operation speed (LIMIT VEL)	▪ Based on the robot coordinate system (given that Force Ctrl ON, CRD=1) ▪ X=5 [mm/s] ▪ Y, Z = 3 [mm/s] ▪ RX, RY, RZ = 1 [deg/s]
Size of force to control (FCset Fd)	▪ It is controlled to maintain the force of Y, Z, Rx, Ry, Rz = 0 : 0N. ▪ X=10 [N]: A 10 N contact force is maintained in the X direction of the robot coordinate system. To assemble, set the size of the force considering the friction between parts.
Robot conditions for force control (FCset Dmp, FLT)	▪ Dt=5, Dr=5: 5-step flexibility control in all directions ▪ FLT: Flexible control with Ff and Bf values. Smaller value results in smoother motion, but they can be accompanied with the delay.
ForceCtrl ON, CRD=1, T=0, BC=1	Execution of force control ▪ CRD=1: Force control operation based on the robot coordinate system (1) ▪ T=0: Force control tool data No. 0 is used. ▪ BC=1: Initializes the force sensor data to start the force control
WAIT (P2.X-P*.X)<=0, 40, 5	▪ The force control is performed until the difference is 0 or less between P*.X (current X-directional position of robot) and P2.X (X-directional position of the robot with the completed assembly). ▪ 40, 5: If the condition is not met within 40 seconds, move to line No. 5 (Force Ctrl OFF) to exit the force control.
ForceCtrl OFF	End of force control

2.6.2. Example of machining (deburring and chamfering)

The following is an example of machining (deburring or chamfering) using the force control. Develop the program for deburring or chamfering with the following example.

```
로봇 프로그램 __
S1  MOVE L,S=200mm/s,A=1,T=1
S2  MOVE L,S=50mm/s,A=1,T=1
    LIMIT POS,+X=20,-X=20,+Y=0,-Y=0,+Z=0,-Z=0
    LIMIT VEL,X=0,Y=0,Z=0,RX=0,RY=0,RZ=0
    FCset Fd,X=-10,Y=0,Z=0,Rx=0,Ry=0,Rz=0
    FCset Dmp,Dt=1,Dr=5
    FCset FLT,Ff=40,Bf=300,St=0,Ft=0,Sr=0,Fr=0
    ForceCtrl ON,CRD=1,T=0,BC=1
S3  MOVE L,S=50mm/s,A=1,T=1
S4  MOVE L,S=50mm/s,A=1,T=1
    LIMIT VEL,X=5,Y=0,Z=0,RX=0,RY=0,RZ=0
S5  MOVE L,S=100mm/s,A=1,T=1
    FCset Fd,X=0,Y=0,Z=0,Rx=0,Ry=0,Rz=0
    ForceCtrl OFF
    END
```

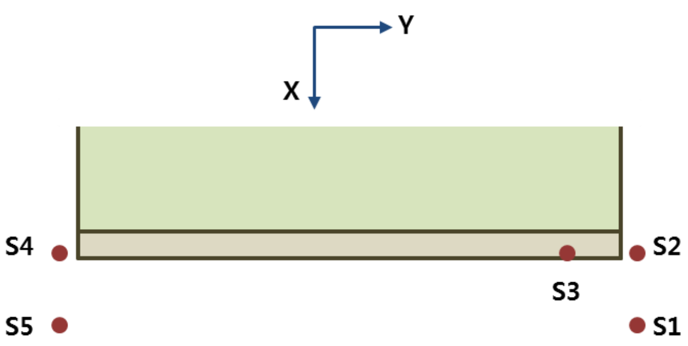

Figure 2.10 Example program of machining (deburring and chamfering)

Table 2-2 Example program of machining (deburring and chamfering)

Robot motion	▪ Move from S1 to the starting point of the work, S2. ▪ Then, turn on the force control but set the LIMIT VEL to 0 so that the force control would not be applied. ▪ Move to S3 without the force control. (Position of S3: Set with about a 10-mm interval from S2.) ▪ Move S4 with the force control by setting the LIMIT VEL. ▪ Move S5 with the force control off by changing the LIMIT VEL to 0. Then, turn off the function to exit the program.
Max. operation area (LIMIT POS)	▪ Set the force control working range from the position of S2 to start the force control based on the robot coordinate system. X=-20–20 [mm] ▪ Only allows X-directional force control.
Max. operation speed (LIMIT VEL)	▪ Based on the robot coordinate system (given that Force Ctrl ON is CRD=1): ▪ S2, S3: 0 [mm/s] ➔ Force control OFF in all directions ▪ S4: X=5 [mm/s] ➔ X-directional force control ON ▪ S5: 0 [mm/s] ➔ Force control OFF in all directions
Size of force to control (FCset Fd)	▪ X=-10 [N]: A 10 N contact force is maintained in the -X direction. ▪ Set the size of the force considering the degree of machining.
Robot conditions for force control (FCset Dmp, FLT)	▪ Dt=1: X-directional 1-step flexibility control ▪ FLT: Flexible control with Ff and Bf values Smaller value results in smoother motion but might cause delay
ForceCtrl ON, CRD=1, T=0, BC=1	Execution of force control ▪ CRD=1: Force control operation based on the robot coordinate system (1) ▪ T=0: Force control tool data No. 0 is used. ▪ BC=1: Initializes the force sensor data to start the force control.
ForceCtrl OFF	End of force control

2.6.3. Example of machining (finishing)

The following is an example of surface processing (finishing) during machining with the force control. Use the following example to develop the program to maintain certain contract force while machining along the shape of the surface.

```
로봇 프로그램 __
S1    MOVE L,S=50mm/s,A=1,T=1
      LIMIT POS,+X=500,-X=500,+Y=500,-Y=500,+Z=500,-Z=500
      LIMIT VEL,X=0,Y=0,Z=0,RX=0,RY=0,RZ=0
      FCset Fd,X=0,Y=0,Z=20,Rx=0,Ry=0,Rz=0
      FCset Dmp,Dt=2,Dr=5
      FCset FLT,Ff=40,Bf=300,St=0,Ft=0,Sr=0,Fr=0
      ForceCtrl ON,CRD=2,T=0,BC=1
S2    MOVE L,S=5mm/s,A=1,T=1 UNTIL ABS(_F*,Z)>=5
S3    MOVE L,S=5mm/s,A=1,T=1
      LIMIT VEL,X=0,Y=0,Z=2,RX=0,RY=0,RZ=0
S4    MOVE L,S=5mm/s,A=1,T=1
S5    MOVE L,S=5mm/s,A=1,T=1
S6    MOVE L,S=5mm/s,A=1,T=1
S7    MOVE L,S=5mm/s,A=1,T=1
      LIMIT VEL,X=0,Y=0,Z=0,RX=0,RY=0,RZ=0
      ForceCtrl OFF
      END
```

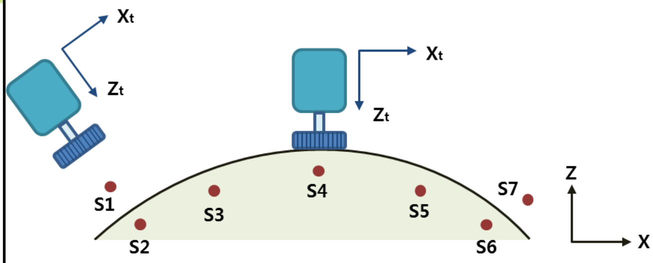

Figure 2.11 Example program of machining (finishing)

Table 2-3 Example program of machining (finishing)

Robot motion	▪ Move to S1 to turn on the force control. Set the LIMIT VEL to 0 to move without using the force control. ▪ Teach S2 to contact the work and move until the Z-directional contact force exceeds 5. ▪ Move S3 with the force control to S6 by setting the Z-directional LIMIT VEL. ▪ Move S7 with the force control off by changing the LIMIT VEL to 0. Then, turn off the function to exit the program.
Max. operation area (LIMIT POS)	▪ Set the force control working range from the position of S1 to start the force control based on the robot coordinate system. ▪ X=-500~500 [mm], Y=-500~500 [mm], Z=-500~500 [mm]
Max. operation speed (LIMIT VEL)	▪ Based on the tool coordinate system (given that Force Ctrl ON is CRD=2): ▪ S2: 0 [mm/s] ➔ Force control OFF in all directions ▪ S3~S6: Z=2 [mm/s] ➔ Z-directional force control ON ▪ S7: 0 [mm/s] ➔ Force control OFF in all directions
Size of force to control (FCset Fd)	▪ Z=20 [N]: A 20 N contact force is maintained in the +Z direction based on the tool coordinate system. ▪ Set the size of the force considering the degree of machining.
Robot conditions for force control (FCset Dmp, FLT)	▪ Dt=2: Z-directional 2-step flexibility control ▪ FLT: Flexible control with Ff and Bf values Smaller value results in smoother motion but might cause delay
ForceCtrl ON, CRD=1, T=0, BC=1	Execution of force control ▪ CRD=2: Force control operation based on the tool coordinate system (2) ▪ T=0: Force control tool data No. 0 is used. ▪ BC=1: Initializes the force sensor data to start the force control
ForceCtrl OFF	End of force control

2.7. Force sensor data monitoring

The force sensor data can be monitored while executing the force control. The monitoring data is effective with the force control configuration and only updated with the ForceCtrl ON command. The displayed data include the force and torque values on the reference coordinate system for the force control.

(『[F1]: Service』 → 『1: Monitoring』 → 『23: Force Sensor Data』)

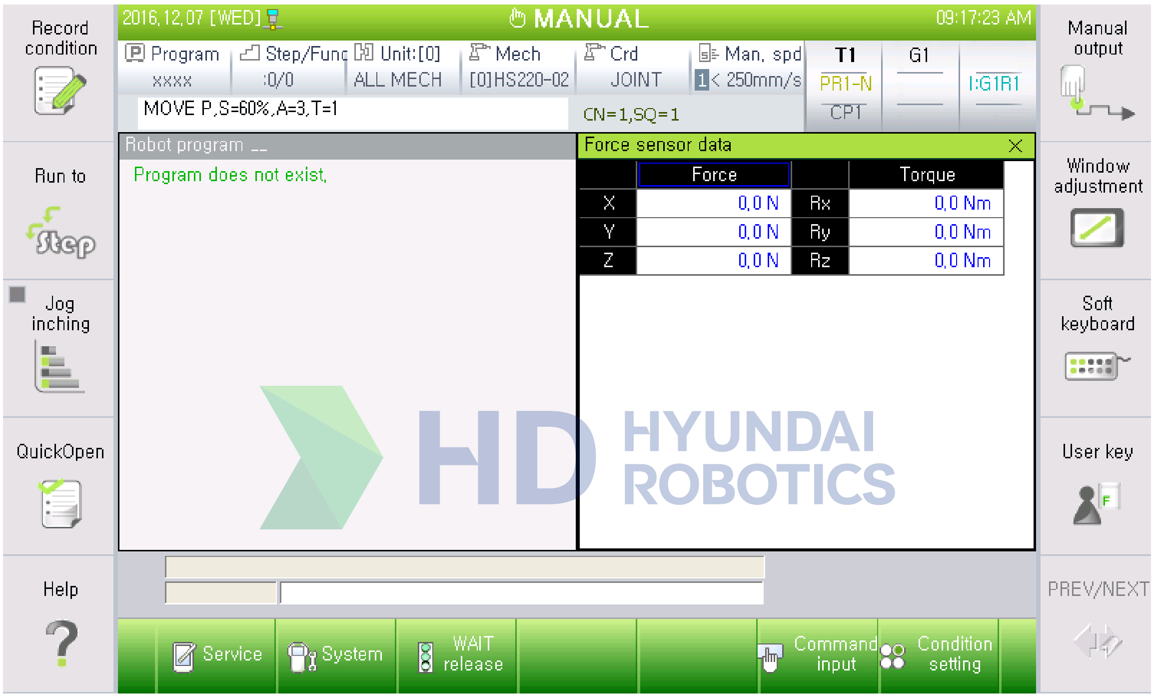

Figure 2.12 Force sensor data monitoring

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3

Error and Warning

3.1. Error

Code	Message	Cause	Action
E0258	Network (EN2) setting error	Network setting of EN2 (IP address, subnet mask, and gateway) is incorrect.	Set the network of EN2 correctly by referring to the function manual.
E0259	Force sensor communication failed	The cable is disconnected or the power is disconnected from the sensor.	Check the cable and power connection between the sensor and controller.
E0260	Force control disabled	The force control is disabled.	Enabled it through the [Force Control]-[Configuration Setting].

4

Appendix

4.1. 6-axis force/torque sensor (from ATI)

This is about the Ethernet-based 6-axis force/torque sensor manufactured by ATI. Refer to it using the function manual.

① Components: 6-axis force/torque sensor, net box, sensor cable, power supply, and LAN cable
② Measuring ranges of sensors

Table 4-1 Measuring range of 6-axis force/torque sensor

Sensor	Delta	Theta	Omega
Axes	SI660-60	SI2500-400	SI7200-1400
Fx, Fy(±N)	660	2500	7200
Fz(±N)	1980	6250	18000
Tx, Ty(±Nm)	60	400	1400
Tz(±Nm)	60	400	1400

③ Attachment of sensor: Attach the sensor in a manner that the coordinate system of the sensor, as shown in Fig. 1, matches the one (Xs, Ys, Zs) marked at the end of the robot as shown in Fig. 2.

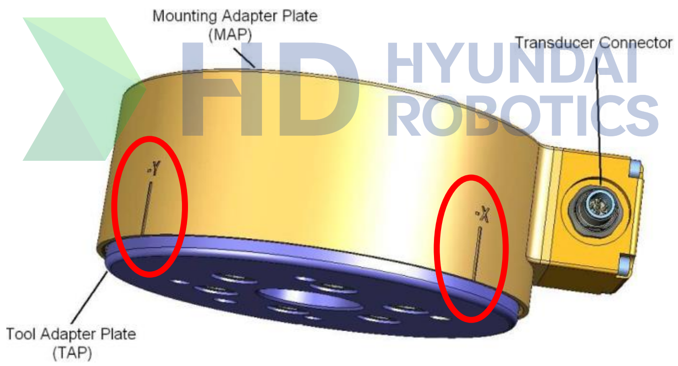

Figure 4.1 Coordinate system of sensor

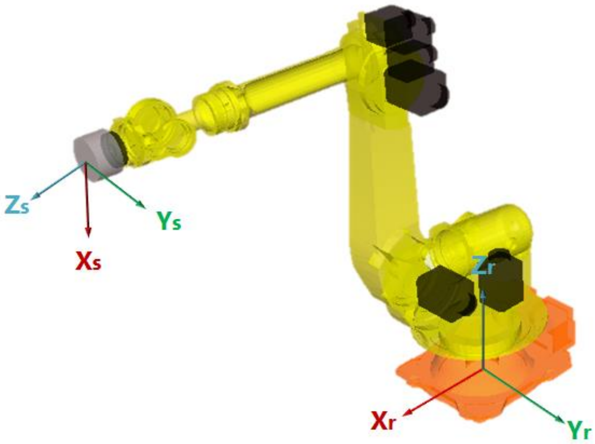

Figure 4.2 Coordinate systems of sensor (Xs, Ys, Zs) and robot (Xr, Yr, Zr)

④ Cable connection: Connect the force sensor with the net box, and the net box with the robot controller using the sensor and LAN cables, respectively.

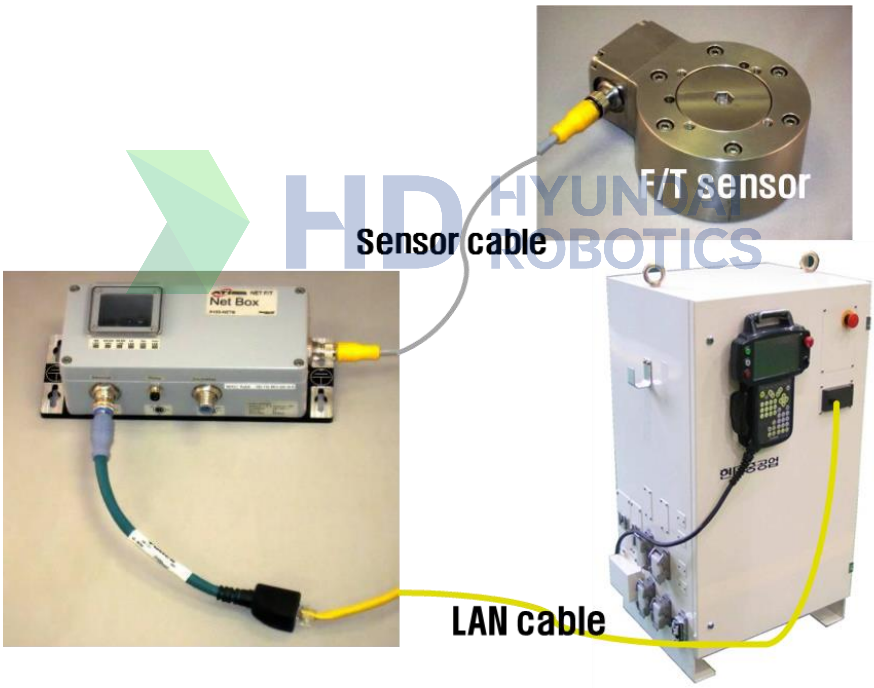

Figure 4.3 Sensor-net box-robot controller cable connection

⑤ Power connection: Connect the power cable to the net box to supply the power (24 V). Check the indicators of the net box. If the cables and power were correctly connected, the indicator would be as shown in Fig. 4. If not, check the cable and power connections again.

Figure 4.4 Checking of power connection to net box and indicators

4.2. Uniaxial load cell (from Burster) and serial communication module (from Beckhoff)

This section describes the serial communication module (RS232) from Beckhoff and uniaxial load cell from Burster. Refer to it with the function manual.

① Components: Uniaxial load cell (amp connected), serial communication module (RS232), and serial cable (RS232)

② Measuring ranges of sensors: The model and measuring range of the amp-connected models are shown in Table 1. Set Fd within the range by referring to this table.

Table 4-2 Measuring range of load cell

Sensor	Measurement range
8532-5500	0 ~ 500 N
8532-6001	0 ~ 1 KN
8532-6002	0 ~ 2 KN
8532-6005	0 ~ 5 KN
8532-6010	0 ~ 10 KN
8532-6020	0 ~ 20 KN

③ Attachment of sensor: To use the uniaxial load cell, install it in a manner that the +Z direction of the tool coordinate system and that of the uniaxial load cell in Fig. 1 match.

Figure 4.5 Coordinate system of sensor

④ Connection of serial communication module: The serial communication module consists of RS232 coupler (BK8100), bus terminal (KL3100), and bus end terminal (KL9010). Assemble them in the order of RS232 coupler, bus terminal, and bus end terminal. Then, set the address setting terminals on the communication module (X1 to 1 and X10 to 0).

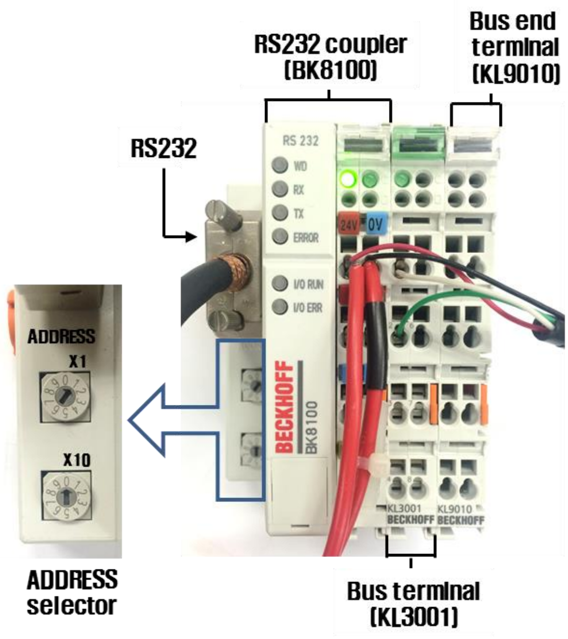

Figure 4.6 Serial communication module

⑤ Connection of load cell line: Connect the signal and power lines of the load cell to the communication module by referring to Fig. 2 and Table 2.

Table 4-3 Wiring between the load cell and communication module

	Load cell	Serial communication module
Signal line (+)	White line	But terminal 1
Signal line (-)	Green line	But terminal 2
Power (+)	Red line	24 V terminal of RS232 coupler
Power (-)	Black line	0 V terminal of RS232 coupler

⑥ Power connection: Connect the power of the serial communication module to the power of the robot controller in order to supply power to the serial communication module and the load cell. As the load cell and serial communication module require 24 V, connect the 24 V and 0 V terminals of the serial communication module to which the load cell is connected to those of the controller, respectively,

⑦ Connection of serial cable: Connect the serial port of the serial communication module and serial port #2 of the robot controller using the serial cable. Use a cross cable with a length of under 15 m as the serial cable.

⑧ Checking of indicators: With the signal, power, and serial cables connected, supply power to the robot controller to check if the green LED of serial communication module would be turned on, as shown in Fig. 2. If the red LED is turned on with the force control, check the connection and communication settings of modules.

⑨ Communication setting: Set the communication setting of serial port #2 by referring to section 2.2.B of the function manual and Table 3.

Table 4-4 Serial communication setting

Baudrate	38400
Number of characters	8
Stop bit	1
Parity bit	Even
Echo	Disabled
Use of port	Sensor
Communication type	RS232

⑩ Command setting: The uniaxial load cell only measures the force (to press the sensor) in the -Z direction of tool coordinate system, so set the force control commands based on the Z direction of the tool coordinate system. By referring to the section 2.5 of function manual and Table 4, set suitable parameters for each command.

Table 4-5 Command parameter

<table>
<tr><td rowspan="3">ForceCtrl</td><td>CRD</td><td>Reference coordinate system</td><td colspan="2">▪ Not applicable</td></tr>
<tr><td>T</td><td>Force control tool number</td><td colspan="2">▪ Not applicable</td></tr>
<tr><td>BC</td><td>Bias Clear</td><td colspan="2">▪ Set BC to 1 if the tool does not come in contact with any external object.</td></tr>
<tr><td rowspan="3">FCset</td><td>Fd</td><td colspan="3">▪ Set the +Z-directional pressurization.</td></tr>
<tr><td rowspan="2">Dmp</td><td>Dt</td><td colspan="2">Set the Z-directional value.</td></tr>
<tr><td>Dr</td><td colspan="2">Not applicable</td></tr>
<tr><td rowspan="2">LIMIT</td><td>POS</td><td colspan="3">▪ Setting of robot operation area under force control, based on the starting position of force control [mm]
▪ Reference coordinate system: Robot coordinate system</td></tr>
<tr><td>VEL</td><td colspan="3">▪ Setting of max. robot operation speed under force control [mm/s]
▪ Reference coordinate system: Tool coordinate system</td></tr>
</table>

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