Hubo-i:

Hubo Protocol commander

Key definitions

[PREV]:	Display page backward.
[NEXT]:	Display page forward
[ESC]:	Escape from the current menu
[ENT]:	Enter the menu
[UP]	Up Arrow key
[DOWN]	Down Arrow key
[LEFT]	Left Arrow key
{RIGHT]	Right Arrow key
1[FET ON]:	Turn ON motor driver.
2[FET OFF]	Turn OFF motor driver.
3[ENC ZERO]	Set position value to zero and Reset error flags.
4[SRV ON];	Turn ON feedback controller.
5[SRV OFF]:	Turn OFF feedback controller.
6[HOME]:	Execute homing process.
7[FUNC 1]:	Toggle the control mode between ‘position’ and ‘current’.
8[FUNC 2]:	Reserved
9[SCAN]:	Scan and find the channel.
0[MENU]:	Enter the MENU function.
#[PLUS]	+ sign key
*[MINUS]	- sign key

Motor control commander

1. Scan menu: Scan and Select the board

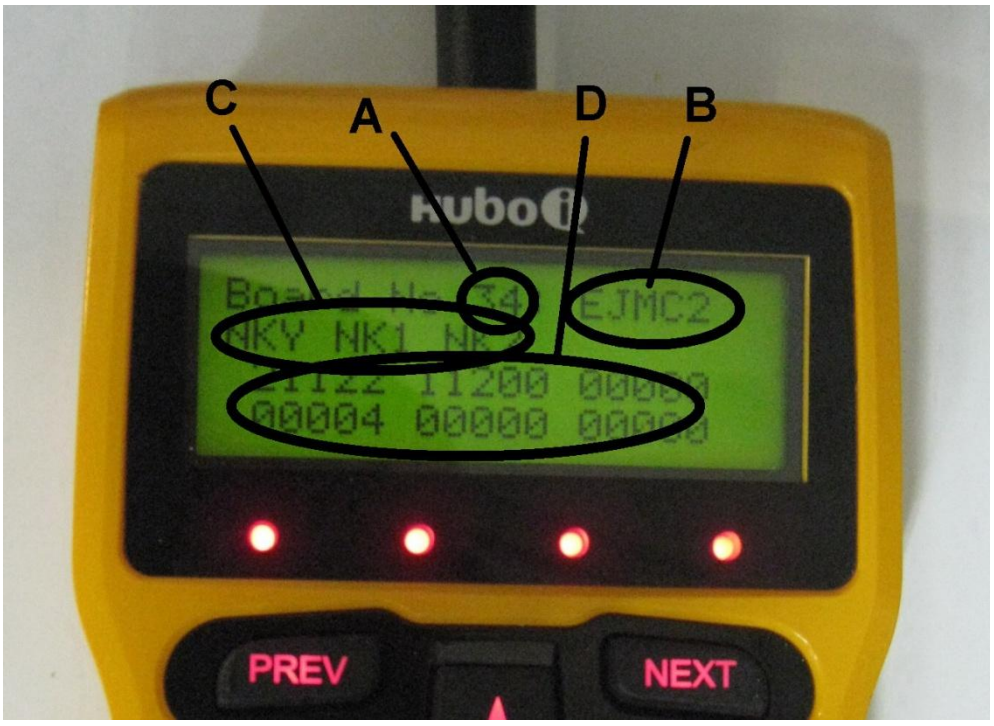
Select the board by moving cursor with arrow keys. Press ENT to enter the Control mode of the Board. The display shows you detail information about the board as the cursor moves:

A. Board No: Board number or BNO.

B. Board attribution number

JMCx :	Joint Motor Controllers
EJMCx:	Extended JMC
FTx	F/T sensors
IMUx:	IMU sensors

C. Name of Axis. See Appendix.



D. Type of boards:

1: 1CH – 2 Motor BLDC Board

2: 2CH – 2 Motor BLDC Board

3: 3CH DC motor Board for Neck joint or 2CH DC Board for Wrist

4: 1CH – 1 Motor BLDC Board for Waist

5: 5CH -5 Motor Board for Hand(Finger)

6: F/T Sensor for Foot

7: Firmware for IMU Board

8: F/T Sensor for Wrist

9: Smart Power Control Board

0: Not available or CAN disconnected

2. Motor control main menu: Control motors.

This menu generates motor commands and displays all the status of the boards.

Displays:

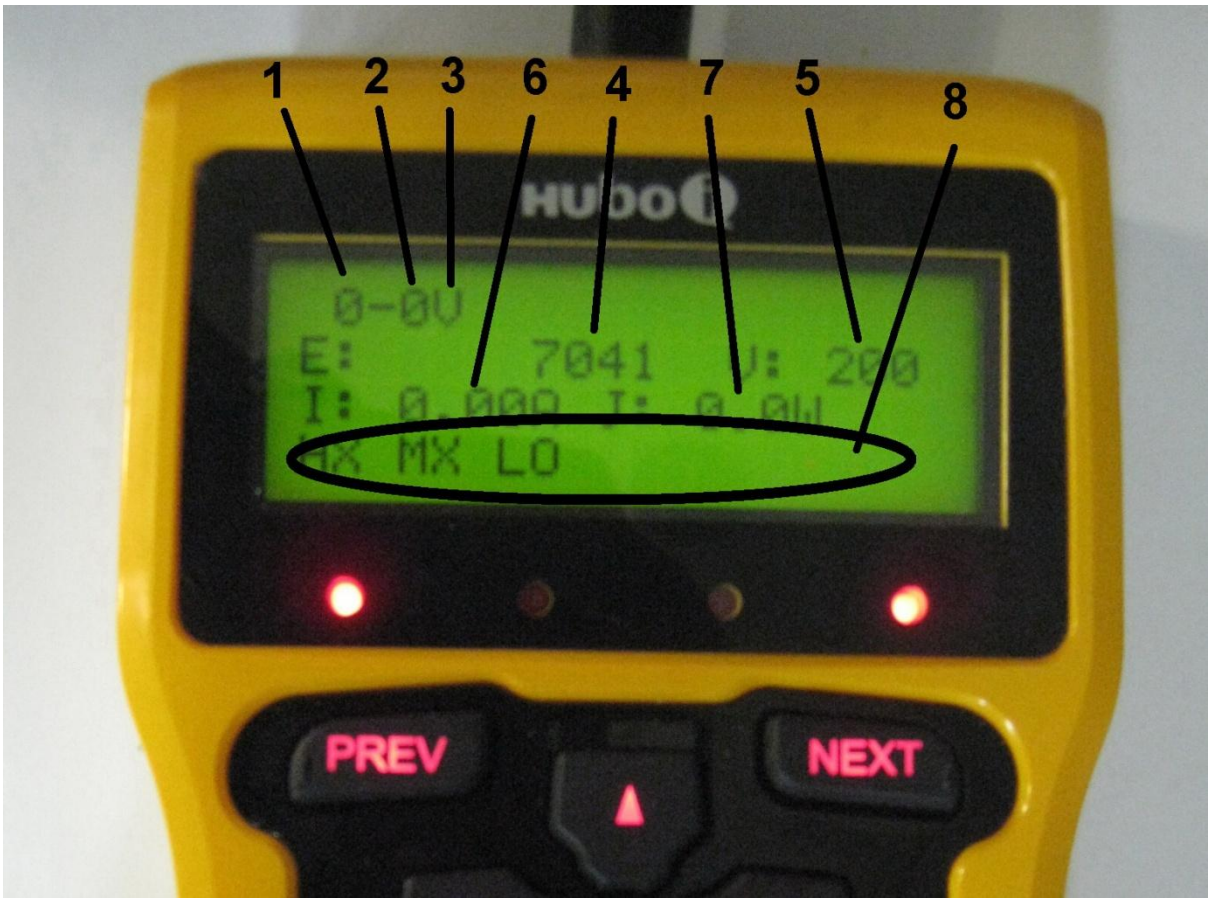
1. **BNO number**
2. **Motor channel number**
3. **Control mode**

    D: Open loop mode

    V: Velocity control mode

    P: Position control mode

    C: Current control mode



4. **Encoder readout**
5. **Command value corresponding to control mode.**
6. **Current in Ampare**

7. **Estimated thermal load for the motor in Watt**.
8. **Board Status and flags:**

HX:	Servo OFF
HO:	Servo ON
MX:	Feedback OFF
MO:	Feedback ON
LX:	Limit switch OFF
LO:	Limit switch ON
F0:	Motor 0 FAULT detected
F1:	Motor 1 FAULT detected
E:	Big Error or Encoder failure detected
B:	Big Input error detected
J:	Motor Jam detected
S:	PWM output saturation detected
L:	Lower limit detected
U:	Upper limit detected
M0:	Motor 0 failed
M1:	Motor 1 failed
V:	Over Max. velocity command detected
A:	Over Max. acceleration command detected

Basic Functions

A. Driver Enable

Long pressing of 1[FET ON] button enables motor driver. 'HO' is displayed

B. Driver Disable

Long pressing of 2[FET OFF] button disables motor driver. 'HX' is displayed.

C. Reset Driver

Long pressing of 3[ENC ZERO] button sets encoder value to zero and reset error flag to zero.

D. Feedback ON

Long pressing of 4[SRV ON] button turns on the feedback control. If the control mode is 'position' then the motor will be position locked. 'MO' or 'CO' are displayed according to the control mode..

E. Feedback OFF

Long pressing of 5[SRV OFF] button turns off the control. If the control mode is 'position' then the motor will be position unlocked. 'MX' or 'CX' are displayed according to the control mode..

F. Execute Homing process

Long pressing of 6[HOME] initiates homing process. The status of searching process will be displayed as follows:

??:	Search for a limit switch.
L :	Limit switch found
LB:	Both limit switch and Index are found
LZ:	Start to move to Offset position.
OF	Move to Offset position
OK:	Homing process is successfully done.
XL:	Backward search of limit switch is failed
LX:	Search of Index is failed
XX:	Search of limit switch is failed

If the homing process is successfully completed the position feedback loop is turned on with displaying 'HO' and "MO". The command mode becomes Open loop mode (D). If the homing process is failed the servo driver and feedback are disabled with displaying 'HX; and 'MX'.

G. Change control mode

Long pressing of 7[FUNC 1] button toggles the mode between 'Position' and 'Current'. Servo driver and feedback control are disabled with displaying 'HX; and 'MX'

Commands:

[NOTE: Symbol Definition]

	Symbol	Unit	BNO 0 ~ 11, 35	BNO 32~34	BNO 36, 37
Encoder Resolution	Er	BAU	4,000	128	64
CAN rate	Cr	Hz	200	100	100
Sampling rate	Fs	Hz	1,000	1,000	1,000
Sampling Period	Ts	sec	0.001	0.001	0.001
Encoder counts	P	BAU	-	-	-

BAU=Basic Angle Unit.

There are two modes for commanding motor: Open loop and closed loop. There are also three kinds of closed loop feedback control modes: current, velocity and position control.

User can select one out of them by changing the control mode by [PREV] and [NEXT] keys or by 7[FUNC 1].

A. Open loop mode (D)

1. Enable servo driver by pressing 1[FET ON] button for more than 1 sec until beep sounds. Confirm 'LO' is displayed.
2. Change duty value by [UP] and [DOWN] keys. The value varies from 0(%) to 100(%).
3. Run the motor in the direction as pressing the arrow keys, [LEFT] or [RIGHT].
4. Long pressing of 2[FET OFF] button disables servo driver. 'LX' confirms the servo off.

B. Velocity mode (V)

1. Enable feedback controller by pressing 4[SRV ON] button for more than 1 sec until beep sounds. Confirm 'MO' and 'LO' are displayed.
2. Change velocity value by [UP] and [DOWN] keys. The value of velocity (v) is given by

   v = P / Ts

   Thus the speed of motor in rpm can be calculated by

   (rpm) = v * Fs / Er * 60

   For example, Velocity value= 200 gives you 3000 rpm.
3. Run the motor in the direction as pressing the arrow keys, [LEFT] or [RIGHT].
4. Long pressing of 5[SRV OFF] button disables servo driver. 'MX' and 'LX' confirm the servo and feedback off.

C. Position mode (P)

1. Enable feedback controller by pressing 4[SRV ON] button for more than 1 sec until beep sounds. Confirm 'MO' and 'LO' are displayed.
2. Change position value by [UP] and [DOWN] keys. The value of position is given by encoder counts.
3. Long pressing of 5[SRV OFF] button disables servo driver. 'MX' and 'LX' confirm the servo and feedback off.

D. Current mode(C)

1. Long pressing the button 7[FUNC 1] toggles the modes between 'velocity' and 'current'.
2. Enable feedback controller by pressing 4[SRV ON] button for more than 1 sec until beep sounds. Confirm 'MO' and 'LO' are displayed.
3. Change current value by [UP] and [DOWN] keys. The value of current is given by Ampare.

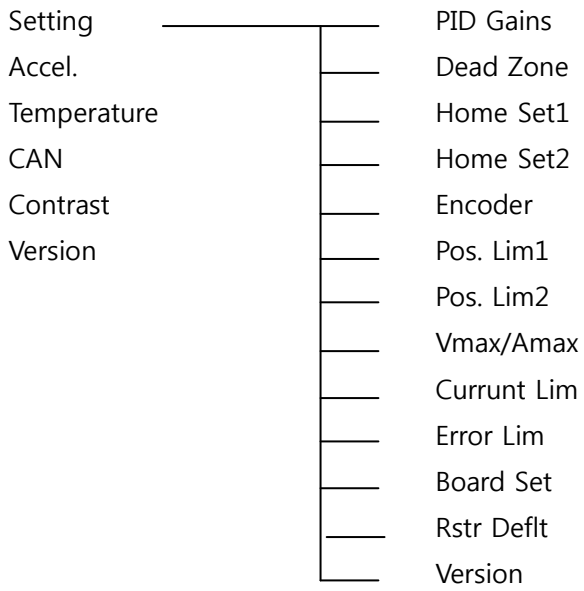
4. Long pressing of 5[SRV OFF] button disables servo driver. 'MX' and 'LX' confirm the servo and feedback off.

Changing the channel

Press [ENT] button for more than 1 sec until beep sounds. Change the channel with number keys when the cursor blinks at the channel number. Press [ENT] shortly to set the channel.

Setting the parameters

Press 0[MENU] button for more than 1 sec until beep sounds. Menu will be listed as follows:



A. Accel.: Set the acceleration value for velocity and position control. The value of acceleration (a) is given by

$(rad/sec^2) = 2\pi * a * Fs^2 / Er$ or

$(P/sec^2) = a * Fs^2$

B. Temperature: Display the temperature of the target board in degree C.

C. CAN: Set the CAN rate in Hz.

D. Contrast: Adjust the LCD contrast by pressing [LEFT] or [RIGHT] buttons.

E. Version: Display HUBO-i version number.

F. Setting: Enter the sub-menu for each channel.

Sub-menus for Setting

A. PID Gains: Set the PID gain of velocity and position control. PID gain is given by

$$(\mathrm{PWM}) = (\mathrm{Kp} + \mathrm{Kd}\frac{\mathrm{d}}{\mathrm{dt}} + \mathrm{Ki}\int \mathrm{dt})(\mathrm{postion\ error})/1000.$$

For current control mode, the PD controller is used with low pass filter for current measurement with cut off frequency, Kf. Kp and Kd are scaled by 1000 as above and Kf is given by Hz.

B. Dead Zone: Dead zone value is determined by FET characteristics. The value is given by encoder counts.

C. Home Set1: Set motor homing parameters 1. There are three values to be set:
Offset: Encoder value to be offset from Index position of the encoder
Home Lim: Search range for limit switch. The value is given by rotation counts of the motor.

Lim dir.: Direction to search a limit switch.

D. Home Set2: Set motor homing parameters 2. There are four or five parameters to be set.
V_max1: Search velocity to find a limit switch.
V_max2: Velocity to get offset from the Index position.
A_max: Acceleration to reach V_amx1 and V_max2.
Lim Mode: Set search mode
0: Search home with limit switch and Index signal
1: Search home with limit switch only
2: Search home with motor stops with the prescribed pwm duty value in %. Default value is 25%. This value can be changed by re-entering Home Set2 menu if it is not shown.

E. Encoder: Set encoder resolution and motor direction
Enc Res: Encoder resolution
Auto Scale: Set auto scale. Default is 1. This function is ignored except finger control boards.
Motor Dir: Set Motor running direction. 1:CW, 0:CCW

F. Pos Lim1:Set lower limit of the motor position
Pos Lim1: Lower limit of the motor position in encoder counts.
Enable(1/0): Enable(1) or disable(0) lower limit function. This function works for velocity and position modes only. If this function is enabled, the motor will stop

below in this position value.

G. Pos Lim2: Set upper limit of the motor position

Pos Lim2: Upper limit of the motor position in encoder counts.

Enable(1/0): Enable(1) or disable(0) lower limit function. This function works for velocity and position modes only. If this function is enabled, the motor will stop over this position value.

H. Vmax/Amax: Set the value for Vmax and Amax. Vmax limits the excessive velocity command to up to Vmax.

$(rpm)_{max}$ = Vmax * Fs / Er *60

Default value of Vmax=1500 yields 22,500 rpm or 2,356 rad/sec

Amax also limits the excessive acceleration command to up to Amax.

$(rad/sec^2)_{max}$ = 2π * Amax * Fs^2 / Er

Default value of Amax=20(P/Ts) yields 31,415 rad/sec^2.

I. Current limit: Set JAM and Power saturation limit.

JAM: Disable motor driver and JAM error flag will be issued if [JAMD]% of duty sustained for [JAM_LIM/10] seconds without movement.

Power Sat: Disable motor driver and power saturation flag will be issued if full duty sustained for PWM_LIM second.

Default values

	Unit	BNO 0 ~ 11,35	32, 33	34	36, 37
JAM_LIM	0.1 sec	3	15	15	15
JAMD	%	50	50	40	80
PWM_LIM	0.1 sec	5	10	10	20
LIMD	%	25	25	20	25
I_ERR	BAU	30,000	10,000	120	120
B_ERR	BAU	20,000	10,000	400	1000
T_MAX	degC	45	45	45	45

J. Error limit: Set Error limits. There are three parameters to be set.

Input err (I_ERR): Disable motor driver Set maximum input reference command change in Cr^{-1} sec. I_ERR can be converted to (rpm) by

$(rpm)_{I\_ERR}$ = I_ERR * Cr / Er * 60.

(ex) $(rpm)_{I\_ERR}$ =30000 * 200 /4000 * 60 = 90,000 (rpm)

Big err (B_ERR): Disable motor driver. Set maximum error between reference and position.

Max. temperature warning(T_MAX): Set the warnig temperature.

K. Board set

Board No: Change board number (BNO). Turn off and re-boot the board to initialize the parameters.

CAN rate: Read only. This value shows actual CAN rate measured by the board's internal clock.

No of CH: Read only.

L. Rstr Deflt: Restore board's parameter with default values. Offset value is remained unchange. Press [ENT] button for 1 second until beeps to execute this function

.

M. Version: Read only. Displays version number.

Seven Segment Display of Motor Driver Board.

1. Initialization

A. **Hard initialization**:

Hard initialization can be performed by one of two ways:

1) Firmware programming at the first time
2) Power ON with pressing reset button.

Hard initialization sets all the parameters with default values and set BNO to zero. Turning Power ON with hard initialization conditions the seven-segment displays the letter 'H' followed by 'A' and two zeros which stands for Board number, BNO=0.

B. **Soft initialization**:

After changing board number (BNO) one should execute power off and on to re-initialize the board for the new setup. Turning Power ON the seven-segment displays the letter 'H' followed by 'A' and two digits which stands for Board number, BNO

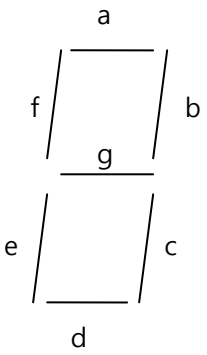
C. Restoring Defaults

Board initialize command (JBR) initiates the defaults restoring process. All the parameters are restored by default values except Offset. During the process the seven-segment displays the letter 'H' followed by 'A' and two digits which stands for Board number, BNO. It is strongly suggested that turn off and on the power after this process.

D. Normal power ON

Turning power on the board the letter 'A' will be displayed followed by two digits which stands for Board number (BNO).

2. Normal operation



A. Blinking g-segment:

g-segment blinks with rate of Timer interrupt frequency divide by 500. The frequency of timer interrupt is 1000Hz.. Thus g-segment should blink 2 times a second if the board is properly working.

B. Alternate blinking of f and b-segment:

f and b-segments blink alternately if 'read' command is received, Blinking these segments usually mean that 'request to send encoder readout' is receiving, i.e., the encoder is read by controller.

C. Alternate blinking of e and c-segment

e and c-segments blink alternately if 'command' instruction is received, Blinking these segments usually mean that position command is receiving, i.e., servo feedback is working

D. Toggling d-segment

d-segment toggles if any status or flags of the board has changed. It is useful to check the status change of limit switch and so on.

E. Blinking a-segment:

a- segment toggles if any state change of CN(change notification) pin.

3. Home Search operation

The seven segment display shows the status progress during home search operation as a number.

1: Start to find the Limit switch.
2: Limit switch-ON is found.
3: Limit switch-OFF is found and go backward. to get ON
4: Index signal detected.
5: Start to move to Offset position.
6: Arrived at Offset position. -> Success!

d: Fail to find backward limit switch signal.
e: Fail to detect Index signal
F:: Fail to find Limit switch

4. Error display

Motor driver will be disabled if critical error condition is encounter. The display shows the status of fatal error starting with 'F' and two successive digits. First digit shows channel number and the second shows the error type. The error types are shown in below:

1: JAM Error
2: Big Input Change Error
3: Power Saturation Error
4: Big Error or Encoder Failure
5: Driver Fault signal detected
6: Motor Failuare(for Board Type 1)

Error status is cleared by pressing 3[ENC_ZERO] or by REZ command.