

WHILL Control System Protocol Specification

	WHILL Control System Protocol Specification	Rev 8
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Contents:

1. Preface	2
2. Communication Overview	2
3. Control Command	2
3.1. Communication Format.....	2
3.2. Control Commands	3
3.2.1. StartSendingData command.....	4
3.2.2. StopSendingData command.....	4
3.2.3. SetPower	4
3.2.4. SetJoystick command.....	5
3.2.5. SetSpeedProfile command	6
3.2.6. SetBatteryVoltaegeOut command (Model CR only).....	7
3.2.7. SetVelocity command	7
4. WHILL state data.....	8
4.1. Communication format.....	8
4.2. Data set 0.....	9
4.3. Data set 1.....	10
5. Response Data.....	12
6. Communication Electrical Specifications	13
6.1. RS232C specification.....	13
6.2. Minimum time between control commands	13
6.3. Maximum interval of byte data in control command	14
7. Sensor (Model CR only)	14
7.1. 3D accelerometer/3D gyroscope sensor	14
8. Connector.....	15
8.1. Pin assignment	15
8.1.1. Model CR.....	15
8.1.2. Model CR2.....	15
8.2. Battery voltage from connector (Model CR only)	16
9. Appendix	17
9.1. Difference between Model CR and Model CR2	17
10. Revision History.....	19

Rev 8	Confidential	Page 1 of 19
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	WHILL Control System Protocol Specification	Rev 8
--	--	--------------

1. Preface

This document describes the specification of the communication protocol and control system related to WHILL of WHILL, Inc.

2. Communication Overview

Communication interface between the host device and WHILL is RS232C.

In basic communication, the control command is sent from the host device to WHILL and WHILL takes actions according to the control command. The WHILL state data will be periodically sent from WHILL to the host device after WHILL receives the control command to send the WHILL state data. The WHILL state data includes speed of WHILL, battery level, battery current, 3D accelerometer/3D gyroscope sensor value and so on. Figure 1 shows the communication overview.

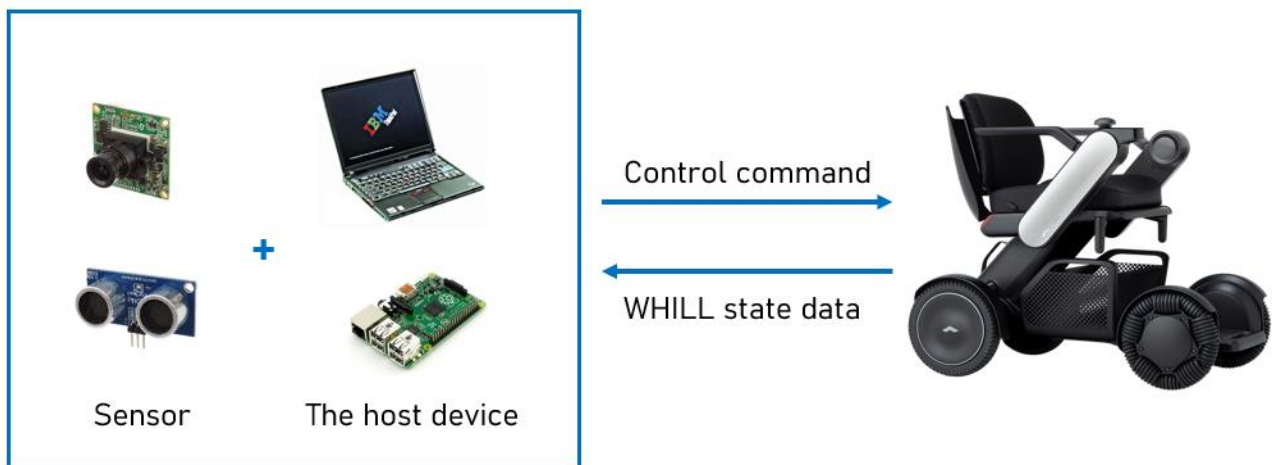


Figure 1 : Communication overview

3. Control Command

3.1. Communication Format

Figure 2 shows the communication format of the control command. The communication format includes protocol sign, data length, control command and checksum.

Protocol sign: At first, protocol sign is sent from the host device. WHILL recognizes the start of control command by protocol sign. Protocol sign is always 0xAF.

Rev 8	Confidential	Page 2 of 19
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Data length: Data length shows byte size behind itself, not includes protocol sign and data length.

Control Command: Control command consists of command ID and command data.

Checksum: Checksum is the value of XOR of protocol sign, data length and control command (command ID and all command data).

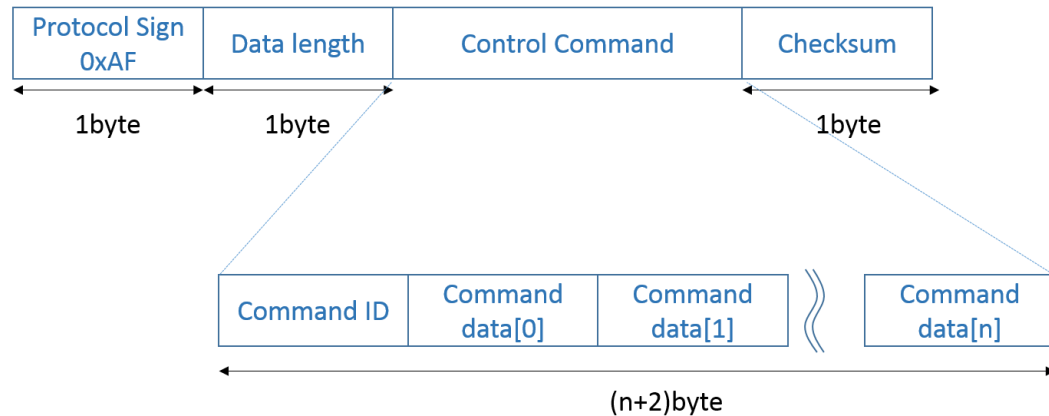


Figure 2 : Communication format of the control command

3.2. Control Commands

The host device can control WHILL using control commands. Table 1 is the list of control command. Each command has a command ID and command data. The detail of each command is described from next section.

Table 1 : List of control commands

Command	Command ID	Description	Implementation	
			Model CR	Model CR2
StartSendingData	0x00	WHILL starts sending WHILL state data	✓	✓
StopSendingData	0x01	WHILL stops sending WHILL state data	✓	✓
SetPower	0x02	Power On/Off WHILL	✓	✓
SetJoystick	0x03	Disable/Enable joystick control and set joystick value	✓	✓
SetSpeedProfile	0x04	Set max speed, acceleration and deceleration	✓	✓
SetBatteryVoltageOut	0x05	Disable/Enable voltage from battery voltage pin of cable	✓	-
reserve	0x06	Don't use this Command ID	-	-
reserve	0x07	Don't use this Command ID	-	-
SetVelocity	0x08	Set velocity of WHILL	✓	✓

device. Before receiving the response data, don't send any commands to WHILL. If the response data isn't sent for 5ms, re-issue SetPower Command to WHILL. See section5 WHILL Response Data for more detail. Figure 5 shows SetPower command format.

Command ID: 0x02

P0: Select Power ON or OFF

P0 = 0: Power OFF

P0 = 1: Power ON

SetPower command

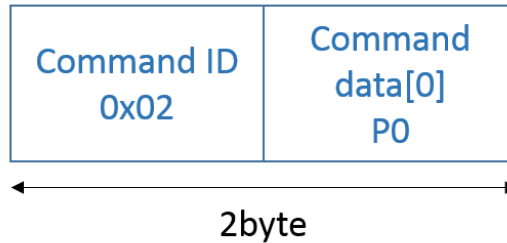


Figure 5 : SetPower command format

Note: After sending “POWER OFF”, the host device must wait for more than 5s to send “POWER ON”.

3.2.4. SetJoystick command

SetJoystick command has two functions. First function is to enable/disable the joystick control of a user who rides WHILL and disable/enable the joystick control of the host device. When the joystick control of a user is enabled (disabled), the joystick control of the host device is disabled (enabled). Second function is to set the value of joystick. The value is valid only when the joystick control of the host device is enabled. With a single SetJoystick command, the setting value is available for 200ms.Keep sending the command within 200ms if keeping WHILL moving more than 200ms.

Figure 6 shows SetJoystick command format.

Command ID: 0x03

U0: Disable/Enable joystick control of user/host device.

U0 = 0: Disable joystick control of user and enable joystick control of the host device

U0 = 1: Enable joystick control of user and disable joystick control of the host device

FB0 : Joystick value in front/back direction (-100~100)

LR0: Joystick value in left/right direction (-100~100)

SetSpeedPrfile command

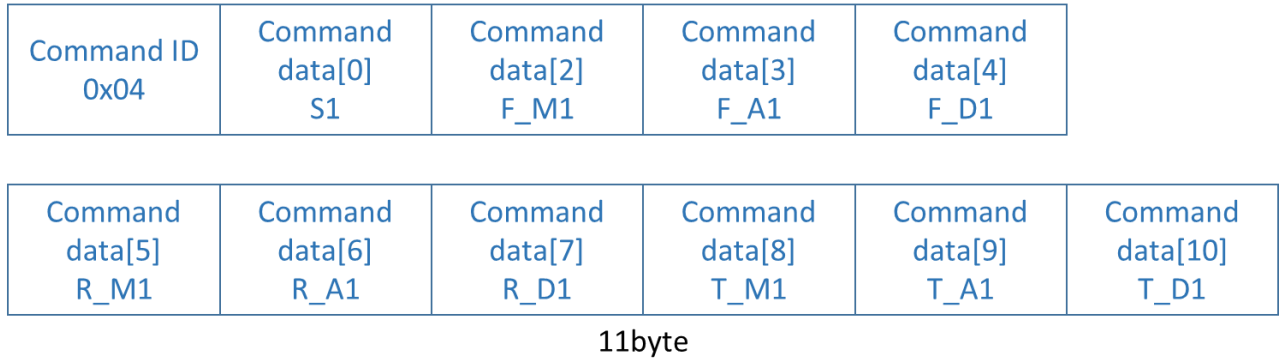


Figure 7 : SetForward command format

3.2.6. SetBatteryVoltaegeOut command (Model CR only)

SetBatteryVoltageOut command is to enable/disable battery voltage from battery voltage pin of cable connector. This voltage is connected to battery voltage. As default, battery voltage from battery voltage pin is enabled. See section 8.2 Battery voltage from connector about battery voltage pin.

Command ID: 0x05

V0: Enable/Disable voltage of battery voltage pin

V0 = 0: Disable

V0 = 1: Enable

SetBatteryVoltaegeOut command

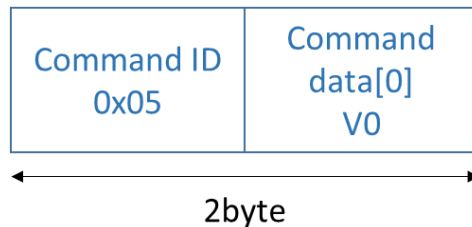


Figure 8 : SetBatteryVoltageOut command format

3.2.7. SetVelocity command

SetVelocity command has two functions. First function is to enable/disable the joystick control of a user who rides WHILL and disable/enable the control of the host device. When the joystick control of a user is enabled (disabled), the control of the host device is disabled (enabled). Second function is to set the value of WHILL velocity. The value is valid only when control of the host device is enabled. With a single SetVelocity

Protocol sign: At first, protocol sign is sent from WHILL. Protocol sign indicates the start of the WHILL state data. Protocol sign is always 0xAF.

Data length: Data length shows byte size behind itself, not includes protocol sign and data length.

WHILL state data: WHILL state data consists of data set number and information.

Checksum: Checksum is the value of XOR of protocol sign, data length and WHILL state data.

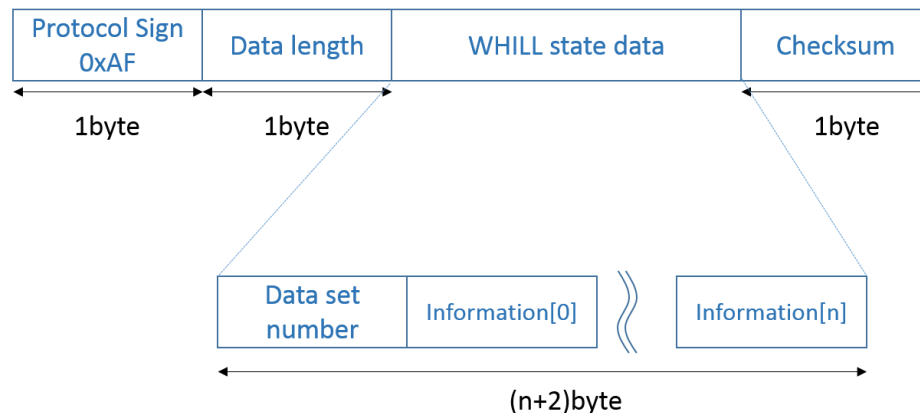


Figure 10: Communication format of WHILL state data

4.2. Data set 0

- 1.1.1 When the host device select data set 0 in StartSendingData command, values of Table 2 will be sent from WHILL. This data is about speed profile. This data set will be changed only when the host device modifies the setting of WHILL. So, it is better to read the data set 0 once when WHILL power-on or the host device changes the settings of max speed, acceleration and deceleration. See section 3.2.5 SetSpeedProfile command to know items in table 2.

Table 2 : Data set 0 contents

Information Number	Value (8bit)	Description	Implementation	
			Model CR	Model CR2
0	SPEED_MODE	Speed mode to send	✓	✓
1	FORWARD_SPEED_MAX	Max speed at forward movement	✓	✓
2	FORWARD_ACCEL	Acceleration at forward movement	✓	✓
3	FORWARD_DECEL	Deceleration at forward movement	✓	✓
4	REVERSE_SPEED_MAX	Max speed at reverse movement	✓	✓
5	REVERSE_ACCEL	Acceleration at reverse movement	✓	✓
6	REVERSE_DECEL	Deceleration at reverse	✓	✓

		movement		
7	TURN_SPEED_MAX	Max speed at turn movement	✓	✓
8	TURN_ACCEL	Acceleration at turn movement	✓	✓
9	TURN_DECEL	Deceleration at turn movement	✓	✓

4.3. Data set 1

When the host device selects data set 1 in StartSendingData command, values of Table 3 will be sent from WHILL. This data set is changing continuously such as acceleration sensor value, battery current and so on.

Table 3 : Data set 1 contents

Information Number	Value (8bit)	Description	Implementation	
			Model CR	Model CR2
0	ACC_X (MSB 8bit)	Acceleration X axis (MSB 8bit) See Note1	✓	-
1	ACC_X (LSB 8bit)	Acceleration X axis (LSB 8bit) See Note1	✓	-
2	ACC_Y (MSB 8bit)	Acceleration Y axis (MSB 8bit) See Note1	✓	-
3	ACC_Y (LSB 8bit)	Acceleration Y axis (LSB 8bit) See Note1	✓	-
4	ACC_Z (MSB 8bit)	Acceleration Z axis (MSB 8bit) See Note1	✓	-
5	ACC_Z (LSB 8bit)	Acceleration Z axis (LSB 8bit) See Note1	✓	-
6	GYR_X (MSB 8bit)	Angular rate X axis (MSB 8bit) See Note2	✓	-
7	GYR_X (LSB 8bit)	Angular rate X axis (LSB 8bit) See Note2	✓	-
8	GYR_Y (MSB 8bit)	Angular rate Y axis (MSB 8bit) See Note2	✓	-
9	GYR_Y (LSB 8bit)	Angular rate Y axis (LSB 8bit) See Note2	✓	-
10	GYR_Z (MSB 8bit)	Angular rate Z axis (MSB 8bit) See Note2	✓	-
11	GYR_Z (LSB 8bit)	Angular rate Z axis (LSB 8bit) See Note2	✓	-
12	JOY_FRONT	Joystick value in front/back direction (-100 ~ +100). Value of real joystick, not value set by the host device	✓	-
13	JOY_SIDE	Joystick value in left/right direction (-100 ~ +100). Value of real joystick, not value set by the host device	✓	-
14	BATTERY_POWER	Battery level. 0 ~ 100%	✓	✓
15	BATTERY_CURRENT (MSB 8bit)	Battery current (MSB 8bit) See Note3	✓	✓

16	BATTERY_CURRENT (LSB 8bit)	Battery current (LSB 8bit) See Note3	✓	✓
17	RIGHT_MOTOR_ANGLE (MSB 8bit)	Angle of right motor (MSB 8bit). See Note4	✓	✓
18	RIGHT_MOTOR_ANGLE (LSB 8bit)	Angle of right motor (LSB 8bit). See Note4	✓	✓
19	LEFT_MOTOR_ANGLE (MSB 8bit)	Angle of left motor (MSB 8bit). See Note4	✓	✓
20	LEFT_MOTOR_ANGLE (LSB 8bit)	Angle of left motor (LSB 8bit). See Note4	✓	✓
21	RIGHT_MOTOR_SPEED (MSB 8bit)	Right motor speed value (MSB 8bit). See Note5	✓	✓
22	RIGHT_MOTOR_SPEED (LSB 8bit)	Right motor speed value (LSB 8bit). See Note5	✓	✓
23	LEFT_MOTOR_SPEED (MSB 8bit)	Left motor speed value (MSB 8bit). See Note5	✓	✓
24	LEFT_MOTOR_SPEED (LSB 8bit)	Left motor speed value (LSB 8bit). See Note5	✓	✓
25	POWER_ON	State of WHILL power. ON:1, OFF:0	✓	✓
26	SPEED_MODE_INDICATOR	Speed mode displayed on indicator of WHILL	✓	✓
27	ERROR	Error code on WHILL. If there is no error, '0' is sent.	✓	✓
28	ANGLE_DETECT_COUNTER	Counter of timing to detect motor angle.	✓	✓

Note1: Acceleration value must be calculated below in order to be converted into unit [mg].

$$V_{acc} \times 0.122 = a$$

V_{acc} : Value about acceleration which is reported from WHILL. 16bit signed value.

a : Acceleration value which unit is [mg].

Note2: Angular rate value must be calculated below in order to be converted into unit [mdps].

$$V_{ang} \times 4.375 = \omega$$

V_{ang} : Value about angular rate which is reported from WHILL. 16bit signed value.

ω : Angular rate value which unit is [mdps].

Note3: BATTERY_CURRENT is 16bit signed value. The unit is 2mA.

Example: 0x035 represents 106mA; 0xFF97 represents -210mA.

The value will be 0 if battery current is in ± 75 mA.

Sampling rate of battery current is 4Hz.

Note4: RIGHT_MOTOR_ANGLE and LEFT_MOTOR_ANGLE is 16bit signed value. The unit is 0.001rad. The range is $\pm \pi$ [rad].

Example: 0x0600 represents 1.536rad

Note5: The value of the item that Implementation is "-" is always 0x00.

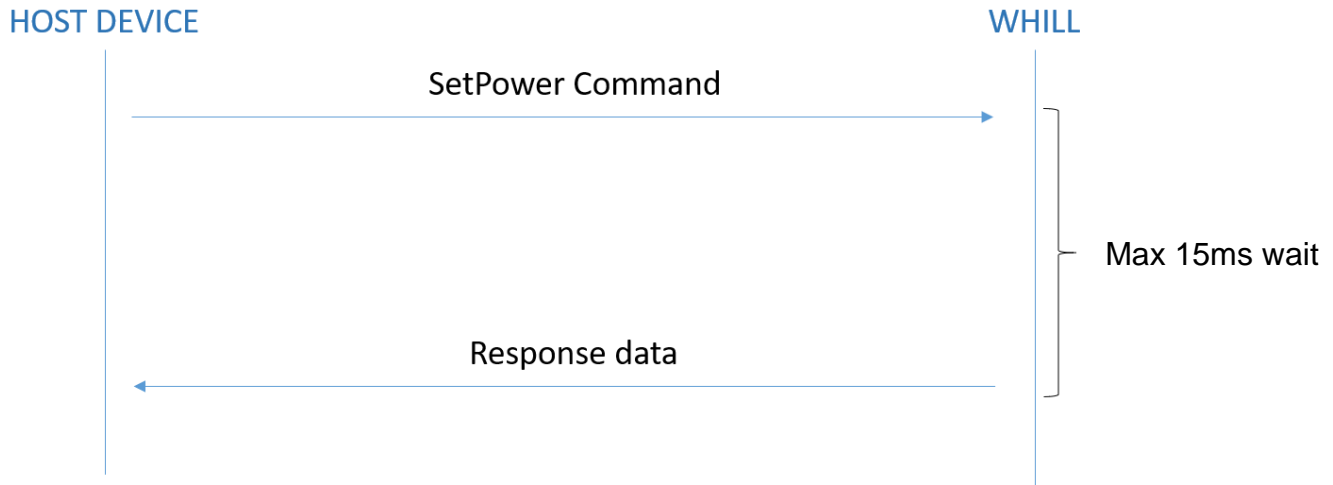


Figure 102: Timing of Response data

6. Communication Electrical Specifications

6.1. RS232C specification

The interface of WHILL's CPU is RS232C base on Table 4. Figure 13 shows RS232C diagram.

Table 4 : UART specification

	Model CR	Model CR2
Baud rate	38400	38400
Parity bit	No	No
Data length	8bit	8bit
Stop bit	2bit	2bit



Figure 13: RS232C diagram

6.2. Minimum time between control commands

The host device must wait for 2ms to the send next control command after sending the previous control command (Figure 14).

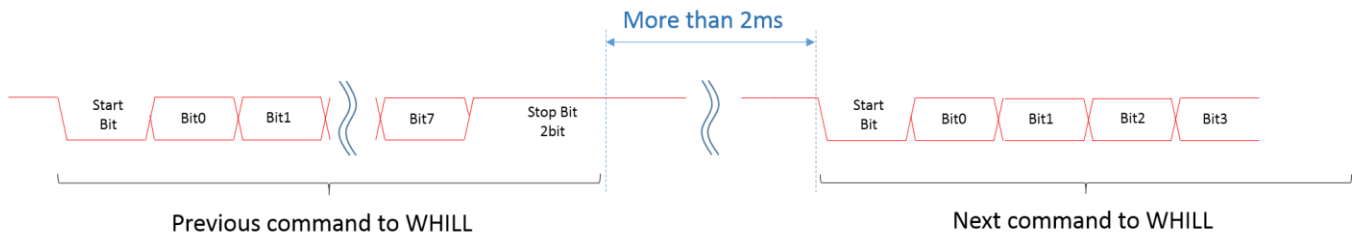


Figure 14: Minimum time between control commands

6.3. **Maximum interval of byte data in control command**

The interval of byte data which constitutes a single control command must be less than 5ms. If the interval is more than 5ms, the previous 1 byte data will be ignored.

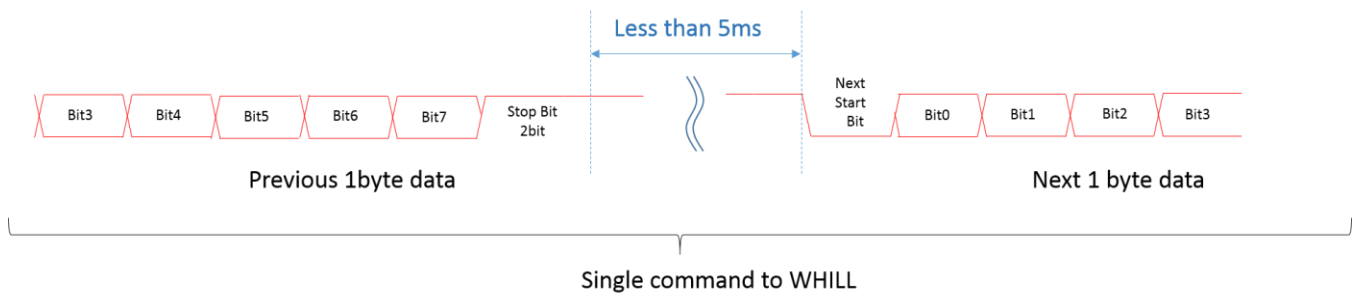


Figure 115: Maximum interval of byte data in control command

7. Sensor (Model CR only)

7.1. **3D accelerometer/3D gyroscope sensor**

3D accelerometer/3D gyroscope sensor is included in WHILL. Acceleration sampling rate is 104Hz and acceleration range is $\pm 4g$. Angular rate sampling rate is 104Hz and angular rate range is $\pm 125dps$. Figure 16 shows direction of the detectable accelerations and angular rate.

For the sensor, LSM6DS3 is included in WHILL. See LSM6DS3 datasheet for more detail.

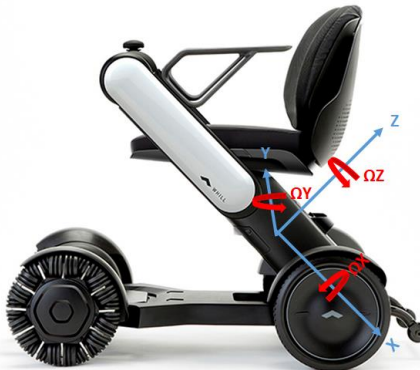


Figure 16 : Direction of the detectable accelerations and angular rate

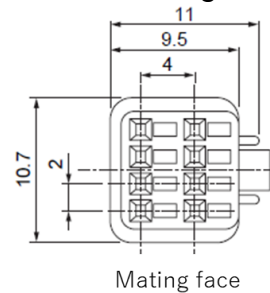
8. Connector

8.1. Pin assignment

8.1.1. Model CR

08R-JWPF-VSLE-D (JST) is used for interface connector. Figure 17 shows pin assignment.

TXD	RXD
GND	BATT
GND	BATT
GND	BATT



TXD : TX pin. Data from WHILL
 RXD: Rx pin. Data to WHILL
 GND: GND
 BATT: Battery voltage pin. This pin connected with battery voltage.

Figure 17: Pin assignment of connector

8.1.2. Model CR2

JEZ-9S-3 (JST) is used for interface connector. Figure 18 shows pin assignment.

D-sub 9pin connector

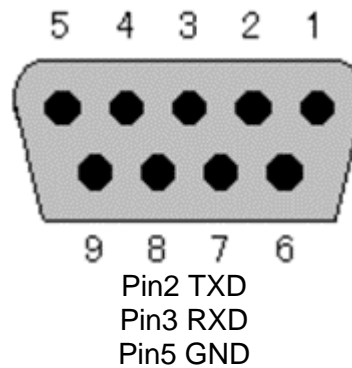


Figure 18: Pin assignment of connector

8.2. **Battery voltage from connector (Model CR only)**

BATT pin in Figure 17 is connected to battery voltage. Battery voltage range from about 19V ~ 30V according to remaining battery level, battery current and battery temperature. This voltage output can be enable / disable by SetBatteryVoltageOut command.

The current from this BATT pin must be under 3A. The fuse between BATT pin and battery will blows if over current flows.

9. Appendix

9.1. *Difference between Model CR and Model CR2*

Below, check-mark ("✓") means IMPLEMENTED.

Table 5 : List of External Pins

External Pins	Model CR	Model CR2
RS232C (TX, RX)	✓	✓
Battery voltage output (24Vout)	✓	-

Table 6 : List of UART specifications

UART specifications	Model CR	Model CR2
Baud rate	38400	38400
Parity bit	No	No
Data length	8bit	8bit
Stop bit	2bit	2bit

Table 7 : List of Control Commands

Command ID	Command	Model CR	Model CR2
0	StartSendingData	✓	✓
1	StopSendingData	✓	✓
2	SetPower	✓	✓
3	SetJoystick	✓	✓
4	SetSpeedProfile	✓	✓
5	SetBatteryVoltageOut	✓	-
8	SetVelocity	✓	✓

Table 8 : List of WHILL State Data (Data Set 0)

Information Number	Value (8bit)	Model CR	Model CR2
0	SPEED_MODE	✓	✓
1	FRONT_SPEED_MAX	✓	✓
2	FRONT_ACCEL	✓	✓
3	FRONT_DECEL	✓	✓
4	REVERSE_SPEED_MAX	✓	✓
5	REVERSE_ACCEL	✓	✓
6	REVERSE_DECEL	✓	✓
7	TURN_SPEED_MAX	✓	✓
8	TURN_ACCEL	✓	✓
9	TURN_DECEL	✓	✓

Table 9 : List of WHILL State Data (Data Set 1)

Information Number	Value (8bit)	Model CR	Model CR2
0	ACC_X (MSB 8bit)	✓	-
1	ACC_X (LSB 8bit)	✓	-
2	ACC_Y (MSB 8bit)	✓	-
3	ACC_Y (LSB 8bit)	✓	-
4	ACC_Z (MSB 8bit)	✓	-
5	ACC_Z (LSB 8bit)	✓	-
6	GYR_X (MSB 8bit)	✓	-
7	GYR_X (LSB 8bit)	✓	-
8	GYR_Y (MSB 8bit)	✓	-
9	GYR_Y (LSB 8bit)	✓	-
10	GYR_Z (MSB 8bit)	✓	-
11	GYR_Z (LSB 8bit)	✓	-
12	JOY_FRONT	✓	-
13	JOY_SIDE	✓	-
14	BATTERY_POWER	✓	✓
15	BATTERY_CURRENT (MSB 8bit)	✓	✓
16	BATTERY_CURRENT (LSB 8bit)	✓	✓
17	RIGHT_MOTOR_ANGLE (MSB 8bit)	✓	✓
18	RIGHT_MOTOR_ANGLE (LSB 8bit)	✓	✓
19	LEFT_MOTOR_ANGLE (MSB 8bit)	✓	✓
20	LEFT_MOTOR_ANGLE (LSB 8bit)	✓	✓
21	RIGHT_MOTOR_SPEED	✓	✓
22	RIGHT_MOTOR_SPEED	✓	✓
23	LEFT_MOTOR_SPEED	✓	✓
24	LEFT_MOTOR_SPEED	✓	✓
25	POWER_ON	✓	✓
26	SPEED_MODE_INDICATOR	✓	✓
27	ERROR	✓	✓
28	ANGLE_DETECT_COUNTER	✓	✓

10. Revision History

Revision	Date	Note
Rev 8	2023/11/10	Add description of Model CR2 (Table1, 2, 3, 4). Add Pin assignment of Model CR2. Add Appendix (Difference between Model CR and Model CR2). Modify waiting time of response.
Rev 7	2019/12/25	Add ANGLE_DETECT_COUNTER in Data set 1. Modify Table3:Data set 1 contents. Add SETVelocity command.
Rev 6	2019/1/10	Modify sentence. Modify description about SetPower and Response data according to new FW.
Rev 5	2018/09/14	Modify Figure 15
Rev 4	2018/01/31	Delete EmergencyBrake command. Modify range of max speed, acceleration and deceleration in setSpeedProfile command.
Rev 3	2017/10/30	Add SPEED_MODE_INDICATOR in Data set 1. Add EmergencyBrake command.
Rev 2	2017/08/23	Modify figures of commands. Modify sentence.
Rev 1	2017/08/22	