WHILL Control System Protocol Specification

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 WILL 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.
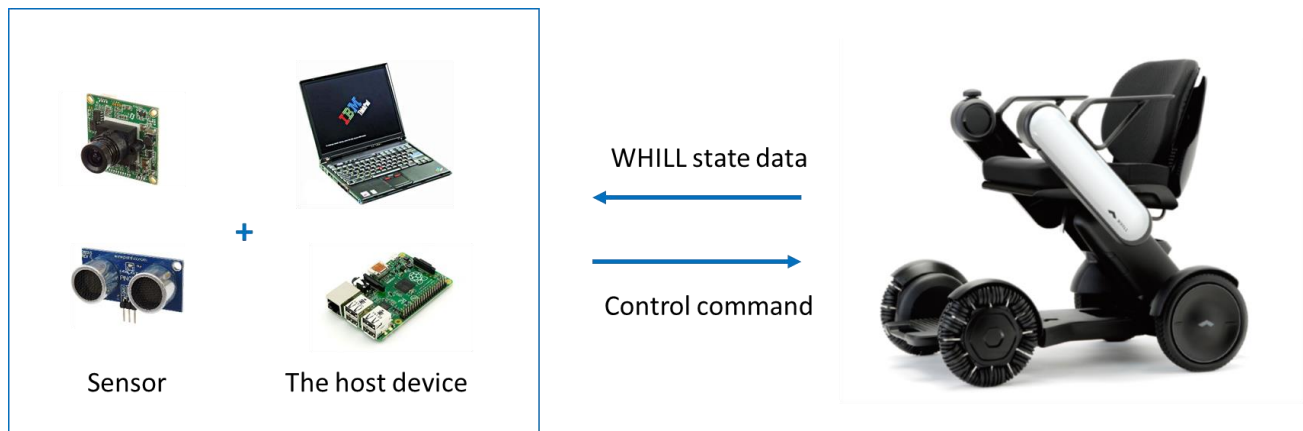

WHILL state data

Control command

Sensor   The host device

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.
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).
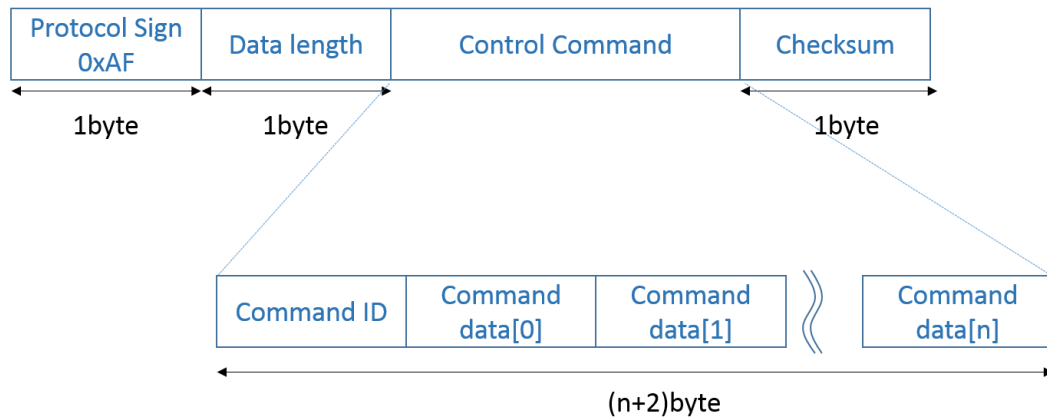
Figure 2 : Communication format of the control command

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	Description
StartSendingData	WHILL starts sending WHILL state data
StopSendingData	WHILL stops sending WHILL state data
SetPower	Power On/Off WHILL
SetJoystick	Disable/Enable joystick control and set joystick value
SetSpeedProfile	Set max speed, acceleration and deceleration
SetBatteryVoltageOut	Disable/Enable voltage from battery voltage pin of cable

3.2.1 StartSendingData command

StartSendigData command makes WHILL start sending the WHILL state data. Figure 3 shows StartSendingData command format.

Command ID: 0x00

D0: Data set number.

D0 = 0: Select data set 0

D1 = 1: Select data set 1

T0~T1: Interval of sending data [ms] (16bit value). T1:MSB8bit, T0:LSB8bit. Minimum interval is 10ms.

S0: Speed mode. Set speed mode in data set 0. See section4.2 Data set 0 for more detail.

StartSendingData command

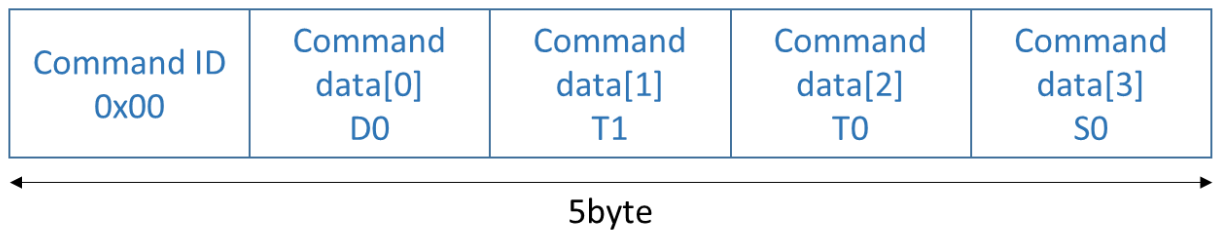| Command ID 0x00	Command data[0] D0	Command data[1] T1	Command data[2] T0	Command data[3] S0

←——————————— 5byte ———————————→

Figure 3 : StartSendingData format

3.2.2 StopSendingData command

StopSendigData command makes WHILL stop sending the WHILL state data. Figure 4 shows StopSendingData command format.

Command ID: 0x01

StopSendingData command

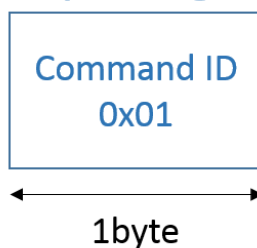| Command ID 0x01 |
|---|

←—— 1byte ——→

Figure 4 : StopSendingData format

3.2.3 SetPower

Function of SetPower command is to power ON/OFF WHILL. When WHILL finishes to power on after receiving SetPower command, WHILL sends Response data to the host device. Before receiving the response data, don't send any commands to WHILL. If the response data isn't sent for 1s, 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

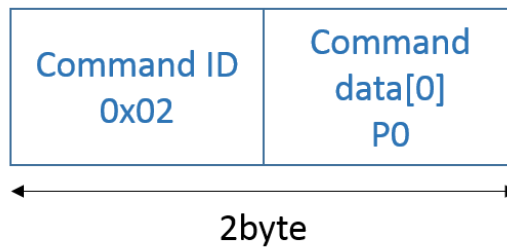| Command ID 0x02	Command data[0] P0

← 2byte →

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）

SetJoystick command

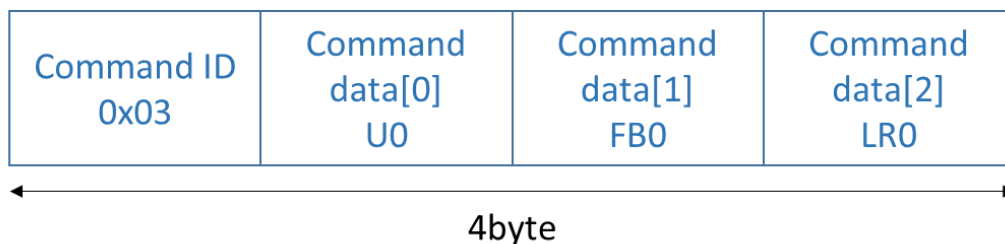| Command ID 0x03	Command data[0] U0	Command data[1] FB0	Command data[2] LR0

← 4byte →

Figure 6 : SetJoystick command format

3.2.5 SetSpeedProfile command

SetSpeedProfile command is to set max speed, acceleration and deceleration at forward movement, reverse movement and turn movement in each speed mode. Figure 7 shows SetSpeedProfile command format.

Command ID: 0x04

S1: Speed mode: Select speed mode to set

  S1 = 0: Select speed mode when user uses joystick and "1" is displayed in indicator of WHILL

  S1 = 1: Select speed mode when user uses joystick and "2" is displayed in indicator of WHILL

  S1 = 2: Select speed mode when user uses joystick and "3" is displayed in indicator of WHILL

  S1 = 3: Select speed mode when user uses joystick and "4" is displayed in indicator of WHILL

  S1 = 4: Select speed mode when host device moves WHILL via RS232C

  S1 = 5: Select speed mode when iPhone WHILL App moves WHILL

F_M1: Max speed at forward movement. The unit of value is 0.1km/h. If 30 is set, max speed is 3.0km/h. The range is (8~60).

F_A1: Acceleration at forward movement. The range is (10~90).

F_D1: Deceleration at forward movement. The range is (40~160).

R_M1: Max speed at reverse movement. The unit of value is 0.1km/h. If 30 is set, max speed is 3.0km/h. The range is (8~30).

R_A1: Acceleration at reverse movement. The range is (10~50).

R_D1: Deceleration at reverse movement. The range is (40~90).

T_M1: Max speed at turn movement. The unit of value is 0.1km/h. If 30 is set, max speed is 3.0km/h. The range is (8~35).

T_A1: Acceleration at turn movement. The range is (10~60).

T_D1: Deceleration at turn movement. The range is (40~160).

SetSpeedPrfile command

Command ID 0x04	Command data[0] S1	Command data[2] F_M1	Command data[3] F_A1	Command data[4] F_D1

Command data[5] R_M1	Command data[6] R_A1	Command data[7] R_D1	Command data[8] T_M1	Command data[9] T_A1	Command data[10] T_D1

11byte

Figure 7 : SetForward command format

3.2.6 SetBatteryVoltaegeOut command

SetBatteryVoltageOut command is to enable/disable battery voltage from battery voltage pin of cable connecter. 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

P0: Enable/Disable voltage of battery voltage pin

      P0 = 0: Disable
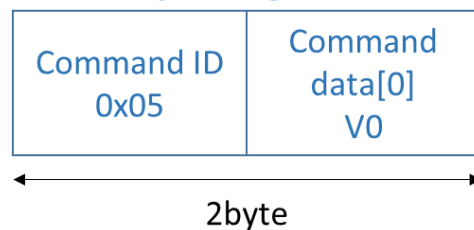
      P0 = 1: Enable

Figure 8 : SetBatteryVoltageOut command format

4. WHILL state data

4.1 Communication format

After receiving StartSendingData command, WHILL starts to send the WHILL state data to the host device. The host device selects the data set number of the WHILL state data. According to the data set number, contents which WHILL sends changes. The WHILL state data conforms to the communication format shown in Figure 9.

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.
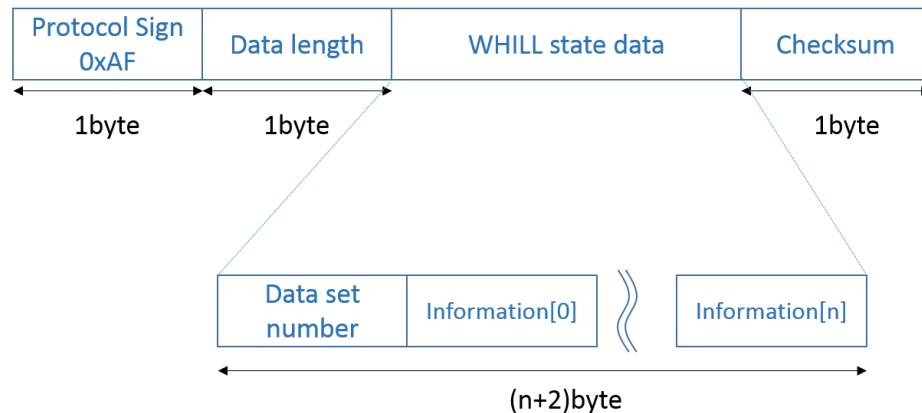
Figure 9 : Communication format of WHILL state data

4.2 Data set 0

4.2.1   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
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	TRUN_SPEED_MAX	Max speed at turn movement
8	TRUN_ACCEL	Acceleration at turn movement
9	TRUN_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
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	Right motor speed value (MSB 8bit) See Note5
22	RIGHT_MOTOR_SPEED	Right motor speed value (LSB 8bit) See Note5
23	LEFT_MOTOR_SPEED	Left motor speed value (MSB 8bit) See Note5
24	LEFT_MOTOR_SPEED	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.

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

$$Vacc \times 0.122 = a$$

Vacc : 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].

$$Vang \times 4.375 = \omega$$

Vang: 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 singed value. The unit is 2mA.
Example: 0x035 represents 106mA; 0xFF97 represents –210mA.
The value will be 0 if battery current is in $\pm$75mA.
Sampling rate of battery current is 4Hz.

Note4: RIGHT_MOTOR_ANGLE and LEFT_MOTOR_ANGLE is 16bit singed value. The unit is 0.001rad. The range is $\pm \pi$ [rad].
Example: 0x0600 represents 1.536rad

Note5: RIGHT_MOTOR_SPEED and LEFT_MOTOR_SPEED is 16bit singed value. The unit is 0.004km/h.
Example: 0x01F4 represents 2km/h.

5. Response Data

When WHILL finishes to powers on after receiving SetPower command, WHILL sends the response data to the host device. The response data is always 0x52. Figure 10 shows the response data format.

Protocol Sign: At first, protocol sign is sent from WHILL. Protocol sign is always 0xAF.
Data length: it shows byte size behind itself, not includes protocol sign and data length. It's '2' at WHILL response data.
Response: It's always 0x52
Checksum: it is the value of XOR of protocol sign, data length and response.

WHILL response data

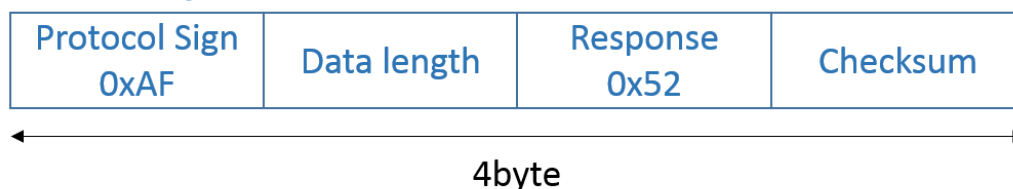| Protocol Sign 0xAF	Data length	Response 0x52	Checksum

4byte

Figure 10 : WHILL response data format

After sending SetPower command to power on WHILL, don't send any commands to WHILL before receiving the response data. If the response data isn't sent for 1s, re-issue SetPower command to WHILL (Figure 11).
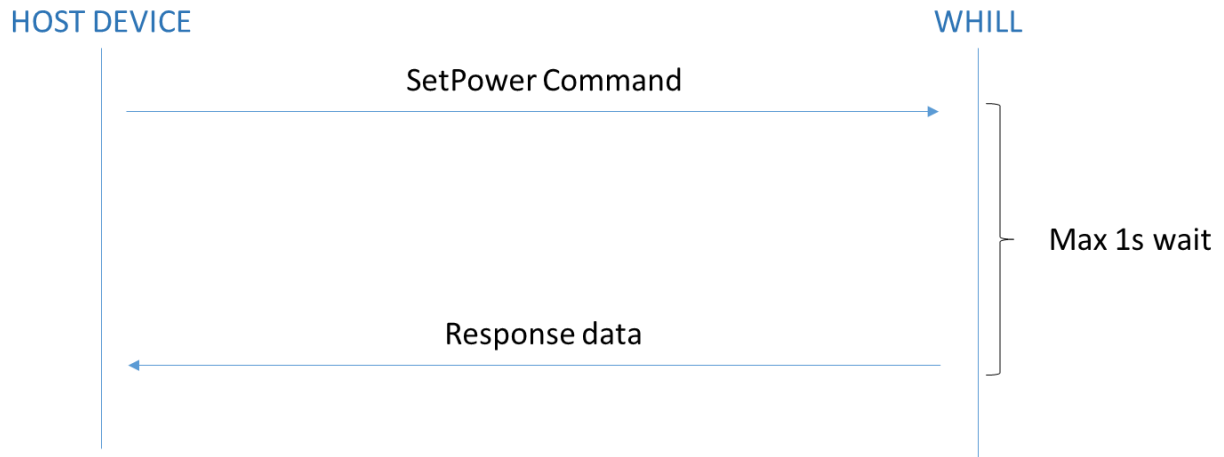

Figure 11 : Timing of Response data

6. Communication Electrical Specifications

6.1 RS232C specification
The interface of WHILL's CPU is RS232C base on Table 4. Figure 12 shows RS232C diagram.

Table 4 : UART specification

Baud rate	38400
Parity bit	No
Data length	8bit
Stop bit	2bit

Figure 12 : 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 13).
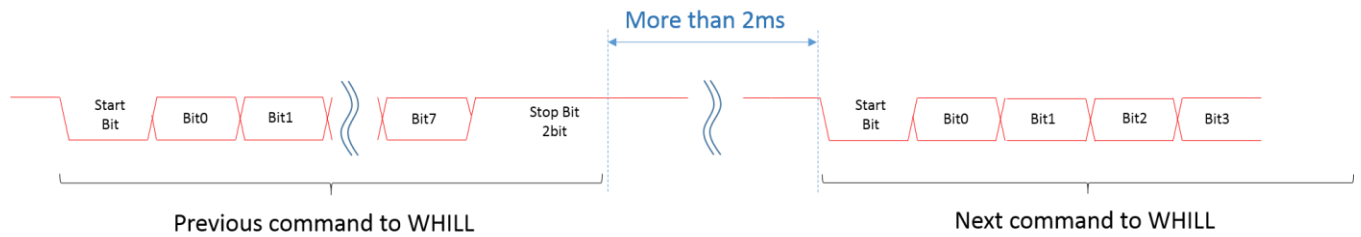
Figure 13 : Minimum time between control commands

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.
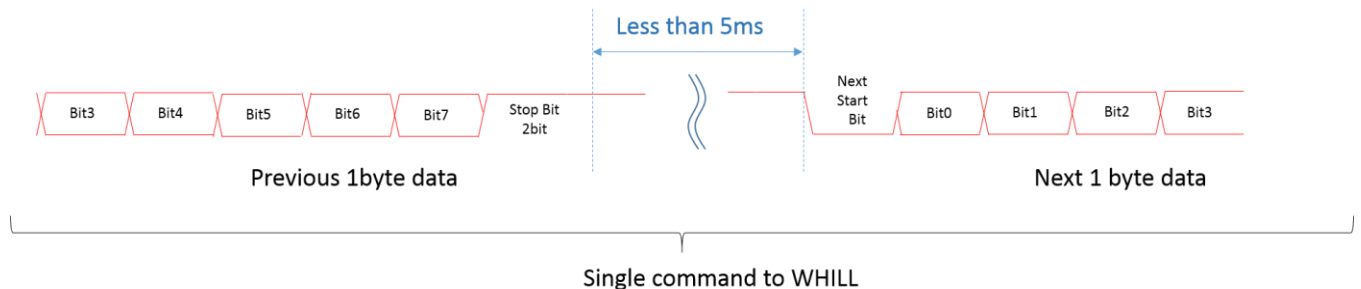

Figure 14 : Maximum interval of byte data in control command

7. Sensor

7.1 3D accelerometer/3D gyroscope sensor

3D accelerometer/3D gyroscope sensor is included in WHILL. Acceleration sampling rate is104Hz and acceleration range is±4g. Angular rate sampling rate is 104Hz and angular rate range is ±125dps. Figure 15 shows direction of the detectable accelerations and angular rate.

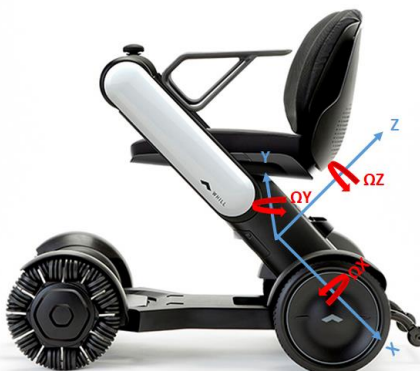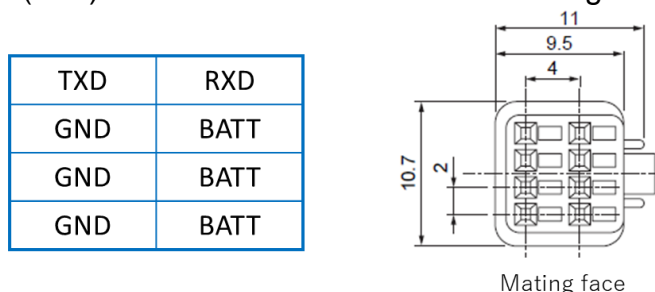For the sensor, LSM6DS3 is included in WHILL. See LSM6DS3 datasheet for more detail.

Figure 15 : Direction of the detectable accelerations and angular rate

8. Connector
8.1 Pin assignment
08R-JWPF-VSLE-D (JST) is used for interface connector. Figure 16 shows pin assignment.

TXD	RXD
GND	BATT
GND	BATT
GND	BATT

Mating face

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 16: Pin assignment of connector

8.2 Battery voltage from connector
BATT pin in Figure 18 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 SetBatteryVoltaegeOut 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. Revision History

Revision	Date	Note
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	