neuroNicle FX2 Communication Specification

LXSDF T2A based data communication

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Abstract - neuroNicle FX2 device uses LXSDF T2A as a data format for Bluetooth serial communication, and this document describes device data allocation information in LXSDF T2A. According to this data communication standard, the neuroNicle FX2 can be Bluetooth-connected with the host device (PC, smart phone, etc.) capable of communicating with the device, and the information provided by the device can be utilized. This document is based on the LXSDF T2A format, so it is only necessary to understand the following essential reference documents.

Required reference documentation

1. LXD10 , "LXSDF T2A communication specification" https://github.com/LAXTHA/LXSDF/raw/master/LXE10_LXSDFT2A_CommunicationStandard_en.pdf

Contents

Overview

This document defines the communication specification of neuroNicle FX2.

neuroNicle FX2 Bluetooth communication

This document defines the Bluetooth serial communication specification of neuroNicle FX2.

neuroNicle FX2 Bluetooth is an SPP profile and is recognized as a serial port (COM port) on host devices such as smart phones and PCs.

Password for connecting Bluetooth: 1234

COM port settings : baud rate : 11520 bps, data bit : 8bit, stop bit : 1, parity : none, flow control : non

This communication standard is based on serial communication format and is based on LXSDF T2A (LX Serial Data Format Type 2A) as a format for transmitting various types of data.

This manual explains what data is placed in the LXSDF T2A format for neuroNicle FX2.

The description of LXSDF T2A is beyond the scope of this document, and must reference the document ID: LXD10 Vx.

LXD10 pdf download :

https://github.com/LAXTHA/LXSDF/raw/master/LXE10_LXSDFT2A_CommunicationStandard_en.pdf

LXSDF T2A Site : http://laxtha.net/lxsdf-t2a/

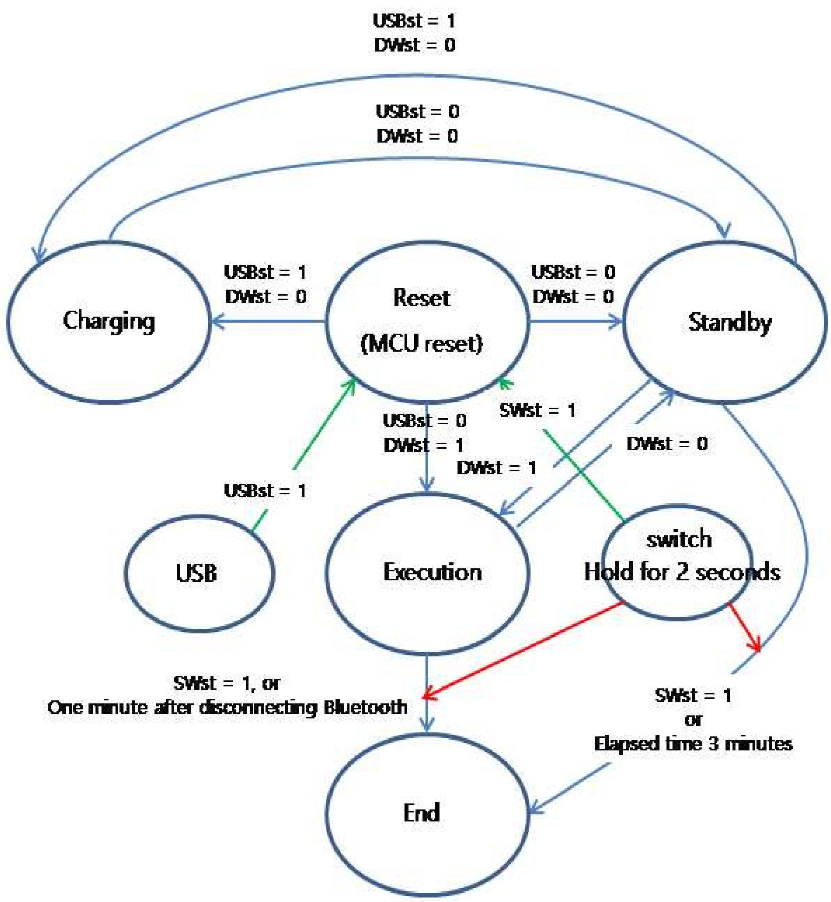
Constants appplide to the LXSDF T2A format from neuroNicle FX2.

Item	Explanation
LXSDF T2A TX 1 packet transmission cycle	250 packets per second (measurement mode), 1 packet per second (standby mode), 1 packet per second (charge mode)
COM Port Search Information: PCD [31]	109
LXDeviceID : PCD[30]	35
ComFirmInfo1 : PCD[29]	0
Number of channels: PCD [28]	6
Number of samples: PCD [27]	1
ComPath : PCD[26]	2 (Wireless Bluetooth SPP)
ComFirmInfo2 : PCD[25]	25 (firmware ID)
ComFirmInfo3 : PCD[24]	0
Reserved(firmware revision): PCD[23]	10

Table [1]. Basic constant of LXSDFT2A applied to neuroNicle FX2.

Device operation mode

The neuroNicle FX2 wireless BHM (Brain Heart Monitor) device operates in standby mode (PPD = 0), measurement mode (PPD = 1), and charge mode (PPD = 2). The state transition diagram of the operation mode is shown in Fig.



Fig[1]. NeuroNicle FX2 operating state transition diagram. Depending on the power supplied to the device and whether or not the device is worn, the operating mode is different. When the mode conversion from the standby mode to the execution mode is performed, a mode conversion time of about 2 seconds is required. If the device still meets the run mode condition after this time, the device will run in run mode.

USB connection status for charging (USBst status value, 0 = not connected, 1 = connected), Whether the power switch is pressed (SWst status value, 0 = no switch pressed, 1 = switch pressed), Each operation mode is determined according to whether the apparatus is worn (DWst state value, 0 = not used, 1 = worn).

Power ON

There are two ways to power the device. Whether you connect a powered USB (USBst = 1), press the power switch for about 1 second (SWst = 1). Power is still supplied to the device after disconnecting and then disconnecting USB. If you press the power switch for about 1 second to turn on the power, press and hold the switch until the green LED turns on. If you release the switch before the green LED turns on, the power is turned off. This is to prevent the device from being powered by an unwanted momentary switch action.

Power OFF

There are three ways of powering down the device. When the device is turned on, the device's power switch is held down for about 2 seconds, or left in standby mode, or the Bluetooth connection is disconnected in RUN mode. Press and hold the power switch until the green LED turns on, then release the switch to turn off the device. If the device is operating in the standby mode, the power is automatically turned off after the waiting time (3 minutes). When the Bluetooth connection is disconnected from the measurement mode, the power is cut off within 1 minute.

Standby mode

If USB is not connected (USBst = 0) and the device is not worn (DWst = 0), it is the operating mode of the device.

In this mode

Execution cycle = 1 second,

BLUE LED blinks according to the execution cycle,

If Bluetooth is not connected, it will blink in purple (BLUE + RED)

Standby hold time is 3 minutes. If you do not enter another mode within the waiting time, the power is automatically cut off. In this mode, the remaining battery level is displayed.

Measurement mode

If the USB is not connected (USBst = 0) and the device is worn (DWst = 1), it is the operating mode of the device.

In this mode

Execution cycle = 4msec,

The RED LED flashes in sync with the heartbeat

GREEN LED blinks every 2 seconds.

If the battery remaining amount is 10% or less, a low battery warning is displayed. In this warning, it is desirable to charge the battery within 10 minutes. If Bluetooth is not connected, it is automatically turned off within 1 minute.

Charging mode

If USB is connected to the device (USBst = 1), this is the operating mode of the device. In this mode

Execution cycle = 2 seconds,

BLUE LED blinks according to the execution cycle,

When charging is completed, the BLUE LED remains ON.

Even if the USB connection is disconnected from the charging mode, the power of the device is turned on. When the device is not worn, it enters the standby mode and maintains the state for the set waiting time (3 minutes). In this mode, charging completion information, charging time, and the like are provided.

Receive data from the device

No data is received from the host device by the "neuroNicle FX2 device". The device is driven according to its operating state without the command of the host.

Device data transmission(LXSDF T2A transmission data)

Depending on the power supplied to the device, its operating mode differs as shown in Figure [1]. Data to be output depends on each operation mode. The contents of the output data for each mode are discussed below.

Transmission data in standby / charge mode

The output data in standby / charge mode is shown in Table [2]. The standby mode may enter the charging mode or enter the measurement mode. Standby mode is reduced to battery consumption before entering measurement mode, and is suitable for monitoring battery level and Bluetooth connection status. If you stay in this mode for more than 3 minutes without entering another operation mode, the power is automatically shut off. The charging mode is the operating mode of the device when the USB power is connected and power is supplied to the built-in rechargeable battery. In the charging mode, data is transmitted in units of 2 seconds, and the data transfer is similar to the standby mode, except that the charging state and the charging progress time are included.

Data item	LXSDF T2A TX Packet data	Explanation
Operation mode	[2]. PPD = 0/2	0 = Standby mode, 2 = Charging mode.
Standby mode hold time / Charging progress time	[3]. PUD0	Standby time remaining in seconds. Starting from the set waiting time (180 (sec)), when it becomes 0, the power is cut off. In charge mode, the charge progress time. In minutes. Keep final value when charging is completed.
Packet Cyclic Count	[4]. PC	0 ~ 31.
Battery remaining (standby mode)	[5]. PUD1 [5]. PUD1.bit0 (Charge state)	% unit. It changes by 5% (standby mode). 0 = charging, 1 = charging complete (charging mode)
-	[6]. PCD[0]~[19]	No data allocation.
CH1 Electrode attached state	[7]. CRD_PUD2_TYPE.bit5	0: not attached, 1: attached; (left forehead)
CH2 Electrode attached state	[7]. CRD_PUD2_TYPE.bit4	0: not attached, 1: attached (right forehead)
REF Electrode attached state	[7]. CRD_PUD2_TYPE.bit3	0: not attached, 1: attached; (earlobe)
-	[8]. CH1_h [9]. CH1_l	No data allocation.
-	[10]. CH2_h [11]. CH2_l	No data allocation.
-	[12]. CH3_h [13]. CH3_l	No data allocation.
-	[14]. CH4_h [15]. CH4_l	No data allocation.

-	[16]. CH5_h [17]. CH5_l	No data allocation.
-	[18]. CH6_h [19]. CH6_l	No data allocation.

Table [2]. Transmit data item in standby / charge mode. Packets are transmitted in 1-second increments. [0] = 255, [1] = 254 is included even if it is not specified. A way to recognize this mode without checking the data is to check the LED status.

BLUE LED blinks in 1 second increments (standby mode). Flashing in 2-second increments (charging mode).

If Bluetooth is not connected, the RED LED blinks (standby mode).

As shown in Figure [1], when the USB is connected in standby mode, it enters the charging mode and enters the measurement (execution) mode when the device is worn. If idle mode is entered or the device power is not forcibly turned off, it is automatically turned off after waiting time (3 minutes).

In the measurement (execution) mode.

The measurement mode is the device operation mode when the device is worn in standby mode (with EEG electrodes). This mode is driven at 4msec period, and transmits 250 packets per second. Data items to be transmitted in this mode are shown in Table [3].

Data item	LXSDF T2A TX Packet data	Explanation
Stream data attributes	[2]. PPD = 1	Measurement mode, It means stream data.
Status monitoring	[3]. PUD0	Bit7: HeartBeat event Bit6: Sensor wear status (1 = wear, 0 = not used) Bit5: Connected earlobe (1 = normal, 0 = abnormal) Bit4: low battery warning (1 = normal, 0 = low battery) Bit3: reserved Bit2: PPG signal Normality (1 = normal, 0 = abnormal) Bit1: reserved Bit0: Starting point of 2 second unit (1).
Packet Cyclic Count	[4]. PC	0 ~ 31.
Heart rate per minute	[5]. PUD1	30 to 240 bpm. Updated at the time of the heartbeat event.
Battery remaining	[6]. PCD[1]	% unit. Change in 5% increments. Low warning at less than 10%.
Left-brain EEG saturation	[6]. PCD[20]	0 to 255. The closer to 0 or 255, the more saturated. The closer to the median value 128, the better.
Right-brain EEG saturation	[6]. PCD[21]	
CH1 Electrode attached state	[7]. CRD_PUD2_TYPE.bit5	0: not attached, 1: attached; (left forehead).
CH2 Electrode attached state	[7]. CRD_PUD2_TYPE.bit4	0: not attached, 1: attached (right forehead).
REF Electrode attached state	[7]. CRD_PUD2_TYPE.bit3	0: not attached, 1: attached (earlobe).
EEG waveform -CH1	[8]. CH1_h [9]. CH1_l	Left brain EEG waveform (15 bit)
EEG waveform -CH2	[10]. CH2_h [11]. CH2_l	Right brain EEG waveform (15 bit)
Power pectrum	[12]. CH3_h [13]. CH3_l	10 times the value of left / right brain power spectrum.
PPG	[14]. CH4_h [15]. CH4_l	PPG waveform (15 bits; AGC waveform)
sdPPG	[16]. CH5_h [17]. CH5_l	Second derivative PPG waveform (15 bit)
Heart rate interval data	[18]. CH6_h [19]. CH6_l	peak-interval (msec). (250 ~ 2000)

Table [3]. Transmission data specification of neuroNicle FX2 device.

Detaioled description of each transmission data item.

When power is applied to the device, the device transmits measurement data to the host device under the LXSDF T2A stream data standard. The host device can secure the corresponding data from the standard information. Which data to use depends entirely on the host device's data selection. In Table [3], each data can be obtained by separating into T2A standard, but the power spectrum item requires additional data separation. Each of these details is described below.

Stream data attributes([2]. PPD)

Indicates the attributes of the currently transmitted data packet. PPDmeans stream data, and the packet size is 20. Simultaneously, it indicates the measurement mode state.

Status monitoring ([3]. PUD0)

Indicates various status values of the device. Each state value item is as follows.

Bit7: HeartBeat event1 = heartbeat detection, 0 = not detected. HRV data can be acquired based on the heartbeat event signal and utilized for HRV. Also, the heart rate data per minute is updated based on this point (see Fig. 3).

Bit6 : Sensor wear status. 1 = Wear, 0 = Not used. When the sensor including the earlobe electrode is worn on the head, the state is indicated. Even if the sensor is worn, if the value is not set (1), it is necessary to check the electrode attachment again.

Bit5 : Earlobe electrode connection. The earlobe electrodes are attached to each other without the sensor being worn. This is an item that informs you of this condition. If the electrode is not attached to the ear before the sensor is worn, the contact state may not be good when the electrode is worn. This is an electrode inspection factor.

Bit4: Low battery warning. Generate a warning signal when the battery level is less than 10% (1 = normal, 0 = low battery When a low-battery warning occurs, it is preferable to stop the measurement within 10 minutes and charge the battery .

Bit3 : reserved.

Bit2 : PPG signal Normality. Indicates whether the current heart rate gap is normal or abnormal. It can also be used for PPG signal steady state confirmation. 1 = the currently measured heart rate interval is in the normal range. 0 = abnormal range. Normal range of heart rate interval; 60% of the past heart rate interval <= current measurement <= 140% of the past heart rate interval.

Bit1 : reserved.

Bit0: Starting point of 2 seconds. Set to 2 seconds (exactly 4 * 512 = 2.048 seconds). f this value is set at 2 second intervals, it becomes the starting point of power spectrum data classification. The index of the power spectrum is set based on this set value.

Packet Cyclic Count([4]. PC)

Packet count value. The range 0 to 31 is repeated every time the packet is transmitted. From this value [6]. PCD [PC] value is secured.

Heart rate per minute([5]. PUD1)

The "heart rate per minute" value is displayed. This value is updated whenever a heartbeat event occurs (PUD0.bit7 = 1). Values range from 30 to 240 (bpm). The accuracy of the value is +/- 1bpm.

Battery remaining([6]. PCD[1])

The remaining battery level during operation of the device is expressed in% (in units of 5%). Measured every 2 seconds and assigned to PCD [1].

Left-brain EEG saturation([6]. PCD[20])

Represents the device input saturation state of the left brain EEG. As this value approaches 0 or 255, the input signal is saturated, indicating that the measurement signal may be unstable. The closer to the median value (128), the more stable the left-brain EEG signal.

Right-brain EEG saturation([6]. PCD[21])

Represents the device input saturation state of the right brain EEG. As this value approaches 0 or 255, the input signal is saturated, indicating that the measurement signal may be unstable. The closer to the median value (128), the more stable the right-brain EEG signal

CH1 Electrode attached state ([7]. CRD_PUD2_TYPE.bit5)

Indicates the value of the human body attachment state of the electrode(left forehead) Ch1. It is set (1) if the device is correctly attached to the body, otherwise it is reset (0). Care should be taken to prevent foreign matter (color cosmetics, hair, etc.) from getting caught between the electrode and the forehead when wearing the device. In addition, the skin needs to be kept cleanEven if the electrode is contacted with the human body, if the electrical contact between the electrode and the skin is poor, the electrode contact may not be correctly detected. Even if the electrodes are judged to be in contact, electrode-skin contact stabilization is required to obtain a stable EEG signal.

CH2 Electrode attached state ([7]. CRD_PUD2_TYPE.bit4)

Indicates the value of the human body attachment state of the electrode(right forehead) Ch2. It is set (1) if the device is correctly attached to the body, otherwise it is reset (0). Care should be taken to prevent foreign matter (color cosmetics, hair, etc.) from getting caught between the electrode and the forehead when wearing the device. In addition, the skin needs to be kept cleanEven if the electrode is contacted with the human body, if the electrical contact between the electrode and the skin is poor, the electrode contact may not be correctly detected. Even if the electrodes are judged to be in contact, electrode-skin contact stabilization is required to obtain a stable EEG signal.

REF Electrode attached state ([7]. CRD_PUD2_TYPE.bit3)

Indicates the value of the human body attachment state of the electrode(right Earlobe) REF. It is set (1) if the device is correctly attached to the body, otherwise it is reset (0). Care should be taken to prevent foreign matter (color cosmetics, hair, etc.) from getting caught between the electrode and the forehead when wearing the device. In addition, the skin needs to be kept cleanEven if the electrode is contacted with the human body, if the electrical contact between the electrode and the skin is poor, the electrode contact may not be correctly detected. Even if the electrodes are judged to be in contact, electrode-skin contact stabilization is required to obtain a stable EEG signal. Since the earphone electrode is equipped with a PPG sensor, care must be taken to attach the electrode to obtain a stable PPG signal..

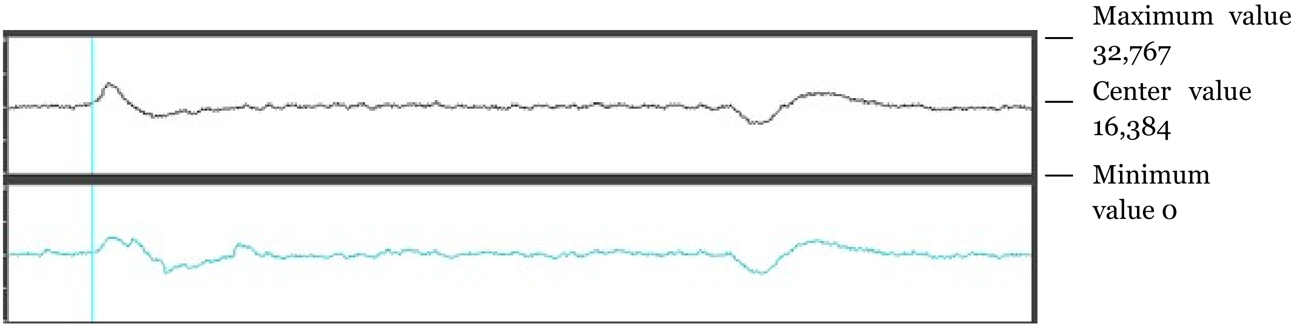
EEG waveform (CH1, CH2)

It represents EEG data measured at the current device. CH1 measured at the left forehead electrode and CH2 measured at the right electrode. EEG waveform data is transmitted in real time in one sampling unit.

AD conversion characteristics of EEG waveforms performed in the device

- Sampling frequency: 250Hz,
- Data Bit : 15bit.

Examples of EEG waveforms.



Picture [2]. Left brain EEG waveform (above), right brain EEG waveform (below).

LXSDF T2A EEG waveform placement

When 1 packet is transmitted, 1 sampling data is transmitted as Ch1_h and Ch1_l (in case of left brain / brain wave).

Sampling data value range: 0 to 32,767; Center value: 16,384 (16,384 means analog 0V point)

Bits 6 to 0 of Ch1_h are assigned the upper 7 bits of 1 sampling data total of 15 bits.

Bits 7 to 0 of Ch1_l are assigned the lower 8 bits of 1 sampling data total of 15 bits.

Processing data received from the host.

Sampling data of EEG waveform = upper 7 bits x 256 + lower 8 bits.

Example: If the value of the upper 7 bits was 9 in decimal and the value of the lower 1 byte was 126

2430 (digit) is obtained by sampling data of the EEG waveform = 9 x 256 + 126.

[Note: The factor to convert to uV is 0.03606 uV / digit.]

Power Spectrum(CH3)

The power spectrum of the brain wave waveform-CH1 and the brain wave waveform-CH2 calculated by the device are shown. The power spectrum is updated every 2 seconds (exactly 2.048 seconds), and the spectrum is obtained by FFT of the brain wave data for 2 seconds, and the value provided by the frequency resolution of approximately 0.5 Hz (precisely 1 / 2.048 to 0.488 Hz) to be. The left brain (CH1) power spectrum and the right brain (CH2) power spectrum coexist in the CH3 stream data. It is necessary to separate data from each stream data into individual channels.

Monitor power spectrum data at PUD0.bit0 = 1 at the start of 2 seconds. After this point, the number of data packets is counted. Assuming that the value is n, it is when PUD0.bit0 = 1 when n = 0.

For the given n, the left brain power spectrum is obtained by Power Spectrum_CH1 [m] (m = n, n = 129 to 256) and the right brain power spectrum is obtained by Power Spectrum_CH2 [m] (m=n – 128, n=129~256). When m = 1, it is a DC value. Every time the index increases by 1, the frequency interval increases by 0.488 Hz. At n> 256, the corresponding data is ignored. When PUD0.bit0 = 1, n must be initialized to 0 again (n = 0). The exact power spectrum value is obtained by dividing CH3 data by 10.

In this power spectrum, the theta-wave region is m = 10 to 17, alpha-wave region is m = 18 to 25, L beta-wave region is m = 26 to 31, M beta-wave region is m = 32 to 41, H beta-wave region is m = 42 to 62, gamma region is m = 63 to 83.

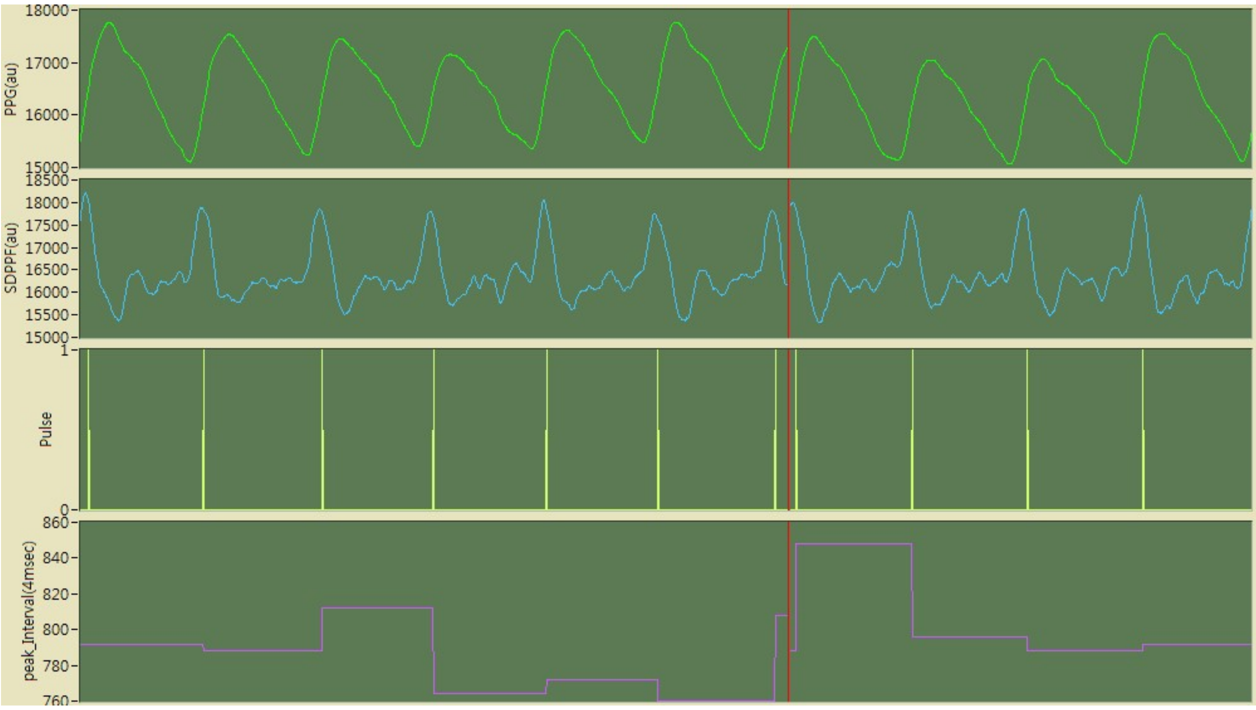


Figure [3]. PPG, sdPPG, Pulse, peak_interval signals. Pulse = PUD0.bit7.

PGG(PPG, CH4)

The waveform of the pulse wave detected by the PPG sensor of the ear lobe is shown. The pulse wave data is represented by 15 bits, and the data range is 0 to 32767. The DC standard is 16384. Since the AGG is set once after the sensor is worn, the amplitude of the PPG signal may fluctuate according to the input signal during the measurement although the AGC (automatic gain control) function is constant without fluctuation of the signal size due to the difference of the subject. Data is provided in real time on a sample-by-sample basis (see Figure [3]).

Secondary differential pulse wave(sdPPG, CH5)

Waveform data obtained by differentiating the pulse wave signal by the second time. The heartbeat pulse (event) is detected from this signal. It is represented by 15 bit, and the data range is 0 to 32767. The DC standard is 16384. Data is provided in real time on a sample-by-sample basis (see Figure [3]).

Heart rate interval data (peak-interval, CH6)

It is the data representing the time length between the heartbeat pulses detected from the sdPPG signal in units of msec. The value is updated every time a heartbeat pulse is generated. Using this data, HRV analysis results can be obtained. The representation precision of the data is 1/250 = 4 msec. The range of values is 250 to 2000 (msec) (see Figure [3]).

Revision History

Release Date	Doc. ID	Description of Change
2018-03-22	LXE141 V1	First release.