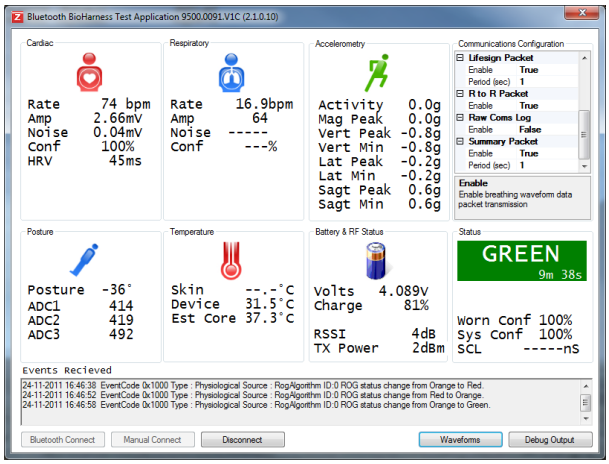
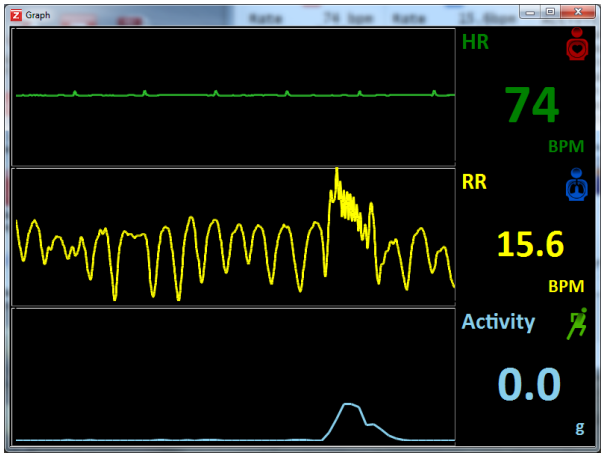
Zephyr technology

BioHarness Bluetooth Developer Kit





User Manual

Contact

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Document History

Version	Date	Description
1.0	1 May 2008	Initial draft for review
1.1	7 May 2008	Data Descriptions section revised
1.2	4 June 2008	Add Troubleshoot Section
1.3	16 Sept 2008	New Test App GUI added
1.4	29 Oct 2008	BlueSoleil Version note
1.5	20 Nov 2008	Update to v1.2.0.0 of Test App grabs
1.6	23 Feb 2009	Update Test App. executable name Added ZPNs
1.7	9 June 2009	Clarify device RF/Log configuration throughout
1.8	28 Jan 2010	Add BT Config Tool
1.9	16 Mar 2010	Add new LED behaviour. Update data descriptions.
1.10	29 April 2010	Add ROG status behaviour
1.11	27 May 2010	Add Button Worn explanation
1.12	2 June 2010	Amend Refs to BT Comms Link doc, BT Logging Interface
1.13	Mar 2011	Replace Research App with Log Downloader. Update Configuration Tool, Test Application v2 Add Firmware Upgrade Utility, Log Downloader source directory.
1.14	July 2011	Remove Cfg Tool section and refer to separate document. Update List of Components.
2.0	Dec 2011	Update for BioH 3.0. Merge Cfg Tool , Updater & download instruction documents

Document Notes

All numbers in this document are written in decimal, except hexadecimal numbers which are prefixed by '0x'. For example 5436 is decimal, while 0x5436 is hexadecimal.

Contents

1. Introduction

1.1. References

Ref #	ID	Description
[1]	9700.0110	BioHarness Bluetooth Comms Link Specification.
[2]	9700.0027	BioHarness Bluetooth API Guide
[3]	9700.0111	BioHarness Bluetooth Logging System Interface
[4]	9700.####	Event Messaging System
[5]	9700.0136	BioHarness 3.0 Data Sheet

1.2. Abbreviations

Abbreviation	Description
Acc	**A**cceleration, **A**ccelerometer
API	**A**pplication **P**rogramming **I**nterface
AT	**A**erobic/Anerobic **T**hreshold
BioH	**BioH**arness module
BT	**B**luetooth
ECG, EKG	**E**lectro**C**ardio**G**ram
GUI	**G**raphical **U**ser Interface
PC	**P**ersonal **C**omputer
PDA	**P**ersonal **D**igital **A**ssistant
ISM	**I**nstrument, **S**cientific & **M**edical Band (~900MHz radio frequency band)
ROG	**R**ed, **O**range, **G**reen subject physiological status indication
SPP	**S**erial **P**ort **P**rotocol

1.3. Product Description

The Zephyr BioHarness is a physiological monitoring system. The subject wears a Smart Fabric chest strap or shirt which incorporates sensors to monitor heart ECG signals, and respiration rate.

Attached to the strap is the BioHarness Module. This contains a temperature sensor and a 3-axis accelerometer for monitoring attitude (subject posture) and activity (acceleration).

Raw sensor data is filtered, processed and analyzed within the device, which can operate in three modes. These modes are software configurable. The commands required to determine and set these modes can be found in the Bluetooth Comms Link Specification document (sections 5.51 Get BioHarness User Configuration & 5.52 Set BioHarness User Configuration).

- Transmit mode
  Data is transmitted by Class I Bluetooth over an 80 meter range (depending on receiver hardware) to a corresponding Bluetooth receiver device. This will allow physiological data to be monitored using any suitably-configured Bluetooth mobile device, such as a laptop, phone or PDA.

  A Bluetooth Test App is provided with the Developer Kit which displays transmitted data in real time. When the Bluetooth connection is terminated, the application generates .csv files containing the transmitted data.

- Record Mode
  Data is logged to internal memory. This data can be accessed when the device is placed in a cradle and connected via USB to a PC. A BioHarness Log Downloader utility is provided which will export log data to external .csv and/or .dat files.

- Transmit & Record Mode
  Data is transmitted and recorded simultaneously. The two utilities mentioned above are used separately to display and record live streaming data, and download log data afterwards.

Note: Zephyr-supplied devices are default-configured to simultaneously transmit and log mode. They must be reconfigured using the Zephyr Cfg Tool to disable either of these modes

1.3.1. BioHarness Module Versions

This version of the Bluetooth SDK is released in conjunction with Bluetooth BioHarness 3.0. This model supersedes the BioHarness 2.0, though both versions of device will continue to be available.

BioHarness 2.0

BioHarness 3.0

The table below summarises the main *differences* between the two device versions.

Parameter	BioHarness 2.0	BioHarness 3.0	Notes
Bluetooth	Class II	Class II	BioH 3 offers improved range
LED feedback	Single bi-color	4 LEDs	
Transmit Duration	9 - 21 hrs	12 - 24 hrs	Dependent upon receiver hardware
Logging Duration	24 hrs	35 hrs	
Temperature Measurement	Infrared sensor + Device Internal sensor	Device internal sensor	Estimated Core Temperature by calculation from BioH 3.0
ECG Waveform	Indicative	EC38 compliant for ambulatory monitor	
Logging Formats	General General + ECG General + Acc	General General + ECG General + Acc Summary Summary + Waveform Event	Summary log has additional parameters over General. Summary + Waveform includes all available waveforms inc. ECG and Acc
Dimensions	75 x 57 x 15 mm	28 x 7 mm	
Weight	35 grams	18 grams	
Strap Attachment	3 x metal conductive snaps	Snap fit into receptacle, spring contacts	
Case Material	ABS	Polycarbonate	

Refer to data sheets for each device for specific comparisons.

Ongoing development work will focus on the BioHarness 3.0.

In 2012 versions will become available which are Apple-compatible, and/or support additional RF protocols such as 802.15.4.

1.4. Documents

1.4.1. BioHarness Bluetooth Developer Kit User Manual

This document.

1.4.2. BioHarness Bluetooth API Guide

This document contains detailed data descriptions, and specifies which messages apply to the Bluetooth Device.

1.4.3. BioHarness Bluetooth Comms Link Specification

This document describes *all* Zephyr request/response messages. This is a superset of the messages specified in the API Guide.

1.4.4. Logging System Interface

This document describes log formats.

1.4.5. Event Messaging System

This document describes the codes for a variety of physiological events which can be indicated by the device, based on internal algorithms which analyze inputs over time.

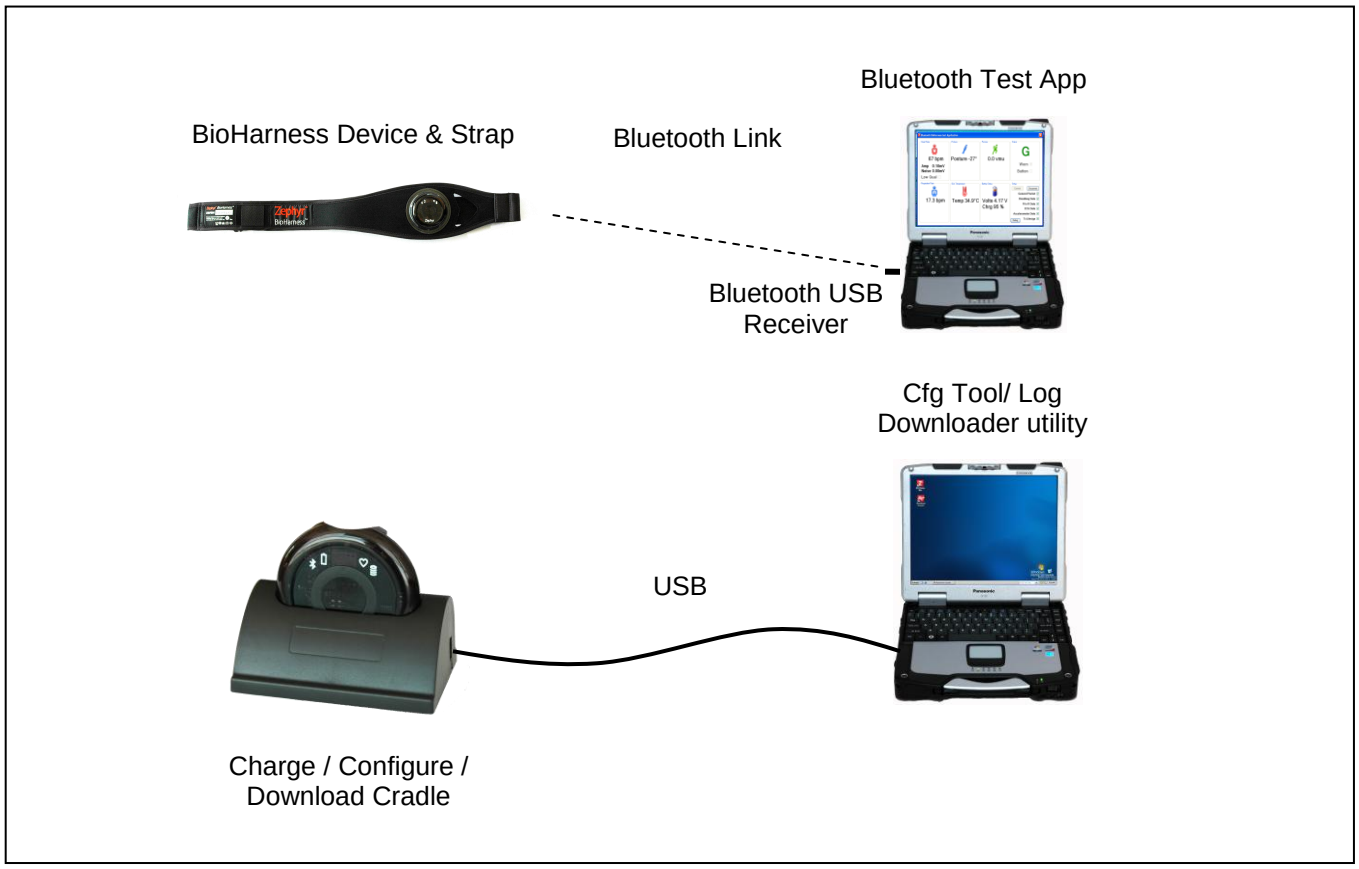
1.5. List of Components

The following components are included in the Developer Kit

Component	Description	Part No.
Hardware		
Smart Fabric Chest Strap	Small (XS – M, 70 – 97cm) and Large (M – XL, 85 – 110cm) available	9600.0262 9600.0255
Shoulder	Wear is optional for extra security	9600.0256
BioHarness 3.0 Module		9600.0254
BioHarness Device USB Cradle		9600.0257
USB/USB-mini connector lead		0015.0003
Software		
Zephyr USB Driver	For connection of BioHarness Device to PC when charging or importing recorded data	9500.0101
BioHarness 3.0 USB Driver		9500.0101
Zephyr Bluetooth Test App	Utility to display Bluetooth transmitted data	9500.0091
Zephyr Cfg Tool	Utility to read device parameters and configure device mode	9500.0096
BioHarness Log Downloader	Utility to Download Log data	9500.0078
BioHarness Log Downloader Source	C# .NET code for the downloader utility.	
BioHarness Firmware Upgrade Utility	Utility to upgrade firmware images	9500.0088
Sample Android Project	Sample project for Android Developers	9500.0094
MATLAB Script File	Script File for importing BioHarness data into MATLAB	9500.0095
Documents		
User Manual	This Manual	9700.0026
BioHarness Bluetooth API Guide	Guide to implementing an API	9700.0027
BioHarness Bluetooth Comms Link Specification	All message and response descriptions, and data packet formatting	9700.0110
BioHarness Bluetooth Logging System Interface	File and data formatting for device internal memory	9700.0029
Event Messaging System		
BioHarness 2.0 Data Sheet		9700.0042
BioHarness 3.0 Data Sheet		9700.0136
BioHarness Side Strap Data Sheet		9700.0024
MATLAB Script File Description		9700.0151
BioHarness BT Android API	User Guide for Android Developers	9700.0150

2. Setup

2.1. System Diagram



2.2. Overview

Do not connect the BioHarness Device to a PC until the relevant driver software has been installed.

The following steps are recommended (in order) for setup and configuration of the system:

- Install Zephyr USB Driver software
- Connect BioHarness Device and cradle to PC for battery charge
- Install Zephyr Bluetooth test Application, Cfg Tool & Log Downloader utilities

The SDK does not contain any dlls or code samples other than that supplied for the Log Downloader and the sample Android Project.

2.3. Installation

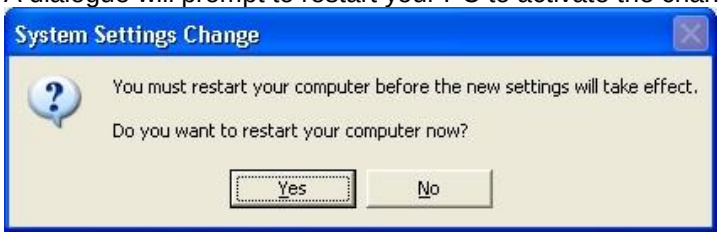
Do not connect the BioHarness Device to a PC until the driver software has been installed

2.3.1. Zephyr USB Driver Install

1. Browse the Bluetooth Developer CD, and locate the ZephyrDeviceInstaller.exe file, in the Zephyr USB Driver folder.
2. Double-click the executable file to begin the installation process.
3. Follow the Wizard:

Click *Install*.

4. A dialogue will prompt to restart your PC to activate the changes.



Click ***Yes*** if you intend to connect any Zephyr hardware to the PC.

2.3.2. Zephyr Hardware Install / Charge BioHarness

The BioHarness Device is powered by a Lithium Polymer cell which is charged via a PC USB Port. To install the hardware, simply connect to your PC in its charging cradle.

Two notification dialogues will display:

When the hardware is installed, the orange LED will blink, to indicate the Device is charging. When fully charged the LED will remain constant.

When using the Zephyr Cfg Tool to read device parameters, battery voltage will *always* indicate 100% when a BioH 3.0 is in the charge cradle. For a BioH 2.0, actual battery charge state will be indicated.

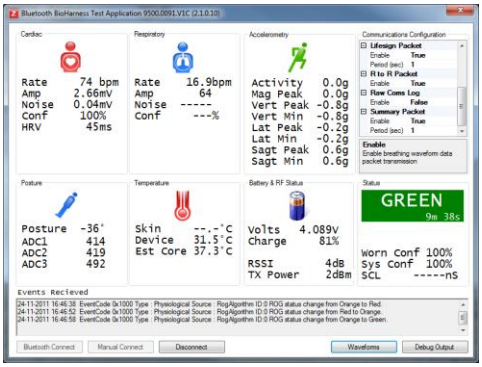
Constant orange LED = fully charged device

2.3.3. .NET 3.5 Framework Install

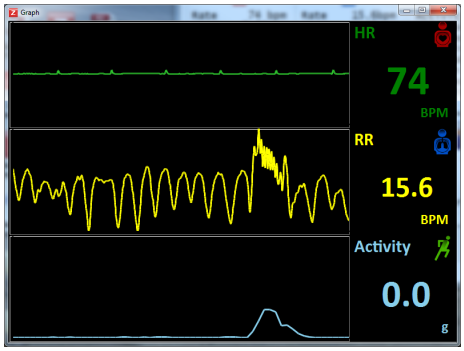
The Bluetooth Test App and Log Downloader Tools require Microsoft .NET 3.5SP1 to be installed. The installer for this is located in both the Test Application and Log Downloader directories. Installation will be automatic when the *setup.exe* is selected in either of these directories.

3. Operation

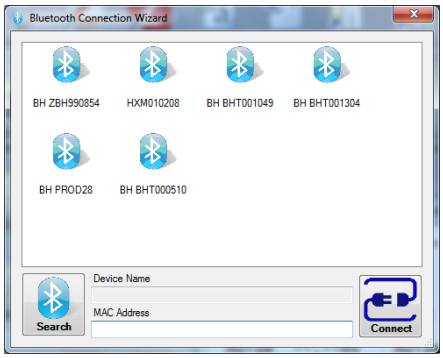
3.1. Zephyr Bluetooth Test App



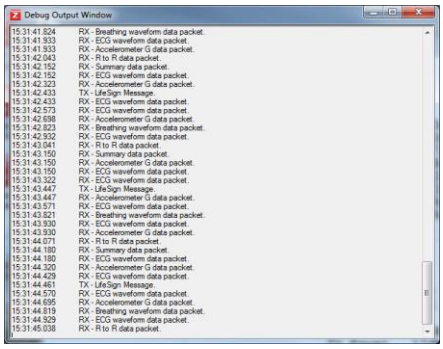
Main window



Waveform window



Connection wizard



Debug window

3.1.1. Connection to BioHarness

- Use the *Bluetooth Connect* button to display the connection window. Search for devices (multiple attempts may be needed) or enter the MAC address of the BioHarness manually if known.
- Use *Manual Connect* to display a serial port connection dialogue. Baud rate setting is displayed but are not relevant for a BioHarness module.

3.1.2. Device Parameters

- Refer to the BioHarness 3 Data Sheet for details on all displayed parameters
- Refer to the *Event Messaging system* document for details on events displayed

3.1.3. Data Packets

- In the *Communications Configuration* panel, all data packets can be enabled or disabled as required. This can be done while transmitting.
- In order to see waveforms in the Waveform window, some data packets must be activated
    - HR waveform – ECG Data Packet
    - RR (Respiration waveform) – Breathing packet
    - Activity waveform – Accelerometer Packet

3.1.4. Debug Output

- The debug output window shows top-level debug messages
- To access raw communications in hexadecimal format, enable the *Raw Comms* data packet and retrieve from csv files outputted at the end of the transmitting session.

3.1.5. CSV Output

- The Test Application generates csv files of all transmitted data, accessible at the end of each transmitting session. They are located at `..\My Documents\BioHarness Test Logs`

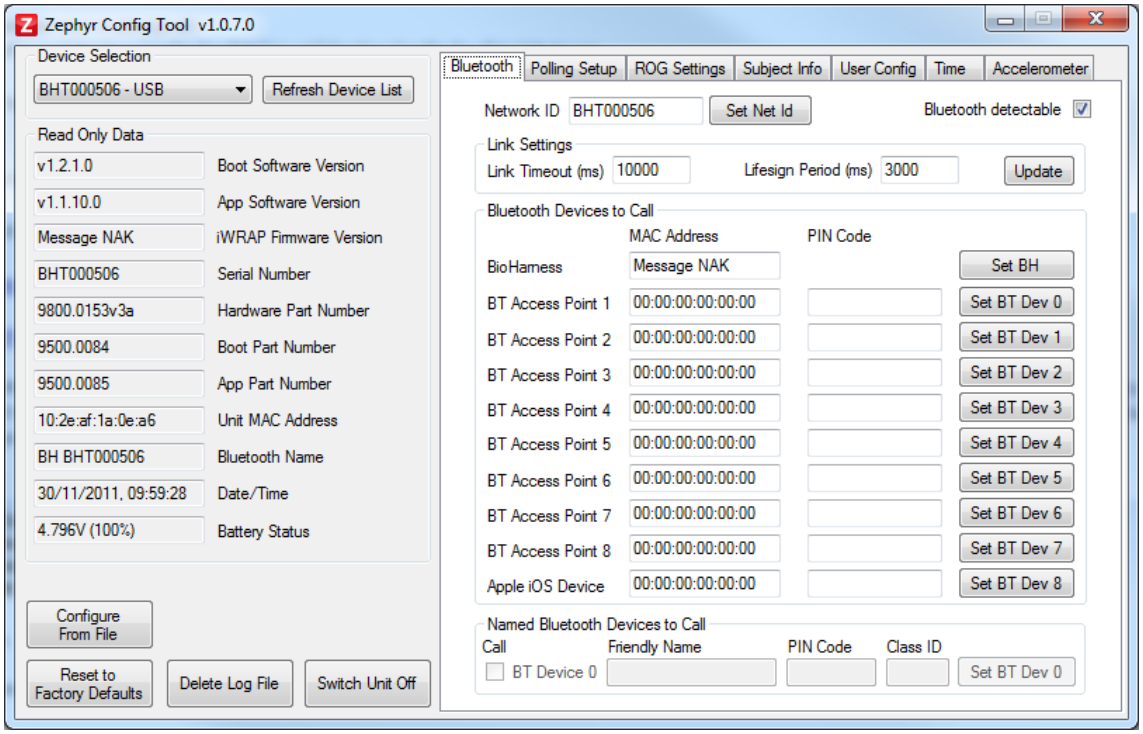
- A new folder is created for each session

- With all data packets enabled, the following files will be created:

CSV File	Reporting Interval (ms)	Description
Accelerometer data	20	X/Y/Z Raw ADC output; for BH3 centred 2048, 83LSB = 1g. For engineering use
Accelerometer G data	20	X/Y/Z in g
BR data	56	Raw breathing sensor output
ECG data	4	Raw ECG sensor output
Gen Data	1000	General Packet – see *Bluetooth Comms Link Document* or data sheet for details
Raw_Comms	Per Msg	
RtoR data	56	RR in ms – alternating signs per detection
Summary data	1000	Summary Packet – see *Bluetooth Comms Link Document* or data sheet for details
Event Data	Per Event	Event information. Refer to *Event Message System* document for details

3.2. Zephyr Cfg Tool

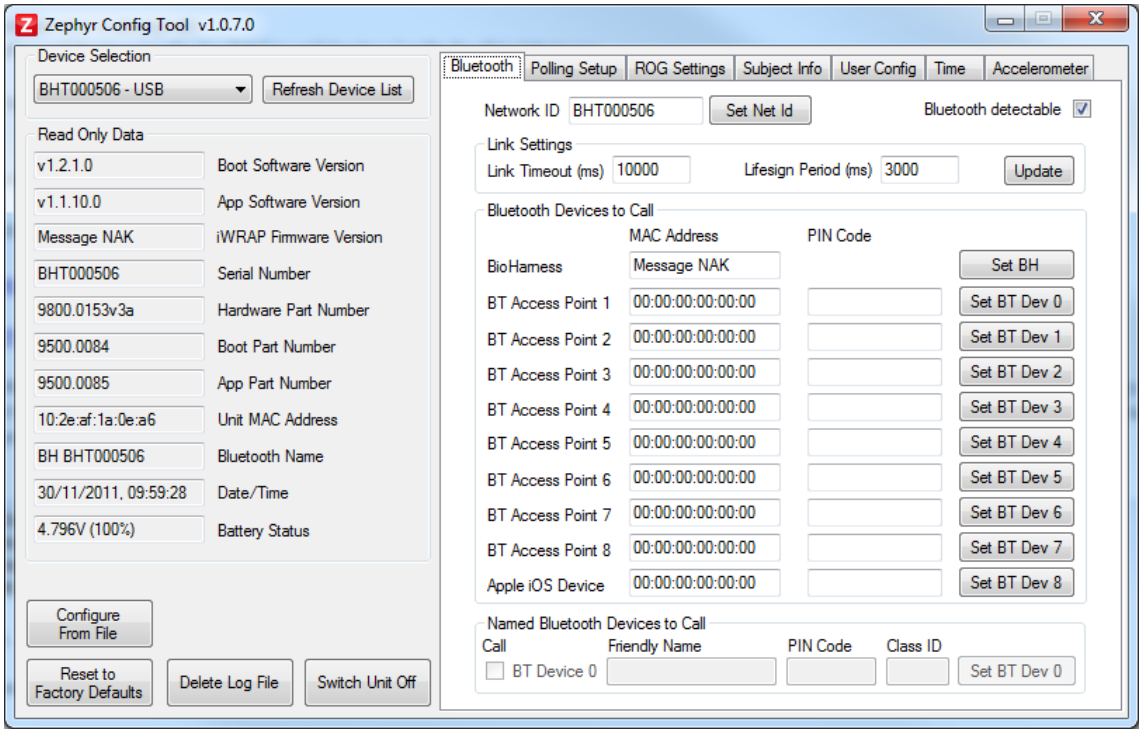
3.2.1. Device Parameters



- A Message NAK (not acknowledged) may mean a software error, or the device is not programmed to provide the value.

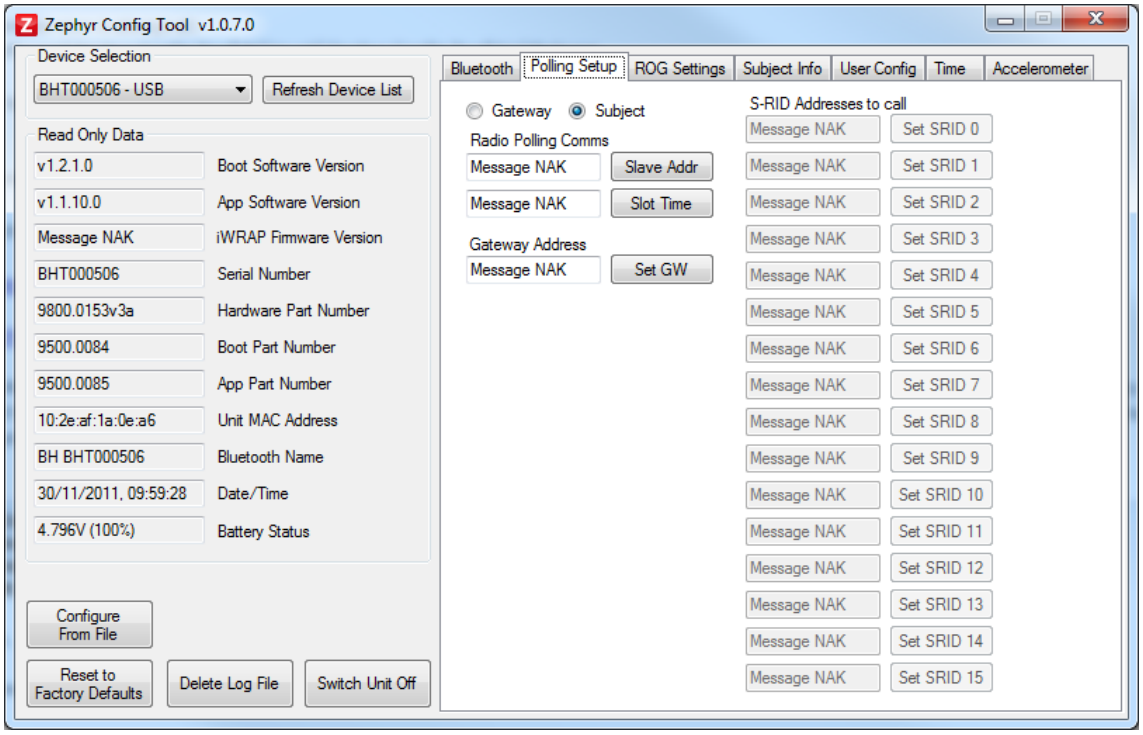
Boot Software Version:	Zephyr bootloader – update is return-to-Zephyr
App Software Version:	Zephyr device firmware – update using Zephyr updater
iWRAP Firmware version:	Bluetooth module firmware – a BioH 3.0 will return a NAK for this parameter
Serial Number:	Device serial number
Hardware Part Number:	Zephyr Part #
Boot Part Number:	Zephyr bootloader Part #
App Part Number:	Zephyr Firmware Part #
Unit MAC Address:	MAC address for Bluetooth communication
Bluetooth Name:	Name which will be seen in a Bluetooth search for the device. BH prefix=BioHarness
Date/Time:	Internal Date & Time when the device is read – does not update in real time
Battery Status:	When in cradle, the charging voltage, *not* the device battery voltage
Buttons:	
Configure from File:	Set all device parameters (all tabs) from a file
Reset to factory Defaults:	Reset all parameters to factory defaults
Delete Log File:	Delete all logs on the device permanently
Switch Unit Off:	Power off microprocessor and internal clock – use for long term storage of the BioHarness, to protect the battery

3.2.2. Bluetooth



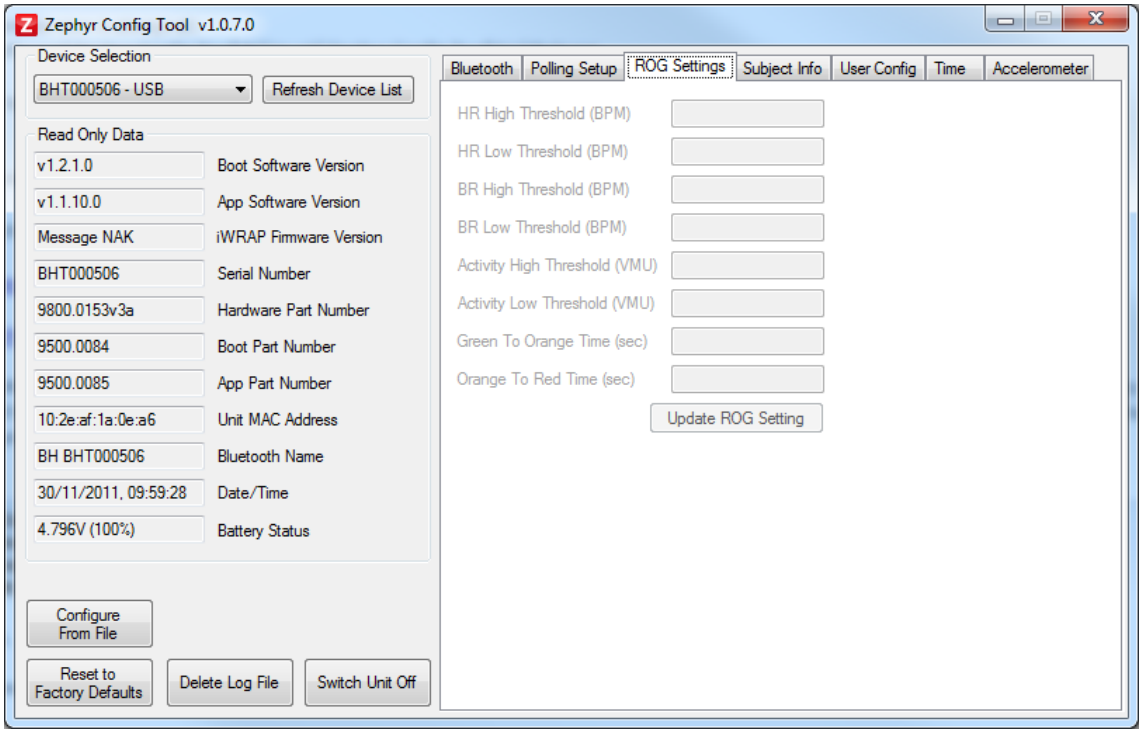
Network ID:	The Bluetooth-searchable name of the device
Bluetooth Detectable:	Uncheck if the device is not to be found during a Bluetooth search
Link Settings:	Bluetooth connection settings
Link Timeout:	Default 10 sec. Set to 0 for the device to never unilaterally disconnect.
Lifesign Period:	Default 3 sec. Set to 0 for the device to never unilaterally disconnect.
Bluetooth Devices to Call:	MAC address and PIN information for calling other Bluetooth devices, such as external sensors or Bluetooth receiving devices. These values are normally sent to the device or programmed into it by the OmniSense application as part of the function of a Zephyr PSM system.
Named Bluetooth Devices to Call:	As above, when the device name is used, rather than its MAC address

3.2.3. Polling Setup



- Polling setup is used for configuring Zephyr Radio Interface Devices, and has no use in a BioHarness context.

3.2.4. ROG Settings

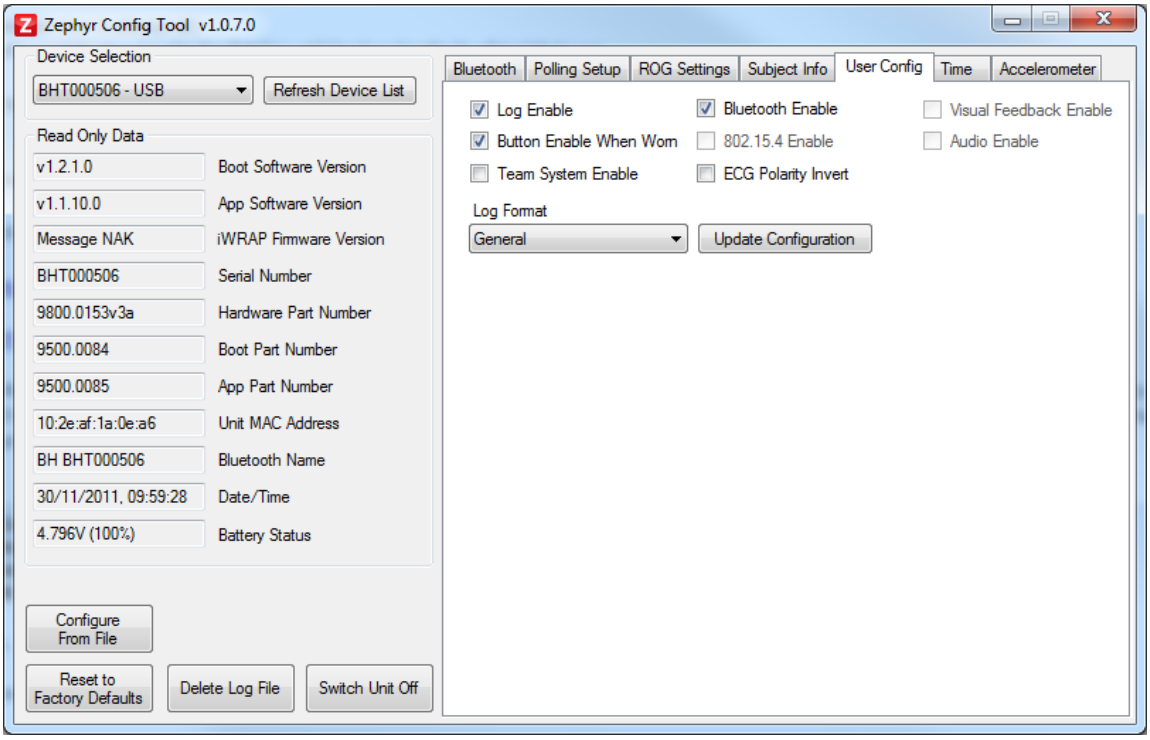


- This tab applies to BioHarness BT v2.0 devices, with firmware which uses version 1 of Zephyr's Red/Orange/Green (ROG) physiological status algorithm. This was used in v2.0 device firmware versions up to release version 2.3.2.0
- Later v2.0 devices, and all v3.0 devices, use version 2 of the ROG status algorithm which requires no user input initially, other than subject maximum heart rate.
- Future versions of this tool will allow for more detailed configuration of the algorithm.

3.2.5. Subject Info

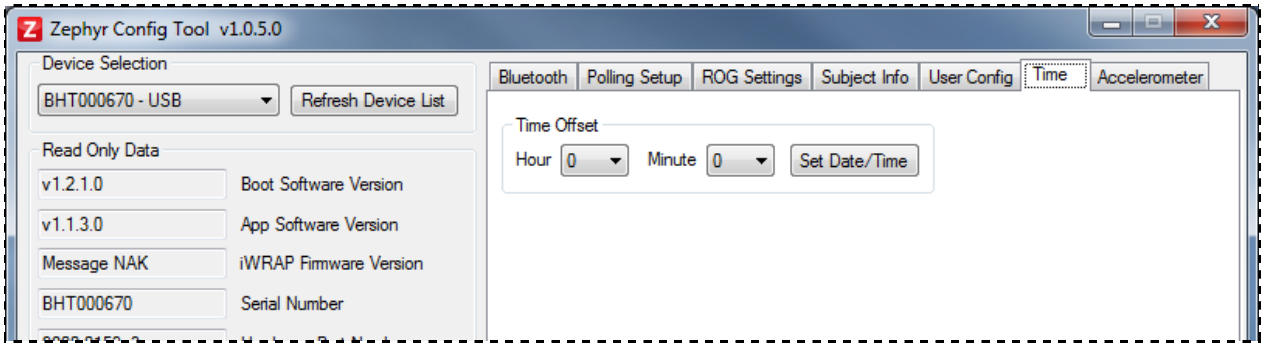
- A detailed description of all the Subject Info parameters used to configure the ROG2 algorithm will be described in a separate document.

3.2.6. User Config



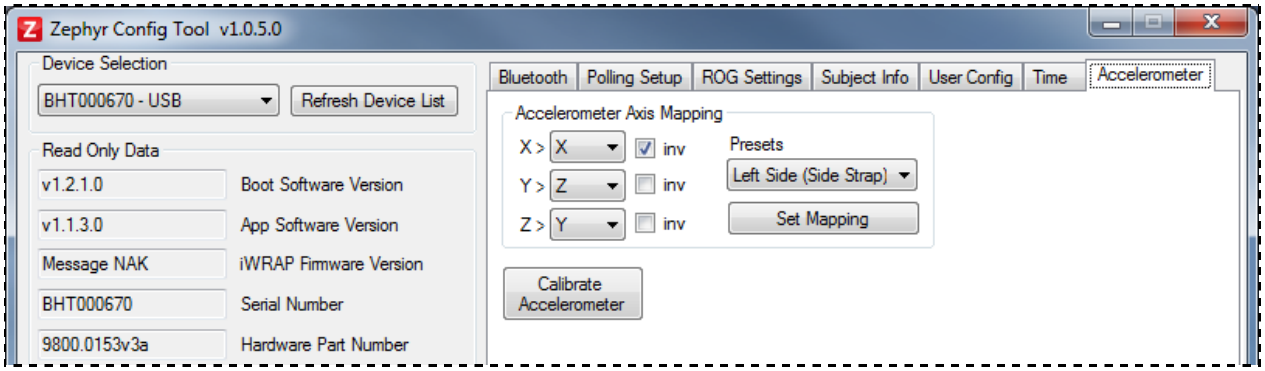
Log Enable:	Check to enable logging(independent of BT transmit)
Bluetooth Enable:	Check to enable BT transmit (independent of logging)
Visual Feedback Enable	Enable or disable device LEDs, except for ON / OFF function
Button Enable When Worn:	Check to allow the ON/OFF button to be used while the device is on the strap. Uncheck to disable the button, and prevent accidental pressure turning off the device while it is worn. For a BioH 3.0 the default behavior in checked – this cannot be reconfigured
802.15.4 Enable	Enable this RF protocol in a BioHarness when it becomes available
Audio Enable	Enable or disable device beeper
Team System Enable:	Check for BioH v3.0 when used with PSM Training 3.0 – automatically configured when adding device to system in OmniSense
ECG Polarity Invert:	This should be checked for a BioH v2.0 in a side strap. The polarity of the ECG snaps is reversed compared to the older legacy front strap. Not required for BioH v3.0
Log Format:	
General:	1Hz summary data, plus 18Hz Heart rate RR & breathing
General & ECG:	Additional 250Hz ECG
General & Accelerometer:	Additional 100HZ Activity level (3-axis vector magnitude)

3.2.7. Time



- Use to reset time to current PC time in the event of a newly-delivered device, or add an offset as required.
- Note that any time data is imported from the device into OmniSense via the Analysis module, the BioHarness clock is automatically re-synchronised with PC time.

3.2.8. Accelerometer



When assigning a device to a subject in OmniSense, garment type is selected and the device configured accordingly. This tab allows for manual setting.

The Presets selector allows for all current and some future garment options – device orientation within the garment may vary, and accelerometer axes must be mapped correctly so that subject posture/orientation is reported correctly. Use this selector in preference to the manual Axis > Axis settings.

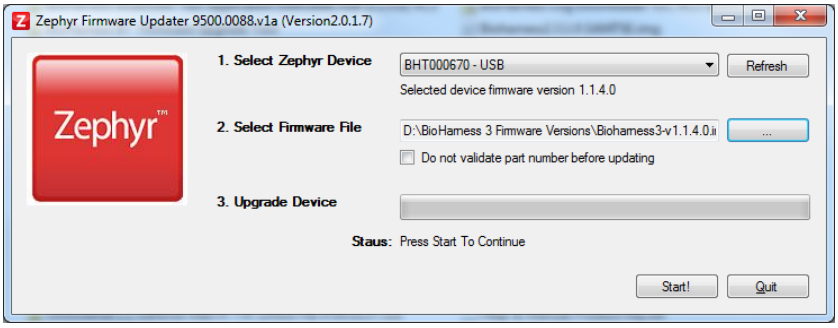
Device accelerometers are factory-calibrated and should *never* normally require recalibration. Should it become necessary, all Factory defaults should be reset first using the Reset to Factory Defaults button, and the device cradle located on a solid horizontal surface. BioH 3.0 device accelerometers *cannot* be user-calibrated. This is done in the factory.

3.3. Firmware Upgrades

1. Connect the device in its cradle, to your PC. Exit any other Zephyr applications or utilities. Disconnect any other Zephyr USB devices from the PC.

2. Locate utility ***ZUSBUpdater.exe*** from the software CD image and double-click to start

3. Click ***Refresh*** and use the pull down selector to choose the device you are programming



4. Click the button marked '***...***' and browse to locate the firmware image file.

   From v2.3.1.0 onwards, there are two alternative firmware image files. They should be labelled according to the hardware part number appropriate for your device e.g.

Hardware Part No	Firmware Image
9800.0153.v3a	BHT_1.1.3.0_9800.0153.img

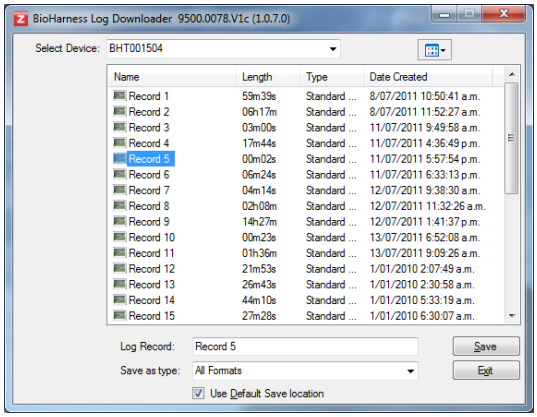
3.4. Logging Modes

The BioHarness can be configured to a number of different log formats. These are set using the Zephyr Cfg Tool. Briefly, the modes are:

General:	1 Hz general parameters + 18Hz breathing waveform & heart rate RR
General + ECG:	General + 250Hz raw ECG waveform
General + Acceleration	General + 100Hz Activity level (accelerometer magnitude)
Summary	Expanded General data
Summary + Waveform	Summary + 250Hz ECG, 50Hz Accleration

Log formats are described in the BioHarness 3 Data Sheet.

3.4.1. BioHarness Log Downloader



Device in cradle

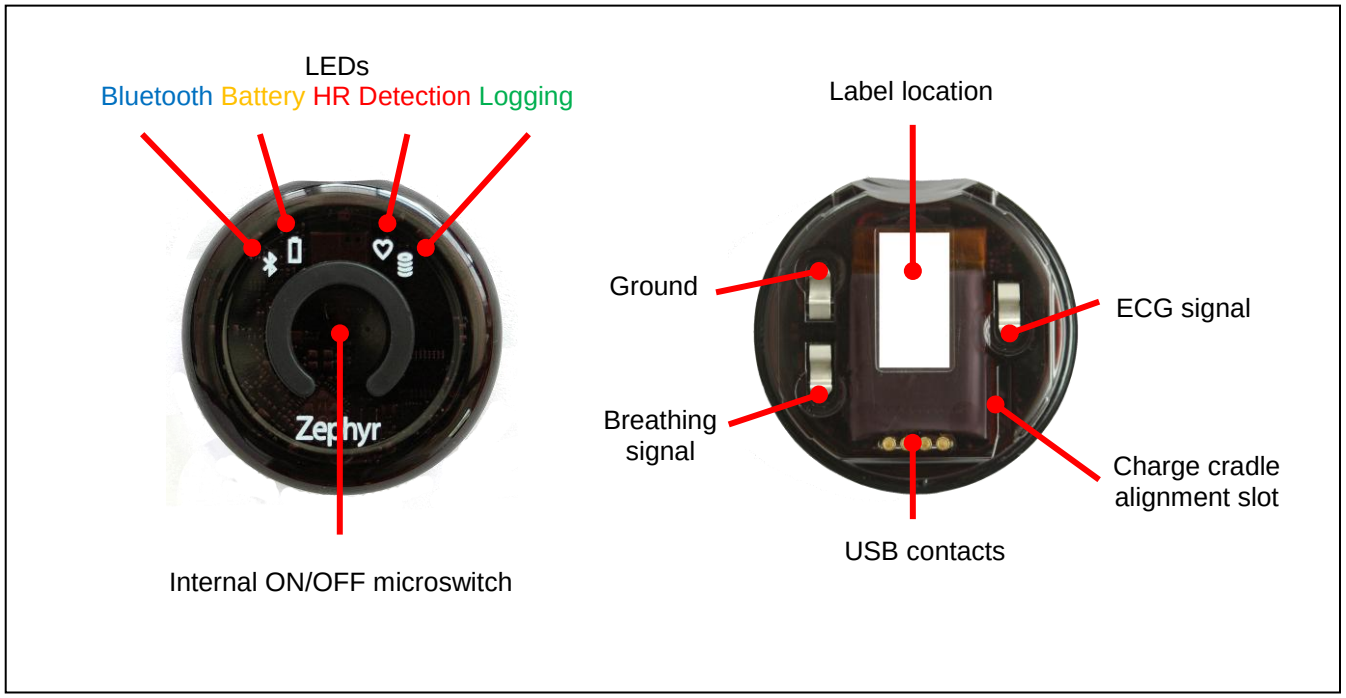
To use the tool:

1. Place your device in the configuration cradle or system case
2. Access the tool
3. Select the device
4. Select the required log session
5. Select *Save as type* for output format
6. Click *Save*
7. The default save location is ***C:\Users****[UserName]****\Documents\BioHarness Test Logs***

The downloader tool can generate two sets of files containing the same data:

- csv format, which can be opened by Excel (Windows default) or Notepad
  - Limit of 1,000,000 lines in Excel = 66mins of ECG
  - Excel graph limit is 32,000 points = 128 seconds of ECG
- .DAT/.HED format, which can be imported into specialized data analysis applications such as DaDISP or Matlab.
  - Preferable for larger data sets – no limit to lines or graph points
- the Log Downloader utility synchronises the BioHarness module internal clock when the device is first connected
- a large file will take some time to download. ECG data should take around 90 seconds for each hour's worth of data.

3.5. BioHarness Device

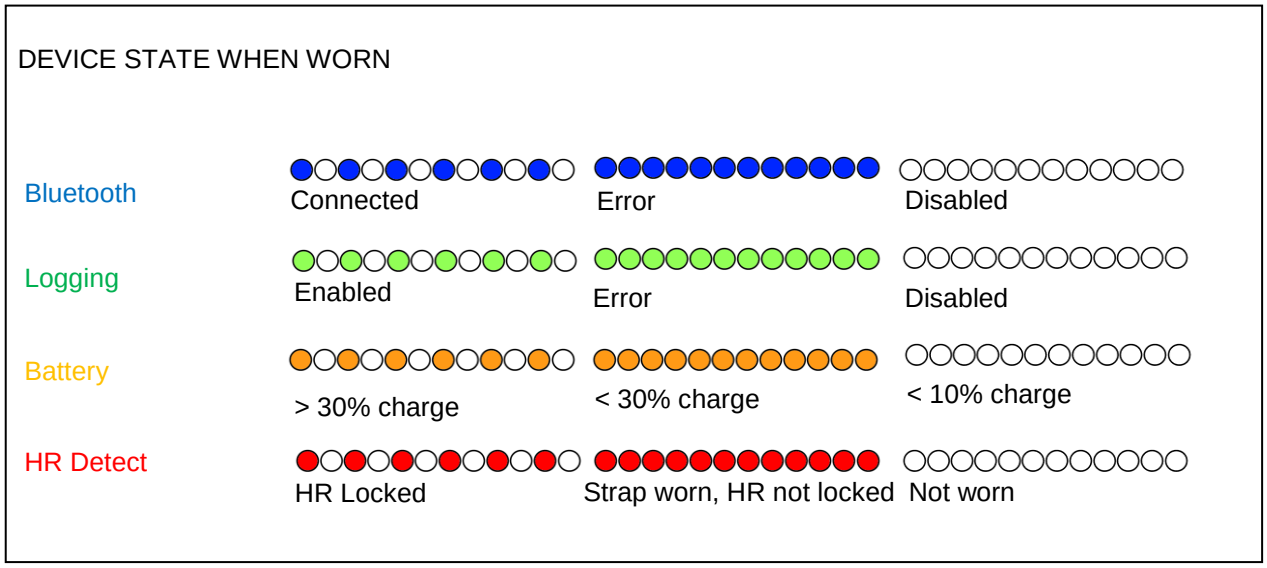


The power button switches the device on and off. The device will then transmit data or log it internally, or transmit and log simultaneously, according to how it has been configured.

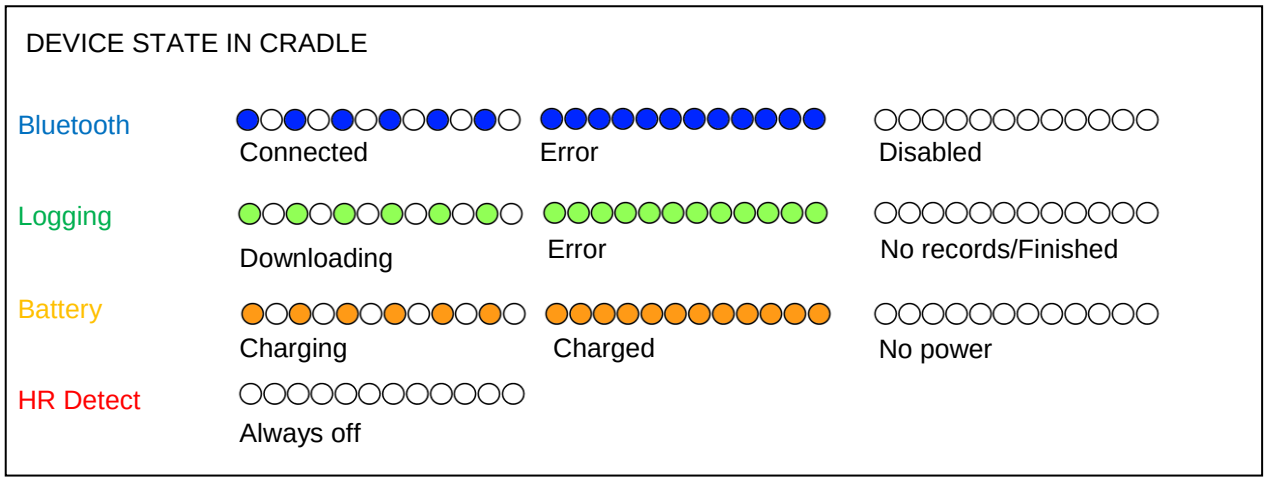
Device configuration can be done using the Zephyr Cfg Tool supplied with this SDK, or using the appropriate messages described in the [1] *BioHarness Bluetooth Comms Link Specification*.

Device configuration is indicated by the LED behavior described in the next section.

3.5.1. LED Behaviour



If power cycling a BioHarness module does not cancel a Bluetooth or Logging error, then a hardware fault is likely – replace the device in the interim.



3.6. Care & Maintenance

3.6.1. BioHarness Device:

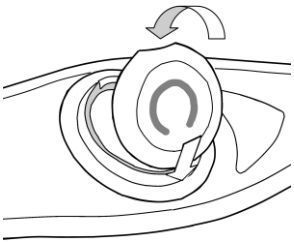
- O-ring sealed and water resistant (DO NOT use for swimming or other water-based activities)
- Wipe with a soft damp cloth and towel-dry
- Clean the Temperature window with a cotton bud
- Do not leave in direct sunlight for long periods (such as in a vehicle)

3.6.2. BioHarness Strap:

- Detach the BioHarness Device
- Rinse the garment in fresh water after use to disperse the salt from perspiration.
- Hand wash, or machine wash on a Cold, Delicate setting after 30 days of use.
- Use a washing pouch if possible.
- Do not spin or tumble dry
- Hang to dry, out of direct sunlight
- Do not use bleach
- Do not iron

3.7. Strap Fitting & Location

1



Fit the device to the strap. An LED will flash

Lightly moisten sensor pads with water for best performance

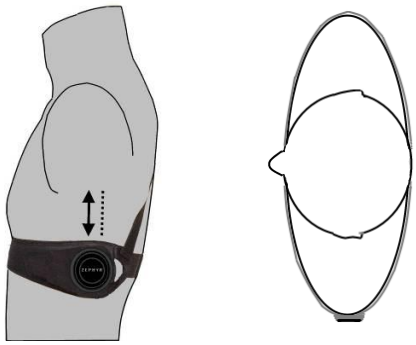
2

Adjust the strap tension at front and rotate into place. Adjust optional shoulder strap for minimal tension if used.

3

Tension indication loop at rear should be flush with strap (shown un-tensioned here) when subject inhales and chest is fully expanded

4

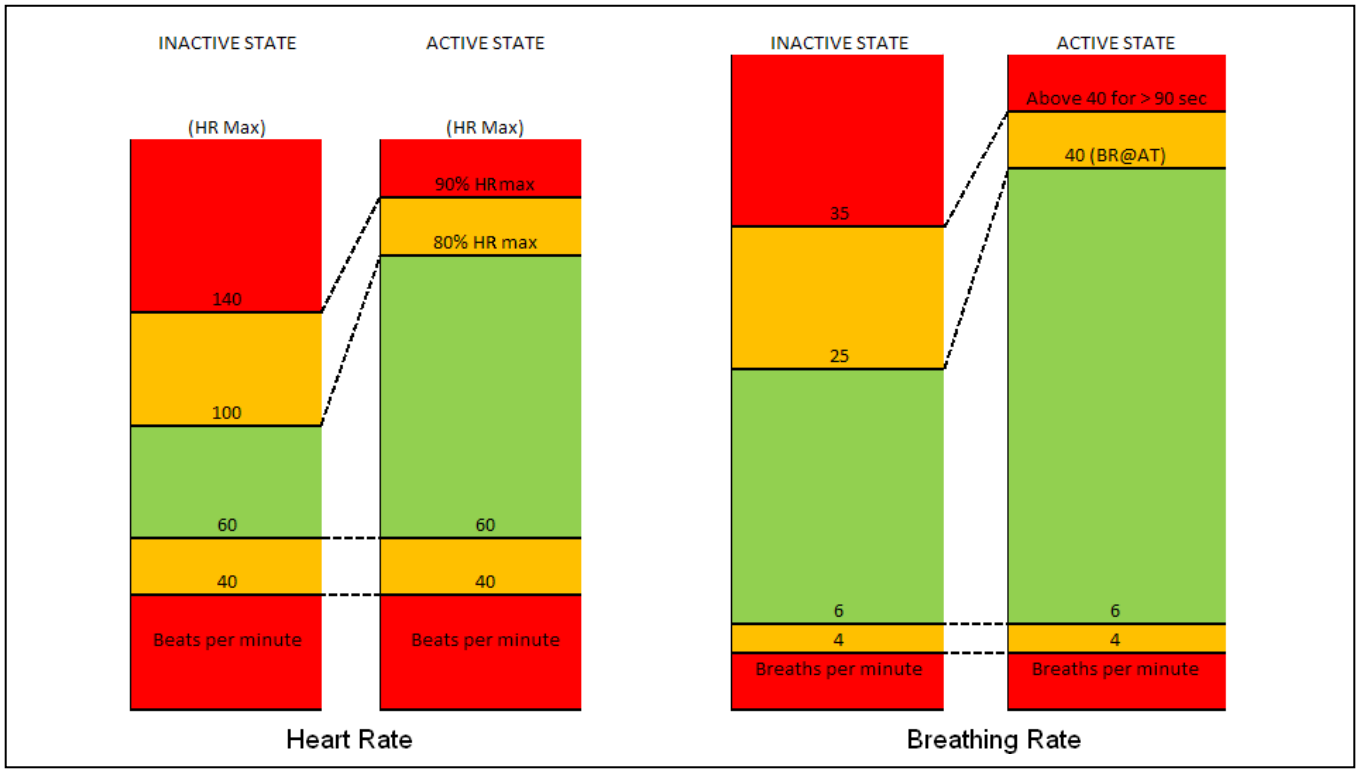


Centre line of the device should be directly under the armpit – for optimum breathing detection device should be at apex of rib curvature. The device can be moved slightly(~1”) to the rear only (dotted line) if the optimum location is uncomfortable.

4. ROG Subject Status Indication

The BioHarness module outputs a subject status indication which has the values:

- Green – subject's physiological parameters are within thresholds as configured
- Orange – one or more of the subject's parameters have crossed the configured threshold values. The subject's data should be monitored more closely.
- Red – one or more of the subject's parameters have exceeded threshold values for a sustained period (configurable). The subject's physiological parameters should be monitored closely, and confirmation sought if there is an indication of stress, fatigue or trauma.



Subject status is an indication of departure from expected norms of heart rate and/or breathing rate of a subject, dependent on their level of activity. In Zephyr applications, this indication is shown on the subject BioGuage.

Green subject status

The ROG algorithm takes into consideration the subject's activity level. This provides superior interpretation of the physiological data inputs by providing configurable thresholds for both inactive and active states.

Subject status becomes orange or red if either the heart rate or breathing rate crosses any of the thresholds shown in the diagram above.

The subject's activity measurement – VMU, measured in g, calculated over the previous second, determines whether the INACTIVE or ACTIVE thresholds are applicable.

VMU < 0.2 = INACTIVE
VMU > 0.2 = ACTIVE

There are two exceptions:

- The INACTIVE thresholds persist 10 seconds after activity level has increased above 0.2, as physiological parameters do not increase in this period, as a rule.
- The ACTIVE thresholds persist for 150 seconds after activity level has dropped, as testing has shown that physiological parameters remain high in this period, unless the subject parameters return to the inactive green zone, in which case the INACTIVE thresholds apply immediately.

These time transition periods are not user-configurable.

4.1.1. ROG Threshold Default Values

Threshold	INACTIVE	ACTIVE
HR Low Orange (Beats/min)	50	50
HR Low Red	40	40
HR High Orange	100	80% HR Max
HR High Red	140	90% HR Max
BR Low Orange (Breaths/min)	6	6
BR Low Red	4	4
BR High Orange	25	40 (BR@AT)
BR High Red	35	As orange, but for > 90 sec

Methods for establishing thresholds:

INACTIVE SUBJECT
HR Low Orange – Use the Resting Heart Rate protocol – the subject should lie down horizontally for a minimum of a minute, from a non-exerted state. Record the peak heart rate achieved after this period, while the subject is still horizontal.

BR High Red - 35 bpm is typically equivalent to a subject in the initial stages of clinical shock (rapid shallow breathing).

ACTIVE SUBJECT
HR High Orange & Red – to estimate, use the formula HRmax = (220 – age)
Factory default settings assume a normative age of 25 for calculations.

An individual's tested maximum heart rate can be determined through a maximal ramped fitness test using a recommended protocol (e.g. Treadmill/Beep tests). The ACSM describes protocols for such tests
BR High Orange & Red - should be typically equivalent to the breathing aerobic threshold (AT). The default is 40 breaths/min. The ramped fitness tests mentioned above can also be used to determine AT.

Absolute BRmax = 70 breaths/min
Absolute HRmax = 240 beats/min

All the above default thresholds can be edited using the appropriate BioHarness Bluetooth configuration tool, or from within application software where it has been designed to do so.

5. Device Worn detection

The BioHarness BT has wear detection circuitry. If the device detects insufficient resistance across the uppermost pair of snaps, then it can respond to a request and send a 'Not Worn' indication. See the *BioHarness Bluetooth Comms Link Specification* document for details on the message and response to determine this.

Using this information, it is possible to configure the device to NOT respond to a button press on the front of the device if it detects it is being worn. This is to prevent accidental powering off of the device in the field.

If this setting is enabled, then the device must be removed from its strap before being powered off. Care must be taken to avoid contacting both upper snaps simultaneously with fingers as you grasp the device to power off, as the resistance detected may prevent device power-off.

The device may not detect it is being worn if there is a poor conductive path while it is actually being worn. This is typically caused by insufficient moisture, either in the sensor pads, or on the subject's skin. Moisten the sensor pads with water if this is observed.

The device may also detect it is worn when the strap is not on a subject, if there is sufficient moisture within the strap itself to create a conductive path – i.e. if the strap itself is saturated. Users should be aware of this possibility.