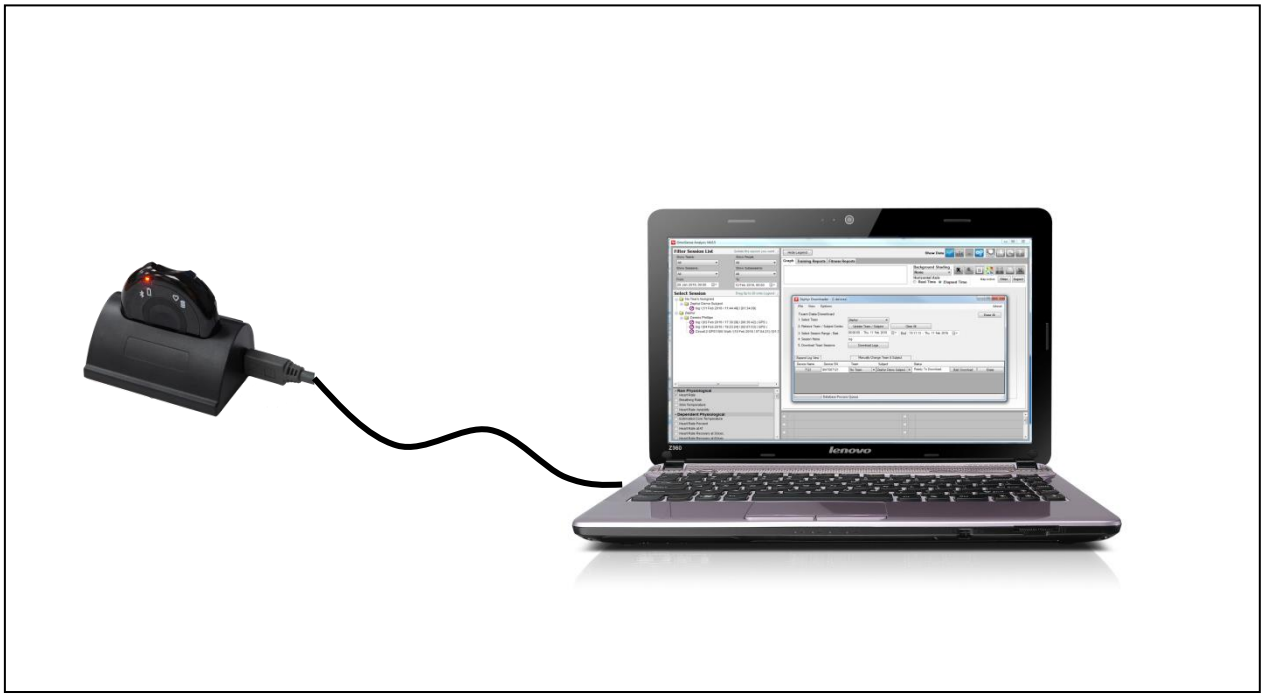
Medtronic

BioModule 3.0



Log Data Descriptions

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Version	Description
2012-07-25	Initial Release
2012-09-03	Addition of further descriptions
2012-09-13	Clarify BioModule 2.0 log format options
2012-10-10	Minor formatting edit
2012-10-12	Clarification of breathing waveform limitations
2012-11-02	Specify Formats supported by OmniSense Analysis – Section 2.2
2013-05-06	Minor corrections, update bit >> mV conversion for ECG
2013-08-13	Add GPS data descriptions
2014-02-04	Add log memory capacity for all formats, minor corrections
2015-11-17	Add additional Accelerometry parameters for Enhanced Log formats
2016-04-07	Add Memory capacity for Enhanced Log Formats
2016-06-14	Rebrand
2017-03-01	Correct error in RR range limits

Reference	Document
[1]	BioModule 3.0 Data Sheet
[2]	Event Messaging System

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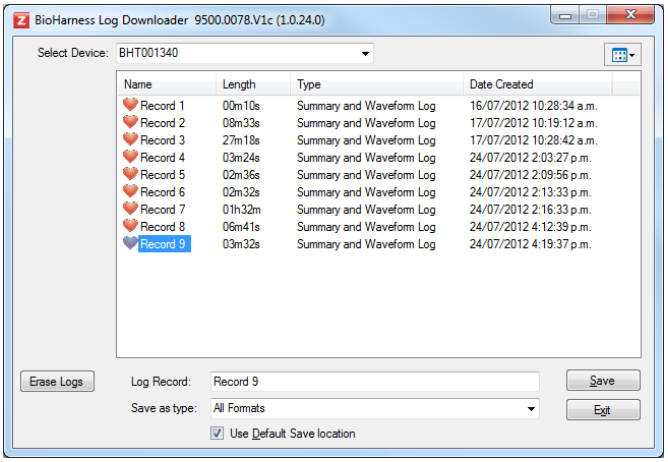
Contents

1. Introduction

This document is a full description of parameters obtained from a Zephyr BioModule, the logs being obtained using the Zephyr Log Downloader Tool. The data was exported as csv files, which were then opened and examined using Microsoft Excel.

BioModule Log data can also be imported directly into Zephyr's OmniSense Analysis module.

GPS location data, with some physiological data, can be exported from the OmniSense Analysis module, to generate a .kml Google Earth file, if the BioModule has been used in conjunction with a supported GPS device.



The featured log used throughout is 3minutes 32 seconds long. The activity scenario consisted of:

1. Subject lying horizontally on floor for a few seconds
2. Subject moving to seated position for ~ 1 minute
3. Subject walking on treadmill at 5kph for ~ 1 minute
4. Subject jogging on treadmill at 9kph for ~ 1 minute
5. Subject resuming seated position for ~ 30 seconds

(*Enhanced Summary Log Data came from a separate session*)

A Zephyr strap was used, with the device configured to log in *Summary and Waveform* format. This provides the most comprehensive set of data, other than Summary and Development, which logs ECG at 1 KHz instead of 250 Hz used in the waveform format.

The GPS data samples are from separate sessions.

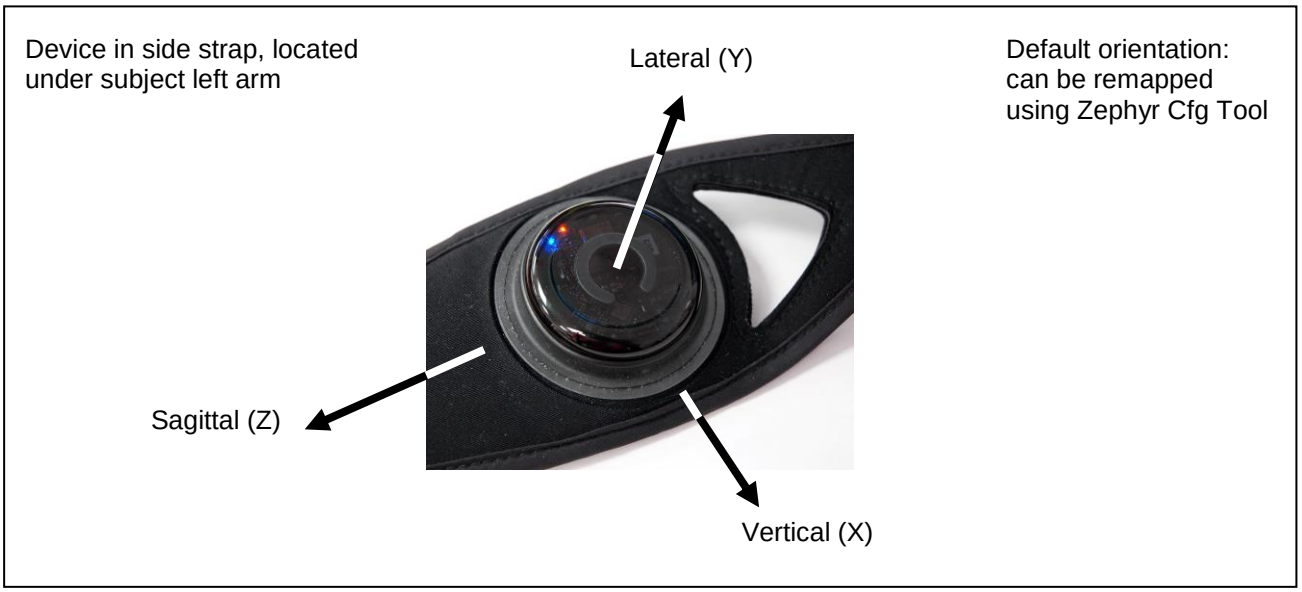
Refer also to the *BioModule 3.0 Data Sheet* for further information.

Data specifications refer to the Zephyr BioModule 3.0 unless otherwise indicated.

The Zephyr BioModule 2.0, with firmware version 2.3.8.0 can be configured to log General, General & Acceleration, or general & ECG log formats only.

1.1 Accelerometer Axis Mapping

A BioModule should be configured for the appropriate garment, using the Zephyr Config Tool. When configured appropriately, the following represent the axes in the positive direction:



1.2 SessionInfo

Later versions of the Zephyr Downloader generate a SessionInfo text file in addition to the log output files. The data in this file is not stored on the device – it is generated by the downloader utility itself:

Sample Data:

```
Subject Information
~~~~~~~~~~~~~~~~~~
Name: UNKNOWN
Gender: UNKNOWN
Birth Year: UNKNOWN
ROG Act Min/Max : UNKNOWN
ROG Resp Min/Max : UNKNOWN
ROG HR Min/Max : UNKNOWN
ROG O2R sec / sec : UNKNOWN

Device Information
~~~~~~~~~~~~~~~~~~
Serial number: UNKNOWN
MAC address: UNKNOWN
Device Friendly Name: UNKNOWN

Session Information
~~~~~~~~~~~~~~~~~~
Log Format: 0011
Log Date: Tuesday, 24 July 2012
Log Time: 4:19:37 p.m.
Log Duration: 00:03:32
Page Period(ms): 1000
```

2. Logging Formats

Descriptions of logging formats can also be found in the Zephyr BioModule 3.0 data sheet.

The logging format of a BioModule is configurable, using the Zephyr Config Tool shipped with both the SDK and Zephyr's OmniSense application. The more comprehensive log formats use more device memory, which consequently reduce the total hours of data which can be contained in the device. Users should configure the device to suit their parameter resolution and total log duration needs.

Zephyr Device	Supported Logging Formats
ISM BioModule	• General
Bluetooth BioModule 2.0	• General • General + ECG • General + Accelerometer
Bluetooth/ECHO BioModule 3.0	• General • General + ECG • General + Accelerometer • Summary (inc. GPS data if supported GPS used in conjunction) • Summary + Waveform • Summary + Development • Enhanced Summary • Enhanced Summary + Waveform • Enhanced Summary + Development

The output from the Zephyr Downloader may generate more than one output file for a given format – parameters which are reported at different frequencies are outputted in separate files.

The Zephyr Downloader, and also the Zephyr Downloader Tool accessed from Analysis, outputs files in more than one format, according to the user needs:

- .csv format (comma separated values) which can be opened using Microsoft Excel, Notepad, or similar, or imported into many data processing applications.
- .dat/.hed file pairs. These are data files design for input of large data sets into a 3rd party data processing application such as DaDISP
- .kml files, if the BioModule is used in conjunction with a supported Bluetooth GPS device

The Default Log Downloader output location is *..\My Documents\BioHarness Test Logs* in a directory identified by the initial log timestamp as displayed in the Log Downloader dialogue.

2.1 Invalid Values

Variants on the Summary Log Formats may contain data values which indicate an invalid value – the data is not available, or the device does not support the parameter. Invalid values are provided where applicable.

2.2 Memory Capacity

The BioModule will continue to log until the memory capacity is full. When this happens, it will erase the oldest log in memory, and continue to write the current log in the space available. This process will repeat until the current logging session is terminated.

When an old log is overwritten by the current one – all of that log will be erased, even if only part of the freed space is used.

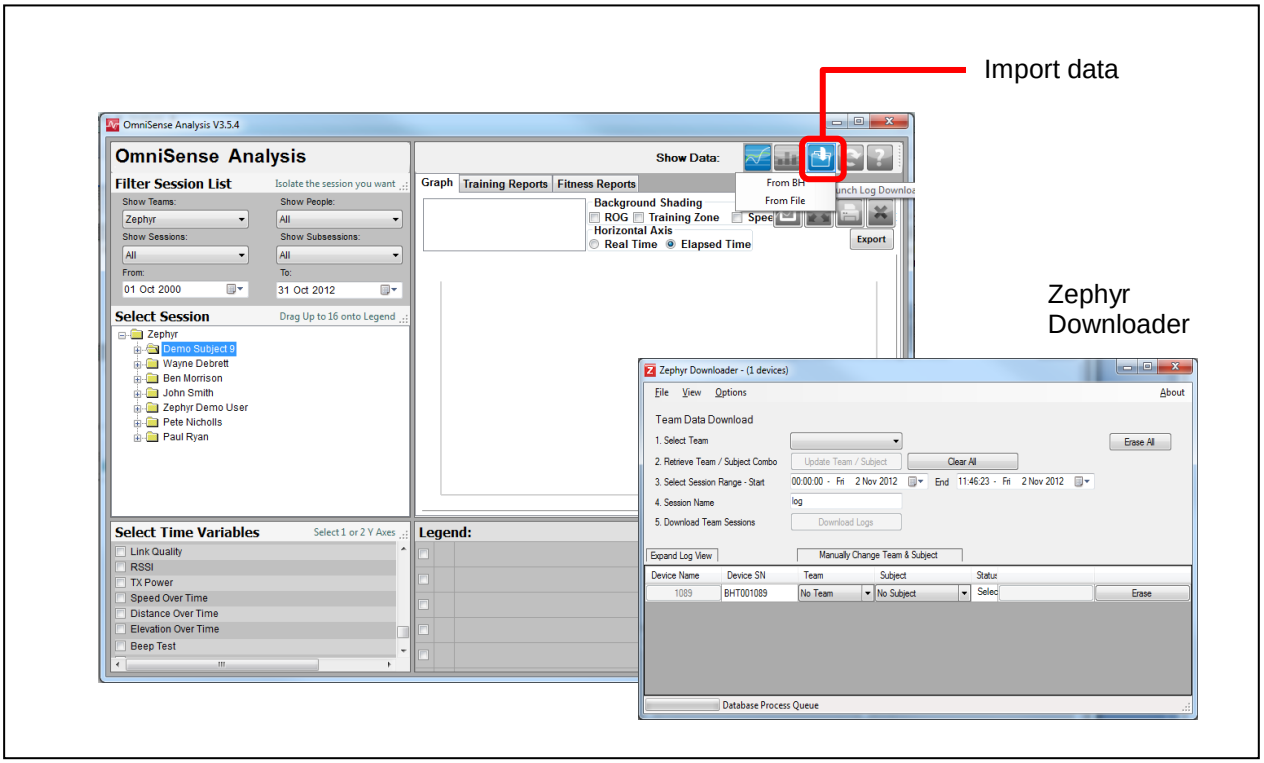
If the device is configured to log in Summary and Development mode, then the maximum possible log duration with new batteries (~35 hours) will exceed the maximum memory capacity of the device (~30 hours). In this situation, the saved part of the current log will be erased, freeing up all memory space. When the logging session is terminated, the only data saved and available for download will that which was logged *after the initial 30 hours*.

BioModule Logging Format	Maximum Memory Capacity (Hours)
General	500
General and ECG	140
General and Accelerometer	280
Summary	450
Summary and Waveform	60
Summary and Development	30
Enhanced Summary	450
Enhanced Summary and Waveform	60
Enhanced Summary and Development	30

2.3 Data Import into OmniSense Application

Zephyr's OmniSense PC application features an Analysis module which is capable of importing logged data in the BioModule, direct into the OmniSense database, for graphical display and analysis.

This is done using a toolbar button.



A Zephyr Downloader Utility will display. Instructions for its use can be found in

Analysis Help > Data Export & Import > Import Log Data From a BioModule

OmniSense Analysis does not display all the parameters a BioModule is capable of logging. Hence only three log formats can be imported into OmniSense:

- General Log data
- Summary Log & Enhanced Summary Log data including supplementary GPS data if the BioModule is used in conjunction with a supported GPS receiver

Data contained in other log formats (waveform & development formats) cannot be imported into, or displayed in, OmniSense Analysis. If the *Write CSV Format Log Files* option is checked from the Zephyr Downloader Menu > Options option, then all log data will be saved to a *..\My Documents\BioHarness Test Logs* directory.

3. Timestamp Formats

A variety of time stamp formats are used in Zephyr csv files. Some are user-friendly, others less so. The latter are normally associated with data parameters which are likely to be of more use to an engineer who is integrating BioModule data into other software applications, who is less concerned with the data being human readable when processed internally.

3.1 Excel Date Format

The default date format used in Excel spreadsheets is a Serial date fomat `xxxxx.xxxxx` which is not human-readable. To change to a readable format:

- highlight the date format column
- right click and select *Format Cells* from the context menu
- select the *Custom* category
- in the *Type* field enter any permutation of dd/mm/yyyy hh:mm:ss.000 to convert the column to a suitable date format
- save the csv file as an .xlsx worksheet to preserve the formatting

4. Output File Descriptions

The actual csv files generated by the Zephyr Downloader for various logging formats are:

Log Format	Reporting Frequency	Parameters	Filename
General	1Hz	Heart Rate Breathing Rate Skin Temperature Posture Activity Acceleration Battery BR Amplitude ECG Amplitude ECG Noise X Acc Min X Acc Peak Y Acc Min Y Acc Peak Z Acc Min Z Acc Peak	yyyy_mm_dd-hh_mm_ss_General
	18Hz	Breathing Waveform Heart R-R	yyyy_mm_dd-hh_mm_ss_BR_RR
	Per event	Event Code Event Type Source Event ID Event Specific Data	yyyy_mm_dd-hh_mm_ss_Event_Data
	Per Download	Subject Information Device Information Session Information	yyyy_mm_dd-hh_mm_ss_SessionInfo.txt
+ ECG	250Hz	ECG	yyyy_mm_dd-hh_mm_ss_ECG
+ Accelerometer	100Hz	Accel Mag (g)	yyyy_mm_dd-hh_mm_ss_Accelmag

Summary (Enhanced Summary in parentheses)	1Hz	Heart Rate Breathing Rate Skin Temperature Posture Activity Peak Acceleration Battery Voltage Battery % BR Amplitude BR Noise BR Confidence ECG Amplitude ECG Noise HR Confidence HRV System Confidence GSR Status ROG Time ROG Vert Acc Min Vert Acc peak Lateral Acc Min Lateral Acc Peak Sagittal Acc Min Sagittal Acc Peak Device Temperature Status Info Link Quality RSSI Tx Power Core Temperature Aux ADC1/2/3 (Impulse Load) (Walk Steps) (Run Steps) (Bounds) (Jumps) (Minor Impacts) (Major Impacts) (Average Rate Force Development) (Average Step Impulse) (Average Step Period) (Jump Flight Time) (Peak g Phi Angle) (Peak g Theta Angle)	yyyy_mm_dd-hh_mm_ss_Summary yyyy_mm_dd-hh_mm_ss_SummaryEnhanced
	Per event	Heart R-R	yyyy_mm_dd-hh_mm_ss_RR
	Per Event	Breathing B-B	yyyy_mm_dd-hh_mm_ss_BB
	Per Download	Subject Information Device Information Session Information	yyyy_mm_dd-hh_mm_ss_SessionInfo.txt
+ Waveform	100Hz	Vertical Acc Lateral Acc Sagittal Acc	yyyy_mm_dd-hh_mm_ss_Accel
	25Hz	Breathing Waveform	yyyy_mm_dd-hh_mm_ss_Breathing
	250Hz	ECG Waveform	yyyy_mm_dd-hh_mm_ss_ECG
	Per event	Event Code Event Type Source Event ID Event Specific Data	yyyy_mm_dd-hh_mm_ss_Event_Data

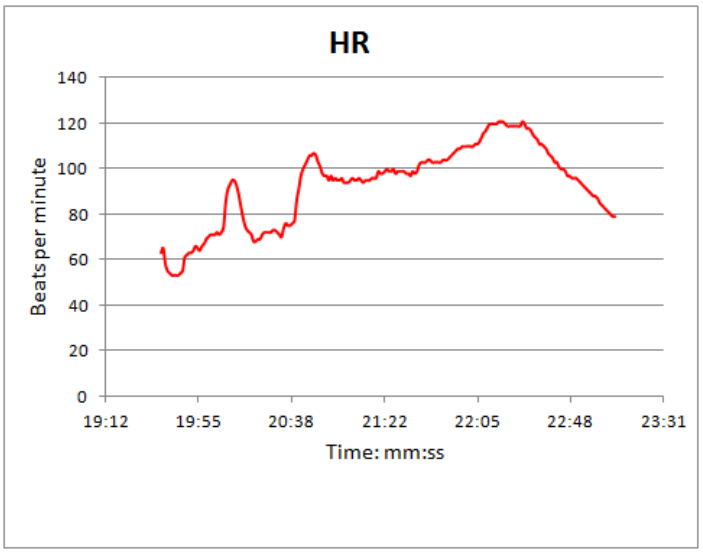
+ Development	1000Hz	ECG Waveform	yyyy_mm_dd-hh_mm_ss_ECG
		Plus all Waveform files – Accelerometer data is reduced in resolution from 12 bit to 10 to accommodate the additional ECG data.	
+ GPS	1Hz	Location (Lat/Long) Altitude GPS fix Quality Speed Over Ground Track Angle HDOP	Yyyy_mm_dd-hh_mm_ss_GPS

5. Data Descriptions

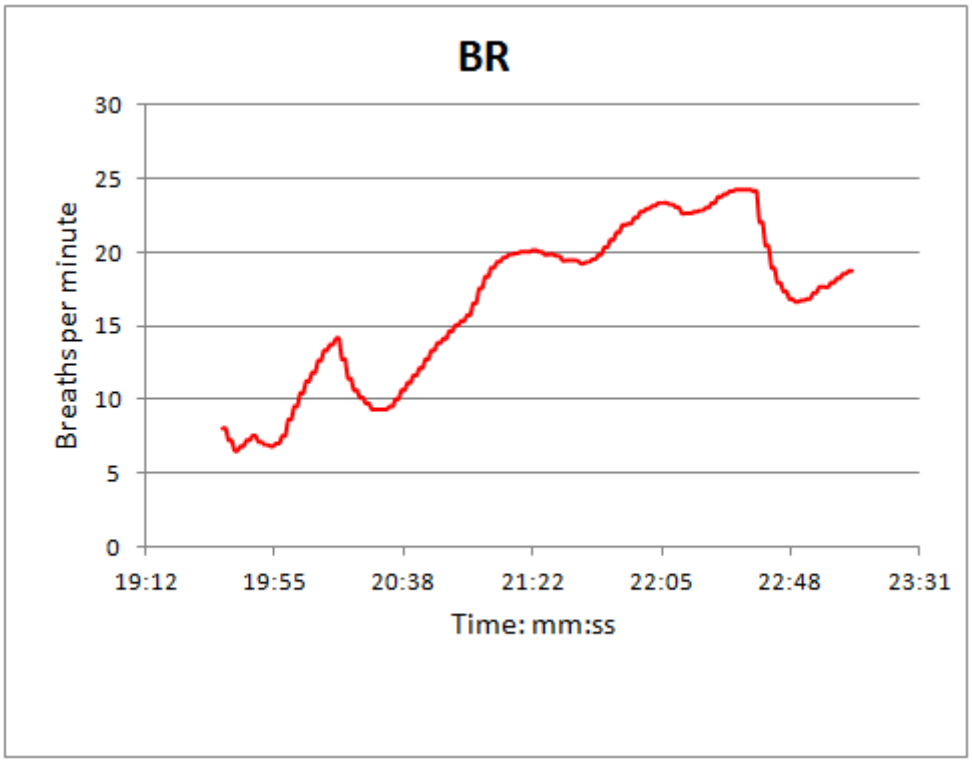
5.1 General Log – General

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

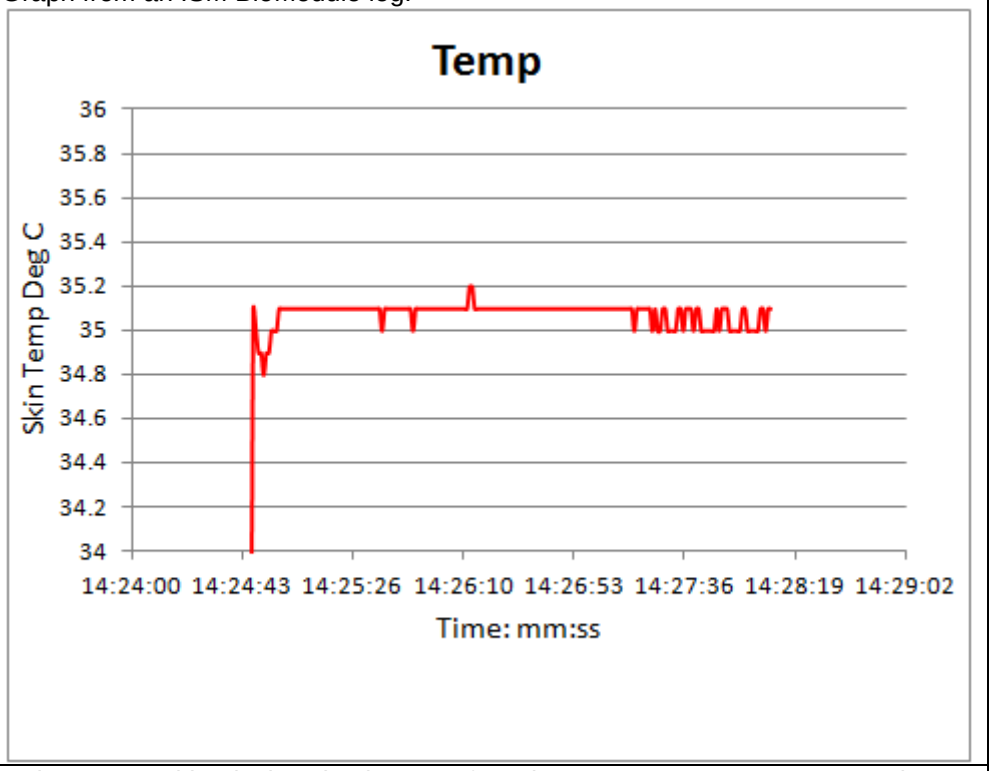
5.1.1 Heart Rate

Sample Data:	105, 106, 95, 89, 86...
Range:	25 - 240
Units:	Beats per minute
'Invalid' Value:	
Sample Graph:	
Notes:	Values consistently above 200+ bpm indicate a noisy ECG signal. Causes include: • Dry sensor pads or skin • Loose strap • Poorly located strap • Poor device/receptacle connection • Device or strap fault Dropouts to 0 usually indicate a mechanical connection problem • Check connection between device and receptacle – handle spring contacts carefully to avoid breaking them Raw ECG data is filtered to account for false or missed R detections, and some smoothing is applied. HR is determined mainly from the preceding 15 seconds of ECG data. The HR detection algorithm initializes at 65bpm. This may show at the beginning of a log for 7 seconds, but be invalid, as the algorithm processes initial data. A flag in the Status Info channel in the Summary Log will indicate whether the HR data is valid.

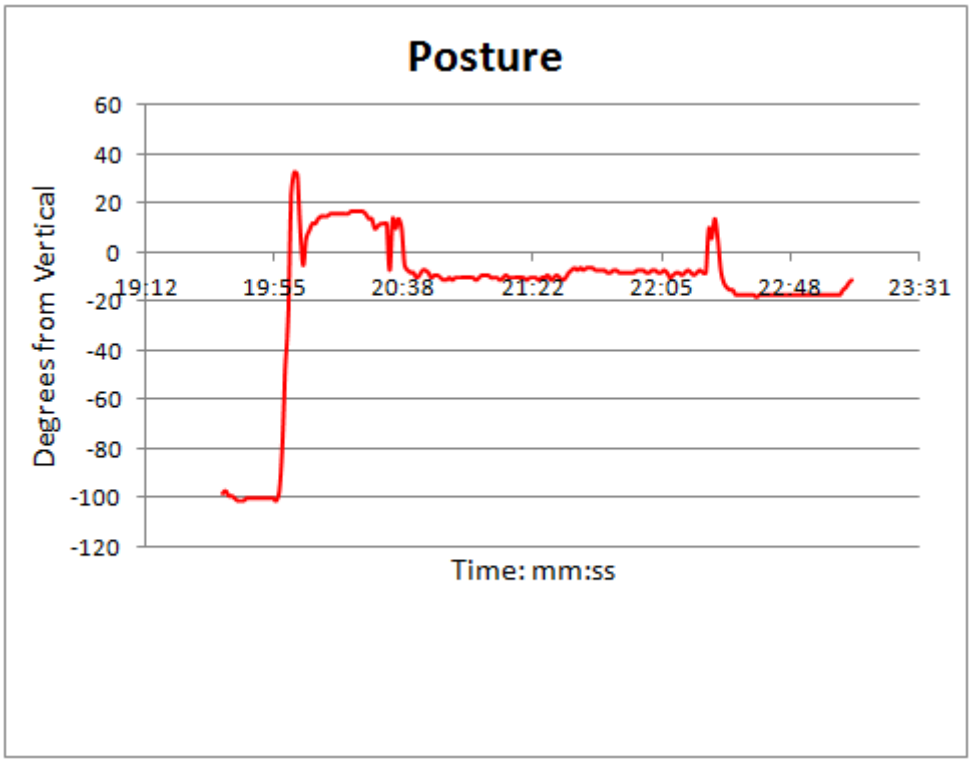
5.1.2 Breathing Rate

Sample Data:	`8.1, 8.1, 7.3, 7.3, 6.6, 6.6`
Range:	4 - 70
Units:	Breaths per minute
'Invalid' Value:	
Sample Graph:	
Notes:	Breathing is detected by a pressure sensor in the strap which detects torso expansion and contraction due to breathing. Several breath cycles are necessary for initial breathing rate indication to stabilize (15 – 45 seconds). Spontaneous adjustment of strap tension or location, or abrupt changes in posture, talking, coughing etc may cause changes in the range of pressure detected by the strap which produce temporary artefacts (peaks or troughs) in breathing rate indication which should be anticipated and potentially ignored when analyzing data.

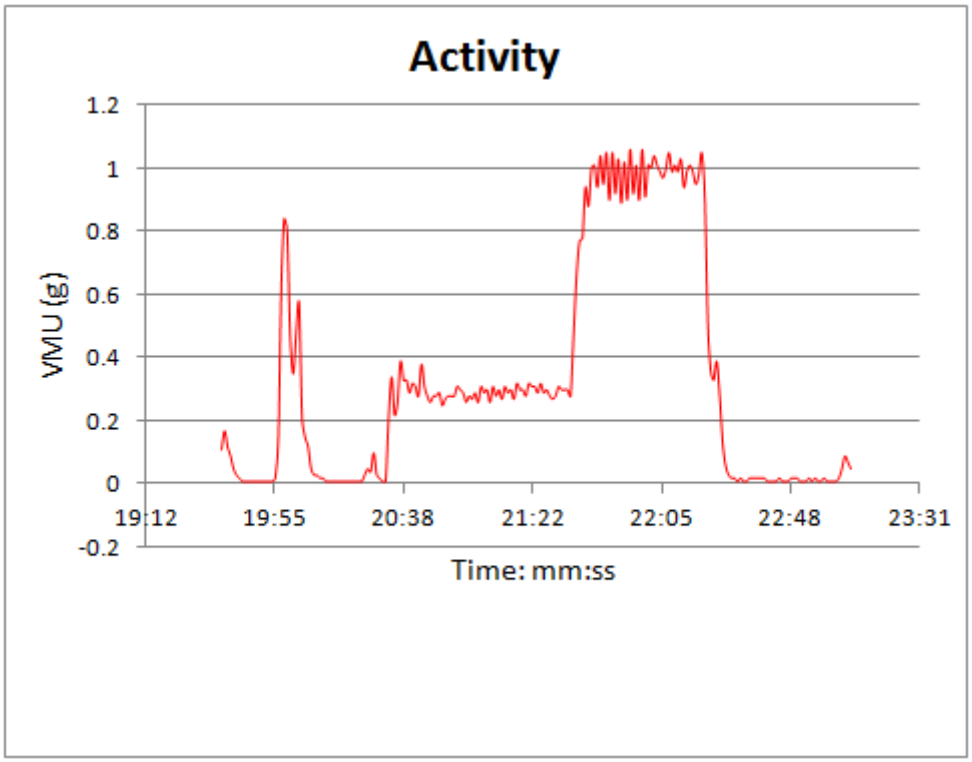
5.1.3 Skin Temperature (Temp)

Sample Data:	`-3276.8, -3276.8, -3276.8... (BioModule)` `31.1, 31.2 30.8... (ISM, BH2)`
Range:	10 - 60
Units:	Deg C
'Invalid' Value:	-3276.8 for BioModule 3.0
Sample Graph:	Graph from an ISM BioModule log: 
Notes:	Only supported by devices having an Infrared temperature sensor – ISM and BioModule Bluetooth 2.0 BioModule returns an invalid value

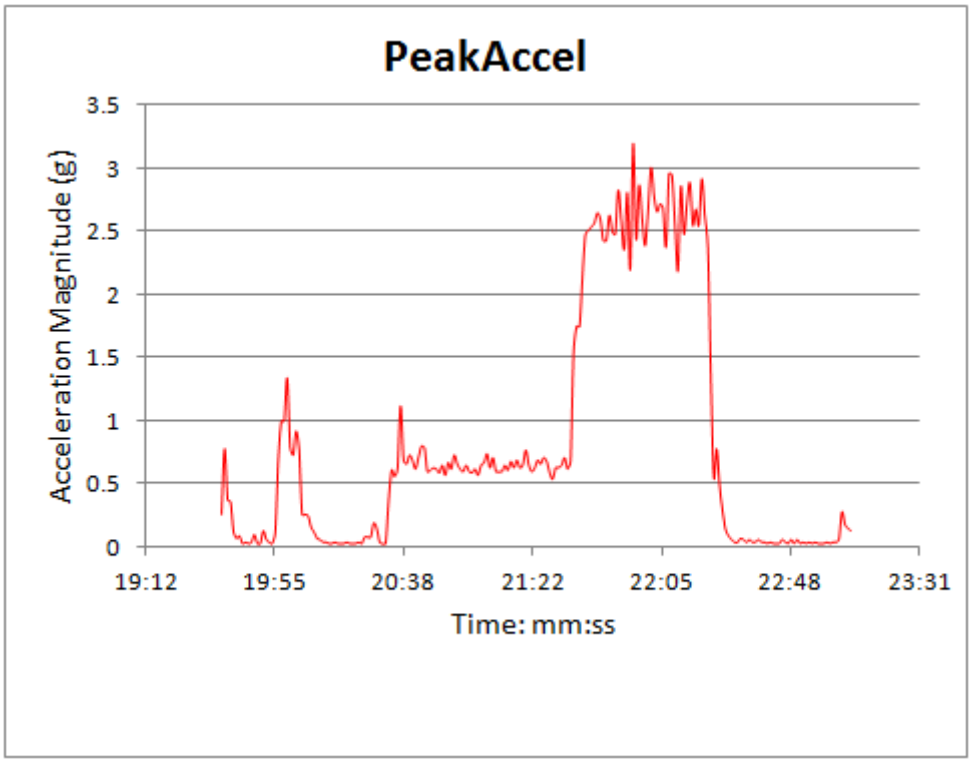
5.1.4 Posture

Sample Data:	-98, -97, -99...
Range:	± 180
Units:	Degrees from vertical
'Invalid' Value:	
Sample Graph:	
Notes:	0° = subject vertical 90°=subject prone (face down) -90°=subject supine (face up) ±180°= subject inverted There is likely to be an offset of ±5 -15° from 0 for a 'vertical' subject due to variations in torso shape, and actual posture.

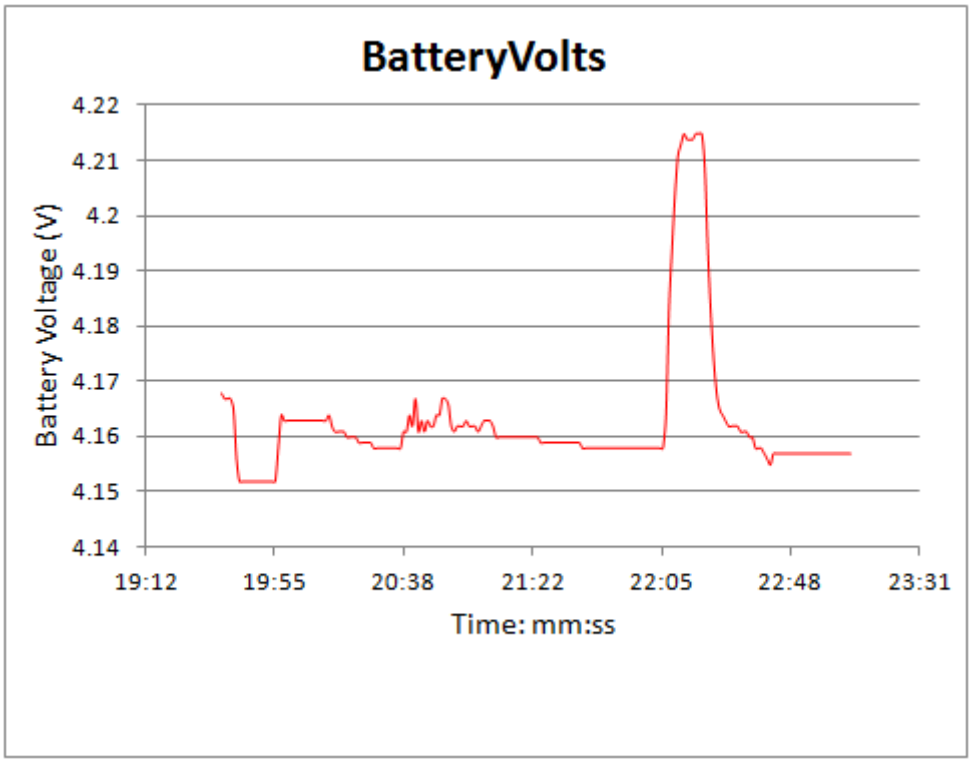
5.1.5 Activity

Sample Data:	`0.11, 0.17, 0.12...`
Range:	0 - 16
Units:	Vector Magnitude Units, measured in g
'Invalid' Value:	
Sample Graph:	
Notes:	VMU = $\sqrt{(x^2 + y^2 + z^2)}$ where x, y and z are the averages of the three axial acceleration magnitudes over the previous 1 second, sampled at 100Hz. Walking ~ 0.2 VMU or greater Jogging ~ 0.8 VMU or greater Axial accelerometer output is band pass filtered, to remove non-human artefacts, and gravity.

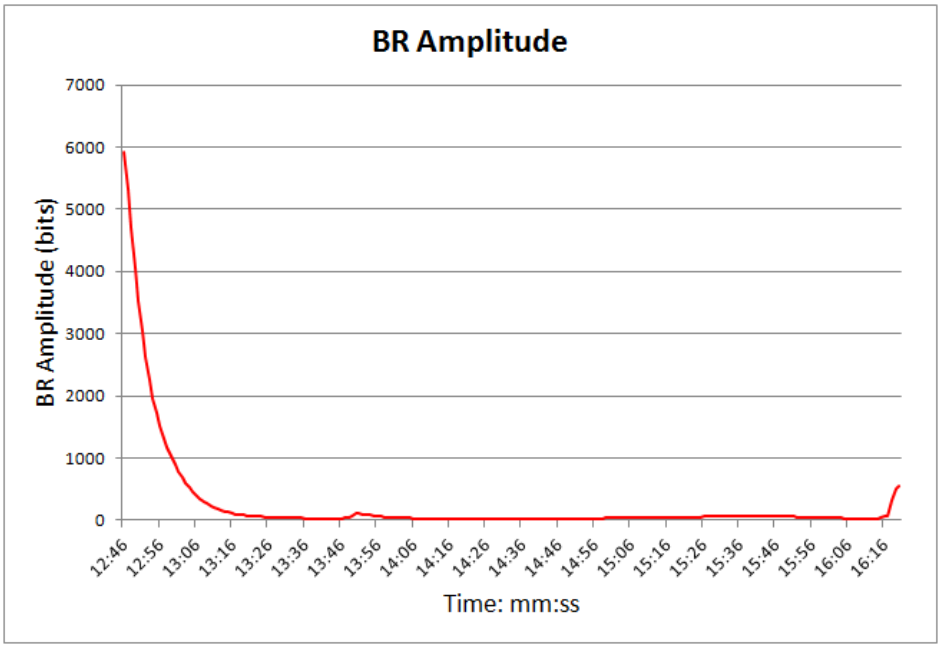
5.1.6 Peak Acceleration

Sample Data:	`0.26, 0.78, 0.38...`
Range:	0 - 16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	The Peak Acceleration Magnitude is calculated for the previous second: Peak Accn = ($\sqrt{x^2 + y^2 + z^2}$)max where x, y and z are the 3 axial acceleration values, sampled at 100 Hz. Raw accelerometer output is filtered to remove non-human artefacts, and gravity. The maximum value is capped at 16g.

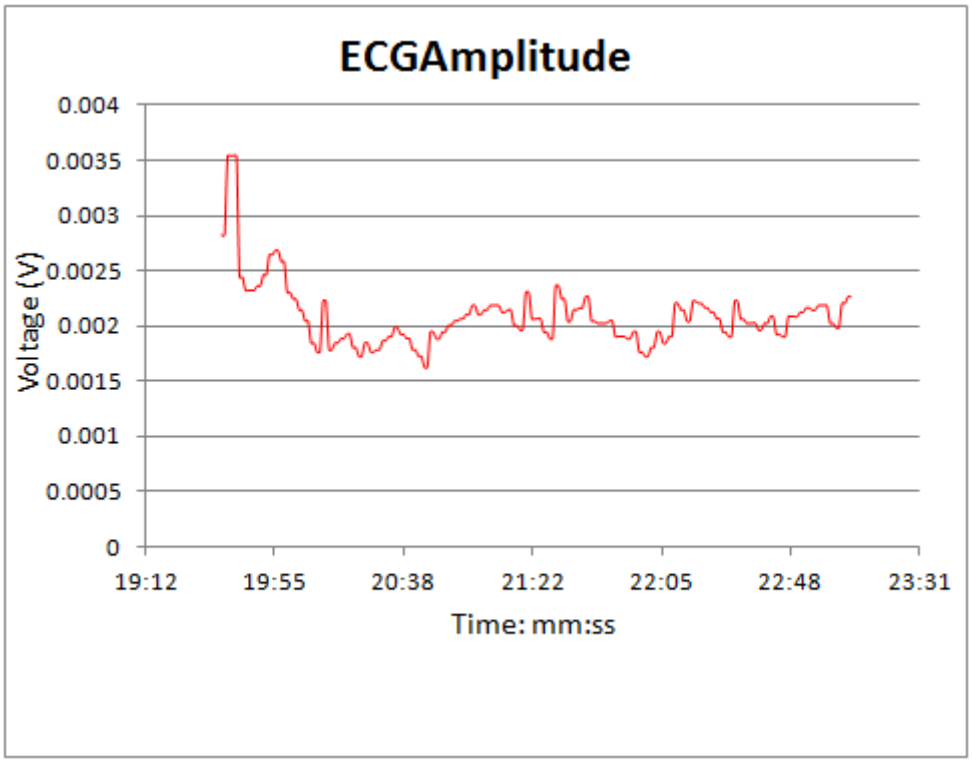
5.1.7 Battery Voltage

Sample Data:	`4.168, 4.167, 4.167...`
Range:	~ 3.6 to ~ 4.2 for a functioning battery
Units:	Volts
'Invalid' Value:	
Sample Graph:	
Notes:	Fully charged ~ 4.2V Fully discharged ~ 3.6V The device processor will turn the device off when battery voltage ~ 3.6V, to prevent further discharge causing permanent damage to the battery.

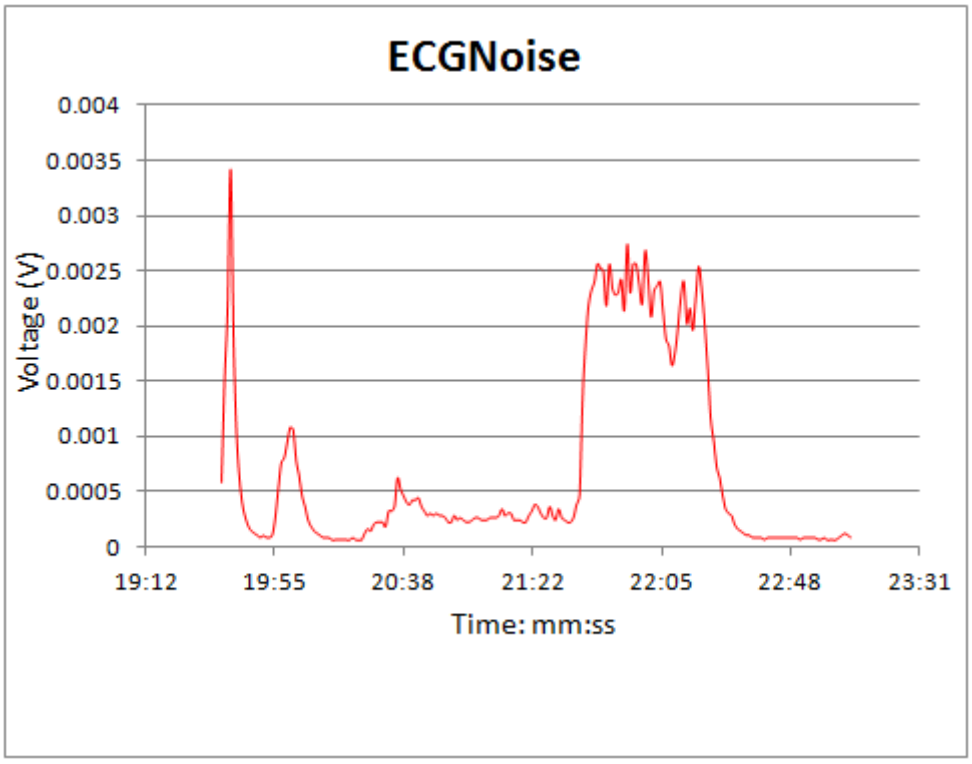
5.1.8 BR Amplitude

Sample Data:	`5864, 5307, 4698...`
Range:	0 - 65534
Units:	16 bit unsigned number
'Invalid' Value:	
Sample Graph:	
Notes:	This is a metric extracted from the breathing detection algorithm, and is used for internal development only. Initial value is large, but reduces rapidly as the algorithm has data to process

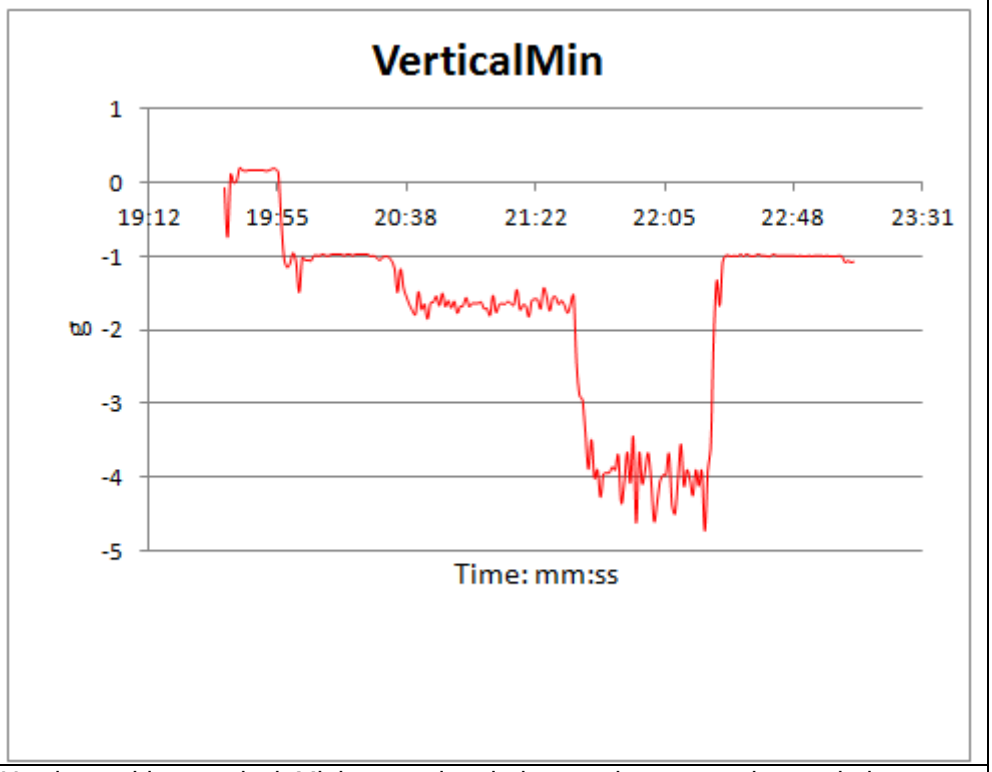
5.1.9 ECG Amplitude

Sample Data:	`0.00282, 0.00282, 0.00354...`
Range:	0 – 0.05
Units:	Volts
'Invalid' Value:	
Sample Graph:	
Notes:	Indicative only – this parameter represents an un-calibrated amplitude (measured from peak of the R wave to peak of the S wave) of the QRS complex. This value is filtered to attempt to remove noise related variation, however will increase during periods of high noise.

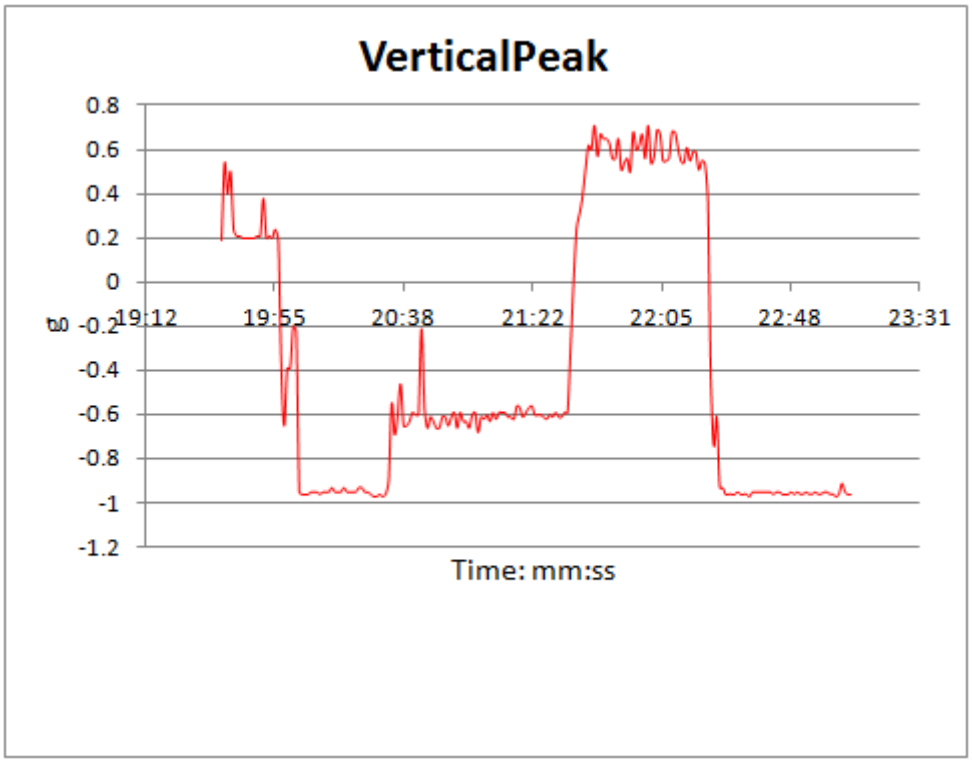
5.1.10 ECG Noise

Sample Data:	`0.00058, 0.0015, 0.00216...`
Range:	0 – 0.05
Units:	Volts
'Invalid' Value:	
Sample Graph:	
Notes:	Indicative only – this parameter represents an un-calibrated amplitude of noise signals measured between QRS complexes. This is directly comparable to the ECG amplitude for SNR calculations.

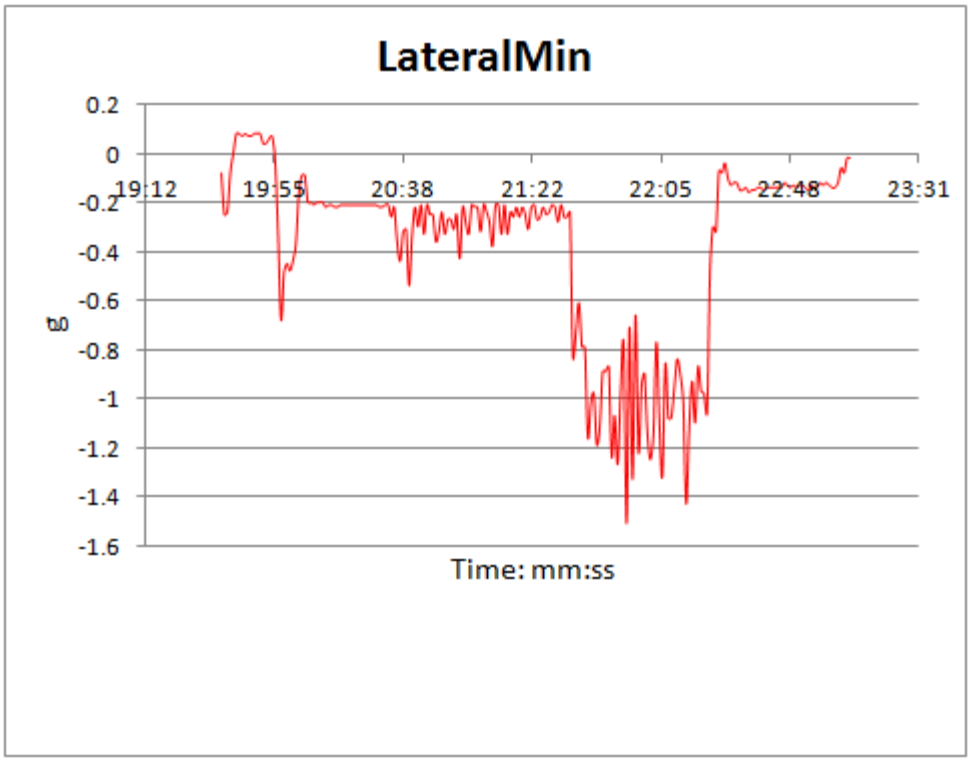
5.1.11 X Acceleration Minimum

Sample Data:	`-0.08, -0.75, 0.1...`
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	X axis = subject vertical. Minimum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

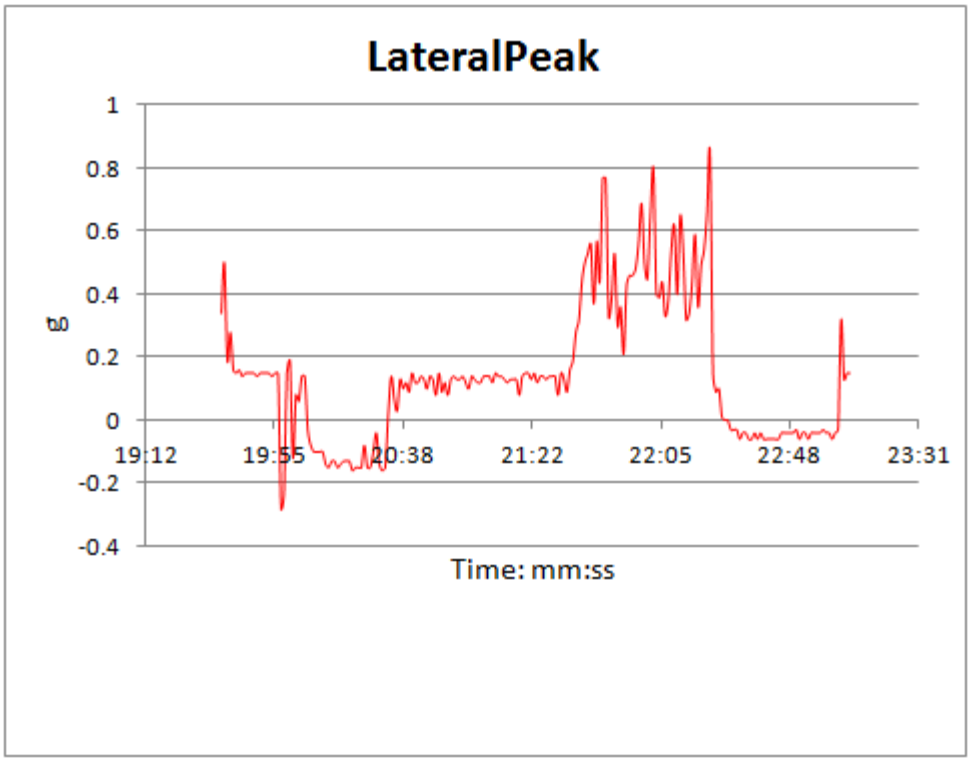
5.1.12 X Acceleration Peak

Sample Data:	0.19, 0.54, 0.4...
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	X axis = subject vertical. Maximum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

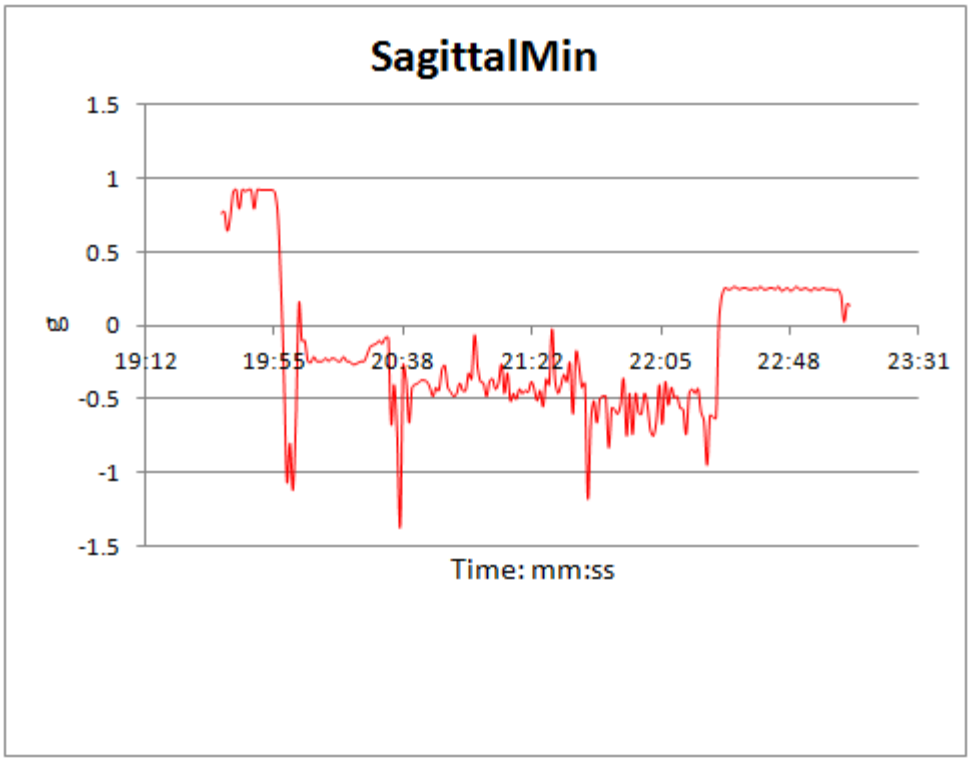
5.1.13 Y Acceleration Minimum

Sample Data:	0.19, 0.54, 0.4...
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	Y axis = subject lateral. Minimum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

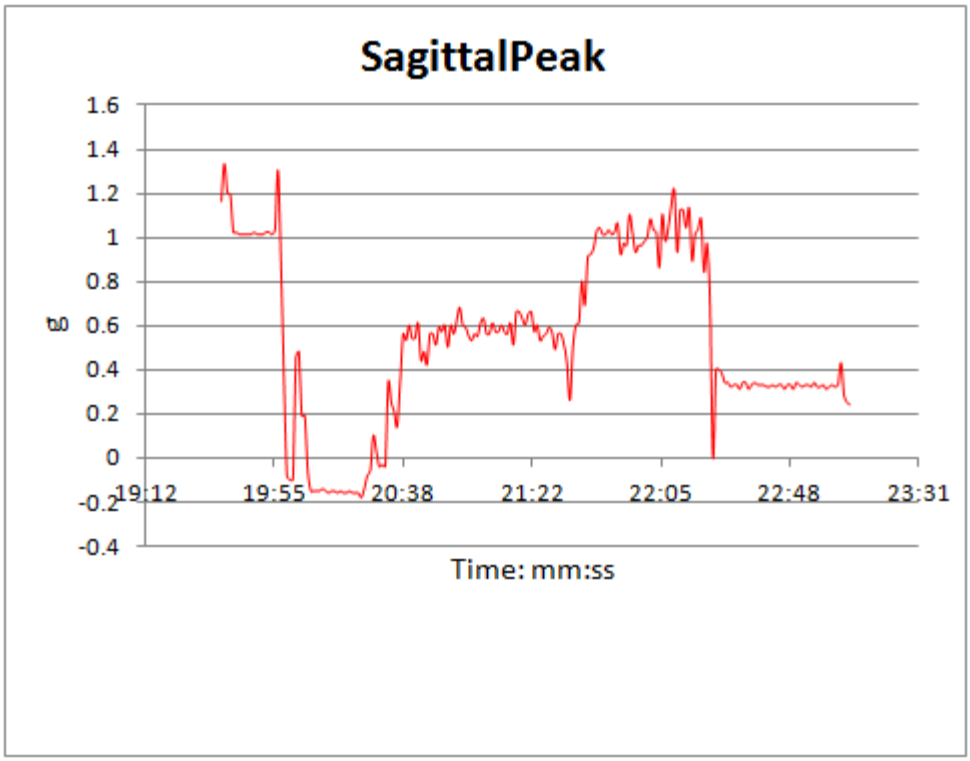
5.1.14 Y Acceleration Peak

Sample Data:	`0.19, 0.54, 0.4...`
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	Y axis = subject lateral. Maximum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

5.1.15 Z Acceleration Minimum

Sample Data:	-0.08, -0.25, -0.24...
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	Z axis = subject sagittal. Minimum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

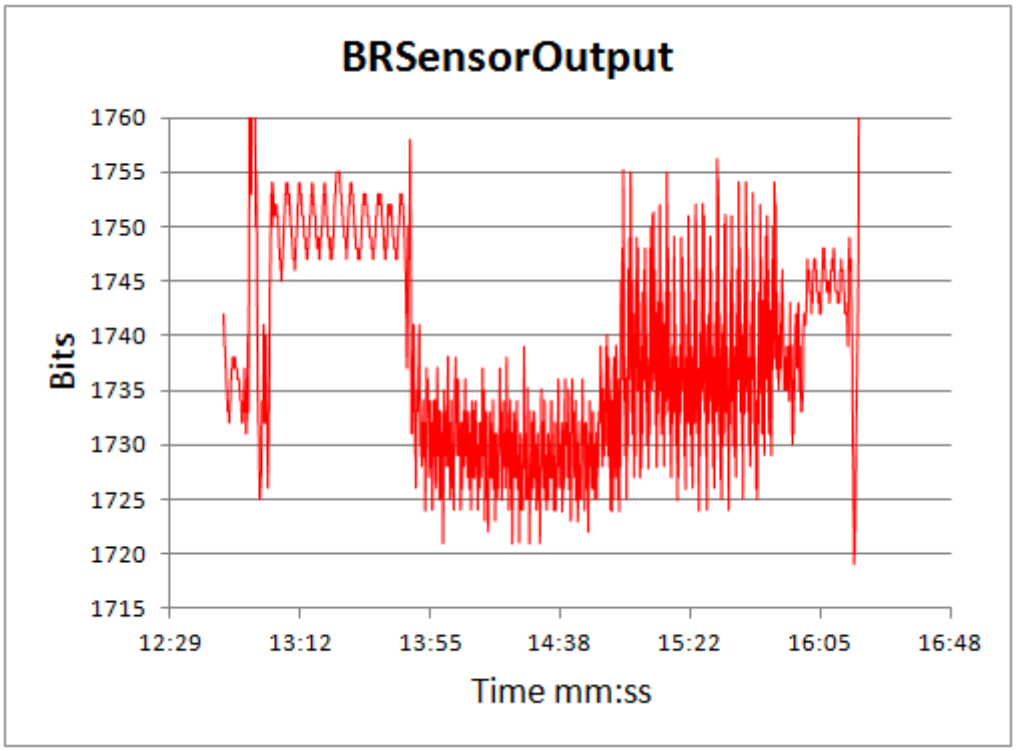
5.1.16 Z Acceleration Peak

Sample Data:	0.34, 0.5, 0.19...
Range:	±16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	Z axis = subject sagittal. Maximum value during previous second, sampled at 100Hz. This is raw, unfiltered data.

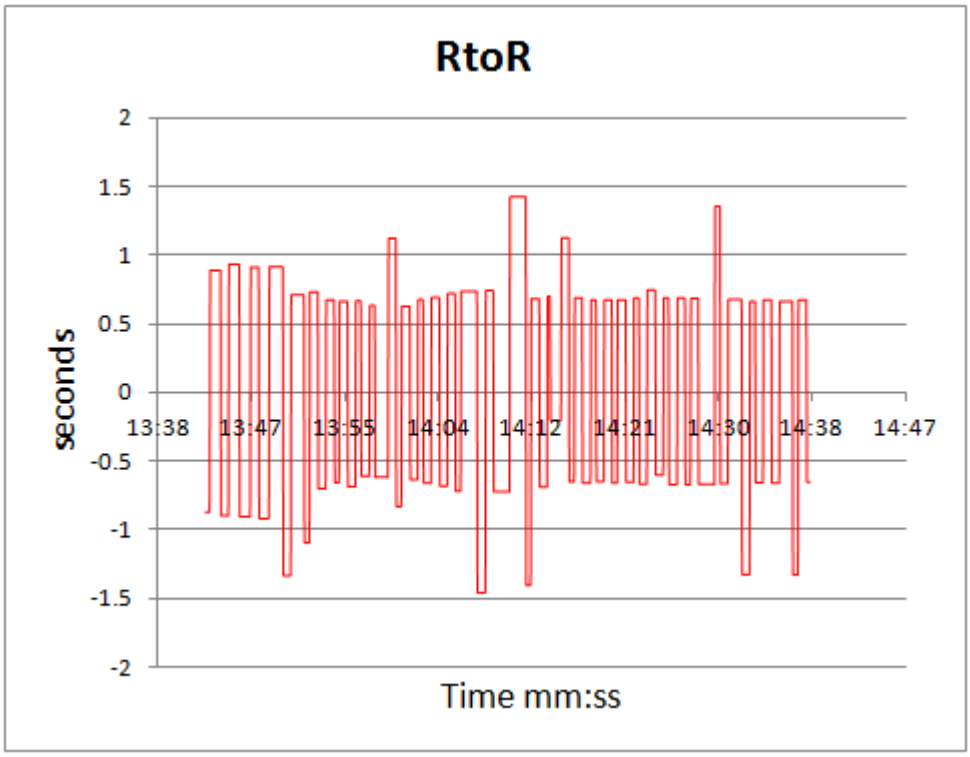
5.2 General Log – Breathing and RR

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	18Hz

5.2.1 Breathing Waveform

Sample Data:	1741, 1742,1741...
Range:	0 - 4096
Units:	bits
'Invalid' Value:	
Sample Graph:	
Notes:	Reported at 18Hz. This is the raw unfiltered breathing sensor output. Its main use is to determine whether there is sufficient dynamic range to indicate that the sensor is functioning correctly – this may be a few tens to a few hundreds of bits, depending on subject breathing mechanics. The data is then heavily filtered and processed in order to establish a respiration rate. It cannot be used to indicate breathing volume or breathing depth. The data is reflecting changes of pressure on the breathing sensor. This will vary according to an individual's breathing mechanics, their body composition, and how tight the strap is fitted. As such no inference can be made on breathing depth or volume from this data.

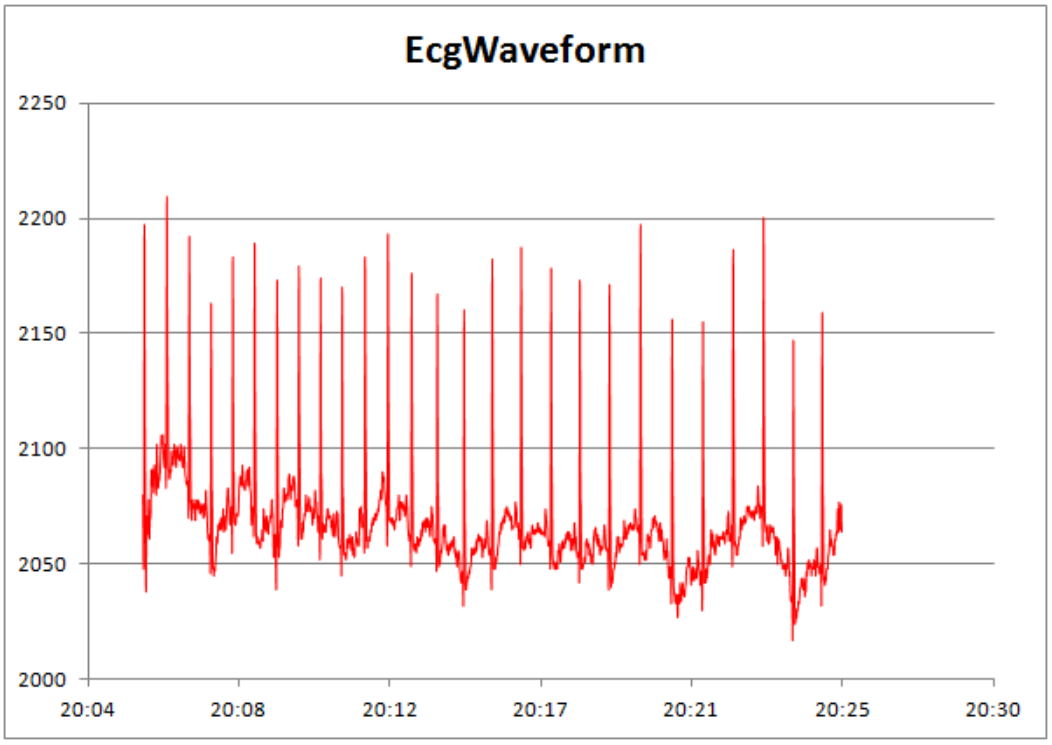
5.2.2 Heart R-R

Sample Data:	`-0.702, -0.702, 0.857...`
Range:	0 – 32.767
Units:	Seconds
'Invalid' Value:	
Sample Graph:	
Notes:	Reported at 18Hz. The last detected R interval is repeated until a new R detection is calculated. Fresh detections are toggled positive/negative so that identical-magnitude detections in sequence can be distinguished. R detections are extracted from contiguous 250ms blocks of ECG data. Because of this, apparent anomalies may be observed between the 56ms reporting intervals, and the 'possible' RR millisecond values calculated.

5.3 General Log + ECG

5.3.1 ECG Waveform

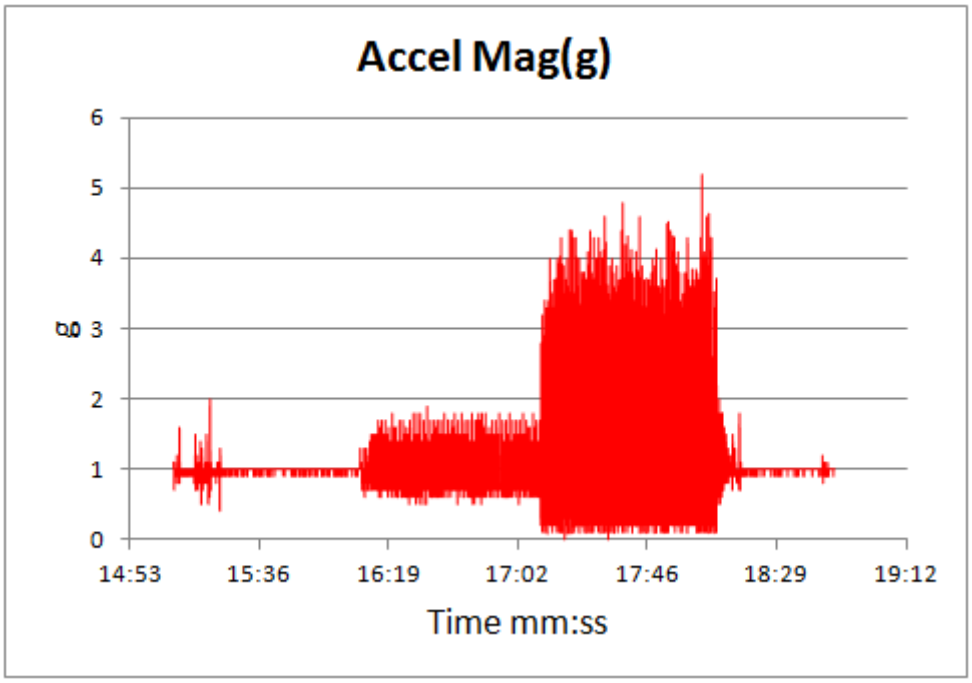
Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	250Hz

Sample Data:	2167, 2167, 2166...
Range:	0 - 4095
Units:	bits
'Invalid' Value:	
Sample Graph:	
Notes:	Sampled at 1KHz Conversion to mV: 2048 bits = 0mV 1 bit = 0.00625mV

5.4 General Log + Acceleration

5.4.1 Acceleration Magnitude

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	100Hz

Sample Data:	1.1, 1.1, 1...
Range:	0 - 16
Units:	g
'Invalid' Value:	
Sample Graph:	
Notes:	Sampled and reported at 100Hz. Magnitude = ($\sqrt{x^2 + y^2 + z^2}$) where x,y & z are the three axial accelerometer values. This is raw, unfiltered data.

5.5 Summary Log – Summary

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

5.5.1 Summary/General Log Format Parameter Parity

The summary log was originally developed as an extended general log format. For this reason many of the parameters are identical to the General log format.

The following a reported identically in the General and Summary logs:

- Heart Rate
- Breathing rate
- Skin Temperature (not supported by BioModule 3.0)
- Posture
- Activity
- Peak Acceleration
- Battery Voltage
- Breathing Amplitude
- ECG Amplitude
- ECG Noise
- Vertical Acceleration Minimum = X Acceleration Minimum
- Vertical Acceleration Peak = X Acceleration Peak
- Lateral Acceleration Minimum = Y Acceleration Minimum
- Lateral Acceleration Peak = Y Acceleration Peak
- Sagittal Acceleration Minimum = Z Acceleration Minimum
- Sagittal Acceleration Peak = Z Acceleration Peak

The additional parameters which complete the Summary Log Format are described in the following sections.

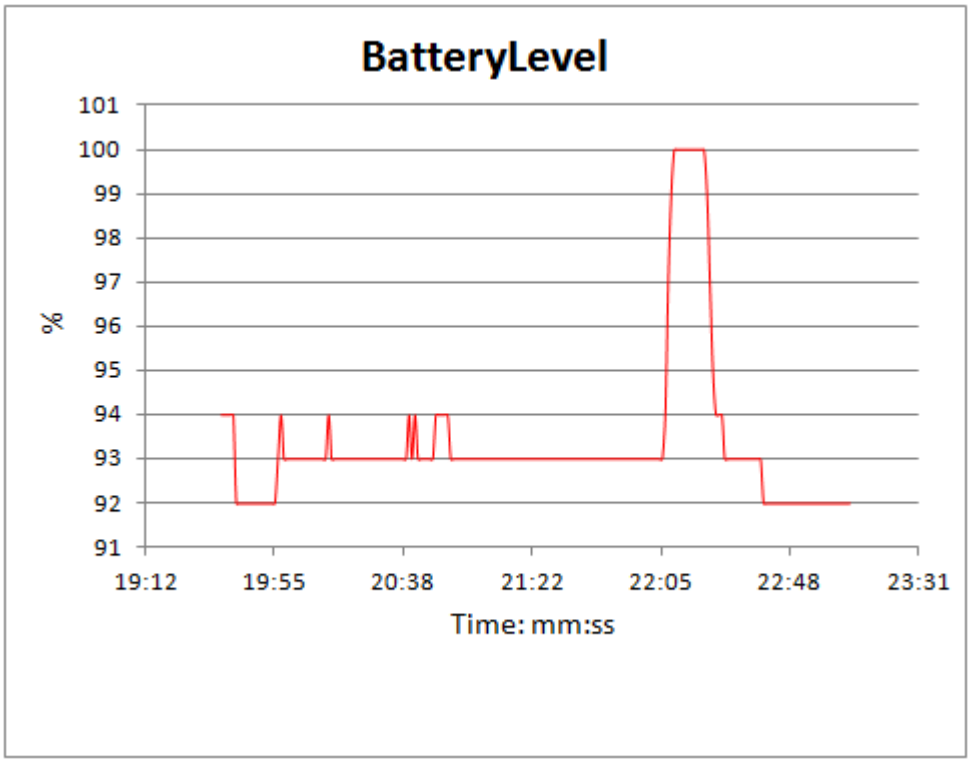
5.5.2 Summary Log supplementary GPS data

If a BioModule is configured to communicate with a supported Bluetooth GPS receiver, then it will add supplementary GPS data to the Summary log format. However GPS data is accessed in separate csv files to those containing the Summary log data.

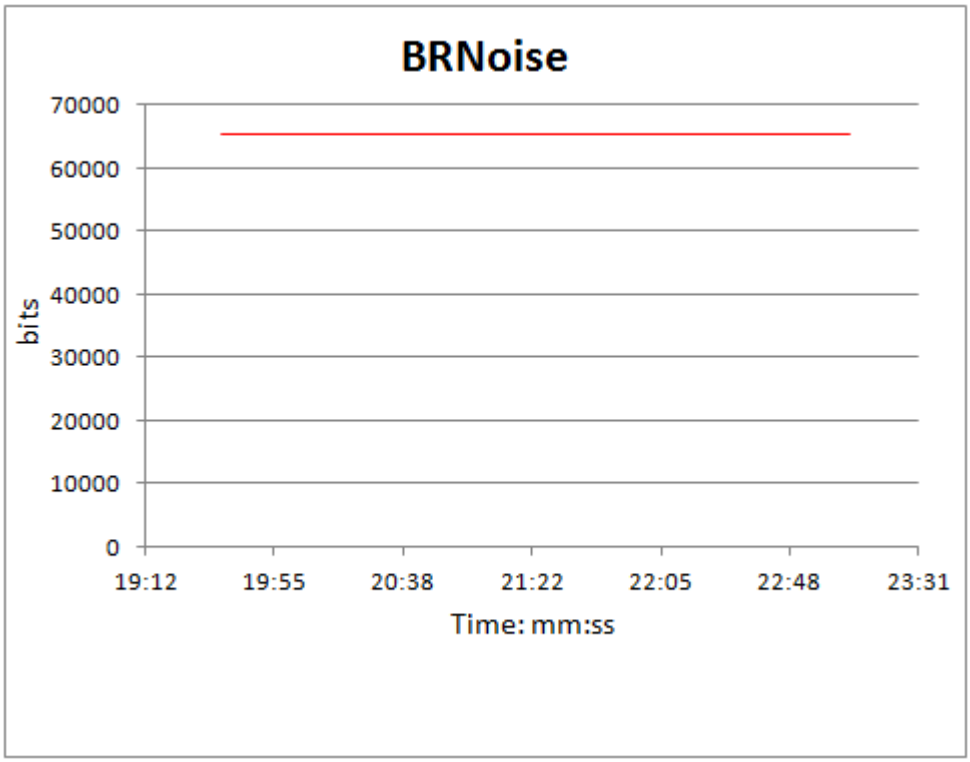
This data can be accessed either by importing the log into OmniSense Analysis. Some parameters can displayed directly in Analysis: Speed, distance covered and elevation – alongside physiological parameters, or the location and some physiological parameters can be exported as a .kml file for display in Google Earth.

Later versions of the Zephyr Downloader will also generate GPS data and kml files.

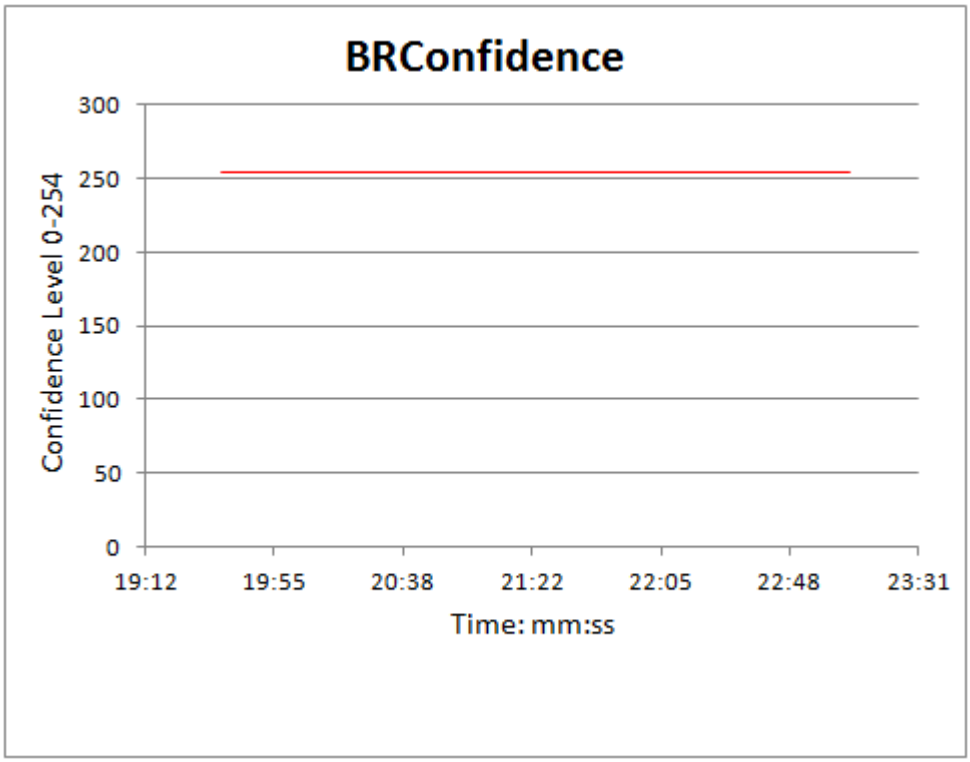
5.5.3 Battery Level

Sample Data:	94,94,93
Range:	0 - 100
Units:	% Charge
'Invalid' Value:	
Sample Graph:	
Notes:	100% ~ 4.2V 0% ~ 3.6V If battery discharged curves are stored historically, battery health can be monitored.

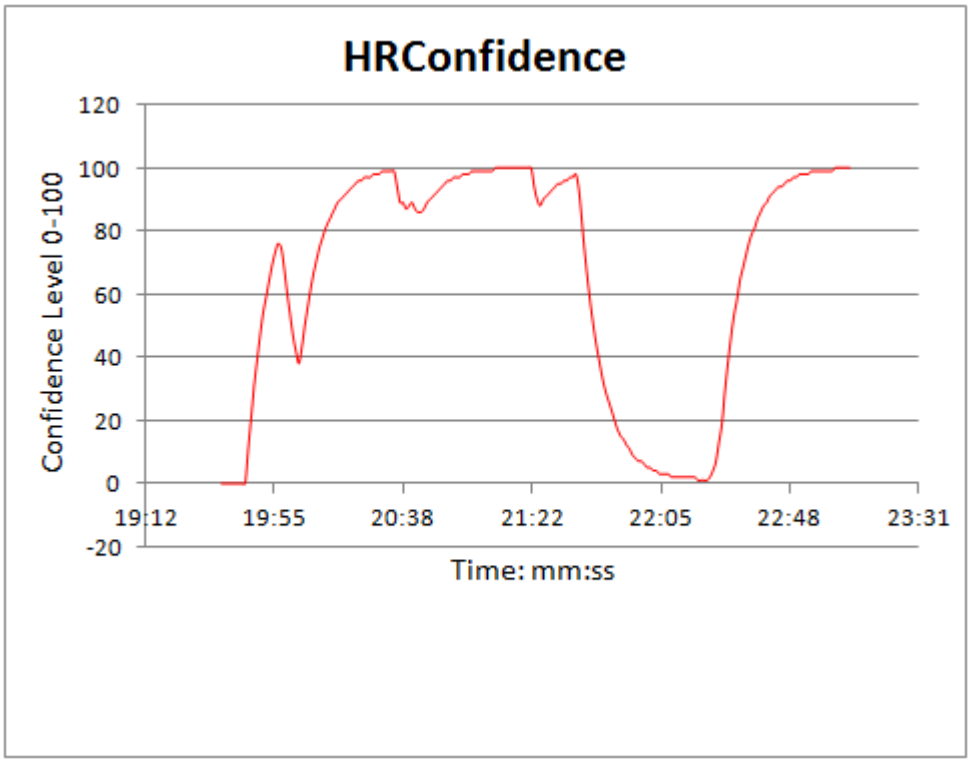
5.5.4 Breathing Noise Level

Sample Data:	65535, 65535,65535
Range:	0 - 65534
Units:	bits
'Invalid' Value:	65535
Sample Graph:	
Notes:	This parameter is not currently implemented – an invalid value is always returned

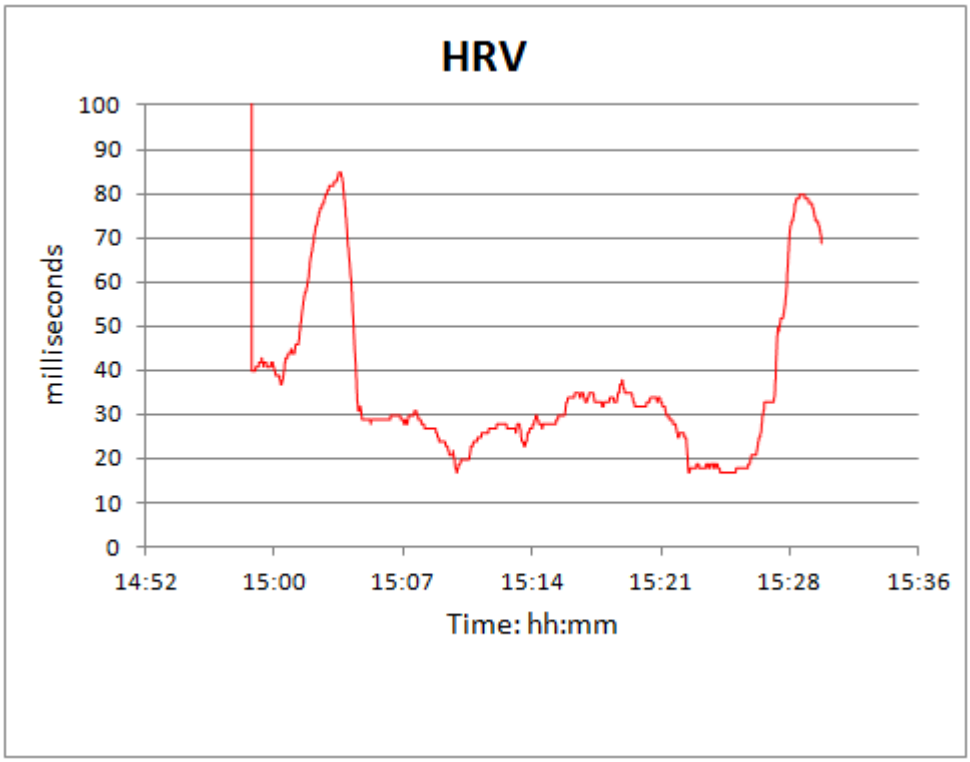
5.5.5 Breathing Confidence

Sample Data:	255,255,255
Range:	0 - 254
Units:	bits
'Invalid' Value:	255
Sample Graph:	
Notes:	This parameter is not currently implemented – an invalid value is always returned

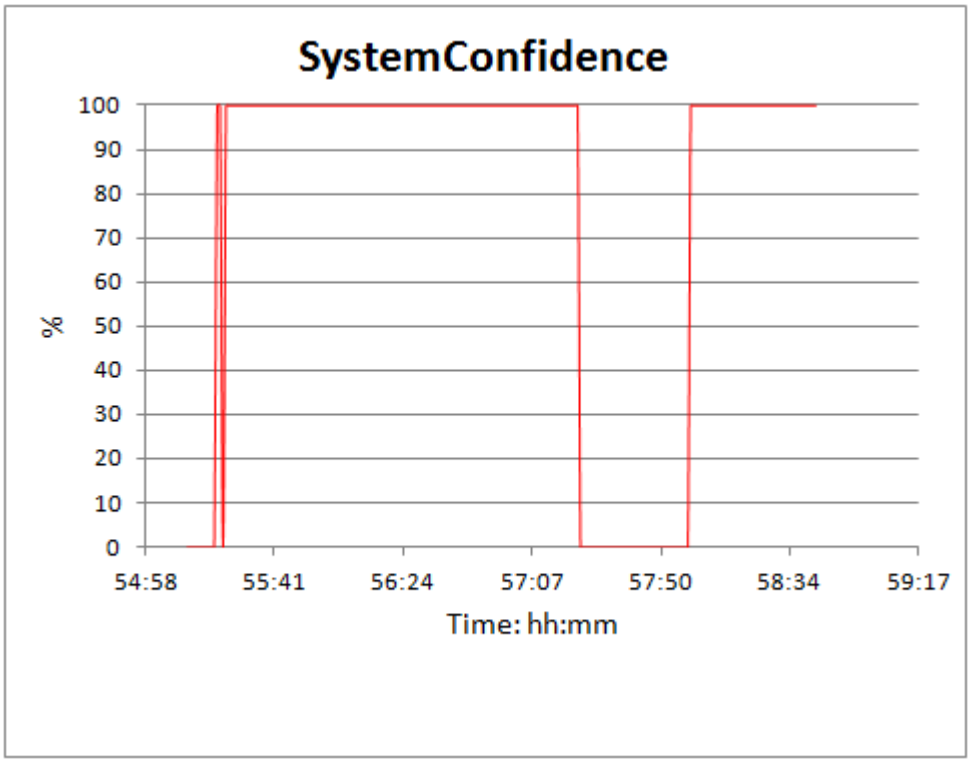
5.5.6 HR Confidence

Sample Data:	0,23,75
Range:	0 - 100
Units:	%
'Invalid' Value:	
Sample Graph:	
Notes:	An algorithm which takes into account a worn detection indication, and the signal-to-noise ratio of the ECG signal is used to establish HR confidence. Above 20% indicates a reliable heart rate. 0% indicates not worn indication or an extremely noisy ECG signal

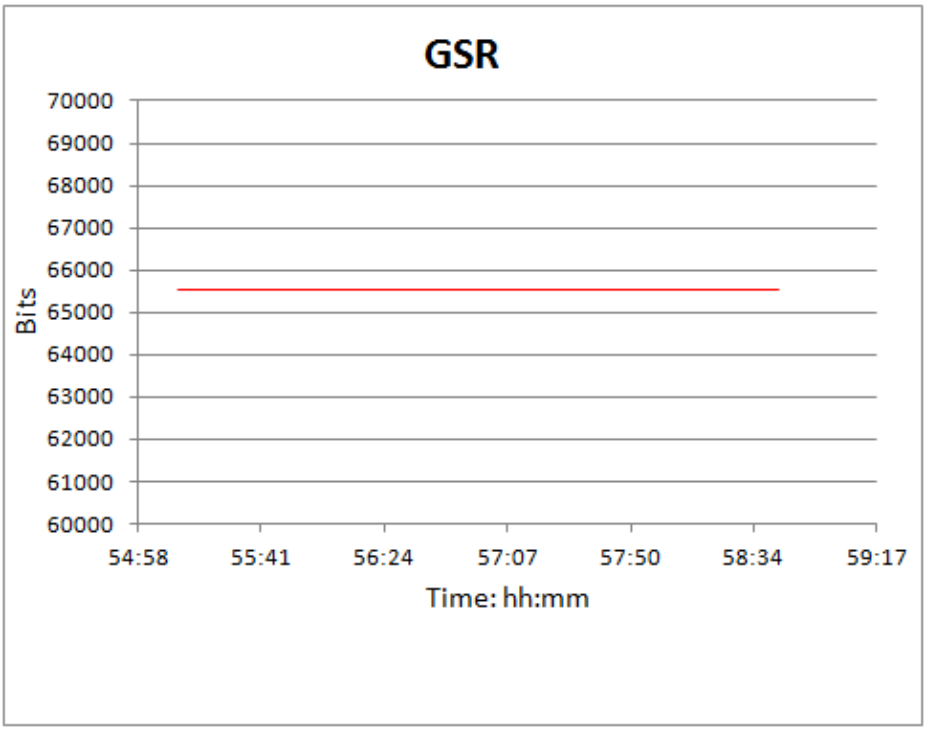
5.5.7 Heart Rate Variability

Sample Data:	`65535 for first 300 seconds`
Range:	0 - 65534
Units:	Standard deviation in milliseconds
'Invalid' Value:	65535
Sample Graph:	
Notes:	An algorithm calculates a rolling 300 heartbeat SDNN HRV value. This is updated once per second. For the first 300 beats of log, an invalid value will be reported.

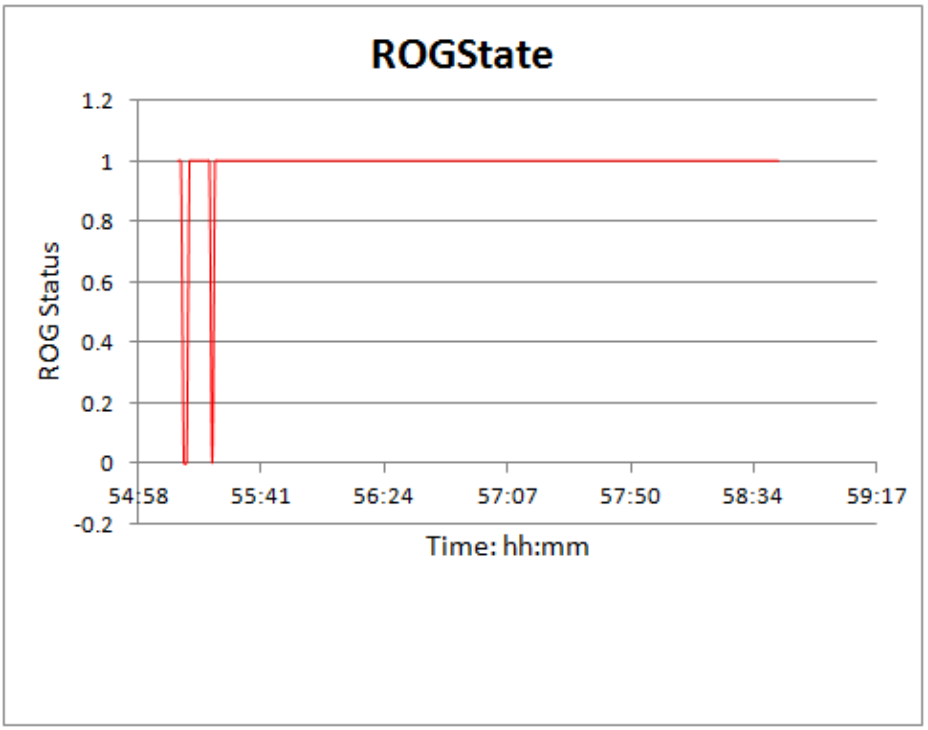
5.5.8 System Confidence

Sample Data:	0, 100
Range:	0 - 100
Units:	%
'Invalid' Value:	
Sample Graph:	
Notes:	System Confidence is a development parameter which will combine HR confidence with other parameters as they become available. At present System Confidence is identical to HR Confidence.

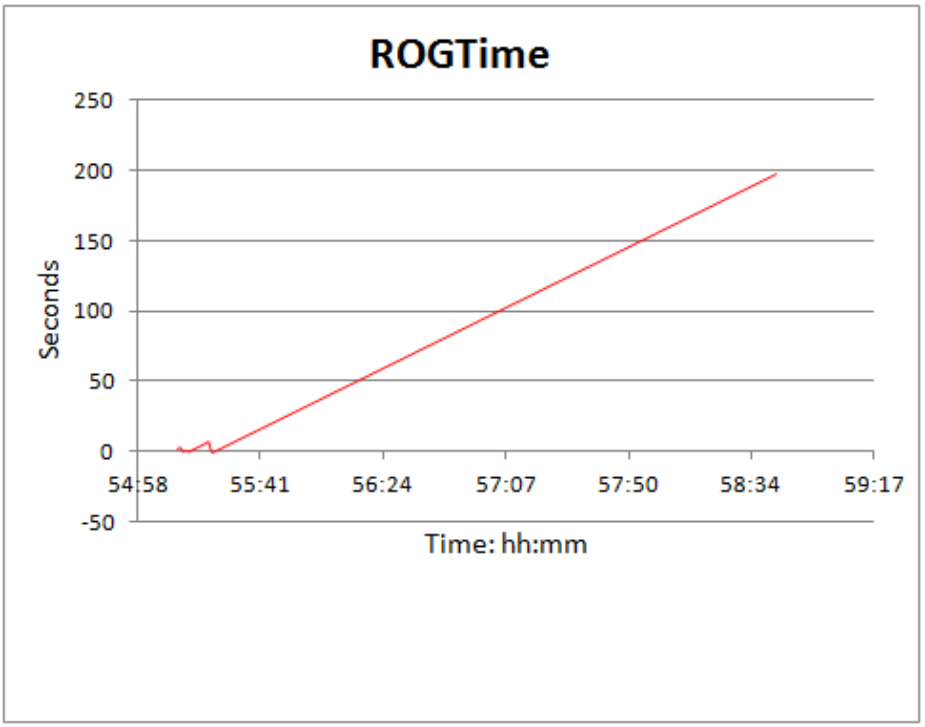
5.5.9 GSR (Galvanic Skin Response)

Sample Data:	65535, 65535, 65535
Range:	0 - 65535
Units:	Siemens
'Invalid' Value:	65535
Sample Graph:	
Notes:	GSR was originally implemented in the BioModule 2.0 It is not supported in the BioModule 3.0

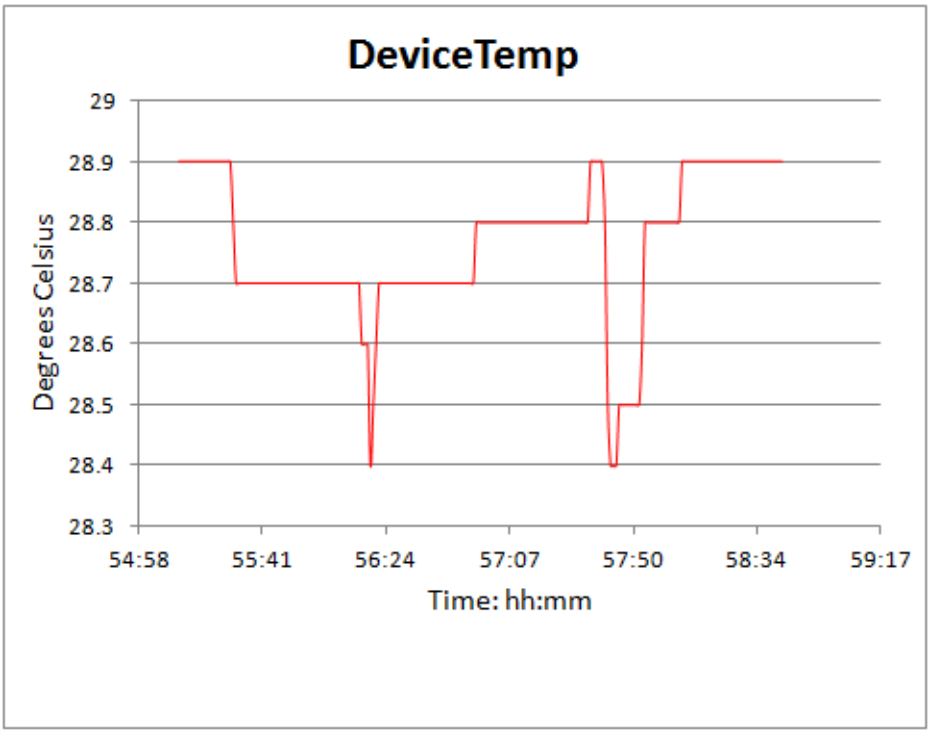
5.5.10 ROG Status

Sample Data:	1,1,0…
Range:	0,1,2,3
Units:	Status indication
'Invalid' Value:	0
Sample Graph:	
Notes:	0=Invalid ROG, 1=Green, 2=Orange, 3=Red

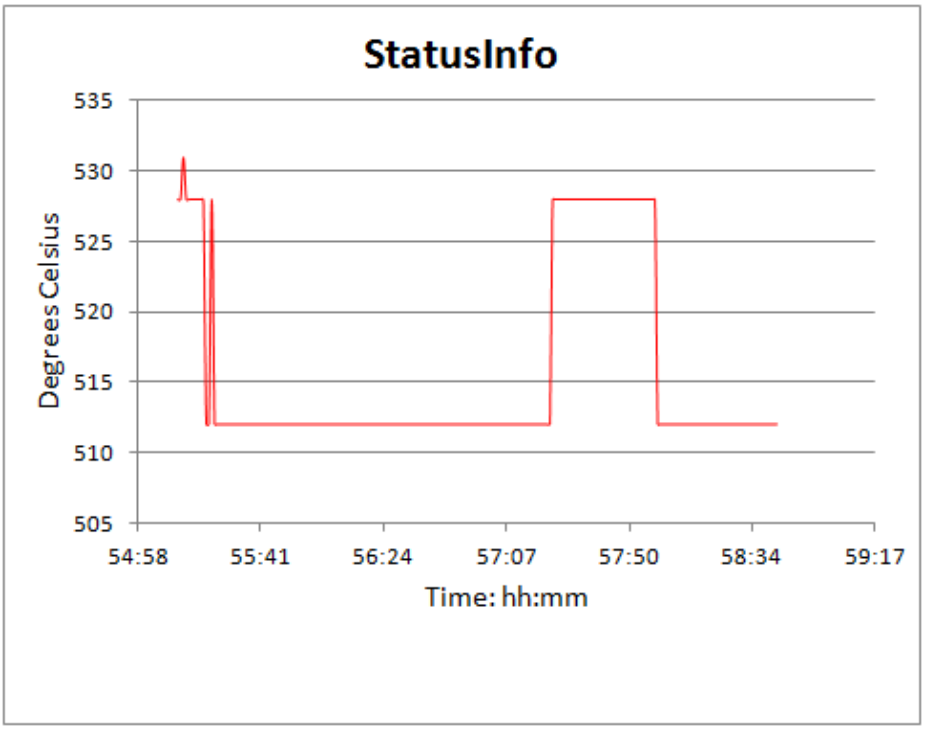
5.5.11 ROG Time

Sample Data:	0, 1, 2…
Range:	0 - 8291
Units:	Time duration in current status
'Invalid' Value:	
Sample Graph:	
Notes:	This value resets to 0 each time status changes, and increments for every second the status remains unchanged

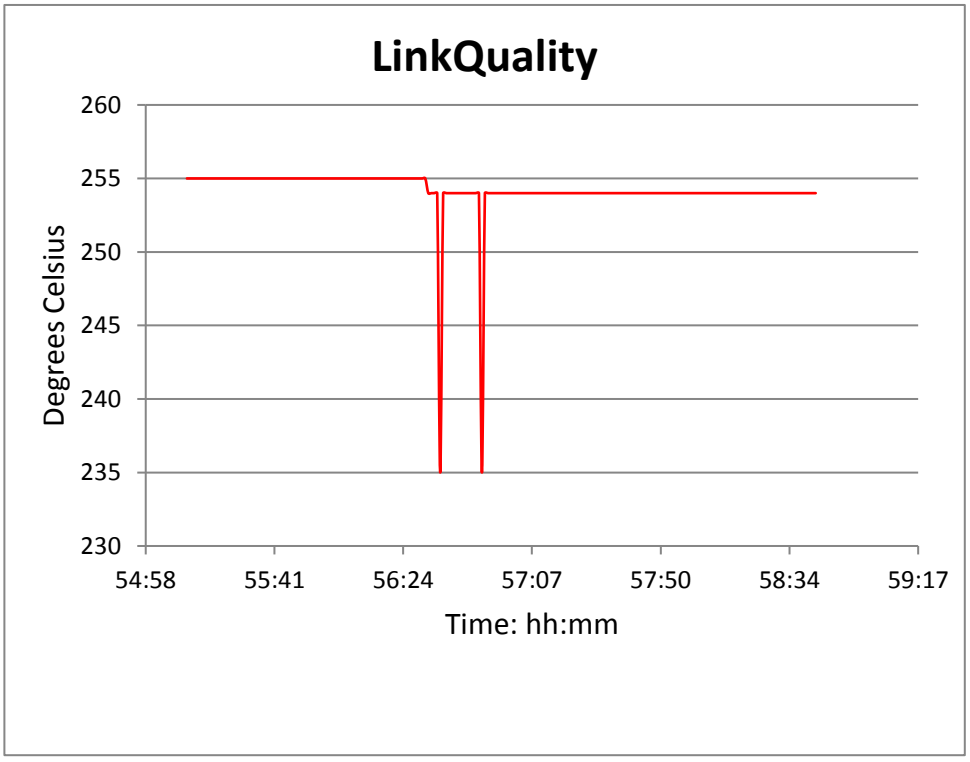
5.5.12 Device Temp

Sample Data:	`28.9, 28.9, 28.9…`
Range:	10 - 60
Units:	Degrees Celsius
'Invalid' Value:	
Sample Graph:	
Notes:	Temperature as measured by a thermistor inside the BioModule. Some conductive heating from the subject may occur as time progresses, resulting in a slow increase of temperature, in the absence of other factors.

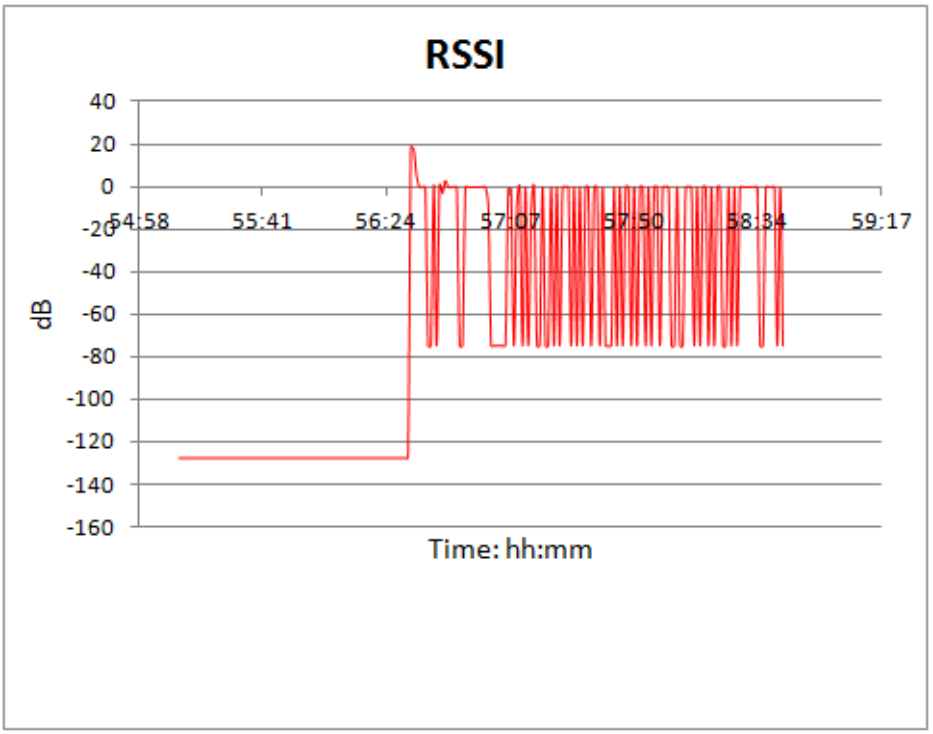
5.5.13 Status Info

Sample Data:	528, 528, 531…
Range:	
Units:	Status Info code
'Invalid' Value:	
Sample Graph:	
Notes:	Status codes must be broken down to a binary representation. Refer to the *Bluetooth Comms Link* document in the BioModule SDK for further interpretation. Details may determine: • Worn detection confidence • Button press detection • Not fitted to garment indication • Heart Rate reliability • Respiration rate reliability • Skin temperature reliability • Posture reliability • Activity reliability • HRV reliability • Estimated Core Temperature Reliability

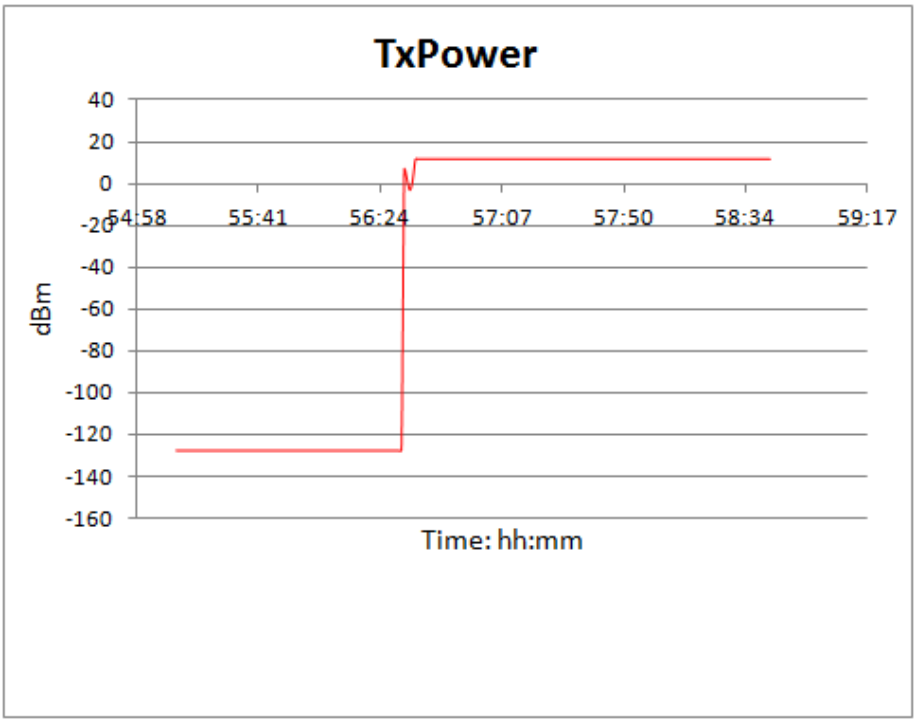
5.5.14 Link Quality

Sample Data:	255, 255, 255…
Range:	0 - 255
Units:	No units – 0=poor quality, 254=high quality
'Invalid' Value:	255
Sample Graph:	
Notes:	A Bluetooth connection with an Android device was established during the session above.

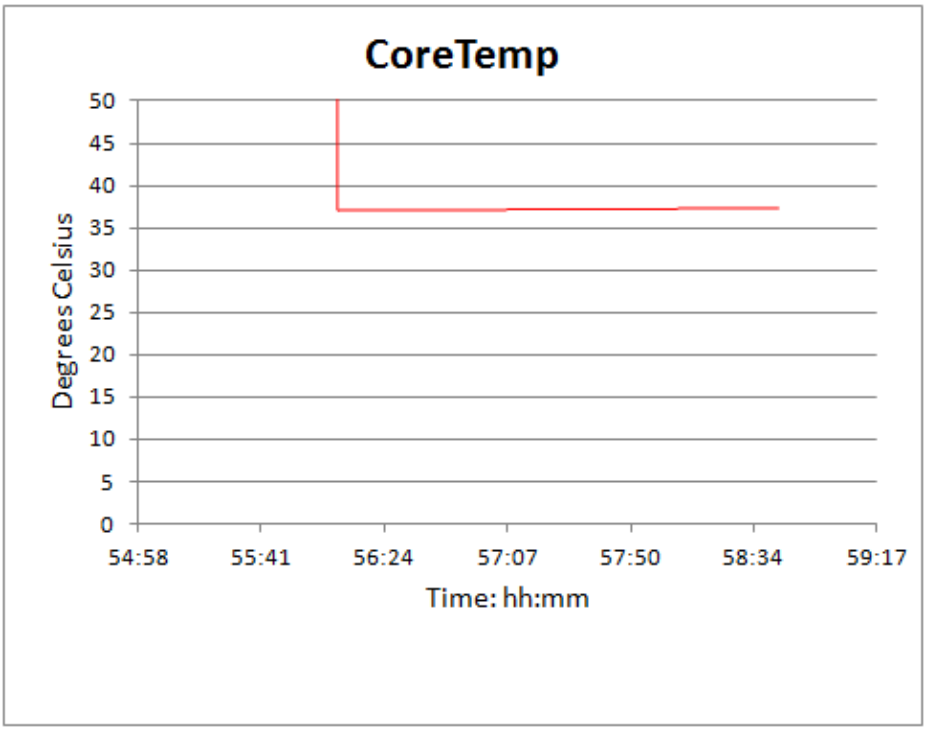
5.5.15 Bluetooth Received Signal Strength Indication - RSSI

Sample Data:	-128, 13, 19…
Range:	-127 to +127
Units:	dB
'Invalid' Value:	-128
Sample Graph:	
Notes:	A Bluetooth connection with an Android device was established during the session above.

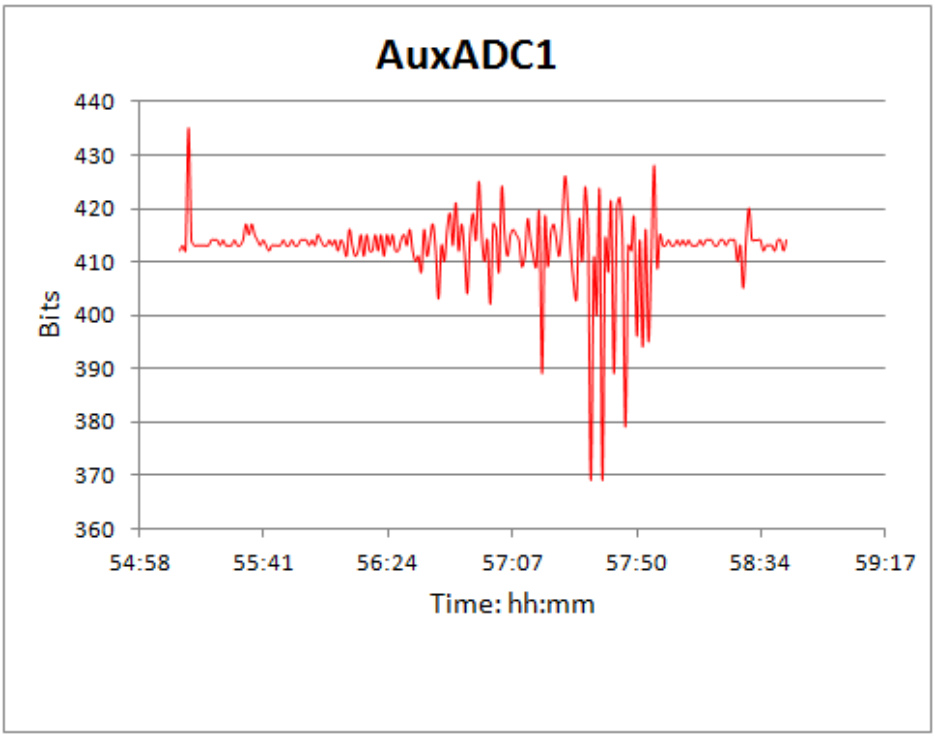
5.5.16 Bluetooth Tx Power

Sample Data:	-128, 13, 19…
Range:	-30 to +20
Units:	dBm
'Invalid' Value:	-128
Sample Graph:	
Notes:	A Bluetooth connection with an Android device was established during the session above. 10=10dBm

5.5.17 Estimated Core Temperature

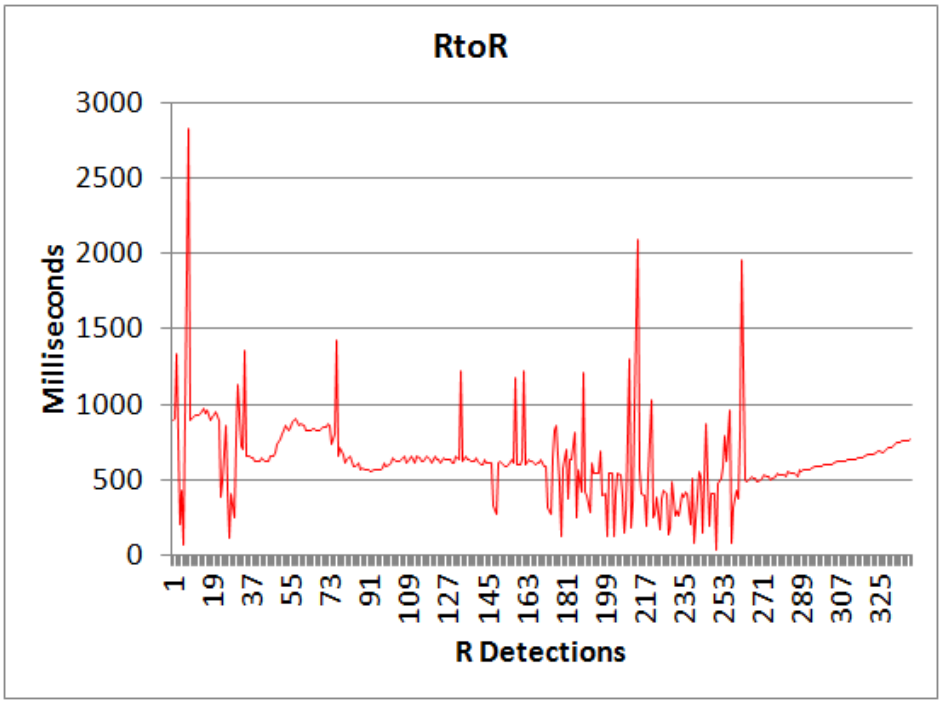
Sample Data:	`6553.5, 37.1, 37.1`
Range:	33 - 41
Units:	Degrees Celsius
'Invalid' Value:	6553.5
Sample Graph:	
Notes:	The algorithm for calculating the Estimated Core Temperature from heart rate data will return an invalid value of 6553.5 for the first 60 seconds from power on.

5.5.18 Aux ADC 1/2/3

Sample Data:	`449, 442, 421…`
Range:	0-65534
Units:	Bits
'Invalid' Value:	65535
Sample Graph:	
Notes:	The BioModule circuit board has three output points for additional functionality. Unless otherwise specified, the data in all three ADC channels represents hardware circuit noise

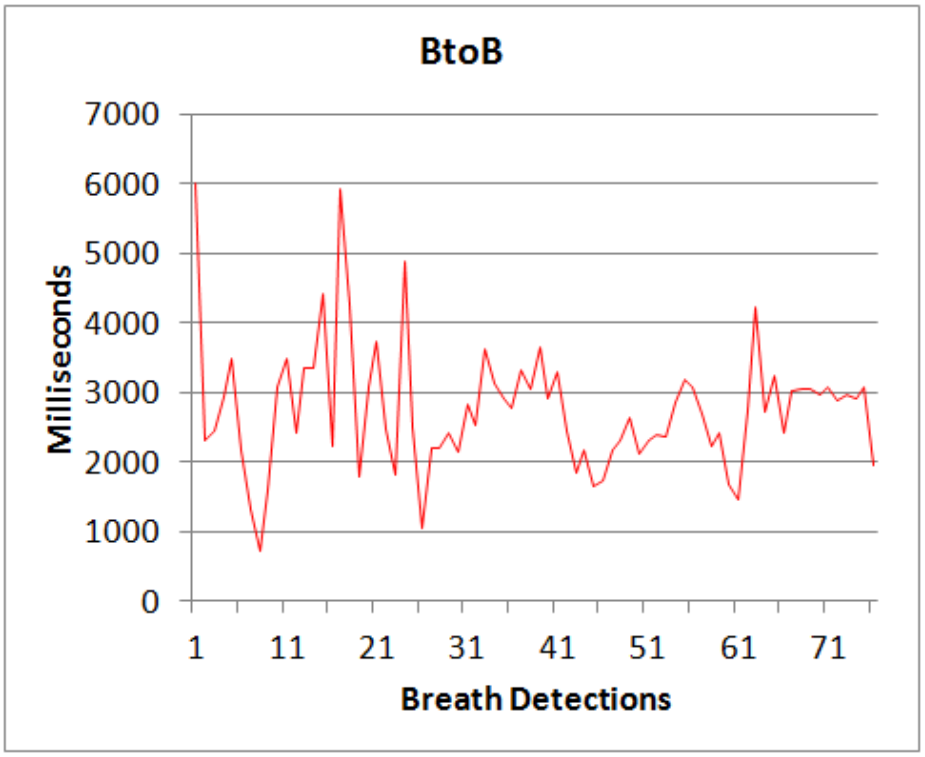
5.6 Summary Log – RR

Timestamp:	No timestamp
Reporting Frequency:	Per R detection

Sample Data:	891, 904, 1332…
Range:	0 - 32767
Units:	milliseconds
'Invalid' Value:	
Sample Graph:	
Notes:	R events are not timestamped. If necessary, a timestamp can be created by initializing the first detection at the the time indicated by the file name, and accumulating RR values to this.

5.7 Summary Log – BB

Timestamp:	No timestamp
Reporting Frequency:	Per B detection

Sample Data:	6000, 2300, 2460…
Range:	
Units:	milliseconds
'Invalid' Value:	
Sample Graph:	
Notes:	Breath events are not timestamped. If necessary, a timestamp can be created by initializing the first detection at the time indicated by the file name, and accumulating BB values to this. BB detections are unfiltered, so values outside the 850 – 15000 range expected by a breathing rate of 4 – 70 breaths/minute can be expected.

5.8 Summary Log – GPS

The following parameters are available after having imported a BioModule Summary log into the OmniSense Analysis module, if the BioModule has been configured to communicate with, and has been used in conjunction with, a supported Bluetooth GPS receiver. (Currently a Qstarz 818XT device).

GPS data is available using the Zephyr Downloader embedded in the OmniSense Analysis application, as well as later versions of the Zephyr Downloader.
Speed & distance can also be displayed within the OmniSense Analysis application, or exported as an external csv file from OmniSense Analysis. A .kml location file can also be exported from the OmniSense Analysis module.

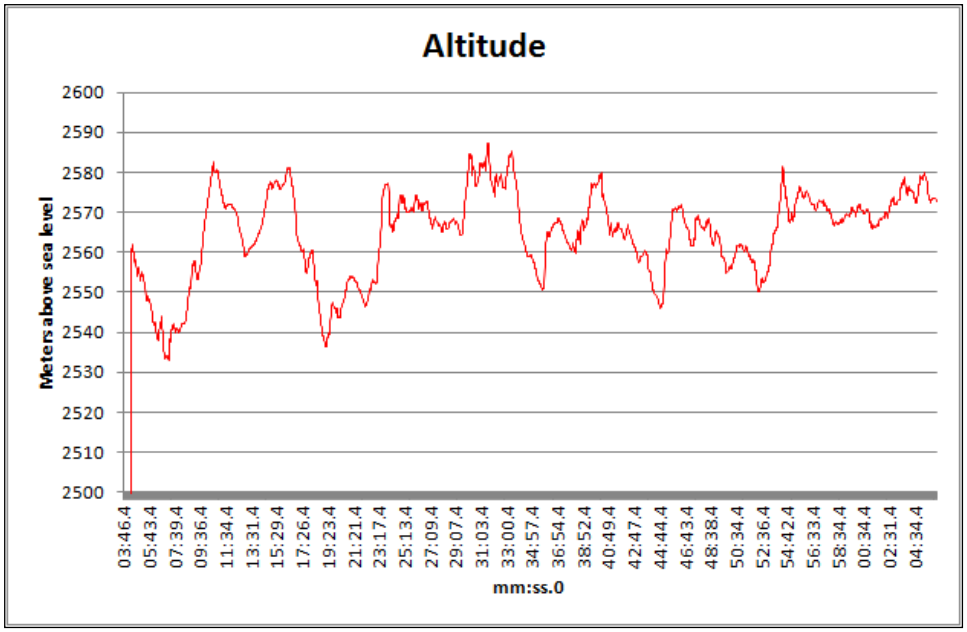
5.8.1 Location

Timestamp:	`hh:mm:ss.000`
Reporting Frequency:	`1Hz`

Sample Data:	`[Latitude] 4 38 40.314 North` `[Longitude] 74 5 25.386 West`
Range:	0 -
Units:	Latitude: Degrees Minutes Seconds North/South Longitude: Degrees Minutes Seconds East/West
'Invalid' Value:	
Sample Graph:	Location displayed directly in Google Earth – see Location kml file
Notes:	Accuracy of GPS data is subject to the number of satellites acquired by the GPS receiver. Increased accuracy can be achieved by enabling DGPS in the GPS receiver. This can be done by downloading the GPS View utility from http://www.qstarz.com/download.htm. A BioModule firmware update will become available from Zephyr which enables DGPS automatically as soon as a Bluetooth connection is made to the GPS receiver. *There will be some gaps in GPS data due to dropped packets between the BioModule and GPS receiver over the Bluetooth connection.*

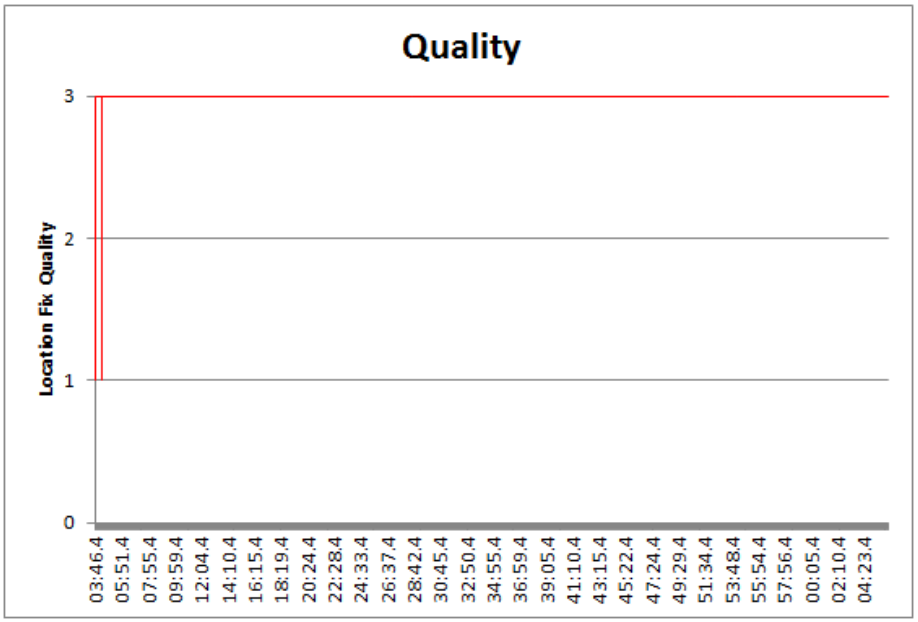
5.8.2 Altitude

Timestamp:	hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	147.3, 149.2, 151.1
Range:	0 -
Units:	Meters above mean sea level
'Invalid' Value:	
Sample Graph:	
Notes:	Accuracy of GPS data is subject to the number of satellites acquired by the GPS receiver. Increased accuracy can be achieved by enabling DGPS in the GPS receiver. This can be done by downloading the GPS View utility from http://www.qstarz.com/download.htm. A BioModule firmware update will become available from Zephyr which enables DGPS automatically as soon as a Bluetooth connection is made to the GPS receiver. There may be some gaps in GPS data due to dropped packets between the BioModule and GPS receiver over the Bluetooth connection.

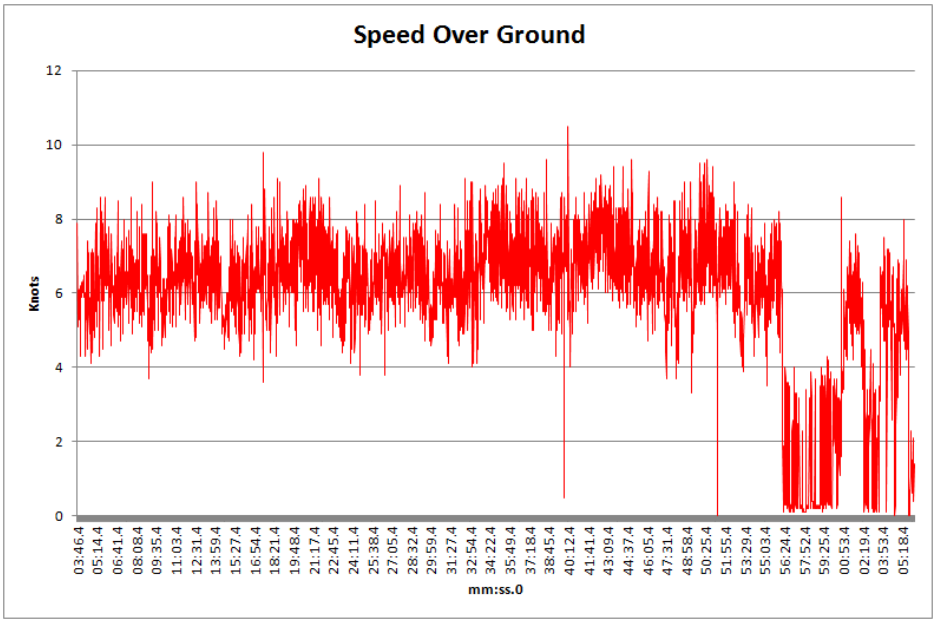
5.8.3 Quality

Timestamp:	hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	1,3,3,2,3
Range:	1,2,3
Units:	n/a
'Invalid' Value:	
Sample Graph:	
Notes:	GPS fix quality. This is dependent on the number of satellites acquired in order to be able to give an accurate calculation of location only (2D), or location + Altitude (3D) 1 = no fix 2 = 2D fix 3 = 3D fix

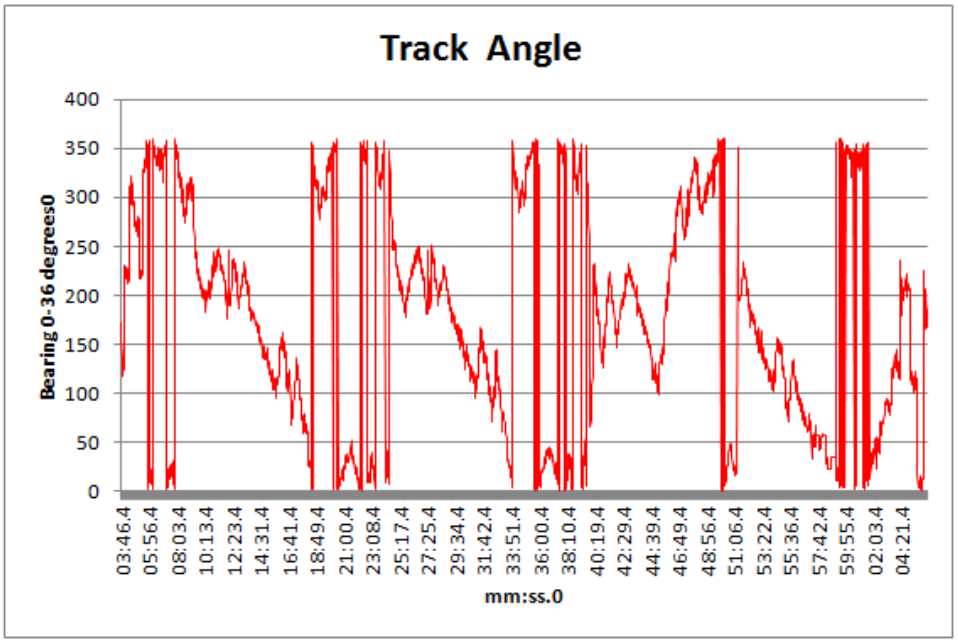
5.8.4 Speed Over Ground

Timestamp:	hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	9.2, 7.9, 5.1
Range:	0 -
Units:	Knots (1 knot = 1.15 miles per hour)
'Invalid' Value:	
Sample Graph:	
Notes:	Accuracy of GPS data is subject to the number of satellites acquired by the GPS receiver. Increased accuracy can be achieved by enabling DGPS in the GPS receiver. This can be done by downloading the GPS View utility from http://www.qstarz.com/download.htm. A BioModule firmware update will become available from Zephyr which enables DGPS automatically as soon as a Bluetooth connection is made to the GPS receiver. There may be some gaps in GPS data due to dropped packets between the BioModule and GPS receiver over the Bluetooth connection.

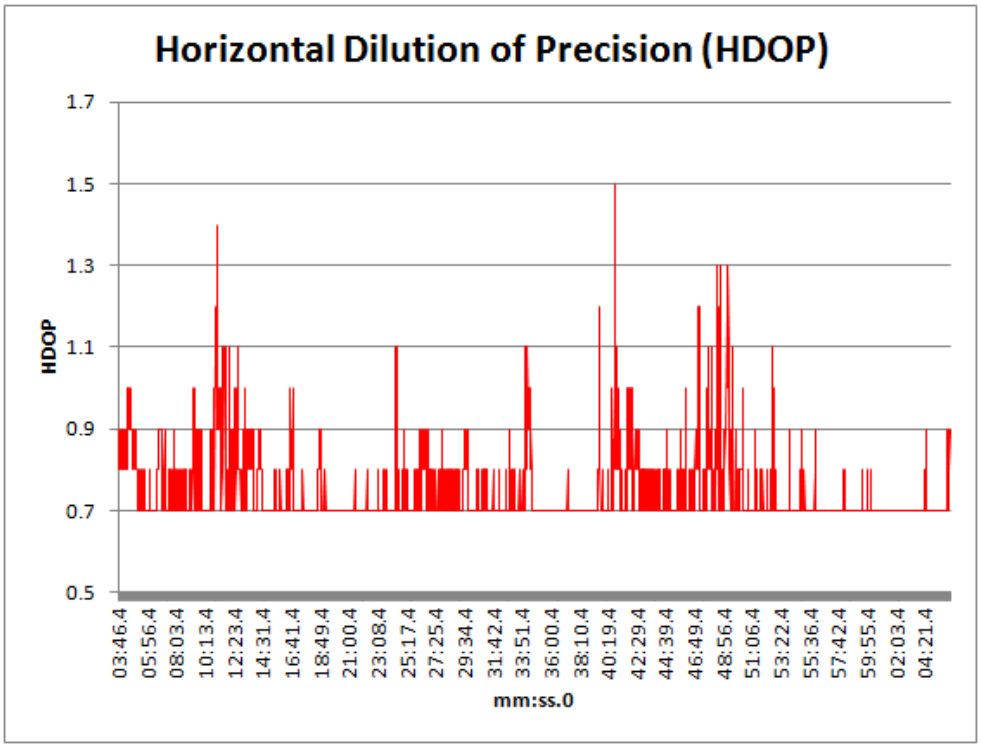
5.8.5 Track Angle

Timestamp:	hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	173.1, 158.8, 153.3
Range:	0 - 360
Units:	Compass bearing in degrees [0=North, 90= East, 180=South, 270=West]
'Invalid' Value:	
Sample Graph:	
Notes:	Accuracy of GPS data is subject to the number of satellites acquired by the GPS receiver. Increased accuracy can be achieved by enabling DGPS in the GPS receiver. This can be done by downloading the GPS View utility from http://www.qstarz.com/download.htm. A BioModule firmware update will become available from Zephyr which enables DGPS automatically as soon as a Bluetooth connection is made to the GPS receiver. There may be some gaps in GPS data due to dropped packets between the BioModule and GPS receiver over the Bluetooth connection.

5.8.6 HDOP

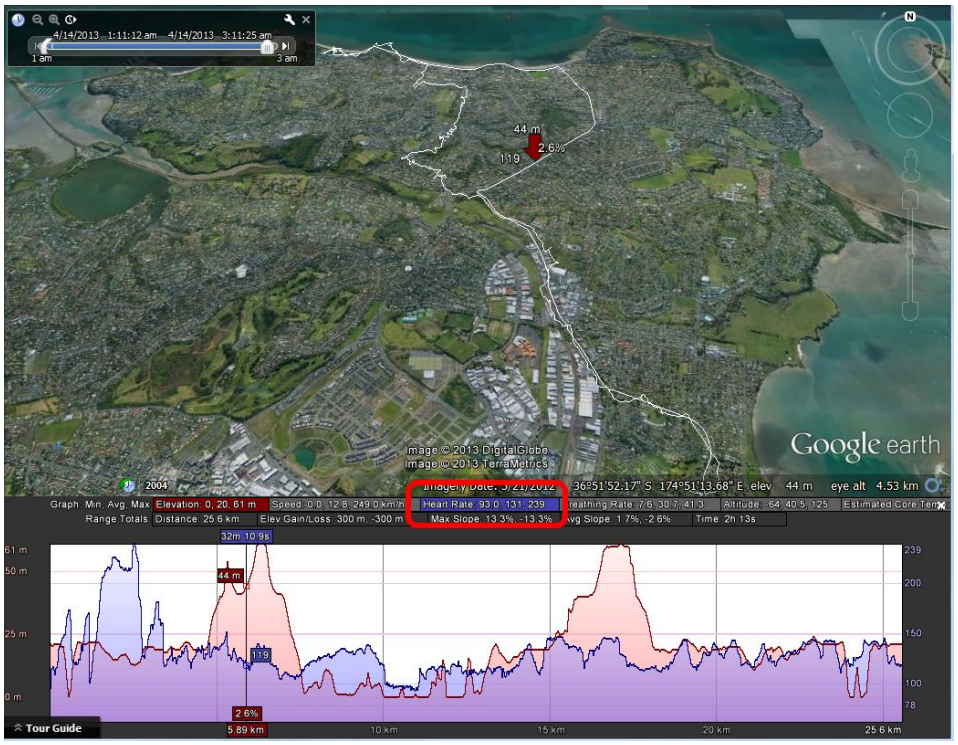
Timestamp:	hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0.8, 0.6, 0.5
Range:	0 -
Units:	n/a
'Invalid' Value:	
Sample Graph:	
Notes:	A smaller value of HDOP indicates greater GPS location accuracy. Accuracy of GPS data is subject to the number of satellites acquired by the GPS receiver. Increased accuracy can be achieved by enabling DGPS in the GPS receiver. This can be done by downloading the GPS View utility from http://www.qstarz.com/download.htm. A BioModule firmware update will become available from Zephyr which enables DGPS automatically as soon as a Bluetooth connection is made to the GPS receiver. There may be some gaps in GPS data due to dropped packets between the BioModule and GPS receiver over the Bluetooth connection.

5.8.7 Location (kml)

Data for kml file exported from OmniSense Analysis

Timestamp:	`yyyy-mm-ddThh:mm:ss`
Reporting Frequency:	`1Hz`

Sample Data:	`Location: 174.852145 -36.9087683333333 40.0999984741211 for location – additional tags for physiological data`
Range:	
Units:	Longitude Latitude Altitude
'Invalid' Value:	
Sample Graph:	 Google Earth ©
Notes:	To access physiological data within the kml file (heart rate, estimated core temperature, activity level, peak acceleration) – right-click the file in the Google Earth *Places* navigation tree, and select *Show Elevation Profile* from the context menu. Click on the various Parameter links below the earth image to display in the graph below.

5.9 Summary & Waveform Log – Summary

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

5.9.1 Summary & Waveform /Summary Log Format Parameter Parity

The Summary & Waveform log was originally developed as an extended Summary log format. For this reason all of the core parameters are identical to the Summary log format.

The following a reported identically in the Summary & Waveform and Summary logs:

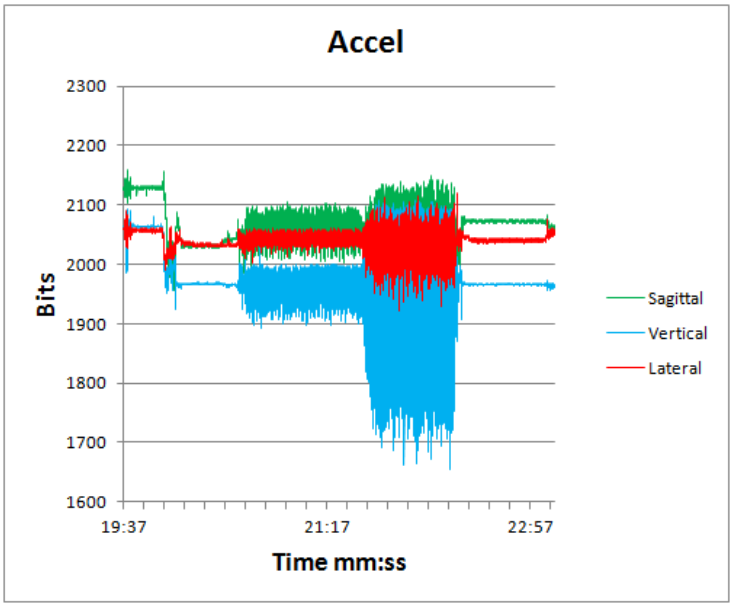
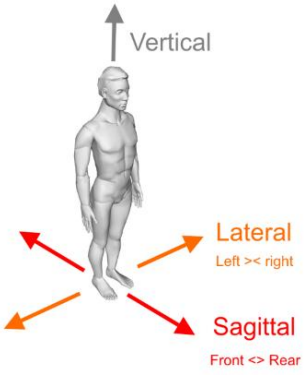
- Heart Rate
- Breathing rate
- Skin Temperature (not supported by BioModule 3.0)
- Posture
- Activity
- Peak Acceleration
- Battery Voltage
- Battery Level
- Breathing Amplitude
- Breathing Noise & Confidence Levels
- ECG Amplitude, Noise & HR Confidence Levels
- HRV
- System Confidence
- GSR
- ROG Status & Time
- Vertical Acceleration Minimum = X Acceleration Minimum
- Vertical Acceleration Peak = X Acceleration Peak
- Lateral Acceleration Minimum = Y Acceleration Minimum
- Lateral Acceleration Peak = Y Acceleration Peak
- Sagittal Acceleration Minimum = Z Acceleration Minimum
- Sagittal Acceleration Peak = Z Acceleration Peak
- Device Temperature
- Status Info
- Link Quality
- Bluetooth Received Signal Strength Indication – RSSI
- Bluetooth Tx Power
- Estimated Core Temperature
- Aux ADC 1/2/3
- RR file
- BB file

The additional files which complete the Summary & Waveform Log Format are described in the following sections.

Ph: 1 (443) 569-3603
Web: www.zephyranywhere.com

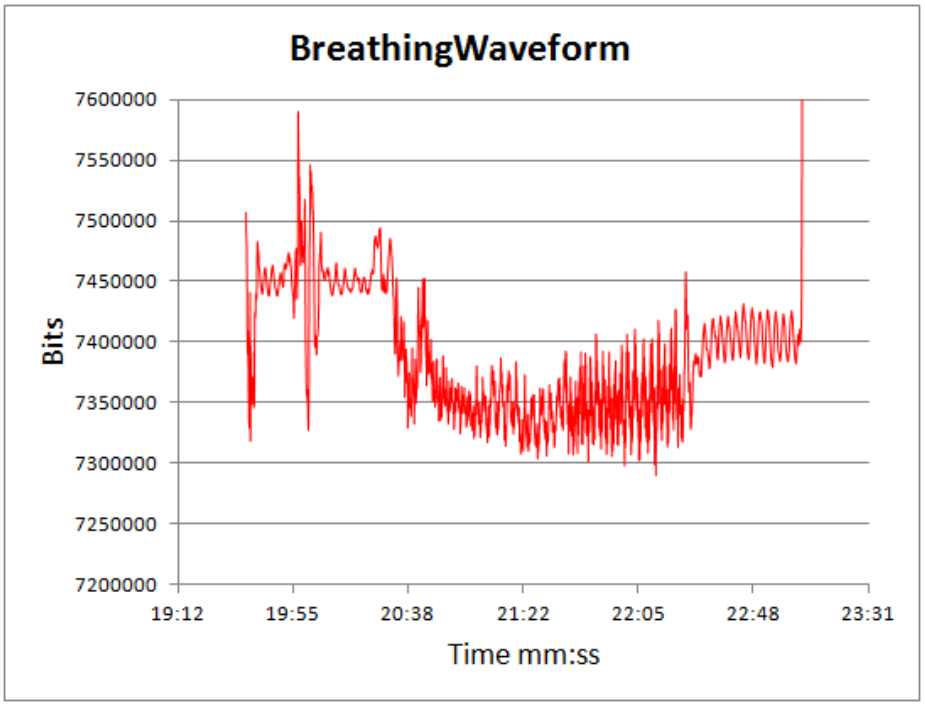
5.10 Summary & Waveform Log – Accel

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	100Hz

Sample Data:	2061, 2063, 2063…
Range:	0 - 4095
Units:	bits
'Invalid' Value:	4095
Sample Graph:	
Notes:	Raw 12 bit unfiltered accelerometer output. Axes refer to subject orientation, if device is configured for the appropriate garment type. Centered at 2048, 1 g = 83 bits 

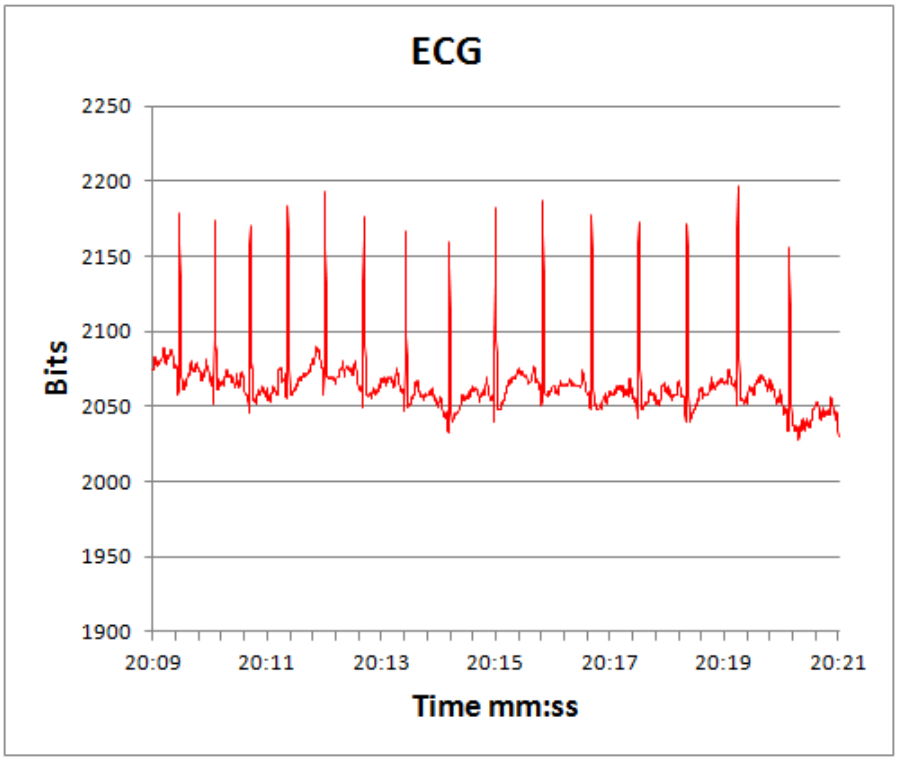
5.11 Summary & Waveform Log – Breathing

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	25Hz

Sample Data:	7506772, 7490787, 7490787…
Range:	1 - 16777215
Units:	bits
'Invalid' Value:	0, 16777216
Sample Graph:	
Notes:	A 24-bit uncalibrated representation of the breathing sensor output

5.12 Summary & Waveform Log – ECG

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	250Hz

Sample Data:	2167, 2167, 2166…
Range:	0 - 4095
Units:	bits
'Invalid' Value:	4095
Sample Graph:	
Notes:	A 12-bit filtered ECG sensor output 1 bit = 0.0067025 mV indicative

5.13 Summary & Waveform Log – Event Data

For a full description of Event Message specifications, refer to the [2] *Event Messaging System* document.

Timestamp:	YYYY MM DD ms
Reporting Frequency:	Per Event

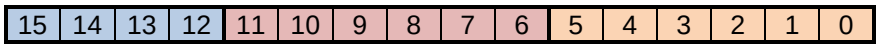
5.13.1 Sequence No

Sample Data:	0
Range:	0 – 255

5.13.2 Time Stamp

Timestamp as indicated above, comma separated.

5.13.3 Event Code

Sample Data:	192,4160, 4096
Range:	0 – 4095
Units:	Bits
Sample Diagram	
Notes:	A 16 bit number. • Bits 15-12=Event Type • Bits 11-6=Event Source • Bits5-0=Event ID

5.13.4 Type

Sample Data:	System, Physiological, Error, Debug
Notes:	No error or debug events are currently implemented

5.13.5 Source

Sample Data:	Diagnosis, WornDetection, RogAlgorithm, HeartRateCalculation
Notes:	Source of the event – source labels are self-evident

5.13.6 EventID

Sample Data:	0
Notes:	Specific to the Event itself. Refer to *Event Messaging System* document

5.13.7 Event Specific Data

Sample Data:	Worn status changed from 100% to 0%
Notes:	Text description of the event. Self evident.

5.14 Summary & Development Log – Summary

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

5.14.1 Summary & Development /Summary Log Format Parameter Parity

The Summary & Development log was originally developed as an extended Summary & Waveform log format. For this reason all of the core parameters are identical to the Summary/Summary & Waveform log format.

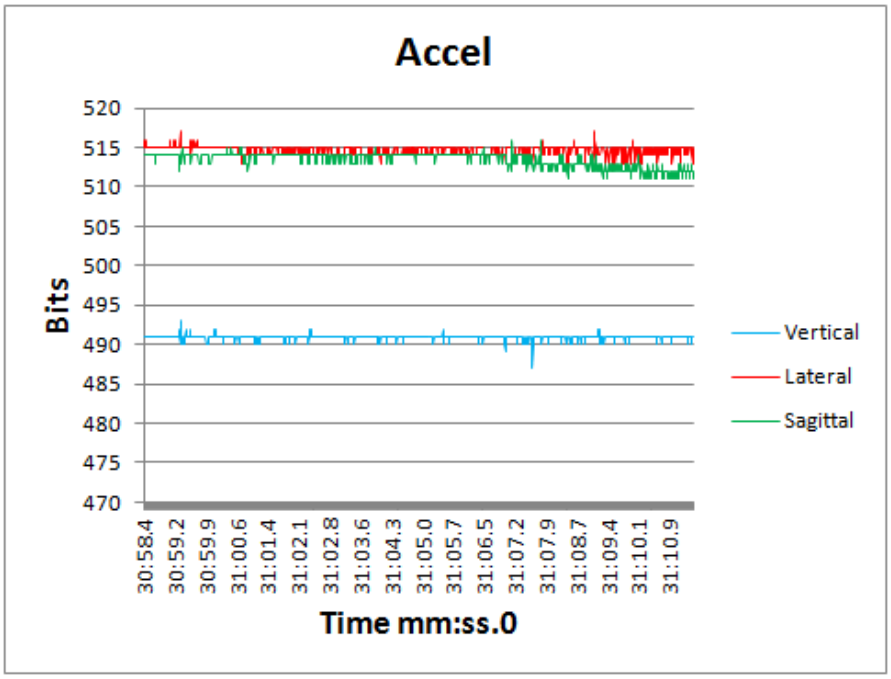
The following are reported identically in the Summary & Development and Summary/Summary & Waveform logs:

- Heart Rate
- Breathing rate
- Skin Temperature (not supported by BioModule 3.0)
- Posture
- Activity
- Peak Acceleration
- Battery Voltage
- Battery Level
- Breathing Amplitude
- Breathing Noise & Confidence Levels
- ECG Amplitude, Noise & HR Confidence Levels
- HRV
- System Confidence
- GSR
- ROG Status & Time
- Vertical Acceleration Minimum = X Acceleration Minimum
- Vertical Acceleration Peak = X Acceleration Peak
- Lateral Acceleration Minimum = Y Acceleration Minimum
- Lateral Acceleration Peak = Y Acceleration Peak
- Sagittal Acceleration Minimum = Z Acceleration Minimum
- Sagittal Acceleration Peak = Z Acceleration Peak
- Device Temperature
- Status Info
- Link Quality
- Bluetooth Received Signal Strength Indication – RSSI
- Bluetooth Tx Power
- Estimated Core Temperature
- Aux ADC 1/2/3
- RR file
- BB file

Those files which differ in the Summary & Development Log format are described in the following sections.

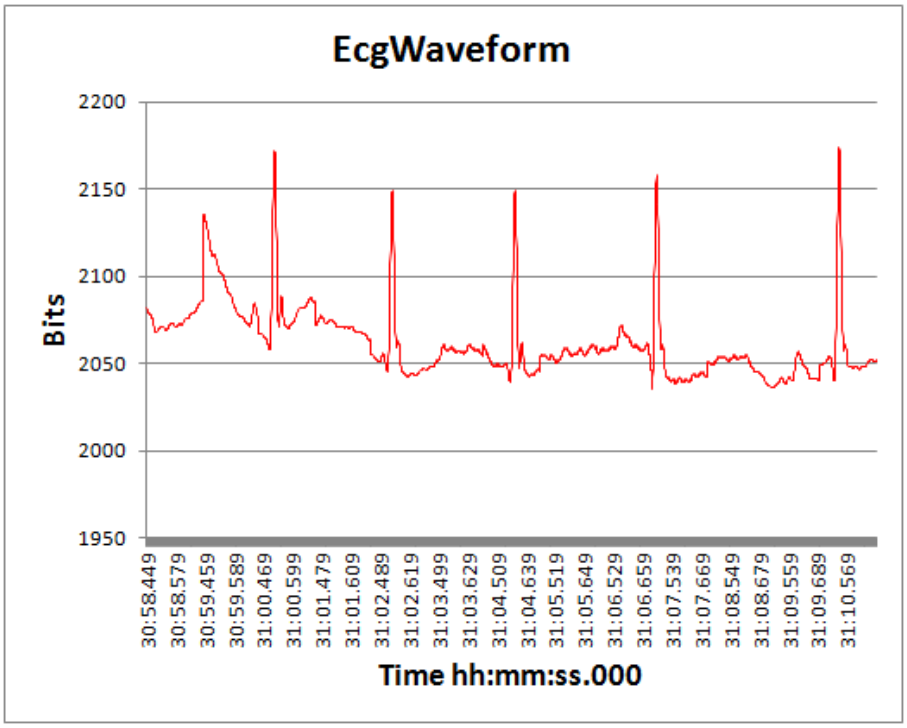
5.15 Summary & Development Log – Accel

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	100Hz

Sample Data:	491, 516, 514…
Range:	0 - 1023
Units:	bits
'Invalid' Value:	1023
Sample Graph:	
Notes:	Raw 10 bit unfiltered accelerometer output. Axes refer to subject orientation, if device is configured for the appropriate garment type. The 12-bit resolution of Accel in the Summary & Waveform is reduced to 10-bit to provide additional space

5.16 Summary & Development Log – ECG

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1KHz

Sample Data:	2167, 2167, 2166…
Range:	0 - 4095
Units:	bits
'Invalid' Value:	4095
Sample Graph:	
Notes:	A 12-bit filtered ECG sensor output 1 bit = 0.0067025 mV indicative

5.17 Enhanced Summary Log – Summary

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

5.17.1 Enhanced Summary /Summary Log Format Parameter Parity

The Enhanced Summary log is an extended version of the Summary log format. For this reason all of the core parameters are identical to the Summary log format.

The following a reported identically in the Enhanced Summary and Summary logs:

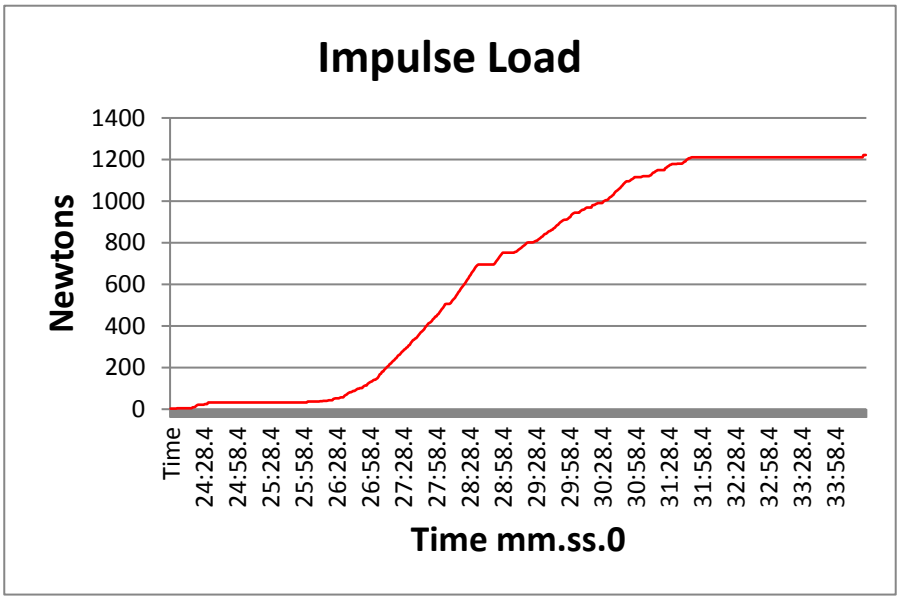
- Heart Rate
- Breathing rate
- Skin Temperature (not supported by BioModule 3.0)
- Posture
- Activity
- Peak Acceleration
- Battery Voltage
- Battery Level
- Breathing Amplitude
- Breathing Noise & Confidence Levels
- ECG Amplitude, Noise & HR Confidence Levels
- HRV
- System Confidence
- GSR
- ROG Status & Time
- Vertical Acceleration Minimum = X Acceleration Minimum
- Vertical Acceleration Peak = X Acceleration Peak
- Lateral Acceleration Minimum = Y Acceleration Minimum
- Lateral Acceleration Peak = Y Acceleration Peak
- Sagittal Acceleration Minimum = Z Acceleration Minimum
- Sagittal Acceleration Peak = Z Acceleration Peak
- Device Temperature
- Status Info
- Link Quality
- Bluetooth Received Signal Strength Indication – RSSI
- Bluetooth Tx Power
- Estimated Core Temperature
- Aux ADC 1/2/3
- RR file
- BB file

The additional files which complete the Enhanced Log Format are described in the following sections.

These parameters are also incorporated into the *Enhanced Summary & Waveform*, and *Enhanced Summary & Developmen*t Log Formats.

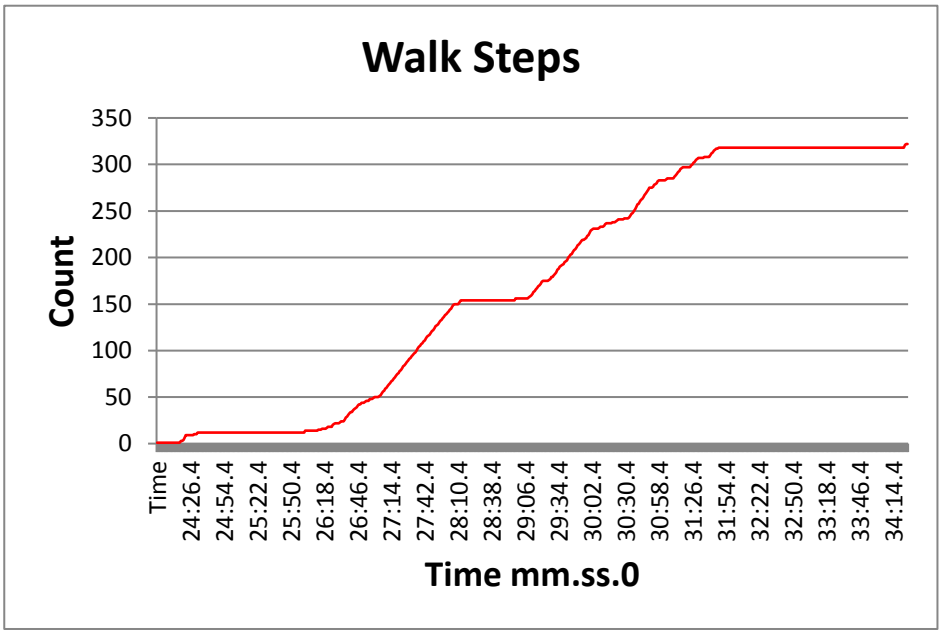
5.18 Enhanced Summary Log – Impulse Load

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	3, 3, 9…
Range:	Cumulative during session
Units:	Newtons
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative measurement of mechanical load – the sum of the areas under the accelerometer magnitude curve for all impulses. Reset when the BioModule is power cycled.

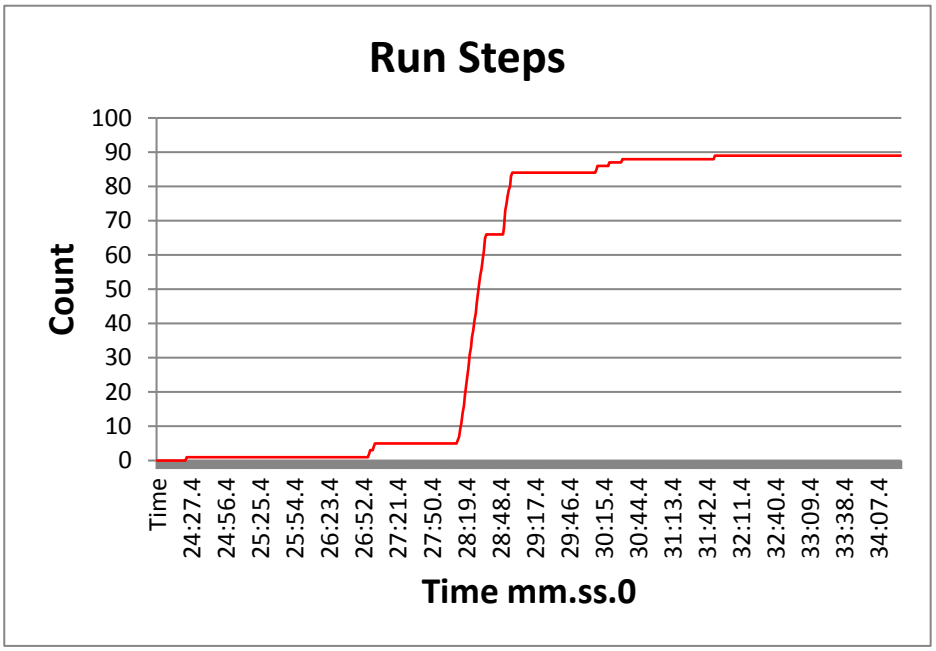
5.19 Enhanced Summary Log – Walking Step Count

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0, 1, 2…
Range:	0 – 262143
Units:	Number
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of detected walking steps. Impulse data is analyzed for magnitude, duration and angle as well as interval from preceding impulse, to determine whether the impulse is an impact or a step. Reset when the BioModule is power cycled.

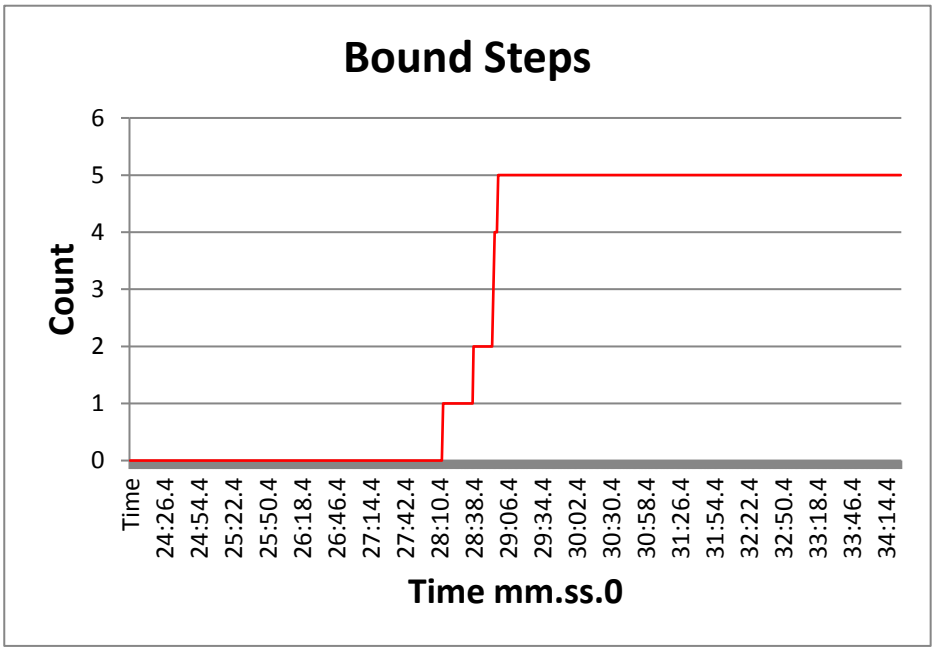
5.20 Enhanced Summary Log – Running Step Count

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	3, 3, 9…
Range:	0 – 262143
Units:	Newtons
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of detected running steps. Reset when the BioModule is power cycled.

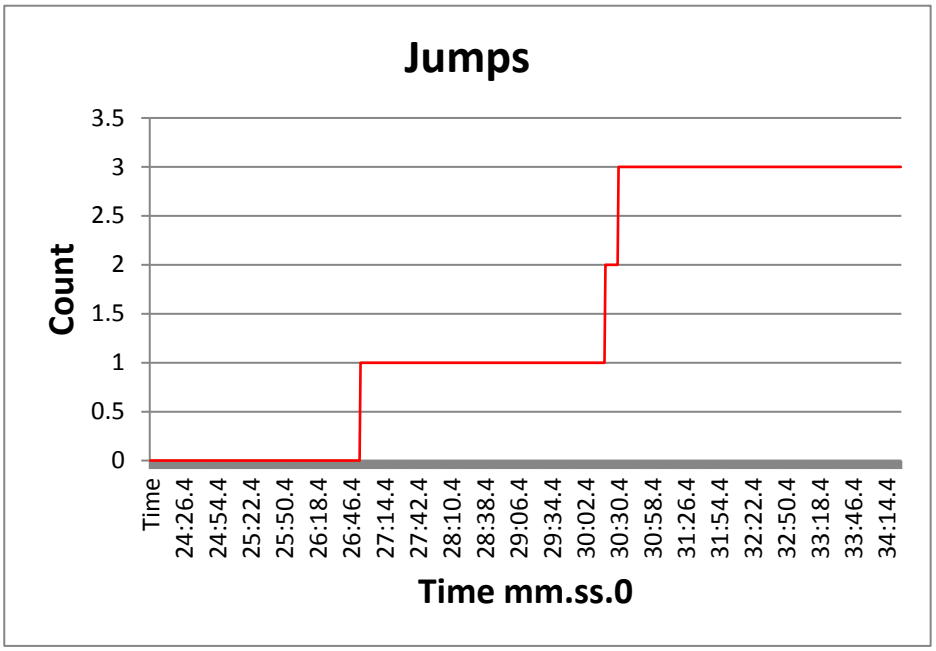
5.21 Enhanced Summary Log – Bound Count

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	
Range:	0 – 1023
Units:	Number
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of detected bounds. Bounds differ from running steps by the time in the air between steps. Reset when the BioModule is power cycled.

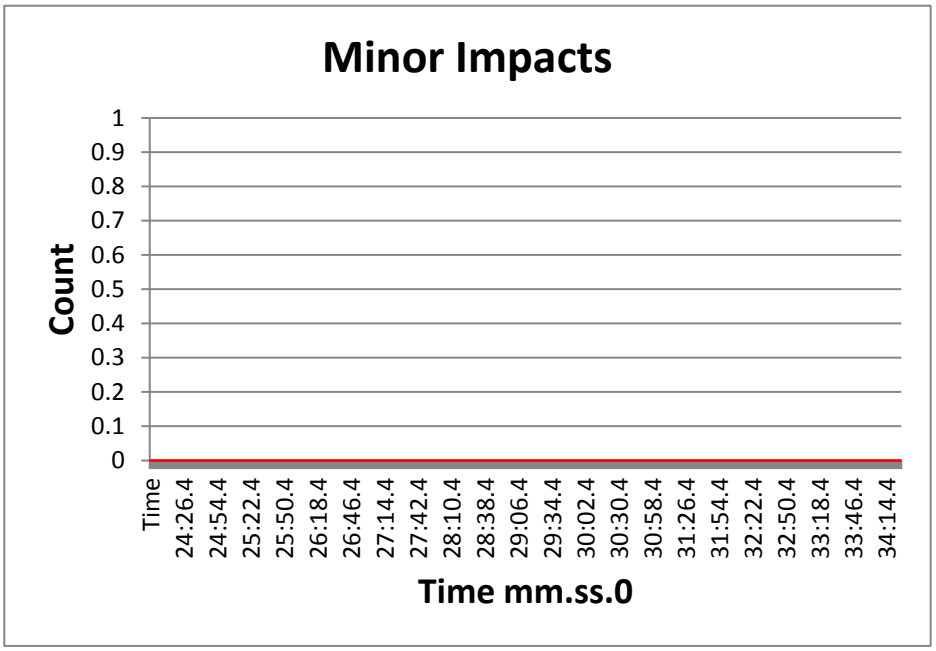
5.22 Enhanced Summary Log – Count of Jumps

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0, 1, 2…
Range:	0 – 1023
Units:	Number
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of detected jumps. Reset when BioModule power cycled.

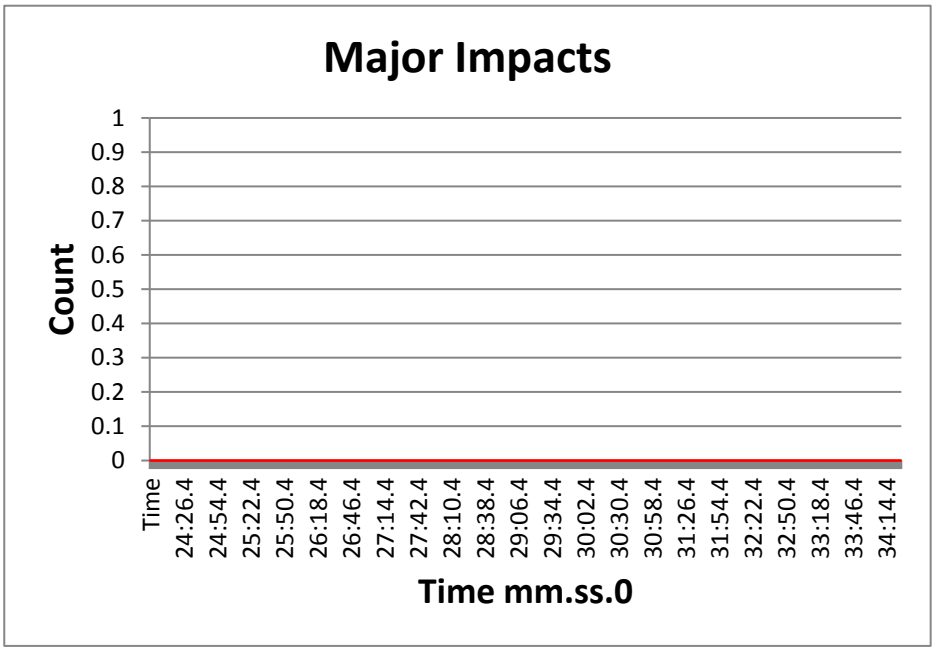
5.23 Enhanced Summary Log – Count of Minor Impacts

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0, 1, 2…
Range:	0 – 1023
Units:	Number
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of impulses classified as minor impacts – peak accelerometer magnitude during the impact is between 3 and 7g and angle of impact meets the criteria for an impact, as opposed to a step.

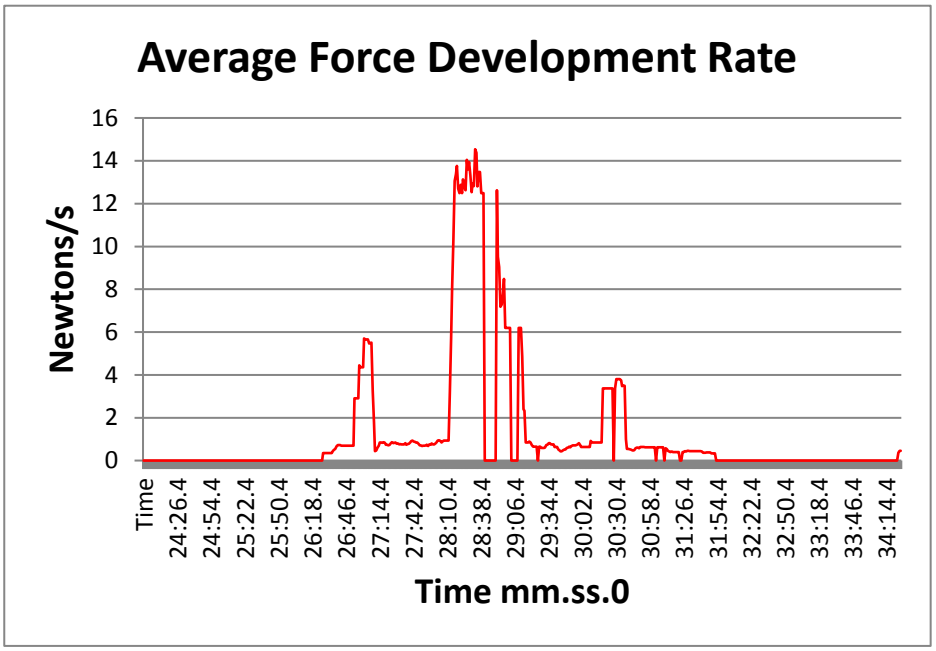
5.24 Enhanced Summary Log – Count of Major Impacts

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0, 1, 2…
Range:	0 – 1023
Units:	Number
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A cumulative count of impulses classified as minor impacts – peak accelerometer magnitude during the impact is greater than 7g and angle of impact meets the criteria for an impact, as opposed to a step.

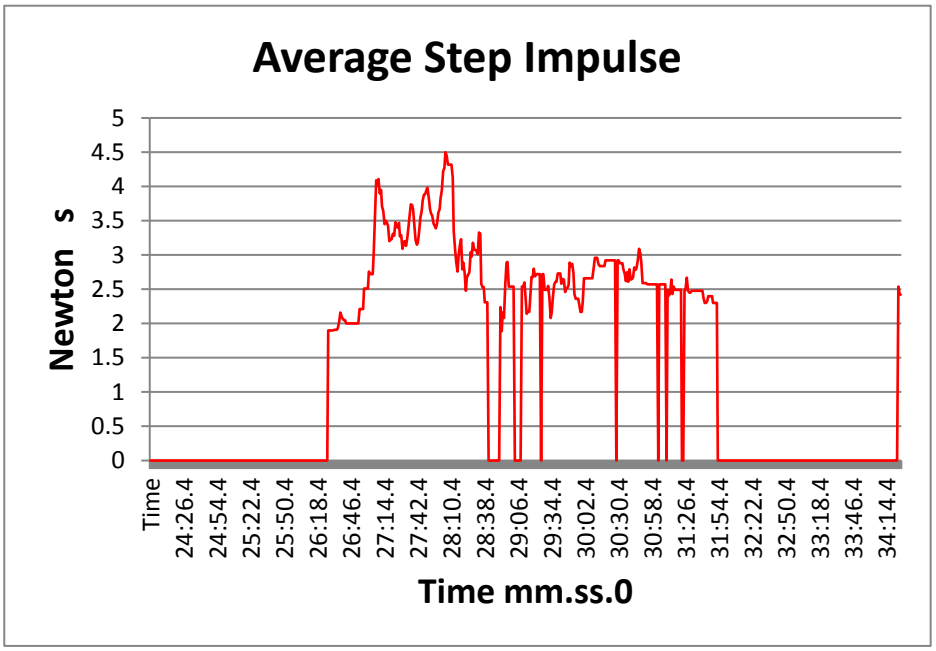
5.25 Enhanced Summary Log – Average Force Development Rate

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0.94, 3.21, 5.78…
Range:	0 – 4095
Units:	Newtons per second
'Invalid' Value:	None specified
Sample Graph:	
Notes:	A measure of explosive power. The gradient of the accelerometer magnitude curve during initiation of the impulse. Averaged for the previous 10 steps. Zero if no steps detected for 5 seconds.

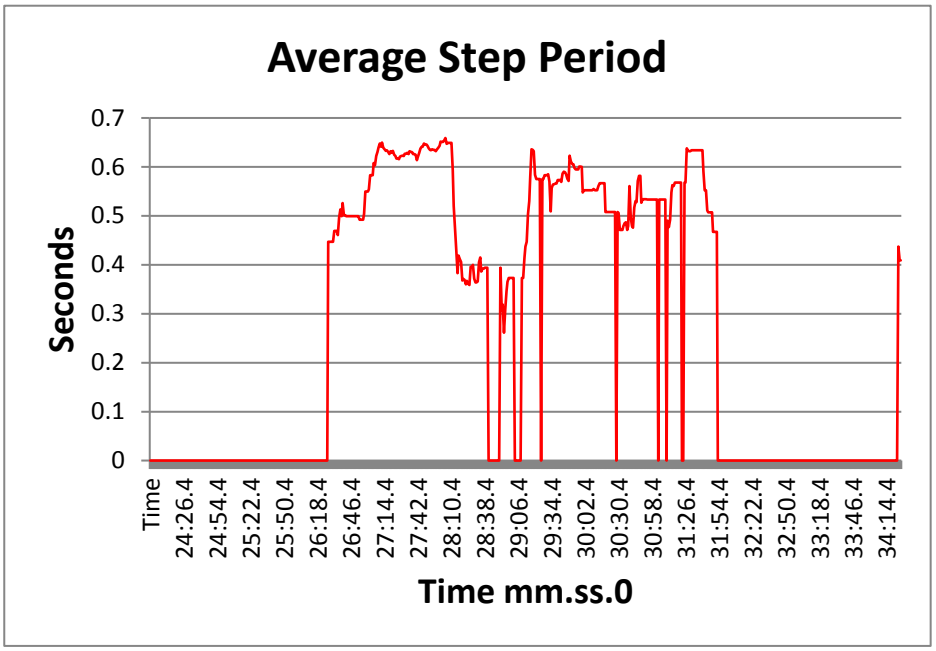
5.26 Enhanced Summary Log – Average Step Impulse

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	2.75, 2.48, 2.67…
Range:	0 – 1023
Units:	Newton seconds
'Invalid' Value:	None specified
Sample Graph:	
Notes:	Area under the accelerometer magnitude curve for a detected step. Averaged over previous 10 steps. A measure of the efficiency of steps, i.e. how much energy is expended during a step. Shorter (in duration) steps expend less energy. Zero if no steps detected for 5 seconds.

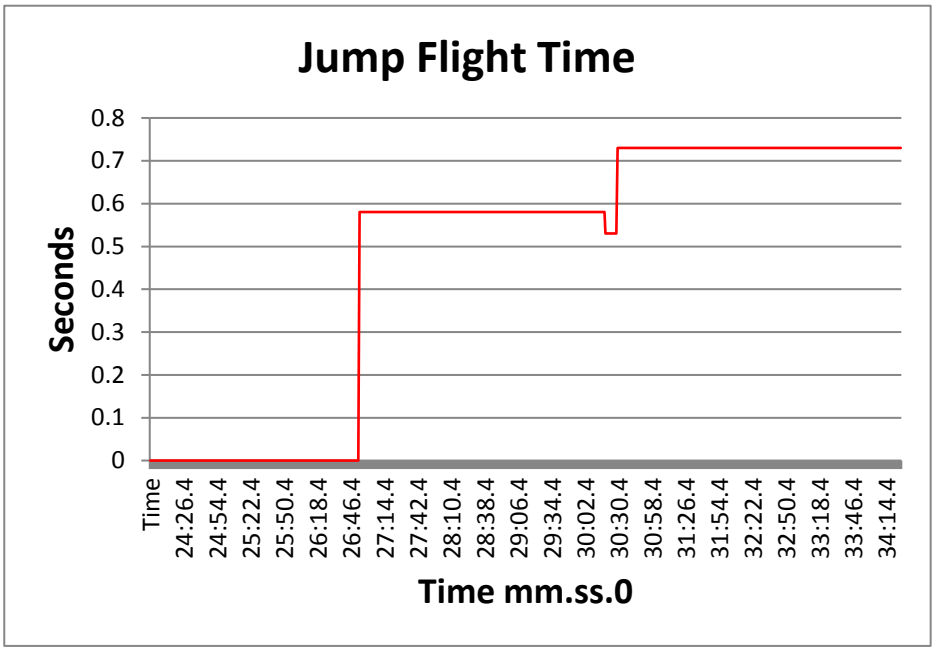
5.27 Enhanced Summary Log – Average Step Period

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0.655, 0.651, 0.647…
Range:	0 - 1023
Units:	Seconds
'Invalid' Value:	None specified.
Sample Graph:	
Notes:	Time duration of a step, averaged over previous 10 steps. Zero if no steps detected for 5 seconds.

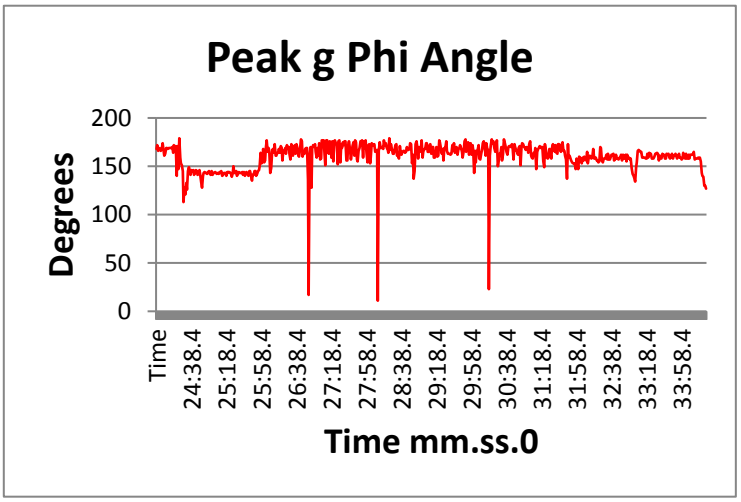
5.28 Enhanced Summary Log – Jump Flight Time

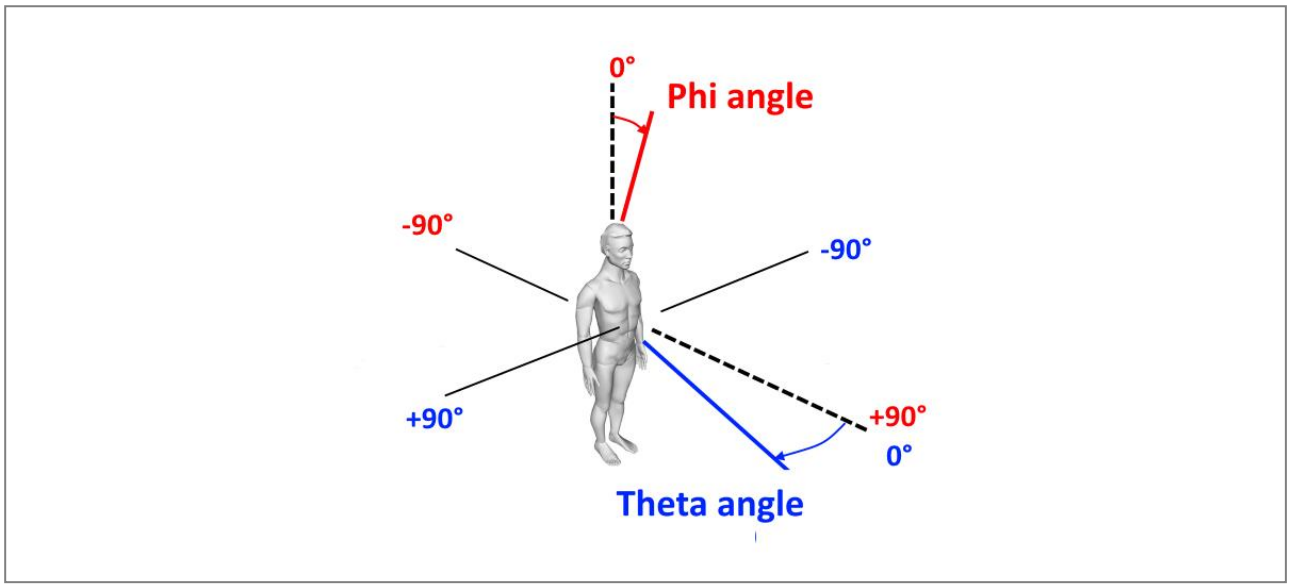
Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	0, 0, 0.58
Range:	0 - 255
Units:	Seconds
'Invalid' Value:	None specified.
Sample Graph:	
Notes:	Last known value repeated until a new jump is detected.

5.29 Enhanced Summary Log – Peak Acceleration Phi Angle

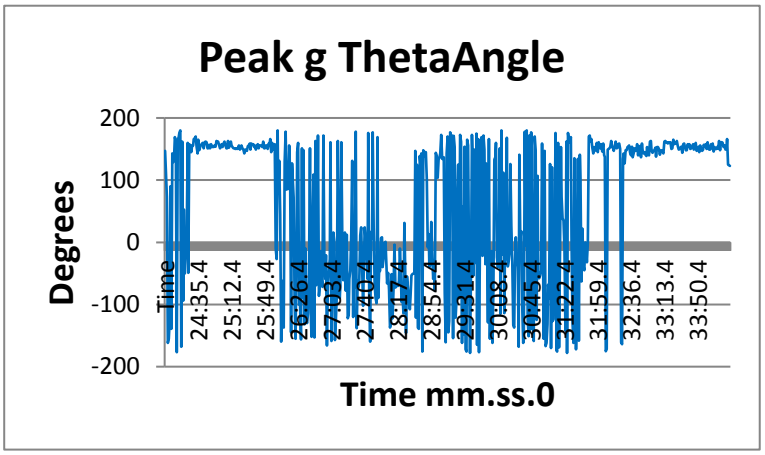
Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

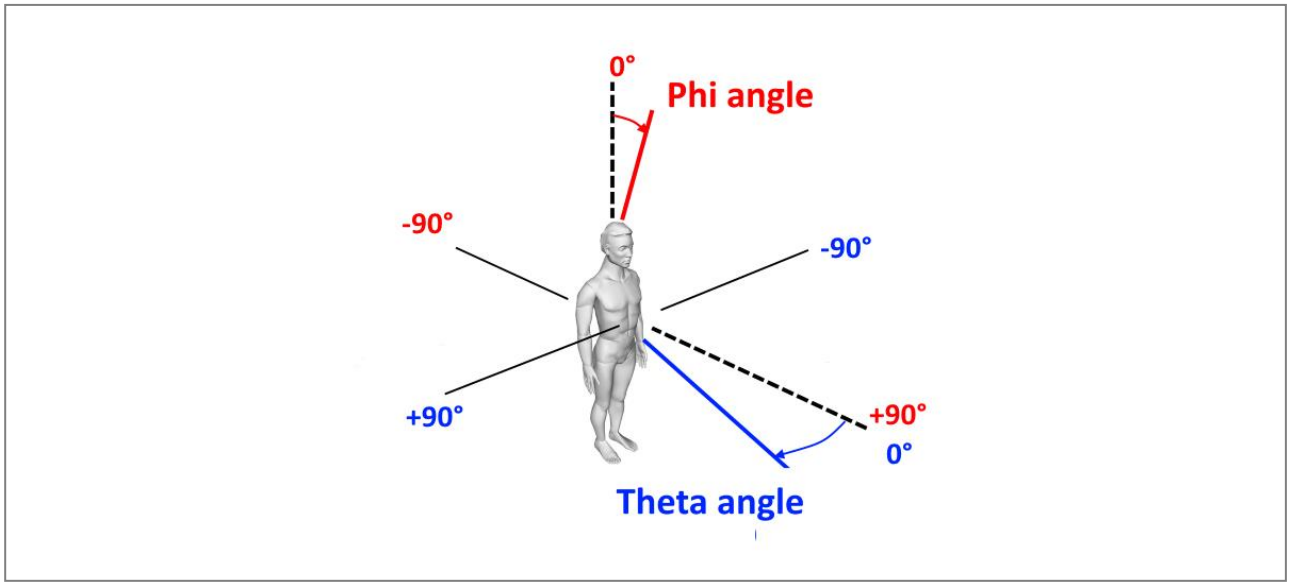
Sample Data:	167, 154, 72
Range:	0 – 180
Units:	Degrees
'Invalid' Value:	None specified.
Sample Graph:	
Notes:	Direction of peak magnitude from vertical during previous epoch



5.30 Enhanced Summary Log – Peak Acceleration Theta Angle

Timestamp:	DD/MM/YYYY hh:mm:ss.000
Reporting Frequency:	1Hz

Sample Data:	167, 154, 72
Range:	-180 to +180
Units:	Degrees
'Invalid' Value:	None specified
Sample Graph:	
Notes:	Direction of peak magnitude from horizontal (zero as shown below) during previous epoch.



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