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Breathpal Sensor manual

Version 3.2 July 2022

Global description

This manual refers to the Breathpal RIP sensor version 3.1.
The features of Breathpal are:

- Easy attachment and operation by use of RIP strap poppers and instant working
- Small and light to allow invisible wearing: 6,2 x 2,9 x 1,0 cm, 18 grams
- Full day battery life and raw data storage. Recharging and logging data retrieval over USB
- Accurate 2 channel RIP measurement: resolution up to 0.02% intersection surface change
- Low temperature drift and mutual influencing of both RIP bands
- Movement and orientation sensor: 3-D 12 bits accelerometer +/- 2G
- Temperature sensor: 1 ^{0}C resolution
- Tactile feedback with integrated vibration motor
- Sample speed up to 10 samples per second, Real Time Data stamps included.
- Green status LED
- Easy firmware upgrade

This document describes

1. ***Operation:***
- How to use the sensor,
- how to attach and detach to a person
- Battery maintenance
2. ***Communication:***
- connect the sensor and/or dongle to a PC
3. ***Status Led indication***
4. ***Data Logging functionality***
5. ***Data formats***
6. ***Breath application***
7. ***Suggestions are welcome***

1. Operation

The full sensor contains following parts:

- 1 Breathpal main cabinet, for abdominal sensor strap, referred to as Breathpal
- 1 smaller device for secondary thorax sensor
- 2 RIP straps
- 1 BLE (Bluetooth 4) dongle Breathpal V.3
- 1 USB to micro-USB cable

Attaching the sensor to a person:

1. Before using the sensor, be sure that the sensor battery is sufficiently charged. See “Battery maintenance”.
2. Place the thorax sensor on the front side the body on chest height, using a RIP strap around the body to keep it in place. Take care that the black cable points downward.
3. Place the Breathpal on the front side the body on navel height, using a RIP strap around the body to keep it in place. Take care that round connector opening points upward. Notice that the sensor only will work when both ends of the abdominal strap are connected to the Breathpal.
4. Connect the black cable of the secondary RIP sensor to the round connector of Breathpal. Push well to get good connection..

It is preferred, to wear the belts and sensors over a thin tight fit T-shirt or underwear.

A strap should need stretching of 5 to 35 cm. when connecting to the sensor. If the strap is too long or too short, a different length must be ordered. Do not fold the strap to shorten it, this will largely influence the measurements.

Detaching:

Above steps in opposite order.
Notice that during storage the abdominal strap must be detached, to stop the logging of data and the draining of the battery.

>> WARNING <<

The Sensor is not tested for medical use. Attaching it to the body and connecting it to a mains powered computer introduces a certain risk of electrical shocks to the body.
Doing so is on the responsibility of the user that decides to attach it to its own body, after being informed on this risk and after waiving the responsibility of the developer or owner.

Battery maintenance

In case the battery status is unsure, attach the Breathpal to a PC or a USB phone charger using the USB cable, without the RIP straps connected. Do not attach the sensor to a person.
Wait until the green light on Breathpal stops blinking and stays permanently on.

2. Communication

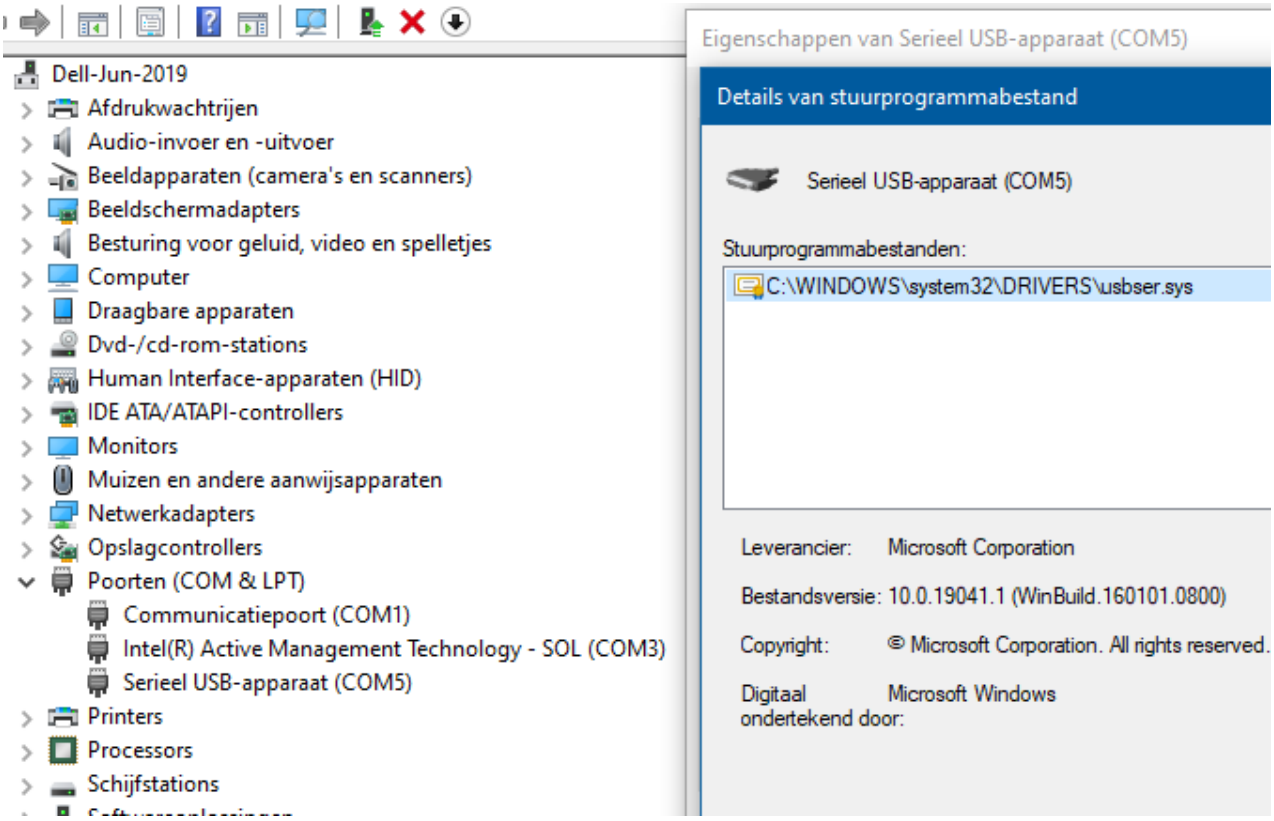
To communicate with Breathpal, reading sensor data or making settings, two options are available:

A. Wireless communication using the dedicated dongle
B. Wired communication using a USB cable.

⚠ Notice that when the sensor is connected to a charger or computer, it should not be attached to a human body for electrical safety reasons. In case of a defect charger or computer, the body could be exposed to electrical currents via the cable.

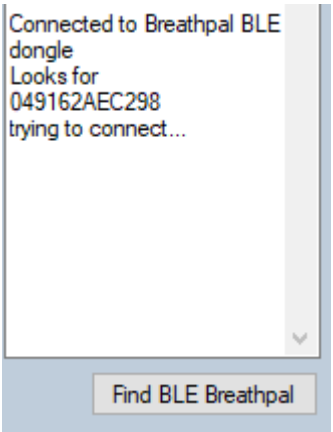
A. Wireless communication

When the dongle is connected to a Windows computer, a virtual COM port is created:



From within an application, i.e. Matlab, this serial port (COM5 in the above example) can be accessed. Use 8 data bits, 1 start bit, 1 stop bit, no parity, 9600 Bd, no handshake (although not critical, while the COM port is a Virtual Com port).

First establish and verify connection between Breathpal and the dongle, using the Breath application. At first use, or if you swapped to another Breathpal device, instruct looking for the device, by pressing the Find BLE Breathpal button.



After a successful connection, the dongle will automatically connect to the sensor next time. Notice that the distance between sensor and dongle should be within some meters, strongly depending whether a body is in between sensor and dongle).

⚠ In case that no connection gets established, disconnect one end

of the abdominal strap from the Breathpal device, and reconnect after some seconds. Further optimization work will be done here.

USB cable communication (B)

- Disconnect the abdominal RIP strap from Breathpal (⚠ if Breathpal is connected via USB cable to a computer, the communication port will not initialize correctly if the RIP strap is still connected)
- Connect Breathpal to the computer using the USB cable. A virtual COM port is created, with the same properties as described above (A). If desired, the RIP straps can now be connected to the sensor again.

The Windows program Breath is available and can be used to make some settings to the sensor and retrieve measurement data, including real time display and export of the sensor data (see 5. Breath Application).

>> REPEATED WARNING <<

The Sensor is not tested for medical use. Attaching it to the body and connecting it to a mains powered computer introduces a certain risk of electrical shocks to the body. Doing so is on the responsibility of the user that decides to attach it to its own body, after being informed on this risk and after waiving the responsibility of the developer or owner.

3. Status LED information

The green status LED visible on the front side of Breathpal has following indications:

When **connected** by USB cable to charger or computer:

- Stable ON: no communication, battery full, charging completed
- Flashing: communication with PC or charging

When **not connected** to charger or computer:

- Off: Abdominal strap not connected (Breathpal not operating) or battery completely drained
- Flashing every 3 seconds: data logging active, no Bluetooth communication
- Flashing quickly: Bluetooth communication going on

4. Data Logging functionality

Breathpal stores RIP data, accelerometer data, chip temperature and Time/Date labels in its non-volatile Flash memory. Memory size is 16 Mbyte, where approx. 15 bytes are used for every measurement. Currently, 2.5, 5 or 10 measurements per second can be taken, the frequency can be set from within the Breath program. At 5 measurements per second, capacity is about 60 hours of logging.
Measurement and data logging starts as soon as both ends of the Breathpal (abdominal) strap are connected (assumed that the battery is charged). Logging stops when the strap is disconnected.
The stored measurements can be retrieved and written to file by use of the Breath program (see chapter 6). The memory can also be erased, which is wise to do before each session.

5. Data formats

Import data using Breath application

The program Breath can save sensor data to file. The format is Comma Separated Values (CSV). The parameters in each line are:

```
R1, R2, X, Y, Z, Timestamp, Sample number, Temperature, Event list
```

And typical lines look like this

```
6114,8358,-2,-86,1036,18/03/2021 09:18:41,152,22,/L12303/POWERUP_USB/2.5HZ/POWERUP_USB/2.5HZ
6114,8358,0,-93,1033,,153,22,
6114,8358,-1,-87,1042,,154,22,
6114,8358,-2,-91,1024,,155,22,
6114,8358,-1,-87,1036,,156,22,
```

The data can be imported into i.e. Excel for further analysis.

The values of R1 and R2 are the measured values of the abdominal and thorax RIP measurement. A value of 0 indicates that a belt is not connected. The values are related with the surface enclosed by the belt: A higher value corresponds to a higher surface. Read values are approximately in the range 5000 to 15000.

X, Y and Z are the readings of the three accelerometer axes, in the range -2048 to 2047, corresponding with acceleration from –2G to 2G.

A Timestamp is added every 10 seconds, in the above shown format `20/11/2019 13:11:40`.

Temperature is in degrees Celsius. The resolution is one degree Celsius. Accuracy is not verified yet.

Event list is a text string with information on status and events, i.e. sample frequency and powerup moments (each separated by '/'). Exact meaning is not important for the scope of this user manual.

Import data directly from serial port

It is also possible to directly read data from the Virtual COM port. The data is arranged in packages of bytes, using a PPP protocol. Some additional documentation is needed to use this protocol. The general structure is the following:

A package first byte is 0x12 (PPP_START, hexadecimal value 12, binary 0001 0010) followed by a number of bytes payload, and ends with 0x13 (PPP_END).

An escape value is defined as PPP_ESC, with value 0x7D.
If a byte *B* in the payload equals PPP_START, PPP_END, PPP_ESC or some other reserved values (0xFC-0xFF), then this byte is replaced by PPP_ESC followed by the exclusive-OR result of the value of byte *B* and the value 0x20 (PPP_SWAPMASK).

The payload starts with a single byte header, which implicitly defines the structure and meaning of the remainder of the payload.

So the basic packet structure is:
PPP_START
Header
Payload bytes
PPP_END

The sensor data payload together with the package boundaries is structured like this:
PPP_START
Header: MES_RIP12ACC8_LIVE_BLE_PNR (0x49)
Most significant byte (MSB) of RIP value abdominal strap (unsigned)
Least significant byte (LSB) of RIP value abdominal strap (unsigned)
MSB of RIP value thorax strap (unsigned)
LSB of RIP value thorax strap (unsigned)
MSB of Accelerometer reading X (one byte, 2- complement)
LSB of Accelerometer reading X (one byte, 2- complement)
MSB of Accelerometer reading Y (one byte, 2- complement)
LSB of Accelerometer reading Y (one byte, 2- complement)
MSB of Accelerometer reading Z (one byte, 2- complement)
LSB of Accelerometer reading Z (one byte, 2- complement)
Packet number (one byte) (unsigned)
PPP_END

NB: After combining the MSB and LSB of accelerometer reading, the value should be divided by 16 to get the correct scaling (+/-2048)

A hexadecimal presentation of a typical stream of data is like this:

```
00000000: 72 62 78 78 2C 20 70 6F  |  72 74 31 31 0D 0A 12 50    rbxx, port11...P
00000010: 7D 05 B5 22 57 02 B0 01  |  70 40 80 D9 13 12 50 7D    }.µ"W.°.p@€Ù..P}
00000020: 05 B5 22 57 02 B0 01 70  |  40 80 DA 13 12 50 7D 05    .µ"W.°.p@€Ú..P}.
00000030: B5 22 57 02 B0 01 70 40  |  80 DB 13 12 53 00 10 13    µ"W.°.p@€Û..S...
00000040: 12 50 7D 05 B4 22 58 02  |  B0 01 70 40 80 DC 13 12    .P}.´"X.°.p@€Ü..
00000050: 50 7D 05 B4 22 58 02 B0  |  01 70 40 80 DD 13 12 50    P}.´"X.°.p@€Ý..P
00000060: 7D 05 B4 22 57 02 B0 01  |  70 40 80 DE 13 12 53 00    }.´"W.°.p@€Þ..S.
00000070: 10 13 12 50 7D 05 B3 22  |  57 02 B0 01 70 40 80 DF    ...P}.³"W.°.p@€ß
00000080: 13 12 50 7D 05 B4 22 57  |  02 B0 01 70 40 80 E0 13    ..P}.´"W.°.p@€à.
```

Also packages with other Header values are defined and may occur during USB connection, i.e. for sending events or information on the non-volatile storage in the sensor. These must be discarded.

Notice that some data is included that is out of the PPP structure, this can be discarded. A software update will be prepared to get rid of this.

6. Breath Application (version 4)

The Windows application Breath.exe features:

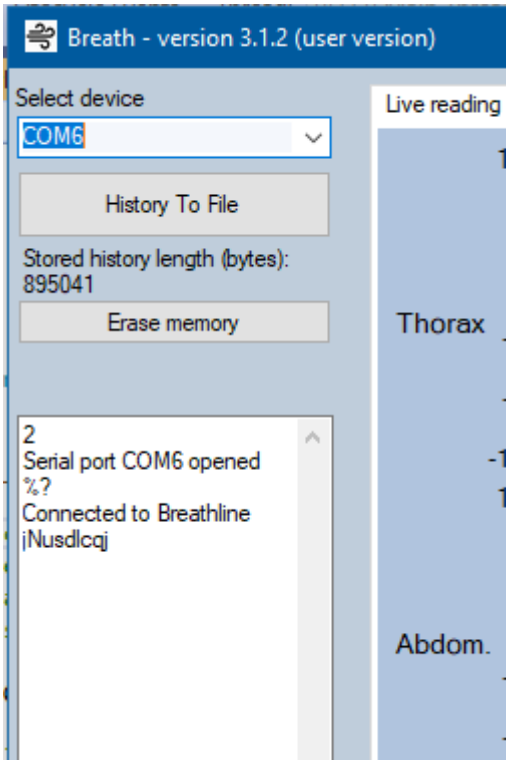
- Retrieval of stored logging data from the sensor, and clearing of the sensor storage.

- Live display of measurements
- Changing of settings of the sensor

An installer for the application can be downloaded from the Breathpal website, page Resources.

Launch Breath application and connect to Breathpal
After launching Breath, choose the COM port to connect to the dongle or sensor. Notice that when connecting to Breathpal by USB, the following sequence is needed:

a. Disconnect Abdominal strap
b. Connect Breathpal to a PC using USB cable
c. Start Breath application
d. Select COM port
e. Connect abdominal strap to Breathpal sensor

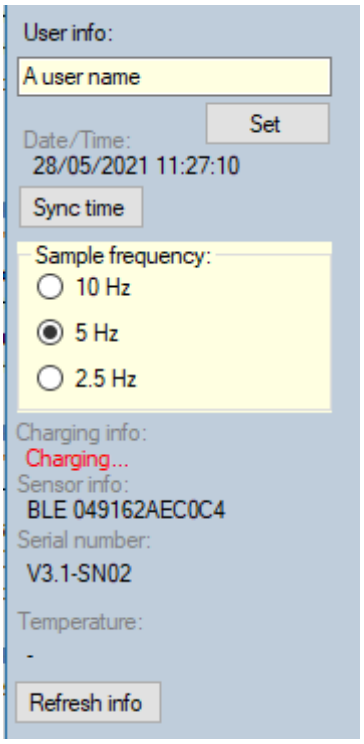


Some activity messages will be shown on the report area at the left side of the window.

Retrieval of stored logging data from the sensor
The length in bytes of the stored data is shown (895041 bytes in above example).
Press ”History to file” to retrieve this data. You are prompted for a .csv file to write to.

After retrieving you are prompted to erase the storage in the sensor (Yes/No). You can erase any other moment by pressing “Erase memory”. If not erased, new information will be appended to the existing storage information. (retrieval is not possible when connected wireless)

View and change settings

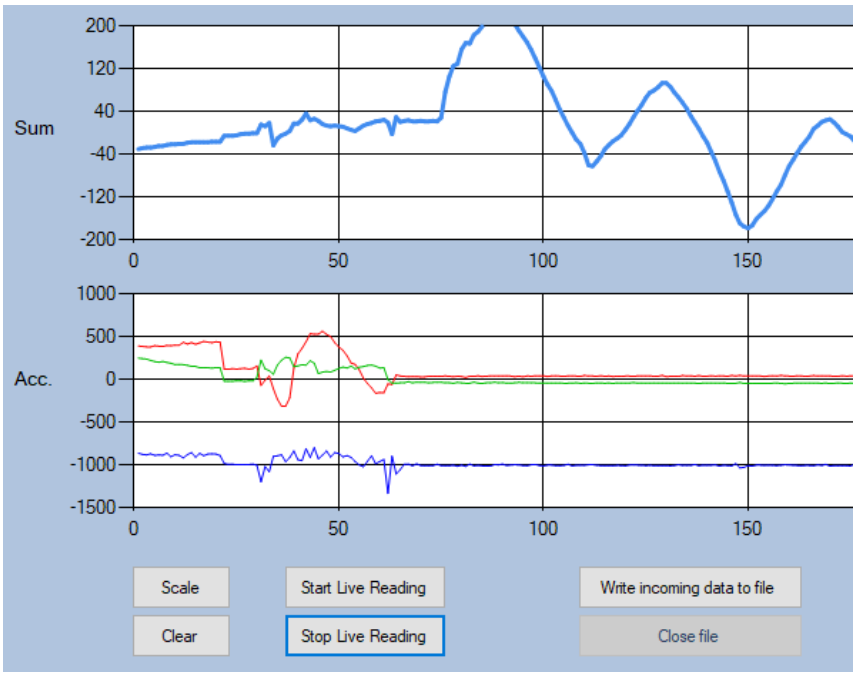


See and set user information
See device Real Time Clock and data info
Sync this RTC with computer clock, if incorrect. Notice that it is synchronised automatically after reading the logging history.
Select sample frequency
See battery charging or battery full state
BLE MAC address of Breathpal device
Serial number
Temperature

The User info can be edited and written to the dongle by pressing “Set”” .
The real time clock can be synchronised to the computer clock by pressing “Sync time”. Notice that it is synchronised automatically after reading the logging history.
The Sample speed can be set to 2.5, 5 or 10 measurements per second.

⚠ When wireless connected, only Sample frequency can be changed.

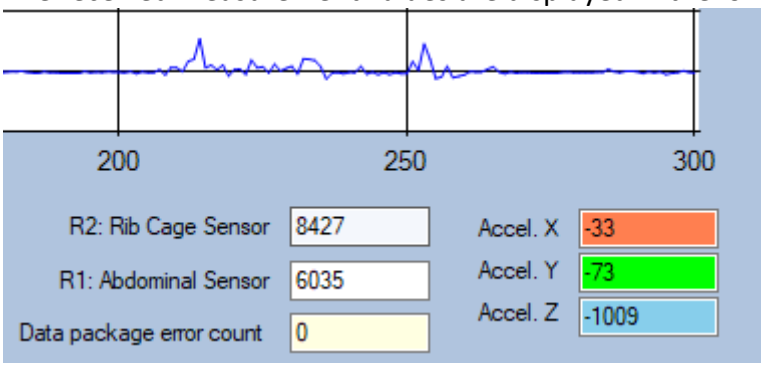
Live display of measurements



Press “Start Live Reading” and “Stop Live Reading” buttons for starting and interrupting of live display of the measurements.
The buttons “Scale” and “Clear” serve to manually change the display of the breathing graphs. “Clear” sets the three graphs to value zero, and from then on the (inverted) offset of incoming values is displayed. “Scale” scales the graphs to show all values. Experiment with this yourself.

The incoming live measurements can be logged to file in .csv format, by pressing “Write incoming data to file”. You will be prompted to select a file. End the file logging by pressing “close file”.

The received measurement values are displayed in the lower right area:



Notice the “Data Packages error count” field. This lists the amount of packages that come in and where the package numbers are not sequential, mostly caused by a packet loss in the BLE connection. Increasing numbers indicate a weak wireless connection, try to lower the distance between sensor and dongle or to avoid objects or bodies between sensor and dongle.
In the .csv file output, single or up to 3 missing samples are replaced by empty values with the EVENT_LIST showing /MISSING or /PACKETGAP. Such .csv lines will look like:

```
,,,,,,,,/MISSING
,,,,,,,,/PACKETGAP
```

Temperature calibration

In rare cases, it can be necessary to calibrate the sensors again to minimize temperature dependency of the readings.
This can be executed by use of the Breath application. You need a stable carton box of approx. 20 x 25 x 25 cm and an electrical hairdryer.

Procedure: Connect Breathpal to the PC, start Breath application, and connect the Thorax sensor + strap and the abdominal strap.

Place the straps around the carton box, so that the straps are stretched for some 10-20 cm and the cabinets stay well in place, as in below pictures

Check that Live reading is OK.

Now select Breath app Temperature Calibration tab, press Start calibration procedure and follow the instructions. You will be instructed to warm the cabinets using the hair dryer, and will be prompted when the heating is sufficient. The new calibration values can be written to the sensor.

7. Suggestions are welcome

Breathpal is still in development. Any suggestions on communication format, behaviour, construction or documentation are welcome, and may yet be easy to implement.