



biosignal acquisition tool-kit for advanced research applications

Respiration (PZT) Sensor User Manual



ATTENTION

Please read this datasheet before
using your biosignalsplux sensor

The information contained in this document has been carefully checked and were made every effort to ensure its quality. **PLUX** reserves the right to make changes and improvements to this manual and products referenced at any time without notice.

The word Bluetooth and its logo are trademarks of Bluetooth SIG Inc. and any use of such marks is under license. Other trademarks are the property of their respective owners.

Please check your systems and sensors after receiving and before using it the first time to confirm if it contains all the ordered sensors, accessories and other components. Contact our support via e-mail at support@plux.info if there are any variations from your original order.

For regulatory information, please see the Regulatory Disclaimer at the end of this document.



PLUX – Wireless Biosignals, S.A.
Av. 5 de Outubro, n. 70 – 2.
1050-059 Lisbon, Portugal
plux@plux.info
<http://biosignalsplux.com/>

TABLE OF CONTENTS

1. General Information.....	4
1.1. General Description	4
1.2. Typical Unfiltered Sensor Output.....	4
1.3. Sensor Specifications	5
1.4. Features	5
1.5. Applications.....	5
1.6. Transfer Function (Conversion Formula)	5
1.7. Physical Characteristics	6
2. Application Notes	7
3. Using the Respiration (PZT) Sensor with biosignalsplex & OpenSignals.....	10
3.1. Connecting the sensor to biosignalsplex Systems.....	10
3.1.1. biosignalsplex 4-Channel Hubs	10
3.1.2. biosignalsplex 8-Channel Hubs	10
3.1.3. biosignalsplex Solo & Single-Channel openBAN Devices	11
3.2. Configuring the Sensor in OpenSignals.....	11
3.2.1. OpenSignals (r)evolution (Windows, macOS, Linux)	11
4. Scientific Publications Using the PZT Sensor	14
5. Safety & Maintenance	15
5.1. Safety Instructions	15
5.2. Transportation and Storage.....	16
5.3. Cleaning	16
6. Ordering Guides, Regulatory & Legal Information.....	17
6.1. Ordering Guide	17
6.2. Guarantee of Quality & Warranty.....	17
6.3. Warranty Voidance	17
6.4. Contact & Support	18
6.5. Regulatory Disclaimer	18

1. General Information

1.1. General Description

The [biosignalsplus piezoelectric Respiration \(PZT\)](#) sensor is an entry-level and affordable solution for basic respiration data acquisition. This sensor consists of a wearable chest-belt with an integrated localized sensing element that measures displacement variations caused by the volume changes of the thorax or abdomen during respiratory cycles (inhaling/exhaling).

The elastic chest-belt can be adjusted in length to be applicable on different anatomies (e.g. male and/or female), body locations (e.g. thorax and/or abdomen), and thorax/abdomen circumferences. Typical applications of this sensor include respiration monitoring to determine respiration cycles, rates, relative amplitudes, and other features.

Together with the [Respiration Analysis](#) add-on for our [OpenSignals software](#), one can easily record and extract meaningful temporal and spectral signal parameters for further analysis of the acquired sensor data.



Figure 1: biosignalsplus PZT sensor (standard version)

1.2. Typical Unfiltered Sensor Output

Figure 2 shows a typical unfiltered **PZT** sensor output acquired while at rest and during a deep breath. The raw digital sensor values received from the [biosignalsplus](#) device ranged between 0 and 2^n-1 (**n=sampling resolution**) and can be converted into the original unit of measurement of this sensor (V) using the transfer function found in section **Transfer Function (Conversion Formula)**.

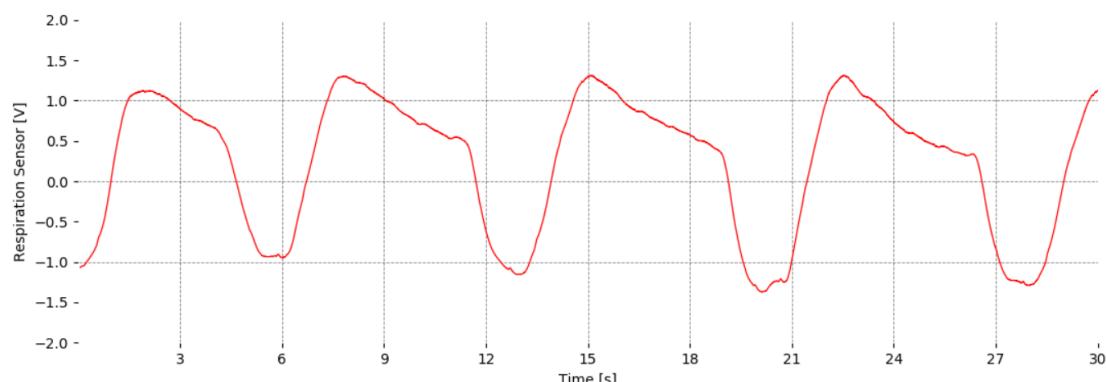


Figure 2: Typical unfiltered sensor output (at rest and during a deep breath)

1.3. Sensor Specifications

> Gain:	1	> Range:	± 1.50 V
> Bandwidth:	0.059-1 Hz	> Consumption:	35 uA
> Input Impedance:	-	> CMRR:	≥ 106 dB [TYP: 130 dB]

1.4. Features

- | | |
|----------------------------------|------------------------------------|
| > Piezoelectric film technology | > Unobtrusive & lightweight sensor |
| > Differential measurement | > Pre-conditioned analog output |
| > Adjustable elastic chest strap | > Displacement measurement |
| > High signal-to-noise ratio | > Ready-to-use form factor |
| > Medical-grade raw data output | > Raw signal output |

1.5. Applications

- | | |
|--|----------------------------------|
| > Thoracic or abdominal respiration analysis | > Respiratory cycles measurement |
| > Sleep studies | > Biomedical research |
| > Biofeedback | > Psychophysiology |
| > Life sciences studies | > Biomedical device prototyping |

1.6. Transfer Function (Conversion Formula)

The analog sensor signals acquired with **biosignalsplus** devices are converted into digital values ranged between 0 and $2^n - 1$ (**n=sampling resolution**, usually 8-bit or 16-bit) and streamed in the raw digital format.

In most applications, the original physical unit of the acquired **PZT** signal is preferred or required. The raw digital sensor samples can be converted back into volt (V) using the following formula:

$$PZT(V) = \frac{\left(\frac{ADC}{2^n - 1} - \frac{1}{2}\right) \times VCC}{G_{PZT}} \quad (1)$$

Valid sensor range: [-1.5V, 1.5V]

with:	$PZT(V)$	PZT signal	Error! Reference source not found. in V
	ADC	Value samples from the sensor/channel (digital value)	
	n	Sampling resolution (default: 16-bit resolution ($n=16$), although 12-bit and 8-bit may also be found)	
	VCC	Operating voltage (3V when used with biosignalsplus)	
	G_{PZT}	Sensor gain (1 Not amplified signal)	

The previous absolute value in **V** can also be converted to a relative measure (**[-50, 50] %**), intended to present (through a percentual value) the degree of extension/compression of the chest band during inhalation/exhalation.

Achieving this format is very simple, and essentially it will only be necessary to replace the **VCC** value (in **V**) by the percentual upper threshold (**100%**):

$$PZT(%) = \frac{\left(\frac{ADC}{2^n - 1} - \frac{1}{2}\right) \times 100\%}{G_{PZT}}$$

1.7. Physical Characteristics

> W1 x L1 x H:	1.6cm x 2.2cm x 0.5cm	> W2:	1.0±0.1cm
> W3:	0.4±0.1cm	> W4:	0.2±0.1cm
> L2:	2.6±0.1cm	> A1:	105.0±0.5cm
> A2:	7.0±0.1cm	> A3:	15.3±0.1cm
> S:	0.3±0.1cm		
>Available sleeve colors: White, Black, Blue, Green, Red, Yellow, Grey, and Brown			

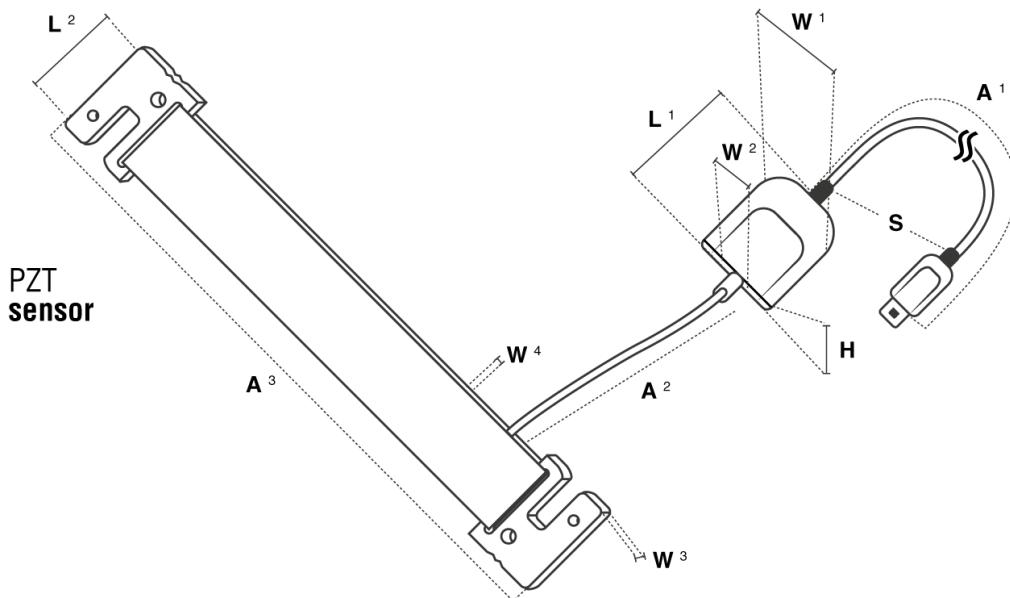


Figure 3: Physical characteristics of the standard Piezoelectric (PZT) sensor.

2. Application Notes

For a proper data acquisition of the respiratory signal using the **PZT** sensor, it will be important to understand the influence of sensor placement on the respiratory signal.

Rib cage diameter is not uniform, with mediolateral dimensions a little bit higher than anterior-posterior diameter [1], [2]. Due to this morphology, during respiration, the rib cage expansion/contraction varies accordingly to the chest point under analysis. Taking into consideration that **PLUX**'s **PZT** sensor measures deformations, it means that respiration signal morphology will be dependent on sensor placement.

As concluded by some studies, during respiration, the anteroposterior displacement is generally higher than the transversal one [3], i.e., during respiration change of rib cage diameter is less accentuated laterally, so, at a first glance we can think that when **PZT** sensor is placed on frontal region it will always register greater peak-to-peak amplitudes during the breathing process (because greater displacements means bigger deformation applied to **PZT** sensor).

PZT sensor measures deformation, so, we should not restrict our analysis to unidimensional measures. Another study went a little bit deeper on this question concluding that during normal breathing abdominal 3-dimensional motion is more accentuated on abdominal points when compared to thoracic markers, but lateral 3-dimensional motion on lateral points were not always smaller than frontal ones [4].

For example, thoracic lateral points revealed a bigger 3D motion, when compared with frontal points, logic that is reversed for abdominal points.

In order to test the validity of **PZT** sensor measurements, data was collected using different sensor positions:

a) **Nipple line;**

- i. Frontal;
- ii. Lateral.

b) **Between 8th and 10th Rib;**

- i. Frontal;
- ii. Lateral.

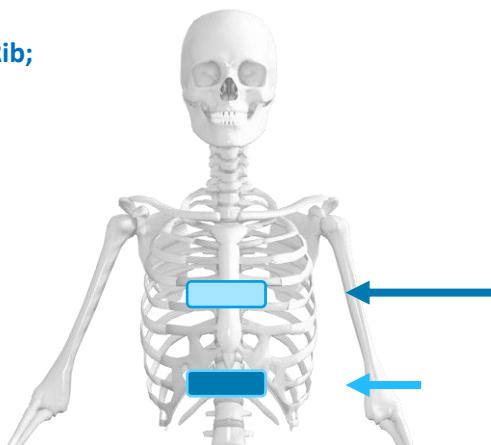


Figure 4: Schematically representation of PZT sensor position.

So, based on past researches, it can be expected that the previous four sensor positions should present the following qualitative results (peak-to-peak amplitude):

Table 1 - Expected Results for PZT Sensor

Major Location	Location	Orientation	3D Motion (expected)	Peak-to-Peak Amplitude (expected)
Thorax	Nipple Line	Frontal	Intensity 1	
Thorax	Nipple Line	Lateral	Intensity 2	
Abdomen	8 th to 10 th Rib	Lateral	Intensity 3	
Abdomen	8 th to 10 th Rib	Frontal	Intensity 4	

Through a simple experimental protocol, the obtained results are in accordance with the theoretical expectations, as demonstrated on the following table, which synthetises the estimations made using [OpenSignals Respiration Analysis add-on](#).

Table 2 – Experimental Results for PZT Sensor

Major Location	Location	Orientation	3D Motion (expected)	Peak-to-Peak Amplitude (Raw 16 bits Data)
Thorax	Nipple Line	Frontal	Intensity 1	7204
Thorax	Nipple Line	Lateral	Intensity 2	16888
Abdomen	8 th to 10 th Rib	Lateral	Intensity 3	14068
Abdomen	8 th to 10 th Rib	Frontal	Intensity 4	20163

In order to these differences can be graphically seen, in the next two figures it is compared the acquired signals from two extreme situations (**Nipple Line Frontal vs 8th to 10th Rib Frontal**).

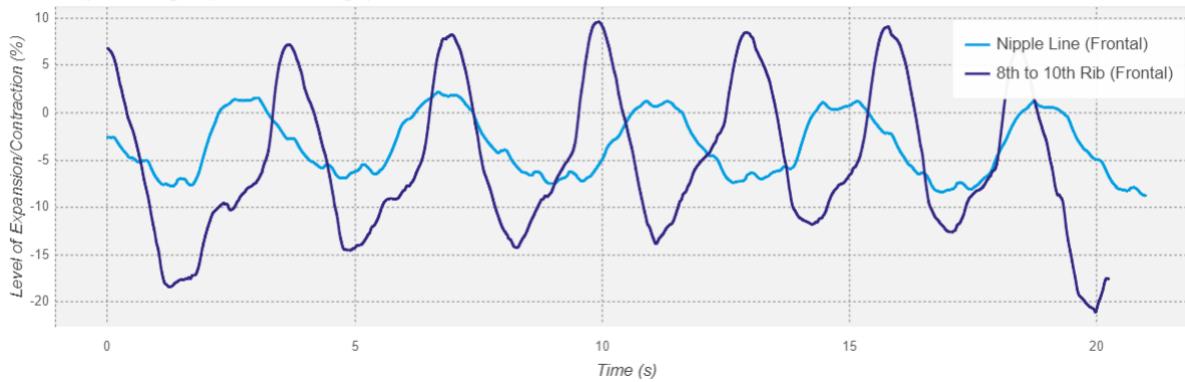


Figure 5: Graphical differences between the two extreme configurations.

As can be seen the **8th to 10th Ribs** configuration is smoother and presents a bigger amplitude, which may be more practical for the researcher and even during the processing stage of respiratory signals while detecting specific events, taking into account that sometimes the rugosity of the signal brings additional processing challenges.

A metric that can be used to understand which is the most adequate configuration, for acquiring data with **PZT Sensor**, is related with the effectiveness of breath cycles count by [OpenSignals Respiration Analysis add-on](#), i.e., configurations that ensure a correct breath cycles count are preferable in order to get access to more precise processing results.

Table 3 – Real vs Detected breath cycles count

Major Location	Location	Orientation	Real Number of Complete Breaths	Automatic Number of Detected Breaths
Thorax	Nipple Line	Frontal	5	6
Thorax	Nipple Line	Lateral	7	7
Abdomen	8 th to 10 th Rib	Lateral	6	7
Abdomen	8 th to 10 th Rib	Frontal	7	7

There are no significative differences on the performance of [OpenSignals Respiration Analysis add-on](#) for the different sensor positions, being the previous test very useful to demonstrate the reliability of **PLUX** processing algorithm.

Bibliographic References

- [1] F. Bellemare, A. Jeanneret, and J. Couture, "Sex differences in thoracic dimensions and configuration," *Am. J. Respir. Crit. Care Med.*, vol. 168, no. 3, pp. 305–312, 2003.
- [2] A. Joshua and Sa. Joshua, "Variations in Dimensions and Shape of Thoracic Cage With Aging: an Anatomical Review," *Anat. J. Africa*, vol. 3, no. 2, pp. 346–355, 2014.
- [3] J. C. Leong, W. W. Lu, K. D. Luk, and E. M. Karlberg, "Kinematics of the chest cage and spine during breathing in healthy individuals and in patients with adolescent idiopathic scoliosis," *Spine (Phila. Pa. 1976)*, vol. 24, no. 13, pp. 1310–1315, Jul. 1999.
- [4] H. Kaneko and J. Horie, "Breathing Movements of the Chest and Abdominal Wall in Healthy Subjects," *Respir. Care*, vol. 57, no. 9, pp. 1442–1451, 2012.

3. Using the Respiration (PZT) Sensor with biosignalsplus & OpenSignals

3.1. Connecting the sensor to biosignalsplus Systems

3.1.1. biosignalsplus 4-Channel Hubs

The [biosignalsplus PZT sensor](#) is compatible with all 4 analog input channels of the 4-channel [biosignalsplus](#) hub, but incompatible with the reference/ground port. Connect the sensor to an analog input to use it with this device.



Figure 6: PZT compatible biosignalsplus channels (green checkmarks).

3.1.2. biosignalsplus 8-Channel Hubs

The [biosignalsplus PZT sensor](#) is compatible with all 8 analog input channels of the 8-channel [biosignalsplus](#) hub, but incompatible with the reference/ground and digital I/O ports. Connect the sensor to an analog input to use it with this device.



Figure 7: PZT compatible biosignalsplus channels (green checkmarks).

3.1.3. biosignalsplus Solo & Single-Channel openBAN Devices

The **biosignalsplus PZT sensor** is compatible with the analog input channel of the **biosignalsplus Solo** (openBAN) device. Connect the sensor to the analog input channel to use it with this device.



Figure 8: Connect the PZT to the analog input channel of the **biosignalsplus Solo** (openBAN).

3.2. Configuring the Sensor in OpenSignals

3.2.1. OpenSignals (r)evolution (Windows, macOS, Linux)

Note

Download OpenSignals (r)evolution here: <https://biosignalsplus.com/index.php/software>

Open the **OpenSignals (r)evolution** device manager to access and configure your **biosignalsplus** device.

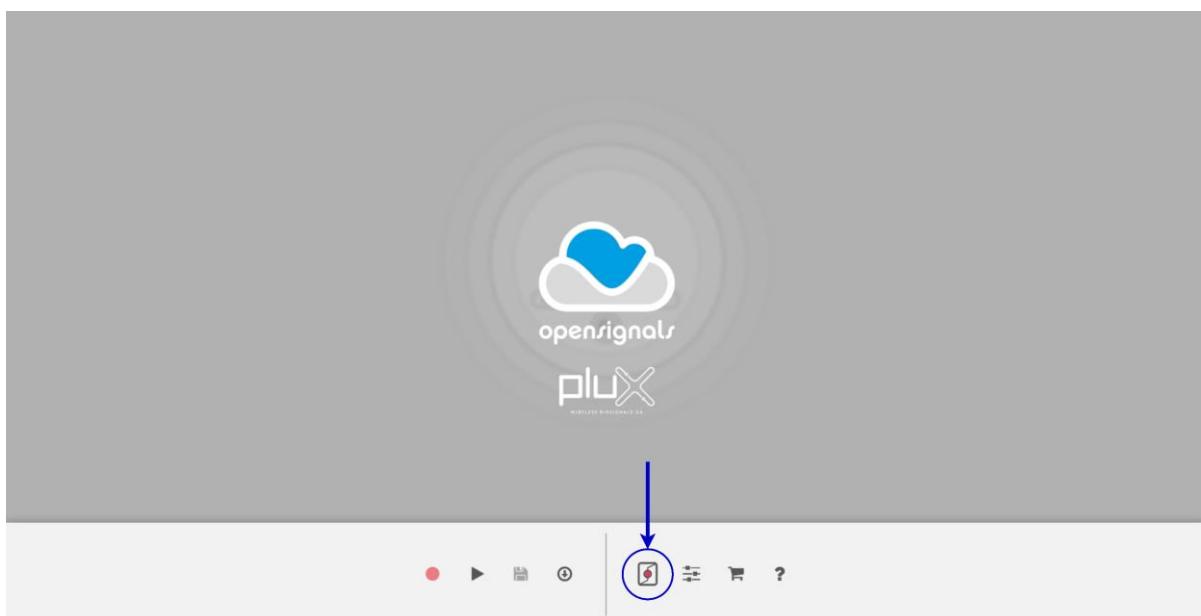


Figure 9: Access the OpenSignals (r)evolution device manager.

Respiration (PZT) User Manual

Select the device you intend to use for acquisition by clicking on *ENABLE button* on the device panel in the **OpenSignals** device manager. The device is activated for acquisition if the **ENABLE** button is blue.

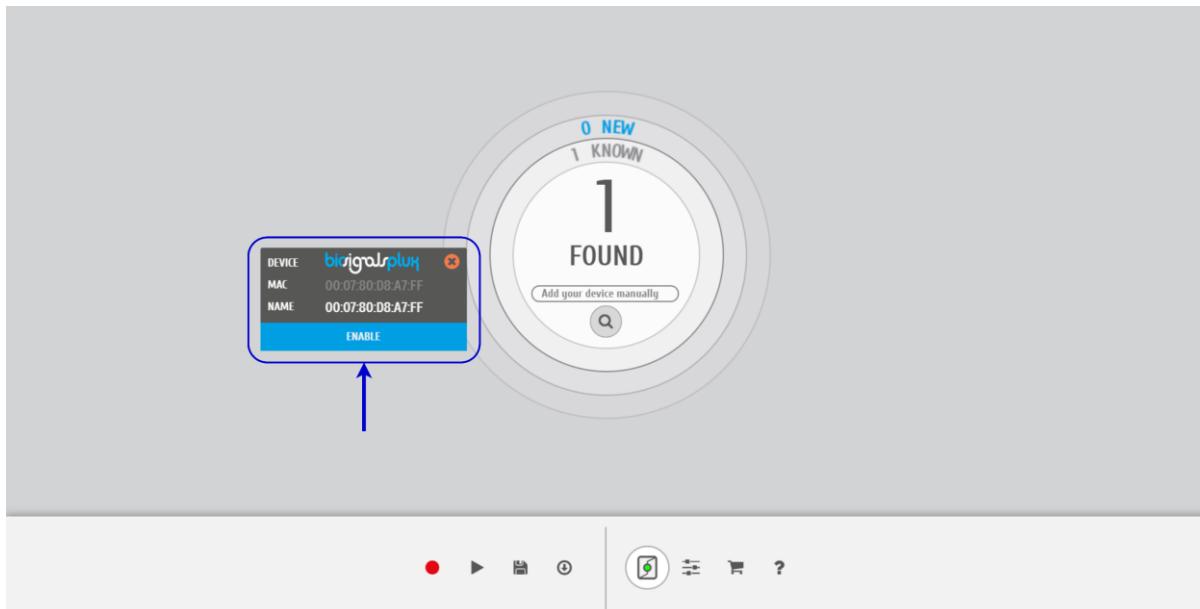


Figure 10: Enabling the device for acquisition.

Click on the **biosignalsplus** logo to access the available settings. Select the channel your sensor is connected to and select the **RESP** from the dropdown menu highlighted in the next screenshot.

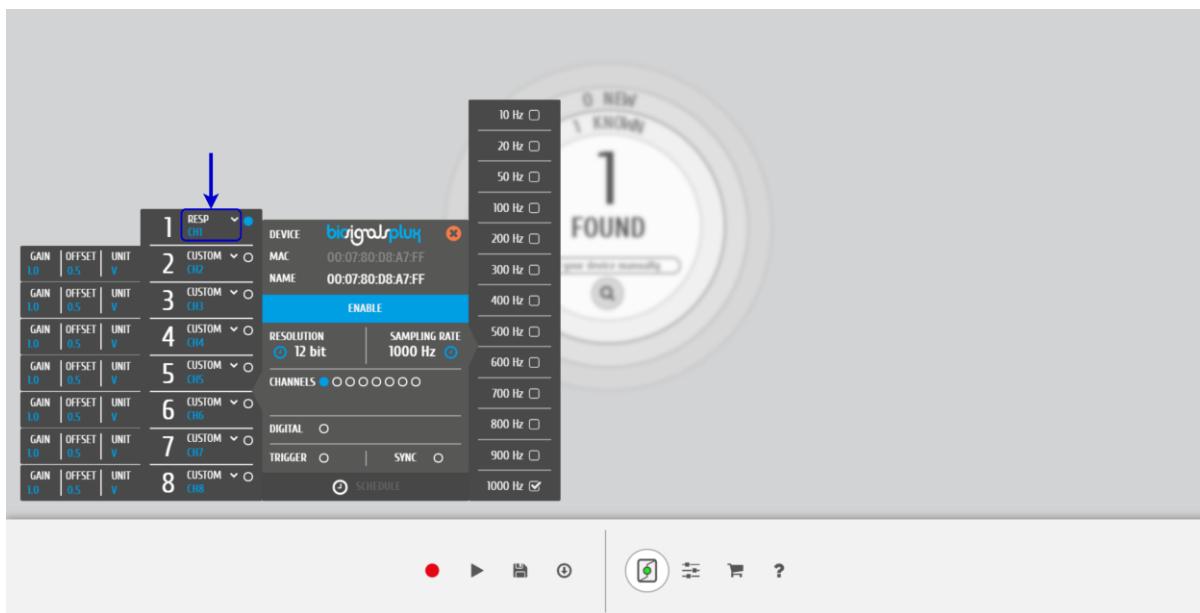


Figure 11: Set the channel type of the channel you have your PZT sensor connected to, to **RESP**.

Activate the channel for acquisition by clicking on the circle next to the channel type (must be blue). If not done before, follow the instruction available in section 2 Application Notes to learn how to apply the sensors and **3.1 Connecting the sensor to biosignalsplus Systems** to learn how to connect your device to your **biosignalsplus** device. Click on the record button in the **OpenSignals** main interface whenever you're ready for your acquisition.

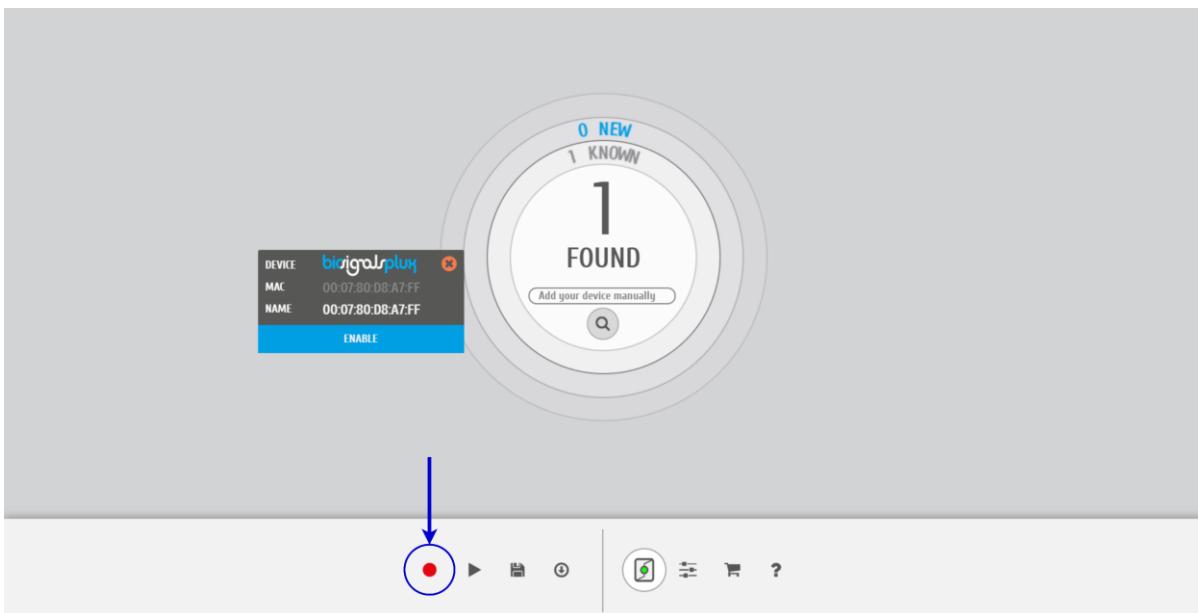


Figure 12: Start the acquisition whenever you're ready.

4. Scientific Publications Using the PZT Sensor

The following scientific is only a small selection extracted from the list of available publications using [biosignalsplus](#). Please visit the following website to access the entire up-to-date list:

A screenshot of a website titled "biosignalsplus Publications". The page has a dark blue header with the title and a white content area. In the content area, there is a single link labeled "List of Publications".

Publications

J. E. Muñoz, A. Gonçalves, T. Vieira, D. Cró, Y. Chisik, S. Bermúdez i Badia, "[Space connection-a multiplayer collaborative biofeedback game to promote empathy in teenagers: A feasibility study](#)" in *Proc. of 3rd International Conference on Physiological Computing Systems*, pp. 88-97, 2016

M. Cheetham, C. Cepeda, H. Gamboa, "[Automated Detection of Mind Wandering: A Mobile Application](#)", in *Proc. of the 9th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC)*, vol. 4: BIOSIGNALS, pp. 198-205, 2016

Y. Xu, I. Hübener, A. Seipp, S. Ohly, K. David, "[From the lab to the real-world: An investigation on the influence of human movement on Emotion Recognition using physiological signals](#)", in *Proc. of the 2017 IEEE International Conference on Pervasiva Computing and Communications Workshops (PerCom Workshops)*, pp. 345-350, 2017

E. Lux, M. Adam, V. Dorner, S. Helming, M. Knierim, C. Weinhardt, "[Live Biofeedback as a User Interface Design Element: A Review of the Literature](#)", in *Communications of the Association for Information Systems*, vol. 43, no. 18, pp. 257-296, 2018

A. Kamenz, V. Bibaeva, A. Bernin, S. Ghose, K. von Luck, F. Vogt, L. Müller, "[Classification of Physiological Data in Affective Exergames](#)", in *Proc. of the IEEE Symposium Series on Computational Intelligence (SSCI)*, pp. 2076-2081, 2018

J. Heinisch, I. Hübener, K. David, "[The Impact of Physical Activities on the Physiological Response to Emotions](#)", in *Proc. of the International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, pp. 824-829, 2018

M. Mateu-Mateus, F. Guede-Fernández, V. Ferrer-Mileo, M. García-González, J. Ramos-Castro, M. Fernández-Chimeno, "[Comparison of video-based methods for respiration rhythm measurement](#)", in *Biomedical Signal Processing and Control*, vol. 51, pp. 138-147, 2019

5. Safety & Maintenance

5.1. Safety Instructions

Please read the following safety instructions **before** using your **biosignalsplus** system with the **PZT** sensor to prevent any damages or problems with the user, test persons and/or **biosignalsplus** devices. Violations of these instructions can lead to inferior signal quality and/or damages to the **biosignalsplus** system and user.

- ! The user should always keep the device and its accessories dry.
- ! The user must turn off the **biosignalsplus** device and contact Technical Support if the system or accessories reach uncomfortable temperatures.
- ! The user should not use the **biosignalsplus** device in noisy environments (environments with microwaves and other similar equipment). Doing so will lead to noise increase in the acquired signals and Bluetooth connectivity issues.
- ! The user must not use the device near the fire or in potentially explosive atmospheres, such as atmospheres with flammable gas.
- ! The user should only use the detection surfaces or other approved accessories purchased from **PLUX** or by a **PLUX** agent.
- ! The user should inspect the sensors on a regular basis to ensure that they remain in good working order.
- ! The user should stop using the **biosignalsplus** device if experience any kind of discomfort or skin irritation.
- ! Do not use the system on persons with allergies to silver.
- ! The user should dispose detection surfaces after using the **biosignalsplus** device. Detection surfaces are single-user and disposable. Reusable electrodes should be reused by the same user. Do not use reusable electrodes on several users.
- ! The user must not place the device in the microwave.
- ! The user must not insert objects into the holes of the device.
- ! The user should not open the **biosignalsplus** device or its accessories. The repair of the same should be only done by properly authorized **PLUX** personnel.
- ! The user should make sure the cables do not obstruct the passage of people.
- ! The user should use the sensor cables with extreme caution to avoid risk of strangulation.
- ! The user should keep a safe distance between the **biosignalsplus** device and other devices to ensure their proper functioning.
- ! The user should only send the device to repair to qualified **PLUX** personnel.

- !** The user should not immerse the sensors or the **biosignalsplus** device, nor clean with liquid or abrasives.
- !** The user should handle the **biosignalsplus** device with caution and not expose the device or accessories to high accelerations and vibrations.
- !** **biosignalsplus** devices should not be used in patients with implanted electronic devices of any kind, including pace-makers, electronic infusion pumps, stimulators, defibrillators or similar.
- !** Do not apply electrodes over damaged or irritated skin.
- !** Do not use your device while charging its internal battery.

5.2. Transportation and Storage

Please follow these recommendations to ensure safe transportation and storage of your **biosignalsplus** equipment and sensors to prevent any damaging of your system.

The **biosignalsplus** equipment and sensors should be stored in the original box in a dry place when those are not being used.

- **Relative humidity:** up to 95% with no condensation
- **Ambient temperature:** 10°C to 30°C
- **Atmospheric pressure** between 500hPa and 1060hPa

Whenever the equipment needs to be transported, it should be placed in the original box, since this was designed and tested to ensure the equipment and accessories are securely stored.

Take care while handling the transportation of the system and avoid dropping it, since the device is not shock-proof and should not be placed under stress or sudden acceleration.

5.3. Cleaning

Please follow these cleaning instructions to prevent any damage of the system or the user because of conducting cleaning methods that may cause any damage.

- The **biosignalsplus** and sensors should be visually checked before each use and cleaning process to ensure that no mechanical damage occurred.
- The **biosignalsplus** equipment and sensors (including the cables) should be cleaned with a slightly damp cloth or suitable absorbent paper, ensuring no liquid enters the equipment or sensors. Do not use detergent or any type of cleaning liquid as these may damage your equipment and/or sensor.
- Do not clean or re-use detection surfaces (electrodes). They are only suitable for single use and should be disposed of after usage except indicated otherwise.

6. Ordering Guides, Regulatory & Legal Information

6.1. Ordering Guide

Please follow the following ordering guide when submitting orders of **PZT** sensors to orders@plux.info. If no specification is provided, the standard version of the sensor will be delivered.

PZT Sensor

SKU Reference	PLUX Code	UPC
SENSPRO-PZT1	820201208	641945696271
Description		
Piezoelectric respiration sensor for respiratory analysis in a wide range of applications. It has a localized sensing element that measures displacement variations induced by inhaling or exhaling and can be adjusted in length.		

Electrodes & Accessories

For a full list of available and compatible electrodes, please visit the [biosignalsplus store](#).

6.2. Guarantee of Quality & Warranty

biosignalsplus sensors have three months quality guarantee from the date of purchase. **PLUX** guarantees that the system, sensors and accessories will be free from material or manufacturing defects for the mentioned time periods following date of purchase.

If **PLUX** receives notification of any such defects within the guarantee period, it will repair or substitute with the same unit/model, any products with proven defects at no cost to the client. During the repair period **PLUX** promises to provide a temporary replacement under the same specification. Repairs will be carried out at **PLUX**'s premises after the equipment has been received.

6.3. Warranty Voidance

Usage of the device that is not in accordance with the handling instructions indicated in the manual, or use with accessories other than those manufactured by **PLUX** will invalidate the warranty of your devices.

Be careful when connecting your **biosignalsplus** devices, sensors and/or accessories to any third party device including the usage of the 3rd party connection components that are available for **biosignalsplus** systems as **the usage of these components will void the electrical warranty of your biosignalsplus device and sensors and, if not indicated otherwise, the warranty of the 3rd party system you're connecting to the device**. Check the electrical specifications of both systems you want to connect to prevent any damage of the user(s) or the systems.

In the case of warranty voidance, the same applies that we expressly disclaim any liability whatsoever for any direct, indirect, consequential, incidental or special damages, including, without limitation, lost revenues, lost profits, losses resulting from business interruption or loss of data, regardless of the form of action or legal theory under which the liability may be asserted, even if advised of the possibility of such damages.

6.4. Contact & Support

Contact us if you are experiencing any problems that cannot be solved with the information given in the [biosignalsplex documentation](#).

Please send us an e-mail with precise information about the error occurrence, device configuration, and, if possible, screenshots of the problem to support@plux.info.

6.5. Regulatory Disclaimer

biosignalsplex products are intended for use in life science education and research applications; they are not medical devices nor are they intended for medical diagnosis, cure, mitigation, treatment or prevention of disease. We expressly disclaim any liability whatsoever for any direct, indirect, consequential, incidental or special damages, including, without limitation, lost revenues, lost profits, losses resulting from business interruption or loss of data, regardless of the form of action or legal theory under which the liability may be asserted, even if advised of the possibility of such damages.

PLUX Wireless Biosignals S.A.

email: plux@plux.info

web: <http://www.plux.info>

Headquarters

Zona Industrial das Corredouras, Lt. 14 – 1°

2630-369 Arruda dos Vinhos

Portugal

tel.: +351 263 978 572

fax: +351 263 978 902

Lisbon Office

Av. 5 de Outubro, n° 70 – 2°

1050-059 Lisboa

Portugal

tel.: +351 211 956 542

fax: +351 211 956 546