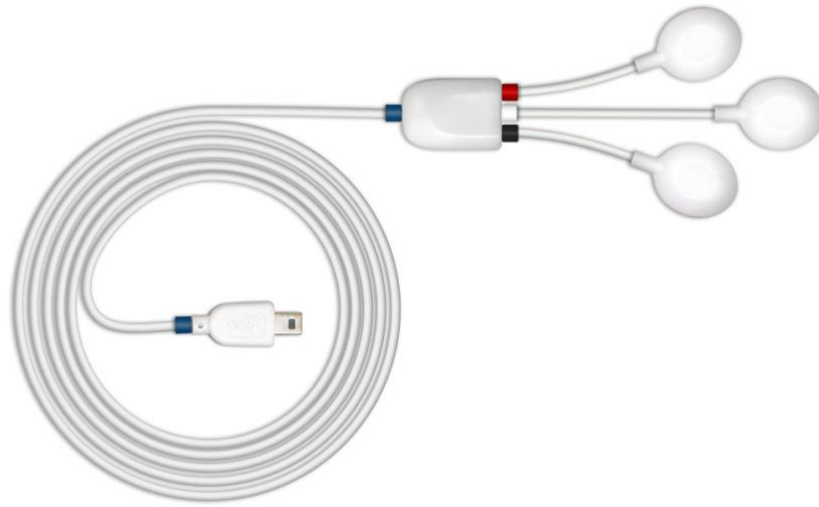




biosignal acquisition tool-kit for advanced research applications

Electrocardiography (ECG) 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.

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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 helpdesk@pluxbiosignals.com if there are any variations from your original order.

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



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1. General Information

1.1. General Description

Our low-noise ECG local differential triode configuration enables fast application and unobtrusive single-lead ECG data acquisition (although custom electrode cable configurations are available). The state-of-the-art design of the analog frontend on this sensor is specifically targeted at analyzing minutiae in the data and provides medical-grade raw sensor data.

This sensor can be used to extract heart rate data and other ECG features, enabling its application in research fields such as biomedical, biofeedback, psychophysiology, and sports, among many others.

Together with the [Heart Rate Variability \(HRV\) add-on](#) for our OpenSignals (r)evolution software, one can easily record and extract meaningful temporal, spectral, and nonlinear signal parameters for further analysis of the acquired sensor data.

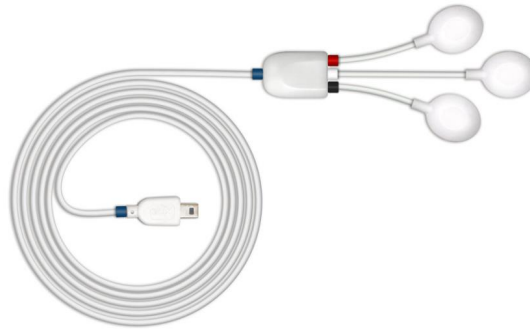


Figure 1: biosignalsplux Electrocardiography (ECG) sensor (standard version).

1.2. Typical Unfiltered Sensor Output

Figure 2 shows a typical unfiltered ECG sensor output acquired while at rest. The raw digital sensor values received from the **biosignalsplux** device ranged between 0 and $2^n - 1$ (n =sampling resolution) were converted into the original unit of measurement of this sensor (mV) using the transfer function found in section Transfer Function (Conversion Formula).

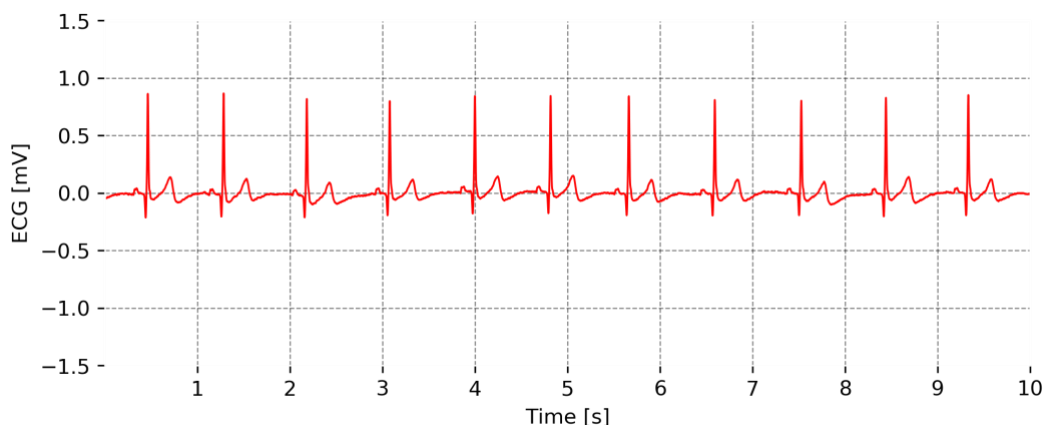


Figure 2: Typical unfiltered ECG sensor output (signal acquired while at rest).

1.3. Sensor Specifications

> Gain:	1019	> Range:	±1.47mV (@ VCC = 3V)
> Bandwidth:	0.5-100Hz	> Consumption:	~0.5mA
> Input Impedance ^[Typical] :	≥ 100GOhm	> CMRR:	100dB

1.4. Features

- > Bipolar differential measurement
- > Pre-conditioned analog output
- > High signal-to-noise ratio
- > Medical-grade raw data output
- > Unobtrusive & lightweight sensor
- > Pre-conditioned analog output
- > Ready-to-use form factor

1.5. Applications

- > Life sciences studies
- > Heart rate & Heart rate variability
- > Biometrics
- > Physiology Studies
- > Biofeedback
- > Biomedical device prototyping
- > Human-Computer Interaction
- > Affective Computing
- > Psychophysiology

1.6. Transfer Function (Conversion Formula)

The analog sensor signals acquired with **biosignalsplux** 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 ECG signal is preferred or required. The raw digital sensor samples can be converted back into millivolt (mV) using the following formulas:

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

$$ECG(mV) = ECG(V) \times 1000 \quad (2)$$

Valid sensor range: [-1.47mV, 1.47mV]

with: $ECG(V)$	ECG signal in Volt (V)
$ECG(mV)$	ECG signal in milli-Volt (mV)
ADC	Value samples from the sensor/channel (raw digital value)
n	Sampling resolution (default: 16-bit resolution ($n=16$), although 12-bit and 8-bit may also be found in older versions)
VCC	Operating voltage (3V when used with biosignalsplux)
G_{ECG}	Sensor gain (1019)

1.7. Electrode Connections & Sleeve Color Meanings

Sleeve Color	Red	Black	White
Electrode Cable	+	-	reference

See section 2 for more information on where to place the electrodes and to connect electrodes cables for ECG acquisitions.

1.8. Physical Characteristics

- > **W1 x L1 x H1:** 1.5cm x 2.1cm x 0.4cm
- > **A1:** 105.0±0.5cm
- > **A3:** 3.0±0.5cm
- > **Available sleeve colors:** White, Black, Blue, Green, Red, Yellow, Gray, and Brown
- > **W2 x L2 x H2:** 1.4cm x 1.7cm x 0.5cm
- > **A2:** 1.5±0.5cm
- > **D:** 0.4cm

Sensor also available with A2 and A3 with 30cm cable lengths. Custom cable lengths for A1, A2, and A3 are possible. For custom lengths, please contact our operations team via sales@pluxbiosignals.com.

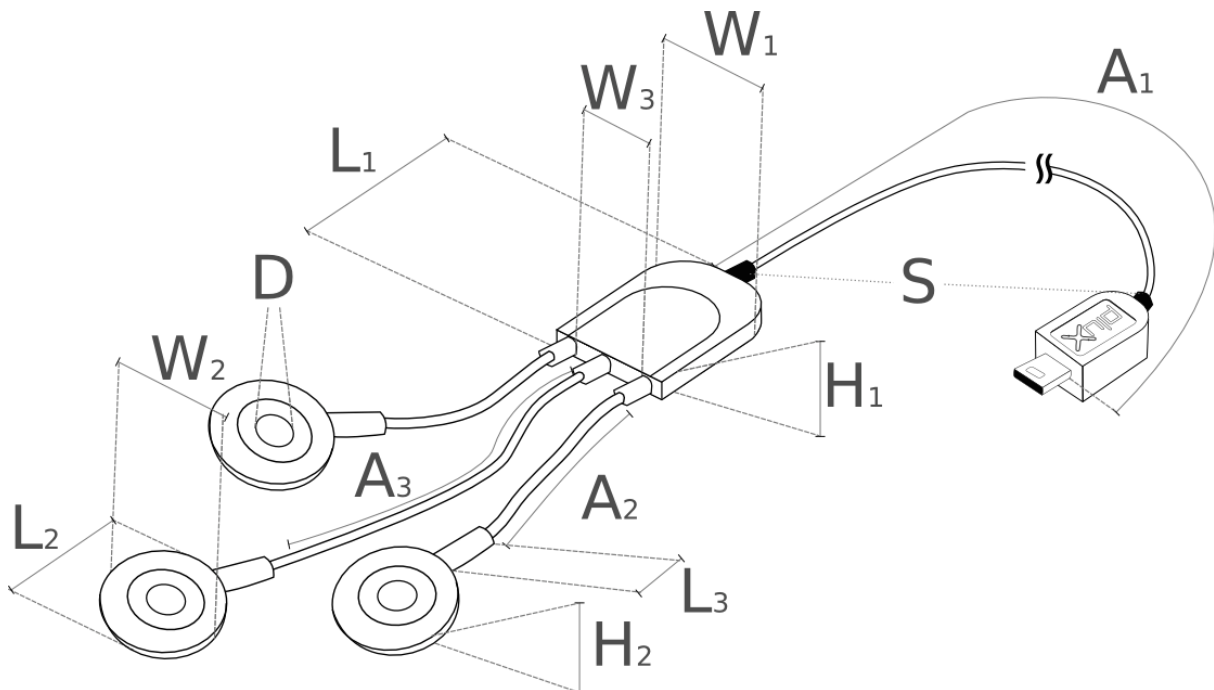


Figure 3: Physical characteristics of the standard Electrocardiography (ECG) sensor.

2. Sensor Application Notes



Download Sensor Sample Data

<https://support.pluxbiosignals.com/knowledge-base/biosignalsplux-sensor-sample-signals-samples/>

The **biosignalsplux** ECG is primarily designed for single-lead ECG acquisitions in the Einthoven configurations. The Einthoven triangle allows you to acquire 3 different ECG leads which only depend on the positioning of your electrode cables:

- Lead I: measures from RA (right arm) to LA (left arm)
- Lead II: measures from RA to LF (left foot)
- Lead III: measures from LA to LF

The illustrations shown in Figure 4 and Figure 5 show the recommended electrode placement for the acquisition of ECG signals in Einthoven configurations depending on the different standard ECG sensors with difference electrode cable lengths.

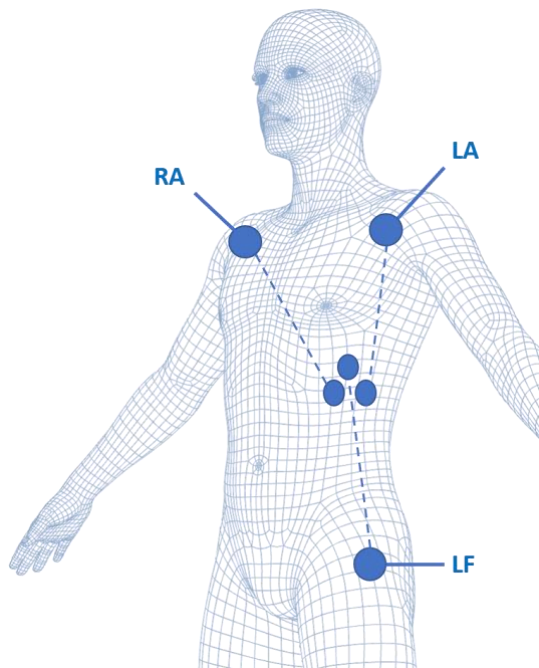


Figure 4: Electrode placements for ECG acquisitions in Einthoven configurations using the standard ECG sensor with electrode cable lengths of 1.5cm (+ & -) and 3 cm (reference).

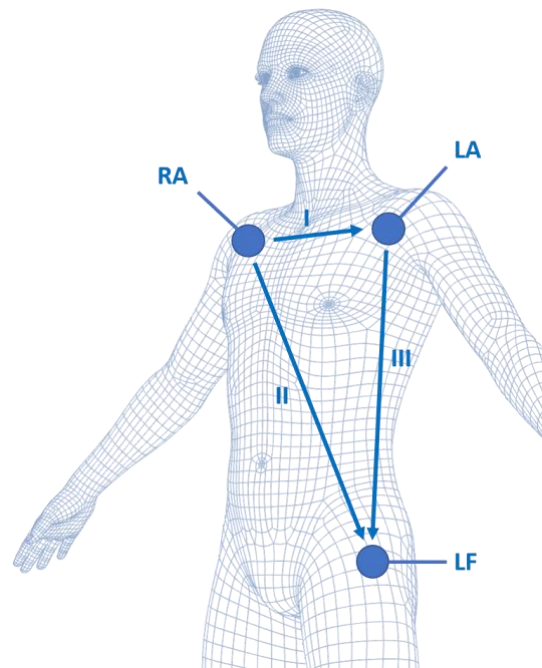


Figure 5: Electrode placements for ECG acquisitions in Einthoven configurations using the standard ECG sensor B with electrode cable lengths of 30cm (+, - & reference).

After placing the ECG electrodes correctly on the body, connect the electrode cables of the ECG sensor according to one of the following configurations:

Table 1: ECG sensor electrode and electrode placement connection.

	Positive Electrode (+) (red sleeve)		Reference Electrode (white sleeve)
Lead I	LA	RA	LF
Lead II	LF	RA	LA
Lead III	LF	LA	RA

It is also possible to use a sensor with only the + and – electrodes (must be custom ordered) without the use of an additional reference electrodes. Such sensors can lead to an increase in baseline noise due to the lack of a reference electrode but can be an alternative to the 3-electrode sensor for applications in which a simplified ECG sensor can be useful (e.g. for the extraction of heart rate data only).

3. Using the Electrocardiography (ECG) Sensor with biosignalsplux & OpenSignals

3.1. Connecting the sensor to biosignalsplux Systems

3.1.1. biosignalsplux 4-Channel Hubs

The **biosignalsplux** ECG sensor is compatible with all 4 analog input channels of the 4-channel **biosignalsplux** hub, but incompatible with the reference/ground port. Connect the sensor to an analog input to use it with this device.



Figure 6: ECG compatible biosignalsplux channels (green checkmarks).

3.1.2. biosignalsplux 8-Channel Hubs

The **biosignalsplux** ECG sensor is compatible with all 8 analog input channels of the 8-channel **biosignalsplux** 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.

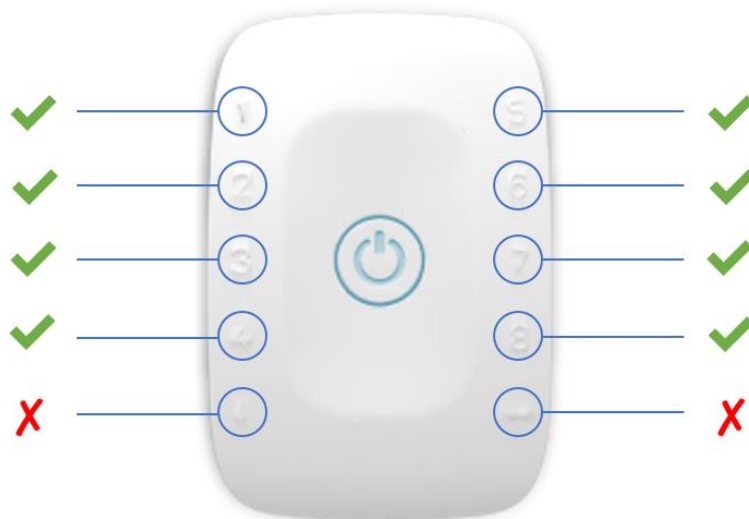


Figure 7: ECG compatible biosignalsplux channels (green checkmarks).

3.1.3. biosignalsplux Solo & Single-Channel openBAN Devices

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



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

3.2. Configuring the Sensor in OpenSignals (r)evolution

 **Download OpenSignals**

<https://support.pluxbiosignals.com/knowledge-base/introducing-opensignals-revolution/>

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

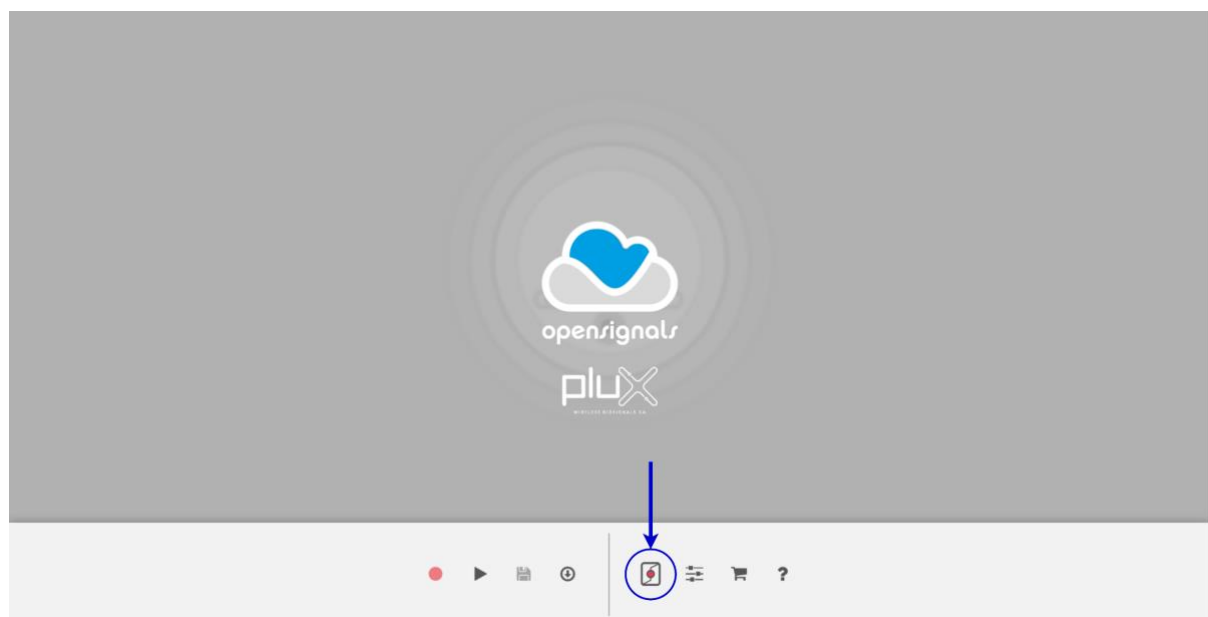


Figure 9: Access the OpenSignals (r)evolution device manager.

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.

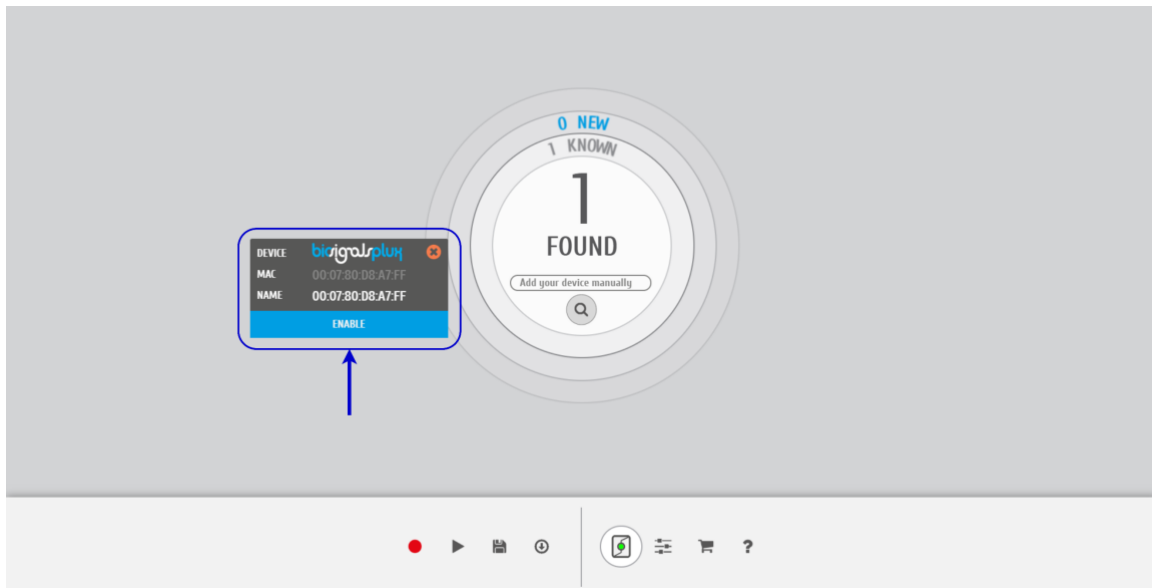


Figure 10: Enabling the device for acquisition.

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

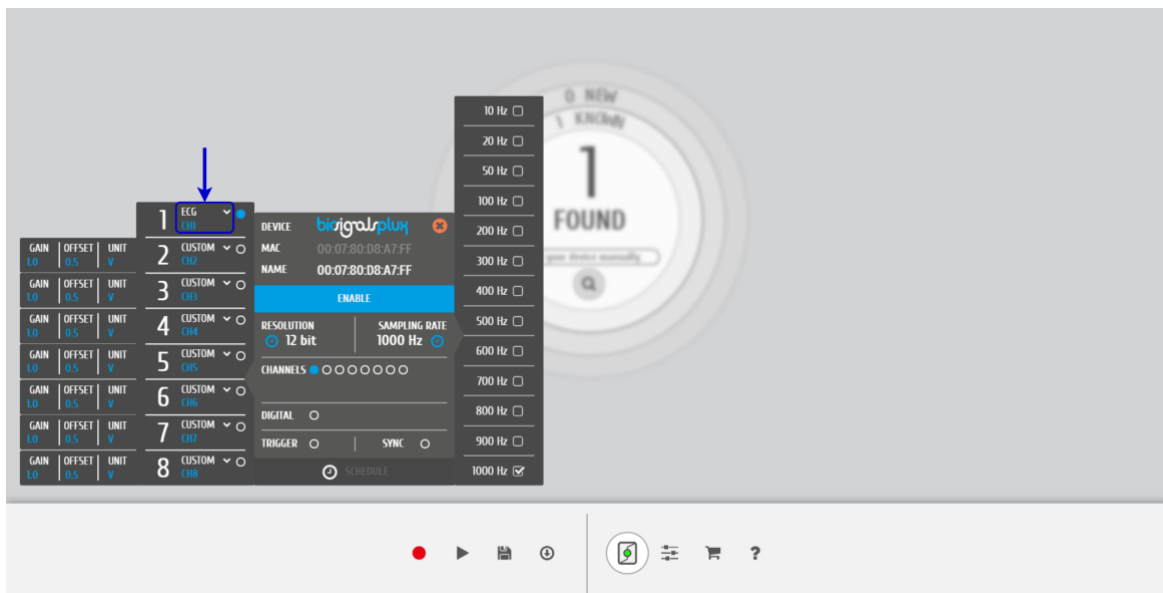


Figure 11: Set the channel type of the channel you have your ECG sensor connected to, to *ECG*.

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 *Sensor Application* Notes to learn how to apply the sensors and 3.1 *Connecting the sensor to biosignalsplux Systems* to learn how to connect your device to your **biosignalsplux** device. Click on the record button in the OpenSignals main interface whenever you're ready for your acquisition.

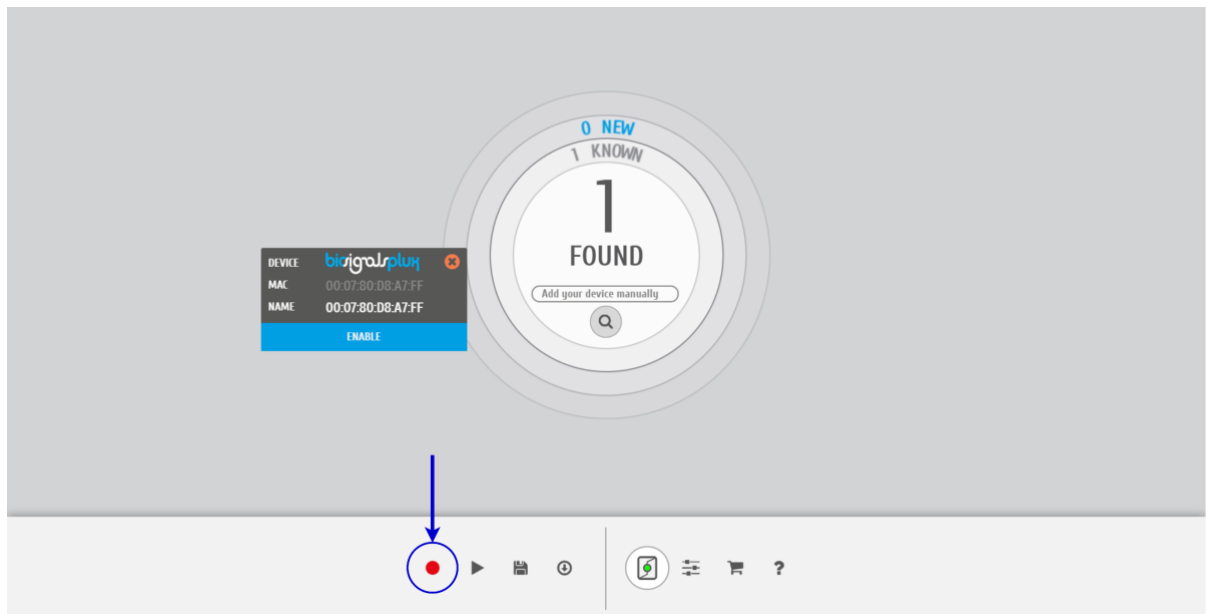



Figure 12: Start the acquisition whenever you're ready.

4. Scientific Publications

The following scientific resource elements is only a small selection extracted from the list of available publications using **biosignalsplux**. Please visit the following website to access the entire up-to-date list.

 biosignalsplux Publications
https://support.pluxbiosignals.com/1352-2/

Publications Short List

C. Gerritsen, J. de Man, J. van der Meij, "Physiological and subjective response to injustice: The Effects of Unjust Evaluations on Physiological Responses and Subjective Experiences", in *Proc. of the IEEE/WIC/ACM Int. Joint Conf. on Web Intelligence (WI) and Intelligent Agent Technologies (IAT)*, vol. 3, pp. 179-182, 2013

A. Reiss, I. Indlekofer, P. Schmidt, K. van Laerhoven, "Deep PPG: Large-Scale Heart Rate Estimation with Convolutional Neural Networks", in *Sensors*, vol. 19, no. 14:3079, pp. 1-27, 2019

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

G. Ramos, M. Alfaras, H. Gamboa, "Real-Time Approach to HRV Analysis", in *Proc. Of the 11th Joint Int. Conf. On Biomedical Engineering Systems and Technologies (BIOSTEC2018)*, vol. 4, pp. 208-215, 2018

M. Knierim, J. Dominik, V. Dorner, "Designing Live Biofeedback for Groups to Support Emotion Management in Digital Collaboration", in *Lecture Notes in Computer Science*, vol. 10243, pp. 479-484, 2017

A. Bernardino, C. Vismara, F. Baptista, F. Carnide, S. Oom, S. Bermudez i Badia, E. Gouveia, H. Gamboa, "A dataset for the automatic assessment of functional senior fitness tests using kinect and physiological sensors", in *Proc. of the 1st Int. Conf. on Technology and Innovation in Sports, Health and Wellbeing (TISHW)*, pp. 1-6, 2016

J. Pagán, J. L. Risco-Martín, J. M. Moya, J. L. Ayala, "Modeling methodology for the accurate and prompt prediction of symptomatic events in chronic diseases.", in *Journal of Biomedical Informatics*, vol. 62, pp. 136-147, 2016

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

J. Cusveller, C. Gerritsen, J. de Man, "Evoking and Measuring Arousal in Game Settings", in *Proc. of the Int. Conf. on Serious Games*, vol. 8395, pp. 165-174, 2014

5. Safety & Maintenance

5.1. Safety Instructions

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

- ! The user should always keep the device and its accessories dry.
- ! The user must turn off the **biosignalsplux** device and contact Technical Support if the system or accessories reach uncomfortable temperatures.
- ! The user should not use the **biosignalsplux** 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 **biosignalsplux** 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 **biosignalsplux** 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 **biosignalsplux** 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 **biosignalsplux** 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 **biosignalsplux** device, nor clean with liquid or abrasives.
- ! The user should handle the **biosignalsplux** device with caution and not expose the device or accessories to high accelerations and vibrations.
- ! **biosignalsplux** 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 **biosignalsplux** equipment and sensors to prevent any damaging of your system.

The **biosignalsplux** 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 **biosignalsplux** and sensors should be visually checked before each use and cleaning process to ensure that no mechanical damage occurred.
- The **biosignalsplux** equipment and sensors (including the cables) should be cleaned with a slightly damp cloth or suitable absorbent paper, ensuring no liquid enters the equipment of 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.

More information on cleaning instructions can be found here:

<https://support.pluxbiosignals.com/knowledge-base/how-do-i-clean-my-plux-products/>

6. Ordering Guides, Regulatory & Legal Information

6.1. Ordering Guide

Visit www.pluxbiosignals.com to place your sensor order online or contact our sales team at sales@pluxbiosignals.com

6.2. Warranty

PLUX offers a standard warranty period of **2 years for all kits and closed products** (e.g., hubs, kits, enclosed sensors), including **2 years for the batteries of these closed products**.

Products for replacement within the warranty period must be submitted to our support team for initial analysis before being sent to our offices. Please refrain from sending your products without prior notice, as this will complicate the warranty analysis and replacement process.

You can find more information about warranty in the following support articles:

What are the standard warranty terms?

<https://support.pluxbiosignals.com/knowledge-base/what-are-the-standard-warranty-terms/>

How can I report a warranty or replacement case?

<https://support.pluxbiosignals.com/knowledge-base/how-can-i-report-a-warranty-or-replacement-case/>

What happens if my warranty period is over and I need help?

<https://support.pluxbiosignals.com/knowledge-base/what-happens-if-my-warranty-period-is-over-and-i-need-help/>

What will void my warranty?

<https://support.pluxbiosignals.com/knowledge-base/what-will-void-my-warranty/>

6.3. Support

You can find support on support.pluxbiosignals.com

Further sensor documentation can be found here:

<https://support.pluxbiosignals.com/knowledge-base/biosignalsplux-documentation/>

6.4. Regulatory Disclaimer

biosignalsplux 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.

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