

Cardiac Signal Processing Module

for Biosignals Studio

Datasheet



www.pluxbiosignals.com



Biosignals Studio

This software module is intended solely for life sciences research and educational purposes. It is not a medical device and is not intended for diagnosis, treatment, or any form of medical use.

For support visit: support.pluxbiosignals.com



PLUX wireless biosignals S.A.
Av. 5 de Outubro 70-2
1050-059 Lisbon, Portugal

+351 21 195 6542

www.pluxbiosignals.com

For support visit [www.support.pluxbiosignals.com](mailto:support.pluxbiosignals.com)

This information is provided "as is," and we make no express or implied warranties whatsoever with respect to functionality, operability, use, fitness for a particular purpose, or infringement of rights. 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.

Table of Contents

General Information.....	4
Datasheet.....	5
Overview	5
Supported Sensors.....	5
Settings	6
Pre-Processing	7
Powerline Filtering	7
Heartbeat Detection	7
RR and NN Intervals.....	7
Extracted Parameters	9
Time-Domain Parameters	9
Long-Term Time-Domain Parameters	11
Frequency-Domain Parameters	12
Non-Linear Parameters	14
Bibliography.....	16
Regulatory & Legal	17
Intended Use & Disclaimer	17
Document Version & Revision History	18
Contact & Support	19

General Information

The **Cardiac Signal Processing Module** for Biosignals Studio turns a raw electrocardiography (ECG) or blood volume pulse (BVP) signal into heart rate and Heart Rate Variability (HRV) parameters in the time, frequency and non-linear domains.

This datasheet describes the technical implementation of the module: supported sensors, settings, pre-processing steps and the formulas used to compute every extracted parameter. For instructions on using the module in Biosignals Studio, visit support.pluxbiosignals.com.

The module processes the selected signal segment in the following order:

1. Powerline (notch) filtering
2. Heartbeat detection (R-peaks in ECG, systolic peaks in BVP)
3. Extraction of the RR Interval (RRI) series
4. Removal of irregular intervals, resulting in the Normal-to-Normal Interval (NNI) series
5. Computation of time-domain, frequency-domain and non-linear HRV parameters

All HRV parameters are computed from the NNI series, in line with the HRV standards of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [1].

Datasheet

Overview

Table 1: General Information

Attribute	Information
Product Name	Cardiac Signal Processing Module
Product Type	Signal Processing Module (software)
Software	Biosignals Studio
Description	Processing module for ECG and BVP signals, providing powerline filtering, heartbeat detection, irregular interval removal and extraction of heart rate and HRV parameters.
Features	1. Powerline (notch) filtering 2. R-peak detection (Pan-Tompkins) and BVP pulse peak detection 3. Irregular interval removal (physiological range and local consistency) 4. Tachogram and NNI histogram 5. Time-domain, frequency-domain and non-linear HRV parameters 6. Export of RRI and NNI series
Use Case Applications	• HRV analysis at rest, under workload and during recovery • Psychophysiology and stress research • Sports sciences • Autonomic nervous system research
Excluded Applications	This module is not a medical device and must not be used for clinical diagnosis or treatment.
Compatible Sensors	ECG and BVP sensors (see Supported Sensors)
Incompatible Sensors	SpO2 and Pulse sensors, and BITalino systems

Supported Sensors

ECG provides the most precise heartbeat timing and is the recommended input for HRV analysis. BVP can be used for heart rate and HRV estimation, but pulse peaks are less sharply defined than R-peaks.

Table 2: Supported sensors and systems

Sensor	System	Supported
Electrocardiography (ECG) Smart Sensor	Biosignals PRO	Yes
Electrocardiography (ECG)	biosignalsplux, Biosignals PRO	Yes
Blood Volume Pulse (BVP)	biosignalsplux, Biosignals PRO	Yes
cardioBAN BLE	Standalone wearable	Yes
SpO2 and Pulse sensors	All systems	No
Cardiac sensors	BITalino	No

Settings

Six user settings control the irregular interval removal, the PSD graph and the powerline filter. All other processing parameters are fixed.

Table 3: User settings

Setting	Symbol	Default	Unit	Effect
Minimum RR interval	$RR_{\min}$	0.3	s	Shortest interval accepted as a normal heartbeat (200 bpm)
Maximum RR interval	$RR_{\max}$	1.5	s	Longest interval accepted as a normal heartbeat (40 bpm)
Neighbour beats before/after	n	20	beats	Number of beats on each side used for the local average
Acceptance margin	m	20	%	Maximum deviation from the local average
PSD graph maximum frequency	f_{PSD}	0.4	Hz	Upper frequency limit of the PSD graph
Notch frequency	f_{PL}	50	Hz	Powerline filter frequency (50 Hz or 60 Hz)

Table 4: Fixed processing parameters

Parameter	Value
Powerline filter	Notch at 50 Hz or 60 Hz
Band-limiting	Sensor hardware (no additional software filtering)
ECG heartbeat detection	Pan-Tompkins QRS detection
PSD estimation	Welch's method, Hamming window
Long-term segment length	5 minutes
NNI histogram bin width	7.8125 ms (1/128 s)

Pre-Processing

The raw signal $x[n]$, sampled at f_s , is filtered, its heartbeats are detected, and irregular intervals are removed before any parameter is computed.

Powerline Filtering

A notch filter at 50 Hz or 60 Hz removes powerline interference. No additional high-pass or low-pass filtering is applied, because the PLUX cardiac sensors limit the signal bandwidth to the relevant frequency range in hardware [PLUX].

Heartbeat Detection

In ECG signals, R-peaks are detected with the Pan-Tompkins algorithm [2]. The algorithm emphasizes the QRS complex through band-pass filtering, differentiation, squaring and moving-window integration, and then applies adaptive amplitude thresholds and timing rules that are updated with every detected beat.

In BVP signals, the module detects the systolic peak of each pulse wave [PLUX].

RR and NN Intervals

Let $t_{R,i}$ be the timestamp of the i -th detected heartbeat. The interval between consecutive heartbeats forms the RR Interval (RRI) series:

$$RRI_i = t_{R,i+1} - t_{R,i}, \quad i = 1, \dots, N_R$$

Not every interval reflects the normal sinus rhythm [1]. Ectopic beats and missed or false detections produce intervals that are unusually short or long. Each interval RRI_i is therefore checked in two steps [PLUX]:

Physiological range: the interval must lie within the minimum and maximum RR interval (defaults 0.3 s and 1.5 s)

$$RRI_{min} \leq RRI_i \leq RRI_{max}$$

Local average: mean of the n intervals before and the n intervals after RRI_i (default $n = 20$):

$$\overline{RRI}_i = \frac{1}{2n} \sum_{\substack{j=i-n \\ j \neq i}}^{i+n} RRI_j$$

Local consistency: the interval must not deviate from the local average by more than the acceptance margin m (default 20%):

$$|RRI_i - \overline{RRI}_i| \leq \frac{m}{100} \cdot \overline{RRI}_i$$

Intervals that fail either check are removed. The remaining intervals form the Normal-to-Normal Interval (NNI) series, NNI_i with $i = 1, \dots, N$, in milliseconds. Both the RRI and the NNI series can be exported.

Extracted Parameters

All parameters are computed from the N intervals of the NNI series, in milliseconds. Standard deviations use the sample estimator ($N - 1$).

Time-Domain Parameters

Table 5: Time-domain parameters

Parameter	Unit	Reference
Mean, Minimum, Maximum Heart Rate	bpm	[1]
SDNN	ms	[1]
RMSSD	ms	[1], [5]
SDSD	ms	[1]
NN50	-	[1]
pNN50	%	[1]

Heart rate: instantaneous heart rate of each NN interval, in beats per minute

$$HR_i = \frac{60\,000}{NNI_i}$$

Mean, Minimum and Maximum Heart Rate: average, lowest and highest value of the heart rate series

$$HR_{min} = \min_i HR_i, \quad HR_{max} = \max_i HR_i, \quad \overline{HR} = \frac{1}{N} \sum_{i=1}^N HR_i$$

Mean NNI: average of all NN intervals, used in SDNN:

$$\overline{NNI} = \frac{1}{N} \sum_{i=1}^N NNI_i$$

SDNN: standard deviation of all NN intervals (overall variability):

$$SDNN = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (NNI_i - \overline{NNI})^2}$$

Successive differences: Change in NNI from one beat to the next, used to compute RMSSD, SDSD and NN50:

$$\Delta NNI_i = NNI_{i+1} - NNI_i, \quad i = 1, \dots, N-1$$

RMSSD: root mean square of the successive differences (short-term variability):

$$\text{RMSSD} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N-1} \Delta \text{NNI}_i^2}$$

SDSD: standard deviation of the successive differences (short-term variability):

$$\text{SDSD} = \sqrt{\frac{1}{N-2} \sum_{i=1}^{N-1} (\Delta \text{NNI}_i - \overline{\Delta \text{NNI}})^2}$$

NN50 and pNN50: number of successive differences larger than 50 ms, and that number relative to the total number of NN intervals:

$$\text{NN50} = \sum_{i=1}^{N-1} [|\Delta \text{NNI}_i| > 50 \text{ ms}], \quad \text{pNN50} = \frac{\text{NN50}}{N} \times 100 \%$$

Long-Term Time-Domain Parameters

Long-term parameters split the NNI series into M consecutive 5-minute segments $j = 1, \dots, M$ [1]. They are not computed for recordings shorter than 10 minutes, and their statistical relevance is limited for recordings shorter than 24 hours [PLUX].

Table 6: Long-term time-domain parameters

Parameter	Unit	Reference
SDNN Index	ms	[1]
SDANN	ms	[1]

SDNN Index: mean of the SDNN values of all 5-minute segments:

$$\text{SDNN Index} = \frac{1}{M} \sum_{j=1}^M \text{SDNN}_j$$

SDANN: standard deviation of the mean NN interval of all 5-minute segments:

$$\text{SDANN} = \sqrt{\frac{1}{M-1} \sum_{j=1}^M \left(\overline{\text{NNI}}_j - \overline{\overline{\text{NNI}}} \right)^2}$$

Frequency-Domain Parameters

The Power Spectral Density (PSD) of the NNI series is estimated with Welch's method [3] using a Hamming window, and split into the following frequency bands [1]. The PSD graph is displayed up to the PSD graph maximum frequency f_{PSD} (default 0.4 Hz); this setting does not change the computed parameters [PLUX].

Table 7: Frequency bands

Band	Frequency range	Notes
Ultra Low Frequency (ULF)	0.000 to 0.003 Hz	Only computed for recordings longer than 24 hours
Very Low Frequency (VLF)	0.003 to 0.040 Hz	0.000 to 0.040 Hz when ULF is not computed
Low Frequency (LF)	0.040 to 0.150 Hz	-
High Frequency (HF)	0.150 to 0.400 Hz	-

Table 8: Frequency-domain parameters

Parameter	Unit	Reference
Absolute Power (per band)	ms ²	[1]
Total Power	ms ²	[1]
Relative Power (per band)	%	[1]
Logarithmic Power (per band)	log(ms ²)	[PLUX]
Normalized Power (LF and HF)	n.u.	[1]
LF/HF Ratio	-	[1]

Absolute power: sum of the PSD within a band from f_l to f_h , where Δf is the frequency resolution of the PSD:

$$P_{\text{band}} = \sum_{f_l \leq f_k < f_h} \text{PSD}(f_k) \Delta f$$

Total power: sum of the absolute power of all computed bands:

$$P_{\text{total}} = \sum_{\text{band}} P_{\text{band}}$$

Relative power: absolute power of a band relative to the total power:

$$P_{\text{band,rel}} = \frac{P_{\text{band}}}{P_{\text{total}}} \times 100 \%$$

Logarithmic power: natural logarithm of the absolute power of a band:

$$P_{\text{band,log}} = \ln(P_{\text{band}})$$

Normalized power: LF and HF power relative to the sum of LF and HF power, in normalized units:

$$LF_{nu} = \frac{P_{LF}}{P_{LF} + P_{HF}} \times 100, \quad HF_{nu} = \frac{P_{HF}}{P_{LF} + P_{HF}} \times 100$$

LF/HF ratio: ratio between the absolute LF and HF power:

$$LF/HF = \frac{P_{LF}}{P_{HF}}$$

Non-Linear Parameters

The Poincaré plot shows each NN interval against the next one (NNI_{i+1} versus NNI_i). Its shape is summarized by an ellipse centered on the identity line, whose standard deviations perpendicular to and along that line are SD1 and SD2 [4]. The Triangular Index and TINN describe the shape of the NNI histogram [1].

Table 9: Non-linear parameters

Parameter	Unit	Reference
SD1	ms	[4]
SD2	ms	[4]
SD1/SD2	-	[4]
STD RR	ms	[1], [4]
STD RR Diff	ms	[1], [4]
Triangular Index	-	[1]
TINN	ms	[1]

STD RR and STD RR Diff: Standard deviation of the NN intervals and of their successive differences, identical to SDNN and SDSD:

$$\text{STD RR} = \text{SDNN}, \quad \text{STD RR Diff} = \text{SDSD}$$

SD1: standard deviation perpendicular to the identity line (short-term variability):

$$\text{SD1} = \frac{\text{STD RR Diff}}{\sqrt{2}}$$

SD2: standard deviation along the identity line (long-term variability):

$$\text{SD2} = \sqrt{2 \text{STD RR}^2 - 1/2 \text{STD RR Diff}^2}$$

SD1/SD2: balance between short-term and long-term variability:

$$\text{SD1/SD2} = \frac{\text{SD1}}{\text{SD2}}$$

The NNI histogram $H(b)$ counts the number of NN intervals in each bin b of width 7.8125 ms (1/128 s) [1].

Triangular Index: total number of NN intervals divided by the height of the histogram (the number of intervals in its most frequent bin):

$$\text{Triangular Index} = \frac{N}{\max_b H(b)}$$

For TINN, a triangle $q(b)$ is fitted to the histogram: q is zero outside the interval from t_N to t_M and peaks at the histogram mode. t_N and t_M are chosen to minimize the squared difference between the histogram and the triangle [1].

TINN - baseline width of the best-fitting triangle, in milliseconds:

$$\text{TINN} = t_M - t_N, \quad (t_N, t_M) = \operatorname{argmin} \sum_b (H(b) - q(b))^2$$

Bibliography

[PLUX] Methods and parameters defined by PLUX for this module, based on the internal requirements specification for the Cardiac Signal Processing Module. This covers the filter configuration, BVP pulse peak detection, the irregular interval removal rules, the logarithmic band power, the PSD graph range and the recording length requirements for long-term parameters.

- [1] Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation*. 1996;93(5):1043-1065.
- [2] Pan J, Tompkins WJ. A real-time QRS detection algorithm. *IEEE Transactions on Biomedical Engineering*. 1985;32(3):230-236.
- [3] Welch PD. The use of fast Fourier transform for the estimation of power spectra: a method based on time averaging over short, modified periodograms. *IEEE Transactions on Audio and Electroacoustics*. 1967;15(2):70-73.
- [4] Brennan M, Palaniswami M, Kamen P. Do existing measures of Poincaré plot geometry reflect nonlinear features of heart rate variability? *IEEE Transactions on Biomedical Engineering*. 2001;48(11):1342-1347.
- [5] Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. *Frontiers in Public Health*. 2017;5:258.

Regulatory & Legal

Intended Use & Disclaimer

PLUX 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.

Document Version & Revision History

Version #	Date	Description / Changes
1.0	14/10/2026	First version



Designed & Made in Portugal

Contact & Support

PLUX wireless biosignals S.A.

Av. 5 de Outubro 70 – 2º
1050-059 Lisbon, Portugal

✉ Email: hello@pluxbiosignals.com

🌐 Website:
www.pluxbiosignals.com

For support & contact visit:

www.support.pluxbiosignals.com



