Blood Volume Pulse (BVP) at Rest

Technical Note

TN 10072018

PHYSICAL ACTIVITY | TASK DESCRIPTION

During the cardiac cycle two major events can be distinguished: the relaxation and contraction of the myocardium (diastole and systole, respectively).
In simple terms, heart is a pumping system, introducing changes in volume content and pressure in the arteries (“distribution” system).
These changes, propagate along the arterial system from arteries to arterioles and capillaries, through a pulsatile dynamic.
When the volume pulse reaches the extremity of the fingers, its opacity to light increases, due to a bigger population of erythrocytes in blood vessels.
This property is essential for the blood volume pulse (BVP) sensors [1], used for monitorization of this phenomenon.
BVP systems can function in transmittance mode, by coupling an emitter (LED) and receptor (photodiode) of light, so that the direction of photon propagation is perpendicular to the receptor surface of the photodiode [2].
Red/Infrared light can easily penetrate the skin, being transmitted or reflected by the red blood cells.
With BVP acquisition it is possible, for example, to monitor heart rate and heart rate variability [3], [4].
The BVP signal sample, referent to the present technical note, was acquired at rest for a period of 1 minute and 45 seconds, in a controlled environment where noise sources were minimised.

SIGNAL CHARACTERISTICS

Typical Frequency Band:

- 0.5 to 5 Hz [More Restrictive]
- 0.5 to 20 Hz [Recommended]
- 0.5 to 40 Hz [Less Restrictive]

SENSOR AND HARDWARE DESCRIPTION

The light emitter (red band - 670 nm) and receptor are encapsulated inside a plastic finger clip, which improves the signal to noise ratio by avoiding that other light sources interact with the photodiode surface (*Fig. 1*).

SUBJECT DESCRIPTION

Healthy male subject with 24 years old and non-smoker (height: 1.70 m; weight: 75 kg - *Fig. 2*).

Fig. 1. Sensor Overview

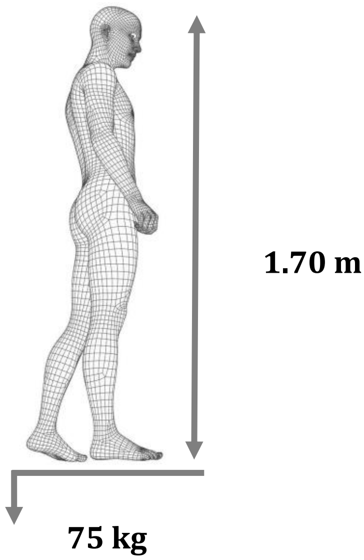

Fig. 2. Anthropometric Measures

bi*signals*plux
wearable body sensing platform

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REV A

PROTOCOL OF ACQUISITION

The subject is in an erect position with the arm suspended at the horizontal direction.

Steps enumeration:

1. Placement of the finger clip in the right-hand forefinger (*Fig. 3*);
2. Turn off external sources of noise, such as electric lights;
3. Start of the acquisition of BVP;
4. Maintenance of position and experimental conditions, for acquiring BVP in rest;
5. End of the acquisition after 1 minute and 45 seconds;
6. Removal of the finger clip from the subject forefinger;
7. Storage of generated files in the desired folder (*Fig. 4*).

Fig. 3. Sensor Placement (right-hand forefinger)

Fig. 4. Signal Storage Operation

QUICK INFORMATION

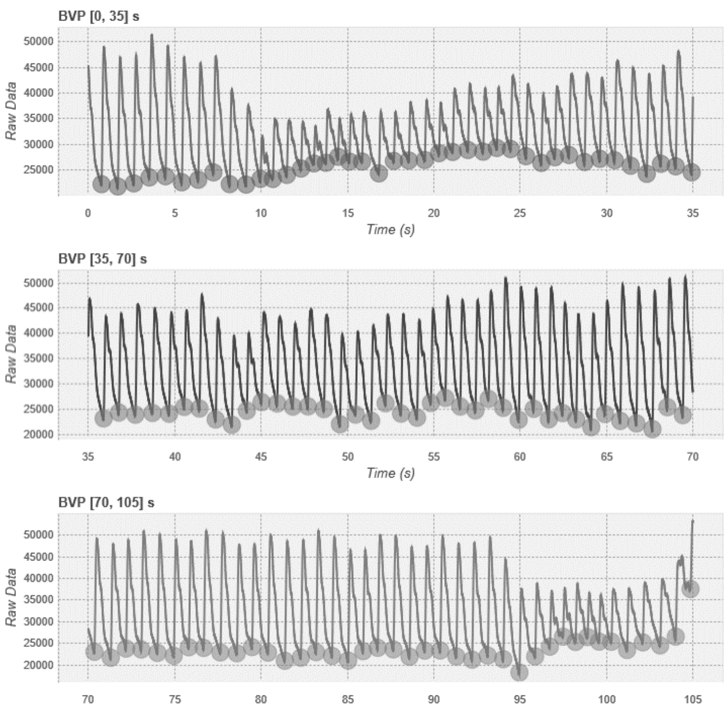

Fig. 5. BVP Signal with the onsets highlighted with circles

Heart Rate main values:

$$Average = 69.09\ BPM$$
$$Standard\ Deviation = 6.29\ BPM$$
$$Maximum = 92.17\ BPM$$
$$Minimum = 59.70\ BPM$$

* *After detection of pulse onsets and determination of the time between each pair of consecutive events* [10]

NOISE EVALUATION PROCEDURE

Signal to Noise Ratio (SNR) is an important metric that classifies objectively the quality of the acquisition, and like the name suggests the relation between the intensity of the signal and the undesired noise in the acquired data ($acquired$), which is defined by:

$$SNR = \frac{V_{pp}^{signal}}{V_{pp}^{noise}} \quad (1)$$

being V_{pp}^{signal} and V_{pp}^{noise} the peak-to-peak amplitude of the $signal$ and $noise$ component, respectively.

In order to SNR be determined the following steps were followed:

1) Division of the acquisition in temporal segments/windows (each segment will be the duration of a BVP pulse – time interval between two consecutive onsets);

2) For each segment:
   a. Application of the acquired signal to a lowpass filter (for removal of high frequency noise);
   Typically, the informational content of BVP is below 5 Hz [5], *in a more restrictive perspective, 10 Hz* [6] *or 40 Hz* [7]. *For choosing an adequate value for the present signal sample the signal power spectrum, generated using the Fourier Transform, was analysed.*
   In electroencephalography the spectral frequency edge at 95 % (SFE95) is an interesting parameter used to objectively classify the anaesthetic depth [8] *or cerebral maturation* [9].
   In general applications, this metric can be used to verify the informative frequency band of a signal.
   For the acquired signal SFE95 is equal to 51.40 Hz (Fig. 6).
   However, between 20 and 51.40 Hz the informational content is very low, exception made to the highlighted peak in Fig. 6, related with 50 Hz noise, which we want to avoid.
   The applied digital filter was a 8th Butterworth with a cut-off frequency of 20 Hz in order to ensure that the 50 Hz peak was attenuated (at 50 Hz the gain is -40 dB).

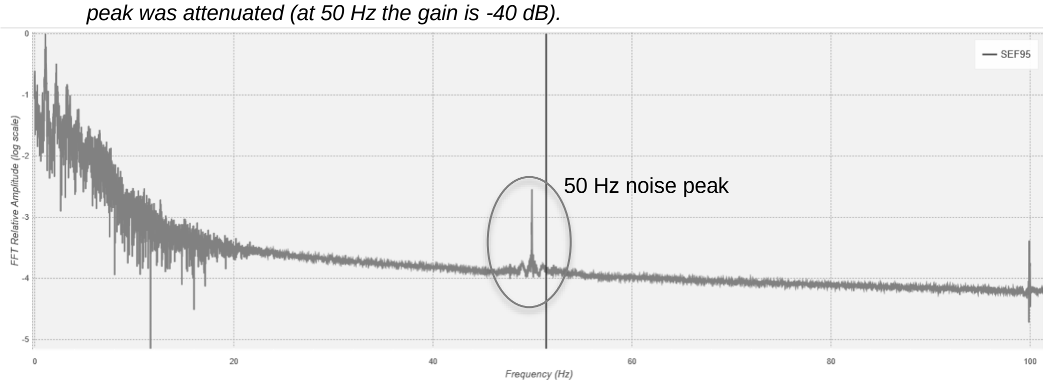

Fig. 6. Signal Power Spectrum and identification of SEF95 value, using a vertical line and of the 50 Hz noise peak inside the ellipse

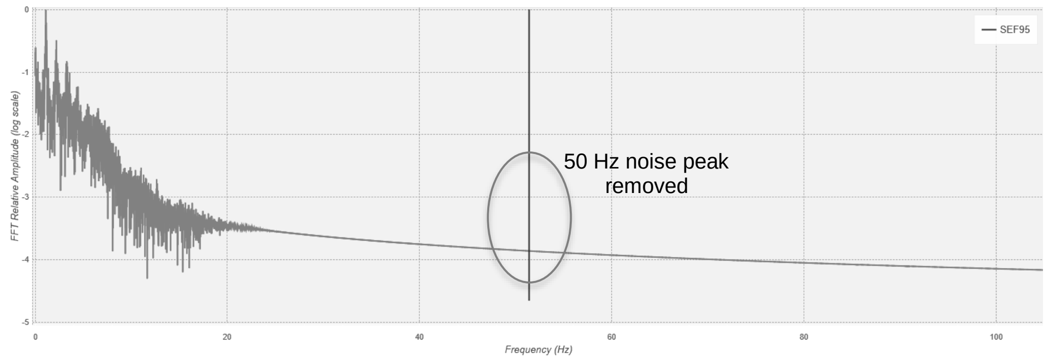

Fig. 7. Filtered Signal Power Spectrum

b. Determination of V_{pp}^{signal} from the smoothed/filtered BVP pulse (*Fig. 8*);

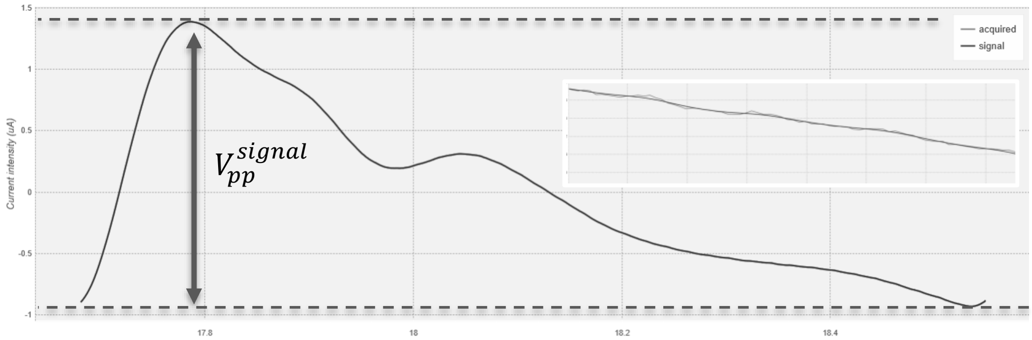

Fig. 8. BVP Pulse of the smoothed data (signal component) and zoomed section

c. Isolation of the noise component by subtracting the filtered data (signal component) from the acquired signal (*Fig. 9*);

d. Determination of V_{pp}^{noise};

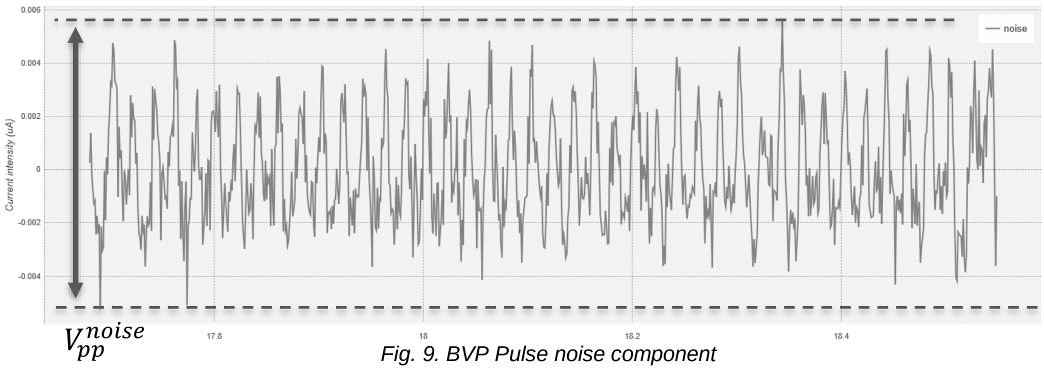

Fig. 9. BVP Pulse noise component

e. Estimation of SNR for the present segment.

3) Average of the SNR values and the respective standard deviation.

$$SNR_{avg} = 318.26 \qquad SNR_{std} = 97.37$$

$$SNR_{avg}^{dB} = 50.06 \pm \frac{2.32\ dB}{3.17\ dB}$$

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