



Beat-to-Beat Blood Pressure Monitor

This invention is applicable to all segments of the blood pressure monitoring market, including ambulatory, home-based, and high-acuity monitoring.

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This device provides non-invasive beat-to-beat blood pressure measurements and can be worn over the upper arm for prolonged durations. Phase and waveform analyses are performed on filtered proximal and distal photoplethysmographic (PPG) waveforms obtained from the brachial artery. The phase analysis is used primarily for the computation of the mean arterial pressure, while the waveform analysis is used primarily to obtain the pulse pressure. Real-time compliance estimate is used to refine both the mean arterial and pulse pressures to provide the beat-to-beat blood pressure measurement.

This wearable physiological monitor can be used to continuously observe the beat-to-beat blood pressure (B3P). It can be used to monitor the effect of prolonged exposures to reduced gravitational environments and the effectiveness of various countermeasures.

A number of researchers have used pulse wave velocity (PWV) of blood in the arteries to infer the beat-to-beat blood pressure. There has been documentation of relative success, but a device that is able to provide the required accuracy and repeatability has not yet been developed. It has been demonstrated that an accurate and repeatable blood pressure measurement can be obtained by measuring the phase change (e.g., phase velocity), amplitude change, and distortion of the PPG waveforms along the brachial artery. The approach is based on comparing the full PPG

waveform between two points along the artery rather than measuring the time-of-flight. Minimizing the measurement separation and confining the measurement area to a single, well-defined artery allows the waveform to retain the general shape between the two measurement points. This allows signal processing of waveforms to determine the phase and amplitude changes.

Photoplethysmography, which measures changes in arterial blood volume, is commonly used to obtain heart rate and blood oxygen saturation. The digitized PPG signals are used as inputs into the beat-to-beat blood pressure measurement algorithm. The algorithm consists of the following main components:

- First harmonic isolation bandpass filters take the raw PPG signals and separate out the first harmonics.
- Three harmonic lowpass filters take the PPG signal and filter out all spectral components outside the first three harmonics. The first three harmonics are used for regeneration of the pulse pressure waveforms.
- Phase analysis engine takes the first harmonics of the PPG signals and computes the phase difference between them in real time using a cross-correlation-based algorithm. The phase difference is to the first order correlated to the MAP (mean arterial pressure).
- Compliance estimation engine takes information on the general shape of the waveforms and the phase delay to compute the local compliance of the

artery. The higher the arterial pressure, the higher the Young's modulus and thus the lower the compliance.

- MAP computation engine obtains the phase delay and compliance information and provides the mean arterial pressure.
- Waveform analysis engine takes the PPG signal containing the first three harmonics and provides the signal processing needed for compliance (elasticity) estimation and pulse pressure computation.
- Pulse pressure computation engine takes the filtered PPG signal and an estimate of the arterial compliance to regenerate the pulse waveform.
- B3P computation engine takes the MAP and the pulse pressure computations and combines them with a blood pressure model and calibration data to produce the final signal of interest — the beat-to-beat blood pressure.

This work was done by Yong Jin Lee of Linea Research Corporation for Johnson Space Center. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to MSC-24601-1, volume and number of this NASA Tech Briefs issue, and the page number.

Measurement Techniques for Clock Jitter

New approach offers more advanced coded modulation techniques.

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NASA is in the process of modernizing its communications infrastructure to accompany the development of a Crew Exploration Vehicle (CEV) to replace the shuttle. With this effort comes the oppor-

tunity to infuse more advanced coded modulation techniques, including low-density parity-check (LDPC) codes that offer greater coding gains than the current capability. However, in order to take

full advantage of these codes, the ground segment receiver synchronization loops must be able to operate at a lower signal-to-noise ratio (SNR) than supported by equipment currently in use.