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POLYSOMNOGRAPHIC MONITORING USING REAL TIME ANALYSIS

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Abstract: Respiration monitoring is an important part of polysomnography. Measurements are based on different principles like impedance pneumography, inductive plethysmography or the thermistor technique. Sensors disturb the patient and influence on the quality of measurement results. In this paper a real time method for computation of the respiration from the photopletysmographic signal is discussed for which only a sensor at one of human's peripheries is needed.
Keywords: Polysomnography, photoplethysmographic signal, real time analysis, measurements in biology and medicine.

1 INTRODUCTION

Polysomnography of infants and children is a medical method for the detection and diagnosis of sleep disorders. It is also helpful to assess the risk for Sudden Infant Death (SID).

In a sleep laboratory during sleep several physiological signals are measured simultaneously. These include the respiration effort at abdomen and thorax, the nasal airflow as well as the ECG, EEG, EOG and the blood gas values oxygen saturation, transcutaneous partial pressure of oxygen and carbon dioxide.

Many sensors disturb the patient during polysomnography and influence on the quality of measurement results. That is why we try to obtain as much information as possible from as little sensors as necessary.

In the following the information of respiration effort is analysed from the photoplethysmographic signal. ZHANG [1] showed that the respiration can be obtained from the blood volume pulse by using the respiratory related fluctuations. In this paper the algorithm is used to display the computed respiration signal in real time.

2 POLYSOMNOGRAPHIC DIAGNOSIS SYSTEM

In cooperation between the Institute of Electrical Measurement at the University of Paderborn and the sleep laboratories of the Vestische Kinderklinik Datteln, Germany, we developed the PC-based hard- and software system POLDI (**Pol**ysomnographisches **Di**agnosis System) for registration and analysis of polysomnographic examinations in infants which is in use since 1992 [2]. It exists of the data acquisition component POLDI-Connect with a PC plug-in card (Figure 1) and two software parts for measuring and analysis.

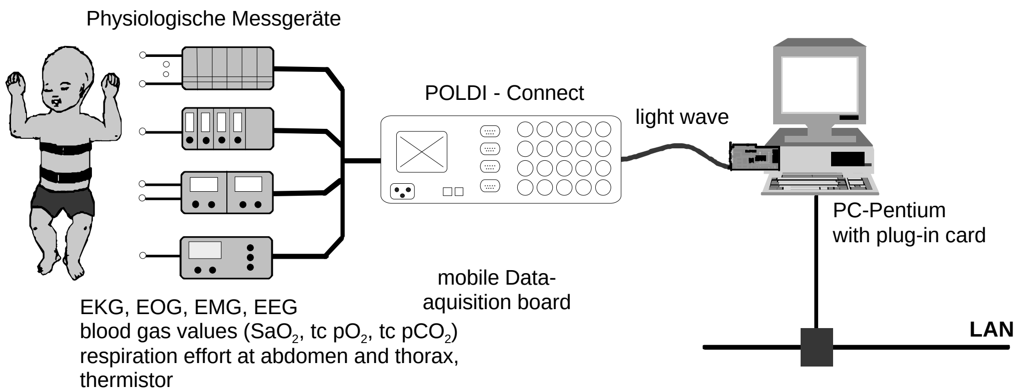

Figure 1. Polysomnographic Diagnosis System POLDI

POLDI-Connect is a general data acquisition frontend for a sleep laboratory. From commercial clinical instruments different physiological signals are measured through their analogue or digital outputs. The measured data are converted to digital and are sent via light wave to a Master-PC.

Figure 2 shows a functional block diagram of POLDI-Connect. A CPU-card manages the measured data as well as the control of the analogue and serial interfaces.

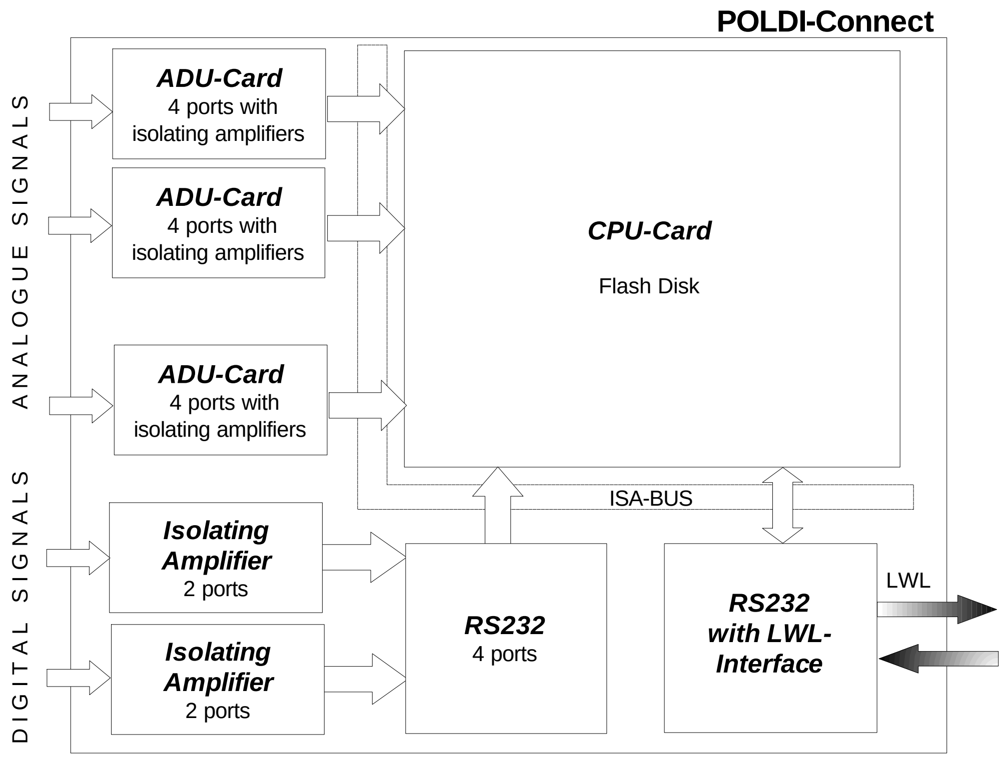

Figure 2. Functional block diagram of POLDI-Connect.

3 RESPIRATION INFORMATION IN THE PHOTOPLETHYSMOGRAPHIC SIGNAL

The blood volume pulse is measured optoelectronically in the patient's finger, toe or earlobe by means of a self developed transmission photoplethysmograph (PPG).

There are two physiological effects influencing on the PPG signal. Besides the pulse wave which is called first order oscillation, it contains other, slower rhythmic fluctuations. On the one hand it carries a heartbeat-synchronous component (Figure 3) and on the other hand also a respiratory part in two different forms:

1. Respiration modulates the heart rate as known from ECG-analysis and hence the frequency of blood volume pulse. This is attributed to the respiratory sinus arrhythmia (RSA).
2. Respiration is superposed additively on the blood volume pulse (Figures 6 and 7). The so called second order oscillation is supposed to be resulted from respiratory fluctuations in arterial blood pressure.

Third order oscillation have a time period of 6 to 20 seconds or longer. Their frequency is often related to respiratory frequency.

Though the photoplethysmographic signal does not follow the pressure pulse but the volume pulse, for real time extraction of respiration the second order wave of arterial blood pressure is used. Assuming that the peripheral arteries have similar characteristics like the aorta there is also a respiratory depending volume wave, which results in a base line fluctuation of the photoplethysomographic signal.

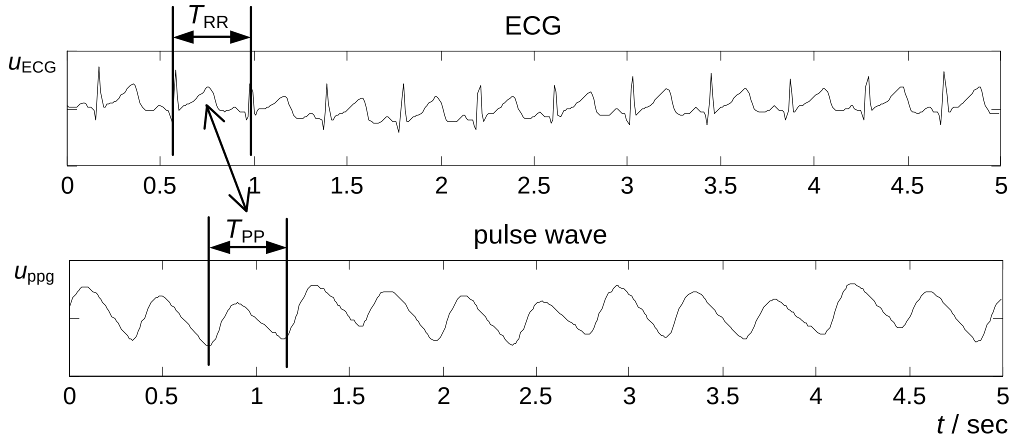

Figure 3. Heart beat synchronous component in ECG and pulse wave signal

4 COMPUTATION OF RESPIRATION INFORMATION FROM THE PPG SIGNAL USING A REAL TIME ALOGORITHM

To compute the respiration effort from PPG signal the effect of respiratory sinus arrhythmia is shown in [1] and [3] with the Wigner-Ville Transformation. This is, however, not suitable for real time computation because of the need of long computation time. In this paper a method is described to display the PPG superposed respiration component.

The program on the CPU-card (*slave*) in POLDI-Connect is upgraded with a real time algorithm to analyse the measured data. It is represented schematically in Figure 4. Data from analogue and serial boards are read out digitally with different frequencies demanded from the Master-PC. The slave sends the data via light wave and additionally they are copied in buffers to be available for further computation. To obtain the respiration the PPG data have to be filtered with a low pass filter with an edge frequency of 1 Hz for infants to extract base line fluctuations. Therefore an recursive digital filter is implemented in the algorithm.

The computed data is send to the Master-PC which displays them in the same way as the original measured data.

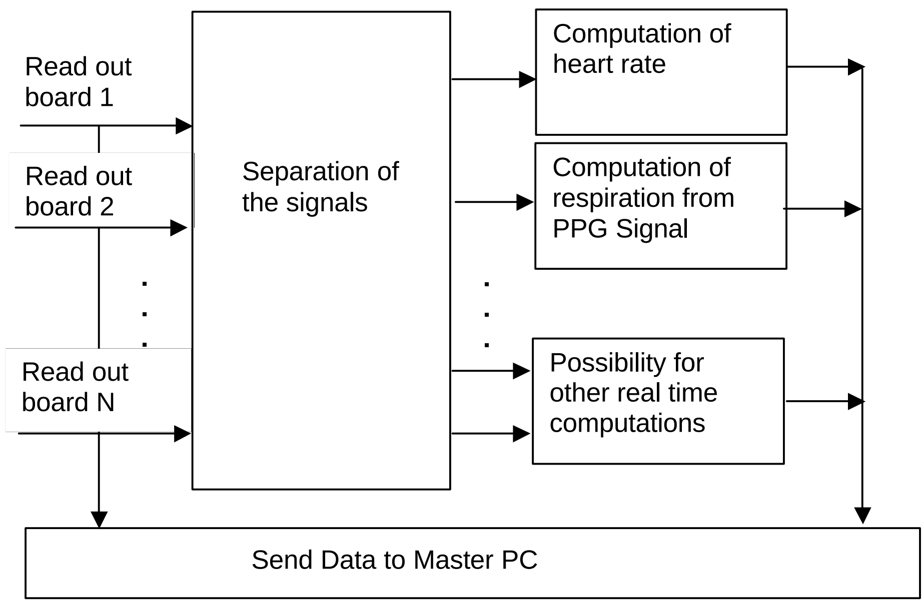

Figure 4. Schematic representation of POLDI's Real-Time-Algorithm

5 RESULTS

Figure 5 shows pulse waves of a patient registered simultaneously at different peripheries with Nellcor Pulsoxymeter N200 [4], MCC Pulse Oxymetry Module Type PO 300 [5] and a self developed instrument. It was not possible to evaluate reliably the pulse waves from the commercial puls-oxymeters' output. Therefore we used the self developed instrument for PPG signal.

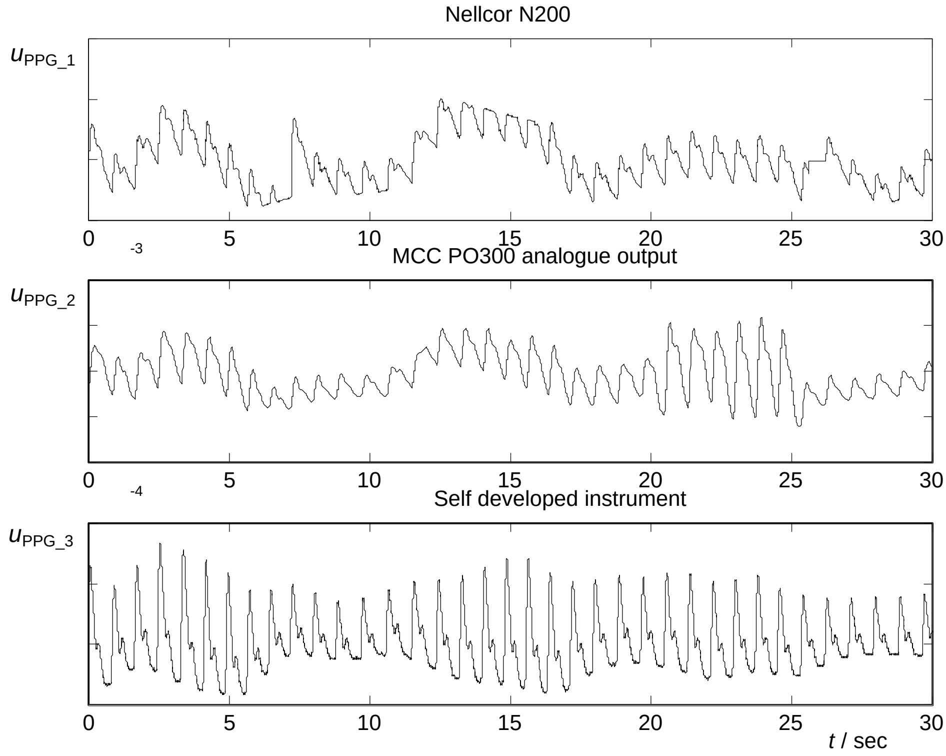

Figure 5. Registered pulse wave with different instruments

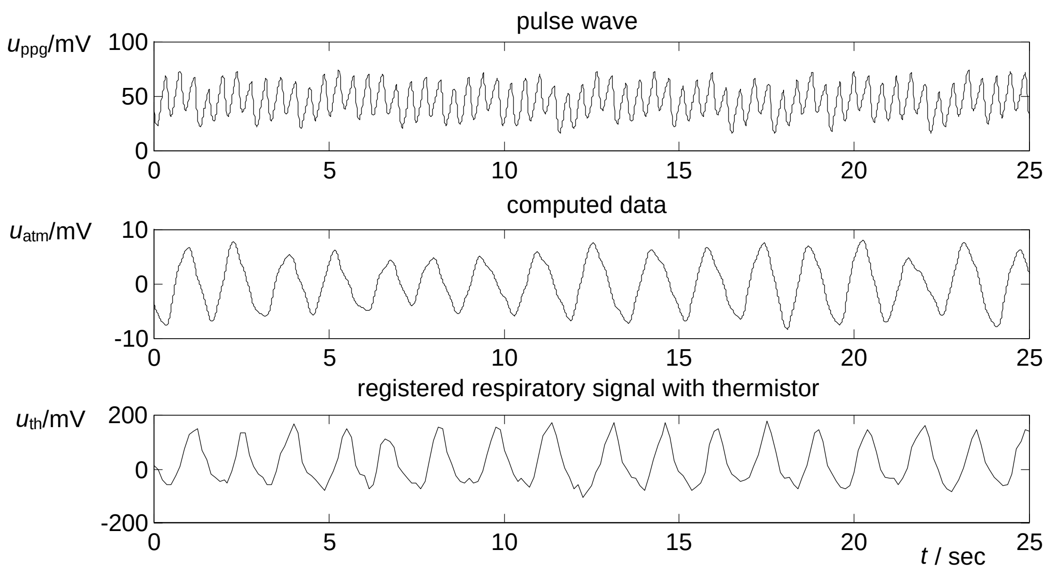

Figure 6. Computed respiratory signal with normal respiration.

Figures 6 and 7 show the photoplethysmographic signal, the computed respiratory effort and as a reference the respiratory signal registered with a thermistor. The pause in respiration is seen in both signals but it occurs with a certain time shift in the computed signal.

We recommend the computed respiratory signal additionally besides the signal of respiration effort at thorax and abdomen and the thermistor registered signal. The signal gives additional information for the interpretation of risky situations.

The real time algorithm offers additional information and relieves the clinical observation. It has the favourable effect of early detection and possible avoidance of risky situations during sleep. All in all it improves the patient's care.

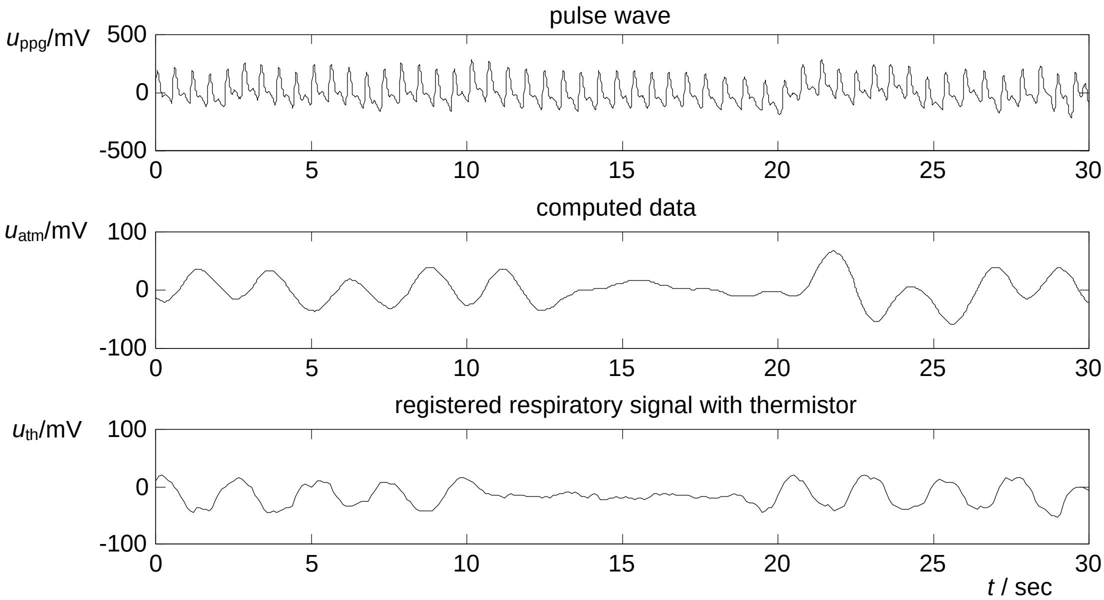

Figure 7. Computed respiratory signal with a respiration pause (apnoea).

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[4] Nellcor: N-200 Pulsoximeter, user's manual
[5] MCC, Manual Pulse Oximetry Module Type PO 300

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