Device for Hemodynamic Parameters Measurement in Veterinary Medicine of Small Animals

Jan Havlík
Faculty of Electrical Engineering
Czech Technical University in Prague
Prague, Czech Republic
email: xhavlikj@fel.cvut.cz, ORCID 0000-0001-9301-6359

Jakub Vitáček
Faculty of Electrical Engineering
Czech Technical University in Prague
Prague, Czech Republic
email: vitacjak@fel.cvut.cz

***Abstract*—The paper describes the design and realization of a device for non-invasive sensing of hemodynamic parameters in veterinary medicine of small animals (dogs and cats). Two main hemodynamic parameters were selected for the measurement blood pressure and heart rate. An oscillometric method was chosen to measure blood pressure. The heart rate is determined from the electrocardiography (ECG) signal, i.e., by sensing the electrical activity of the heart from the body surface. The realized device saves the measured data on the SD card after measuring the signals. To evaluate them, a MATLAB script, which determines the values was implemented. The control of the measuring device and communication with the user is provided by the ESP32 microcontroller. The advantage of the realized device is the possibility of displaying oscillometric pulsations, which is not usually available in commercial devices. Thanks to the simultaneous measurement of the mentioned biological signals, the possibilities of the signal evaluation can be further extended, e.g., by measuring the pulse wave velocity measurement.**

***Index Terms*—hemodynamic parameters, veterinary medicine, blood pressure, heart rate, oscillometric method**

I. INTRODUCTION

Hemodynamic parameters are one of the basic clinical parameters, which should inform about an overall health state and indicate potential risks both in human and veterinary medicine. The hemodynamic parameters reflect blood flow in the vascular bed. The primary hemodynamic parameters are heart rate and blood pressure [1].

The first measurements of blood pressure were (invasively) realized at the beginning of 18. century by Stephen Hales [2]. The non-invasive blood pressure was firstly determined in 1896 by Italian physician Scipione Riva Rocci [3]. The blood pressure is a pulsatile pressure in arteries, which is characterized by systolic (maximal), diastolic (minimal), and mean values. In 2007, the recommendation for blood pressure measurement was created by the American College of Veterinary Interna Medicine (AVCIM) [4]. The updated recommendation was published in 2018 [5]. The method, which is frequently used for non-invasive blood pressure measurement currently, is oscillometry measurement [6], [7]. The typical values of blood pressure in veterinary medicine of small animals are roughly 140 mmHg systolic pressure, 77 mmHg diastolic pressure, and 99 mmHg mean arterial pressure for healthy cats [8], and 119 mmHg systolic pressure, 67 mmHg diastolic pressure and 94 mmHg mean arterial pressure for dogs [9].

The heart rate is defined as the number of ventricular contractions per unit time and is usually given in beats per minute (bpm) [10]. There are several methods for heart rate determination, such as photoplethysmography (PPG) [11] or electrocardiography (ECG) [12]. The ECG method offers a straightforward approach to heart rate, which is not influenced by the health state of peripheral vessels; thus, it is the reason this approach was selected for the study. The typical signal, which is frequently used for heart rate determination from ECG, is lead II (electrodes placed on the right arm and the left leg). The amplitude of the QRS complex in lead II is typically about 2 mV for dogs (about 2.5 mV for bigger races) and about 0.9 mV for cats [13].

The study aims to design and realize a device for non-invasive sensing of basic hemodynamic parameters (heart rate and blood pressure) in veterinary medicine of small animals (typically cats and dogs) and to design and implement signal processing methods for the determination of derived hemodynamic parameters, such as pulse transition time and pulse wave velocity.

In Section II, the design of the device is described. The features of blood pressure measurement and ECG measurement parts are specified, and the related signal processing is described. In Section III, proof of the proposed concept is presented. The device was evaluated on a human volunteer. In Section IV, the results and future steps are briefly discussed.

II. METHODS

The device is designed as a stand-alone measurement device, which consists of several principal blocks (see Figure 1). The whole device is controlled by a microcontroller ESP32 (240 MHz dual-core microcontroller) with an integrated 802.11 b/g/n (WiFi) transceiver/receiver and dual-mode Bluetooth. The data are stored on an SD card for off-line processing and could also be transferred via WiFi network for processing immediately during data acquisition. The main parts of the device are blood pressure measurement and heart rate measurement blocks. The user interface is realized using buttons and LCD. The device could also communicate by the web interface. The power supply unit is designed both for supply from DC voltage sources, such as DC adaptors or from build-in LiON accumulator.

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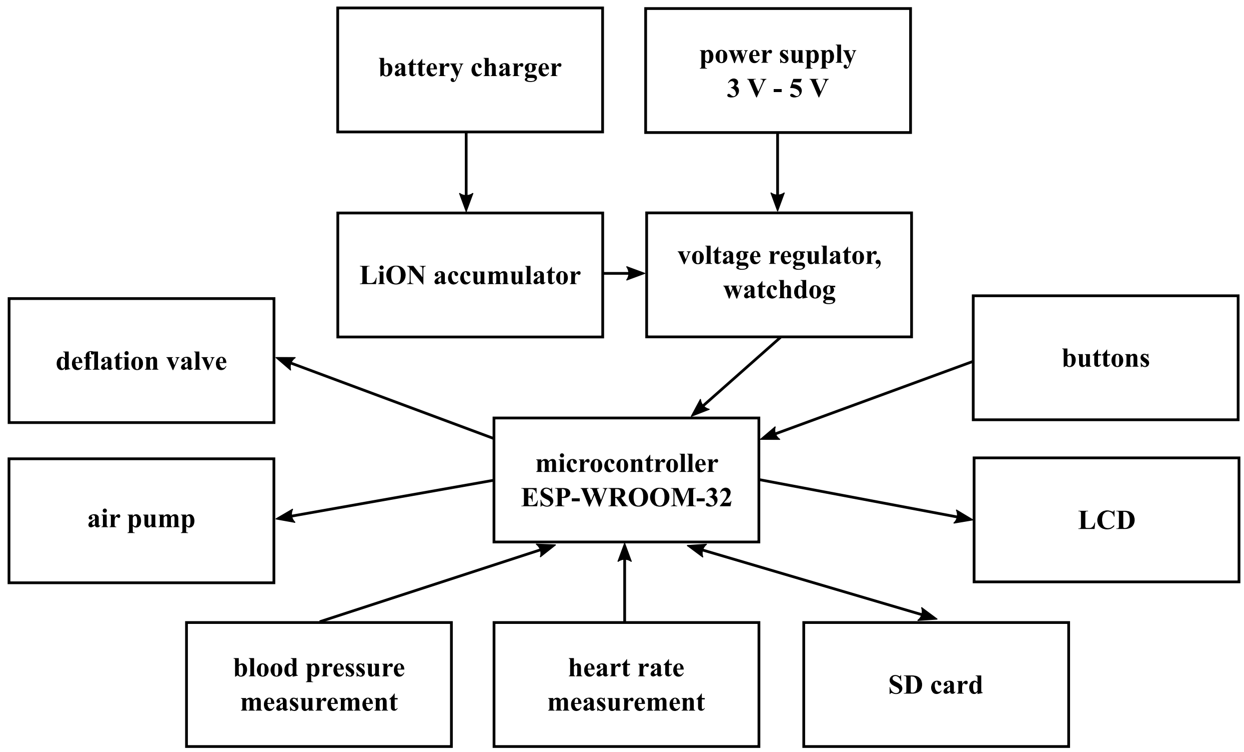

Fig. 1. Block diagram of the device

A. Blood Pressure Measurement

The blood pressure measurement is based on the oscillometry method. The hardware realization of the blood pressure measurement part could be divided into a pneumatic circuit and an electronic part. The pneumatic circuit consists of an air pump for inflating the cuff and a deflation valve. The electronic part includes the pressure sensor MP3V5050 (NXP Semiconductor) [14] and the analog filter (1st order low-pass filter with cut-off frequency 650 Hz) [15]. The signal from the pressure sensor is digitalized by the ADC integrated into the microcontroller. A two-tube newborn size cuff is used for blood pressure measurement.

B. Heart Rate Measurement

The ECG part is based on the single-lead heart rate monitor front-end AD8232 (Analog Devices) [16]. The gain is set to 100 [-], common-mode rejection ratio is at least 80 dB (DC to 60 Hz). Two analog filters are used for a better detection of heart rate by emphasizing the QRS complex in ECG signal. The first one is a 2nd order high-pass filter with cut-off frequency 7 Hz, and the second one is a 2nd order Sallen-Key low-pass filter with cut-off frequency 24 Hz. The additional gain of the filter is 11 [-].

C. Signal Processing

The acquired signals are processed off-line in PC. Firstly, the oscillometry pulsations are extracted from the cuff pressure by band-pass filter with cut-off frequencies 0.5 Hz and 3.5 Hz. Consequently, the envelope of the signal is computed. Afterwards, the mean arterial pressure is determined as a pressure in the cuff at the moment of maximal oscillation (maximum amplitude algorithm) [17]. The systolic and diastolic pressures are determined using the ratio method [18].

Simultaneously, the recorded ECG signal is processed to determine the heart rate. The PanTompkins algorithm is used for ECG signal processing [19].

III. RESULTS

As a proof of concept, the device was evaluated on a human volunteer. The proband was a young healthy woman (25 years, 174 cm, 67 kg). The ECG electrodes were placed on the right arm (RA electrode) and the left leg (LL), the acquired signal corresponding to lead II. The cuff was placed on the left hand. The working range of blood pressure (from 60 mm Hg up to 160 mm Hg) and ECG signal (the amplitude of QRS complex about ones of mV) in human medicine is the same of working range of blood pressure and ECG signal in veterinary medicine of cats and dogs [8], [9], [13].

The acquired ECG signal is shown in Figure 2a in detail, the one-minute record is shown in Figure 2b. All R peaks were detected correctly (highlighted using red triangles). The instantaneous value of the heart rate determined from the ECG signal is shown in Figure 2c.

The signals relating to the blood pressure measurement are shown in Fig 3. The cuff pressure acquired during the deflation of the cuff is shown in Figure 3a. The record of oscillometry pulsations extracted from the cuff pressure is

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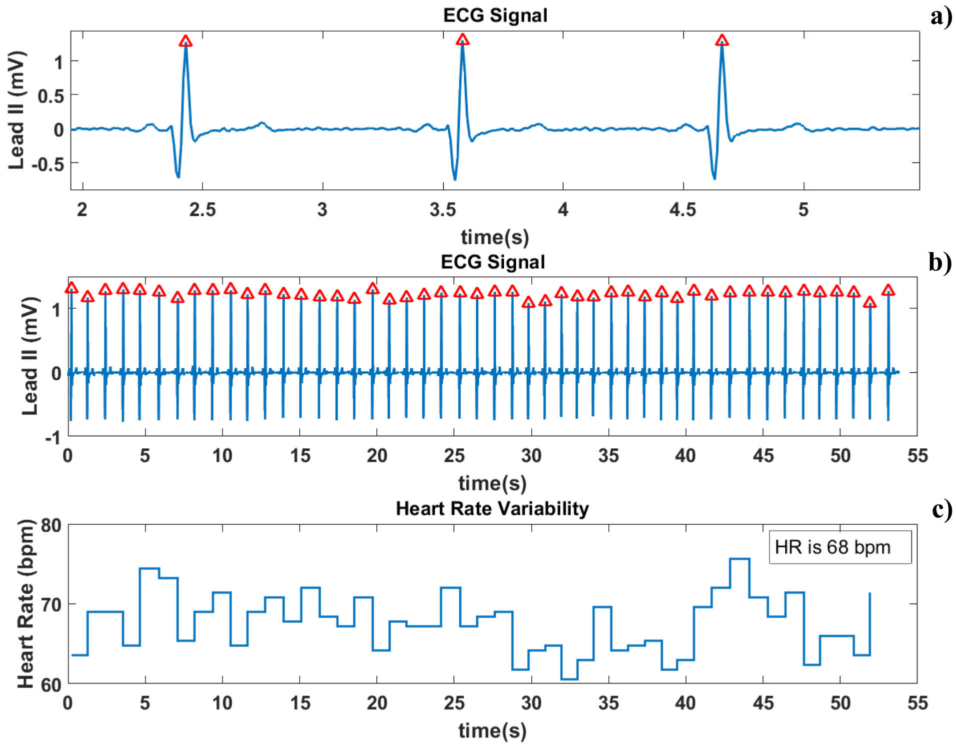

Fig. 2. Example of the ECG signal (lead II) acquired on a human volunteer: a) the detail of the signal, b) the one minute record, c) the instantaneous value of the heart rate determined from the ECG

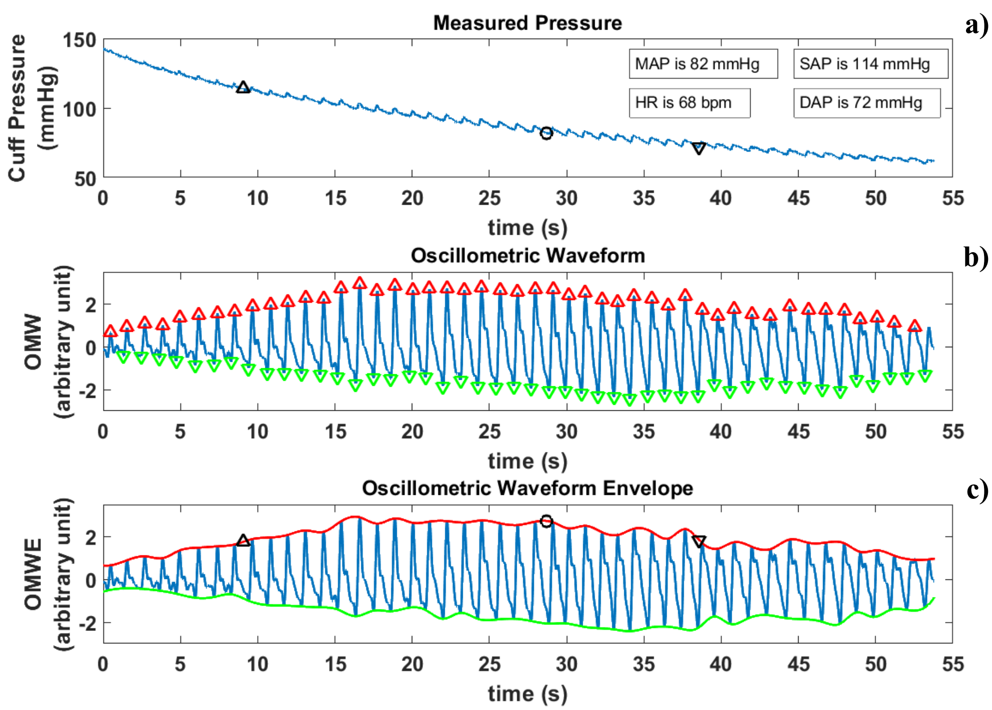

Fig. 3. Example of the blood pressure signals acquired on a human volunteer: a) the cuff pressure acquired during the deflation of the cuff, b) the oscillometric pulsations, c) the oscillometric waveform envelope

shown in Figure 3b, the local extremes of the signal are highlighted by red and green triangles. Consequently, the oscillometric waveform envelope is shown in Figure 3c. The mean arterial, systolic and diastolic pressures determined from the signal envelope are highlighted by a black circle and black triangles, respectively.

IV. CONCLUSION

The paper presents the partial results of the research in progress. The design and realization of a device for non-invasive measurement of ECG and blood pressure in veterinary medicine of small animals have been done.

The concept of the device allows not only the measuring of ECG signal and blood pressure but also the possibility to determine additional hemodynamic parameters, such as pulse transition time (a time difference between the R-peak in ECG and a related maximum of the pulse wave in oscillometric pulsations) or pulse wave velocity.

The future steps will contain the evaluation of the device on small animals in clinical practice and the design and implementation of additional signal processing algorithms for enlarging the set of determined hemodynamic parameters.

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