Data Synchronization for Independent USB Devices

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***Abstract* – This paper deals with solving of the data synchronization problem during the data retrieval from independent devices. The data – oscillometry and photoplethysmography signals – are acquired using three independent measuring devices connected to PC via USB ports. The task is to obtain synchronized data. It means the problem is to sample signals in each device at the same time. The sampling of signals is triggered by internal counters independently in each device, the counters are commonly synchronized by general synchronization packets. The presented sampling method is robust and independent of the state of operating system on superordinate PC.**

I. INTRODUCTION

One of the most frequent affects of cardiovascular system is Atherosclerosis. It is a very dangerous disease, because it produces irreversible changes in cardiovascular system. Atherosclerosis causes that lipids are stored on the walls of blood vessels. It leads to decrease of vessels' elasticity, decrease of vessels' diameter and decrease of blood flow [1]. All of these consequences could be very dangerous for a patient with untreated Atherosclerosis. Unfortunately it is very hard to diagnose Atherosclerosis in an early phase.

The blood pressure measurement is a commonly used basic method for monitoring the cardiovascular system condition. It is used in both hospital and home care. The most frequently used method is non-invasive oscillometry based on evaluation of amplitude envelope of the oscillations in the sphygmomanometer cuff. This method is the standard method for automated blood pressure measurement.

It seems that the oscillometry method could be slightly rearranged. After the rearrangement the method would be able to provide not only information about blood pressure, but also other cardiovascular (hemodynamic) parameters. These could be used for early screening of Atherosclerosis. [2, 3]

The measurement of three signals – oscillometric pulsations from arm and wrist cuffs and photoplethysmographic curve – is required for accurate determination of blood pressure and other hemodynamic parameters. For measuring these signals, three independent modules could be used. The first one is a pulse oximeter that provides photoplethysmographic curve from the finger [4]. Next two modules are kits for non-invasive blood pressure measurement [5].

The modules are connected to a PC and the data from them are synchronized. Software application on the superordinate PC allows to control all devices via USB, synchronize the incoming data and save them into one file. It is possible then for example, to load the data and process the signals in MATLAB.

II. PRINCIPLE OF MEASUREMENT

Two types of measurement kits were used for acquiring the data.

For stopping the blood flow the blood pressure meter with an arm cuff has been used (see Fig. 1). It works in the principle of automated oscillometry measurement [5]. Second measurement kit is also a blood pressure meter with a wrist cuff. The cuff is inflated to pressure under diastolic pressure (typically 40 mmHg or 45 mmHg) and senses the pulses of blood flow on the wrist.

Both modules were developed for research in the field of signal processing and classification. They allow to measure and save raw data. Detailed description of the modules is in [5].

The third module is the module of pulse oximeter. It enables to sense the photoplethysmograph curve on a finger (see Fig 2). Unlike standard devices, the module allows to set some hardware parameters manually and to save raw data.

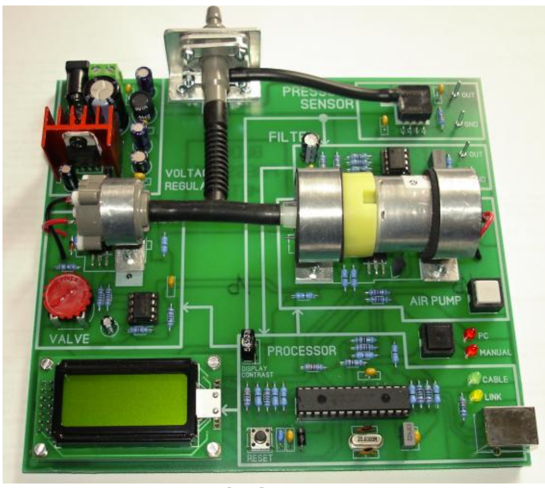

Fig.1: Blood pressure meter

Each module is connected to a PC via USB interface. One software application can control all modules, synchronize data and save them.

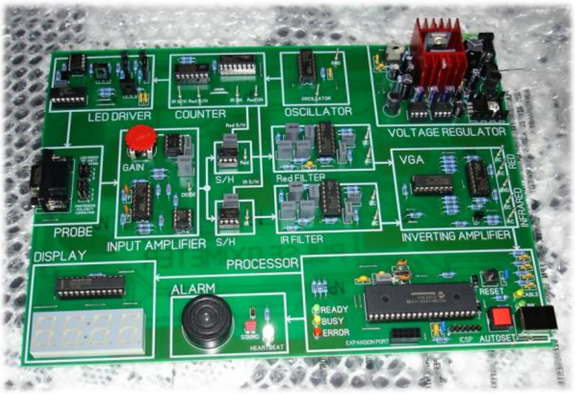

Fig. 2: Pulse oximeter

III. SYNCHRONIZATION

All three modules were developed as standalone modules. They communicate with superordinate PC via USB HID protocol as an independent devices, it means that no driver in PC is required. It is very convenient and easy for users, but it produces some problems. The main problem of using independent devices is to acquire synchronized data from all of them. For accurate processing and classification of obtained signals it is crutial to have signals sampled in the same time.

The solution of this problem has to fulfill some requirements. Firstly it has to be done without intervention to the current hardware realization and with minimal intervention to the current firmware. The second but not least requirement is to maintain compatibility with existing software applications.

Sampling frequency of signals in both types of modules is designed to 100 Hz, but internal interrupt loop runs in the frequency of 1 kHz at all modules. Each interrupt increments local variable. If the variable reaches 10, the analog values are read and sent to a PC and the local variable is set to zero. This solution gives the possibility to simple increase the sampling frequency, but it is not necessary because the maximal frequency component in measured signal is certainly lower than 50 Hz.

The synchronization of all modules is in general based on synchronization packets. Each synchronization packet is sent into all modules roughly at the same time.

Synchronization packet causes reset of local counters. Thus the accuracy of synchronization is 1 ms in total. An example of timing diagram from all modules before and after the synchronization packet is in the Figure 3. The upper part of figure shows the sequences of sampling pulses in non-synchronized devices, the lower part shows the sequences of sampling pulses in synchronized system.

We tested that Windows creates only very small delay to HID output packet (certainly less than 1 ms) in normal case. The problem can appear when you use HUB between modules and a PC. Windows XP SP2 and SP3 contain a bug on HID, which delays HID output report over interrupt OUT endpoint, just when a hub is inserted. For HID input, there is no delay in any Windows version. This problem is described in Microsoft Knowledge Base, article ID 940021 [6].

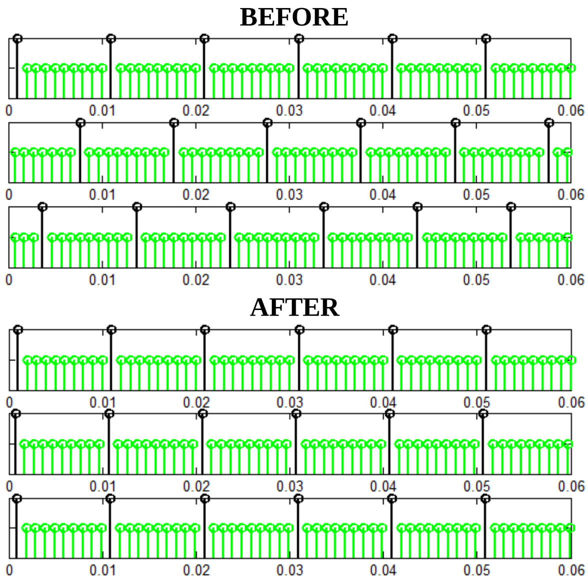

Fig. 3: Timing diagram, black (long) stem means time of reading analog value, green /short) stem is increment of local counter

IV. SOFTWARE

The hardware part is supported by a simple software application (see Fig. 4). The application controls all three modules separately.

Firstly, parameters of the pulse oximeter like red LED and IR LED light intensity and the gain of signals have to be set.

Next step is to inflate the wrist cuff to the pressure under diastolic pressure. This ensures that blood in the artery flows and we sense only pulses. After the measurement, the air valve is released and the cuff is deflated.

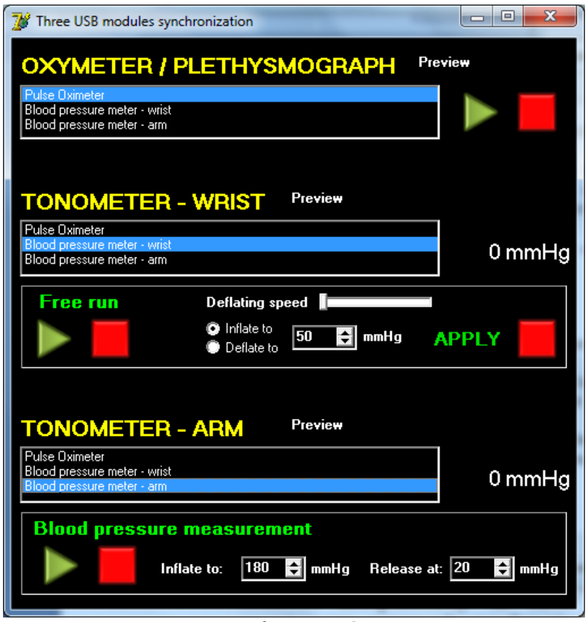

Fig. 4: Software application

Lastly, the measurement could be run. The arm cuff is inflated slightly above limit which is set in the application. It is usually pressure around 180 mmHg. Then, while the arm cuff is being deflated, the absolute pressure and oscillations are acquired.

After the measurement, the data are saved into a CSV file which can be loaded for example in MATLAB.

V. DATA VISUALISATION

Recorded signals could be visualized and analyzed using the supporting SW application (see Fig. 5). The figure shows that if the pressure in cuff is equal to the patient's systolic blood pressure, both the pulses in the wrist cuff and photoplethysmograph pulsations will appear. Systolic pressure can be calculated from oscillations in arm cuff, for example by the standard ratio method [7]. Systolic blood pressure can be determined by selecting the underlying pressure that corresponds to the amplitude of approximately 55% of the maxima amplitude of oscillations (which is mean arterial pressure, MAP) before the point of MAP. Using this method the diastolic blood pressure could be also determined as the underlying pressure that corresponds to the amplitude of approximately 85% of the maximum amplitude of oscillations after the point of MAP.

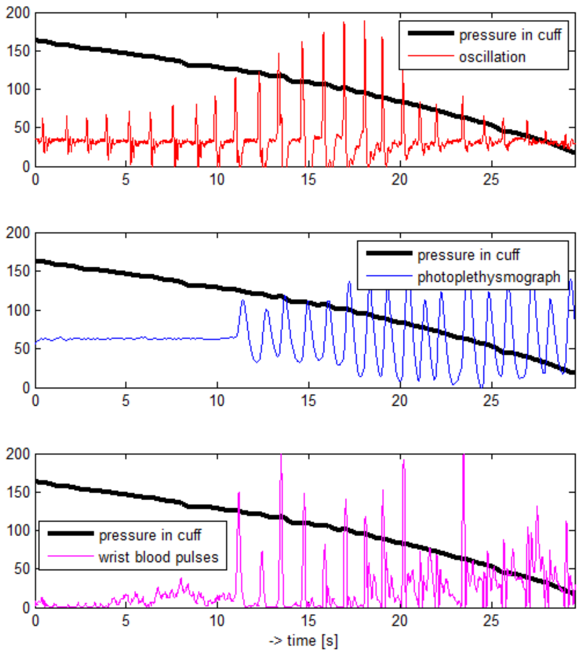

Fig. 5: Data visualization

VI. CONCLUSION

The principle of data synchronization of the independent USB devices was described. We used this method for synchronization of analog samples during a measurement of hemodynamic parameters of the cardiovascular system with minimal intervention on the current laboratory kits. From the visualization, we can see the systolic pressure measured with several automated methods. With this system, we can compare all methods in terms of their accuracy, repeatability and possibility of automated calculation. From all signals, we can also calculate several hemodynamical parameters of cardiovascular system like systolic and diastolic blood pressure, mean arterial pressure, pulse wave velocity, or augmentation index.

The developed application is very simple and allows to continuously read synchronized samples from all the devices. Raw data are saved into a text file that can be processed in MATLAB or another program.

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