Wrist-Located Pulse Detection using IR Reflection due to Pulse Added Volume of Arterial Blood

Jung-Man Hwang, Jung-Min Park, and Seong-Ook Park, Member, IEEE

Department of Engineering, Information and Communications University, 103-6 Munji, Yousong, Daejeon, Korea

Abstract— **This paper presents real time arterial pulse which measured by variable reflection beam due to pulse added volume of arterial blood. Blood Volume Pressure (BVP) and Acceleration BVP (aBVP) is detected by optical reflection on the tissue. LED and Photo Diode (PD) is used as radiator and receiver, respectively. A cold duration test (CDT) is an experiment that measures the variation of the arterial pulse after finishing immersion in 10°C water.**

Key Words— **Blood Volume Pressure (BVP), Acceleration Blood Volume Pressure (aBVP), Cold Duration Test (CDT), Arterial Pulse, and Base-band system**

I. INTRODUCTION

The Arterial Pulse has been used as a fundamental way for diagnosis in traditional Chinese medicine. A physician of the Chinese diagnoses and analyzes the condition of the patient only using their finger's sensibility. This method requires long experiences and an expert skill, and interpretation is subjective, depending on the practitioner. There are some characteristic of the arterial pulse such as fast or slow, tense or tender, floating or sinking, large or small, empty or full, *etc*.. One of the world's recent Chinese medical trend is to develop a quantitative and systematic measurement, analysis and diagnosis [1-2]. In order to analyze patient's hygienic condition accurately, the special measurement such as cold pressor test (CPT) has been tried [3].

In this paper, we propose a novel method to measure the change of BVP, acceleration BVP and CDT. The CDT is the test how long the condition of BVP or aBVP is continued at the special situation. We used optical sensor consisted of LED and photo diode. Compared with previous measurement [3], optical reflecting measurement (ORM) is much more sensitive and can precisely detect signal without pressure for the test point. The ORM can be used at test point where can't employ finger probe.

The system is consisted of photo diode, LED, baseband, and computer. We used pulse signal to operate LED and sample and holder (SAH) so that signal to noise ratio (SNR) is improved and current consumption is reduced.

This paper explains the configuration of the implemented system and presents results of aBVP in the room temperature and aBVP's variation after immersion in cold water.

II. CIRCUIT DESCRIPTION OF THE SYSTEMS

The proposed system is consisted of optical sensor and baseband part. Its detailed block diagram is shown in Fig. 1.

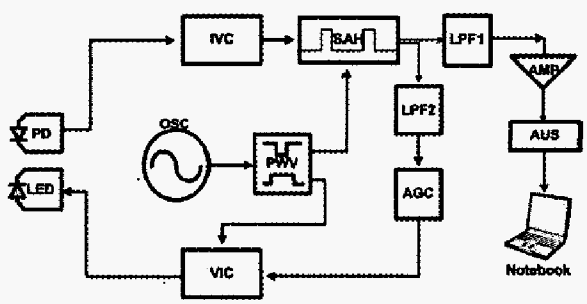

Fig . 1. Block diagram of the aBVP detection system

A. Optical sensor

Infra-red light-emitting diode (LED) which radiate about 900nm wavelength is a source to measure a blood vessel's physical sign. Photo Diode (PD) receives the reflected signal on tissues such as arterial blood, venous blood, capillaries, muscle, and skin. The photo diode wavelength is 900nm. Pliers shape probe has been mainly used to measure BVP or aBVP in hospital. The probe can detect light signal penetrated through tissue that has information of a blood vessel's activity. The resulting signal which reflected on the tissue is detected by a optical sensor, which is located on the wrist at distance about 10mm around the optical source. Fig. 2 shows actual experience.

B. Baseband part

The current signal at the PD output is converted into the voltage in current to voltage converter (IVC). The SAH keep the signal up the DC level. Here the pulse width variation

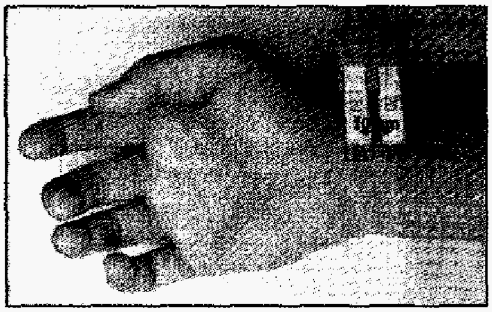

Fig . 2. The actual test of the arterial pulse

(PWV) is employed to supply SAH and VIC with pulse signal, respectively. LPF2 which get rid of low frequency has a cutoff

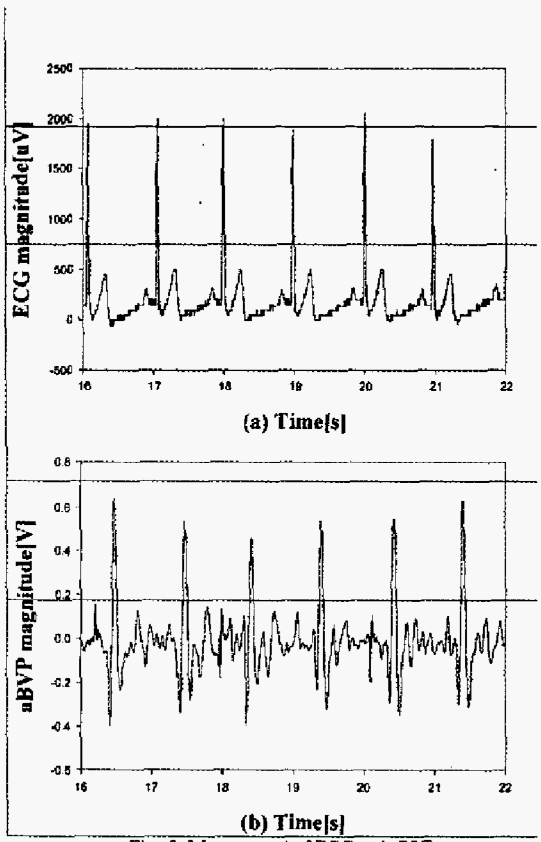

Fig . 3. Measurement of ECG and aBVP

frequency of 0.2Hz. The voltage level controller (LVC) and LPF2 compose important feedback loop to control the LED. The second order derivative circuit (DIF) extract aBVP signal from BVP signal. LPF1 eliminate high frequency signal generated by PWV pulse signal and main 60Hz power supply. We can see the real time arterial pulse signal by means of computer and oscilloscope. Fig. 1 shows entire baseband configuration. We can easily realize baseband stage to detect BVP if we exchange DIF for high pass filter (HPF) which has

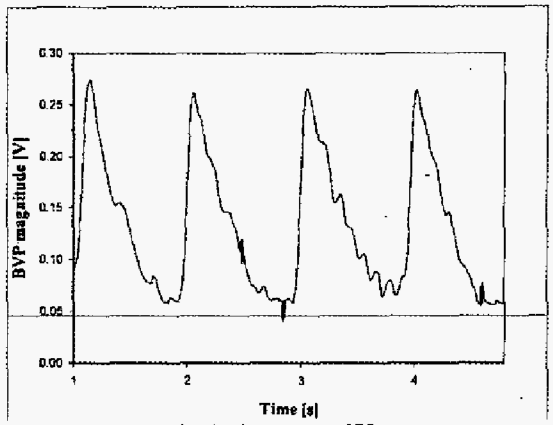

Fig . 4. Measurement of BVP

a cutoff frequency of 0.2Hz and will remove DC offset effect. The last signal is transmitted to notebook computer using USB interface.

III. EXPERIMENTS

A. Test I

The measured aBVP signal detected from the proposed system is compared with those of the electrocardiogram (ECG) signal of monitor which is used for patient monitoring in hospital. We obtained simultaneously ECG and aBVP. Fig. 3 shows that the aBVP signal delayed 0.41 second as compared with the ECG. The LED and PD are separated with the distance 10mm at right wrist as seen in Fig. 2. Subjects rested stretched in our laboratory for more than ten minutes before the test. The measurement keeps going for ten minute. We can find that the aBVP peak points are synchronized with the small pulse of ECG and have corresponding to the period of ECG. If the functional aspect of the period in Fig. 3 can be analyzed, the measurement of the period pulse may have clinical usefulness.

The peak point of aBVP magnitude has a period and fluctuations near by peak. Because the aBVP magnitude is different according to each subject, we used changeable amplifier to adjust the pulse magnitude.

We can also show the blood volume pressure (BVP) when we substitute second order derivative circuit (DIF) by high pass filter (HPF). Fig. 4 shows BVP pulse shape.

B. Test II

A cold duration test (CDT) is similar to cold pressor test (CPT) [3]. In the CDT, we can observe the recuperative power of blood vessel.

First of all, the subject takes a rest about ten minutes before the CDT. And the BVP signal is measured about five minute at the steady state condition. Fig. 5 shows the result. The period of arterial pulse is about one second. And the aBVP peak of arterial pulse has a period which reiterate large and small.

At the next test, the subject immerses his right hand at 10°C cold water for five minutes while the room temperature was 24°C. Thirdly, the hand was taken out of the water, dried and kept in the air for one minute. If the outside temperature drops, our body temperature automatically drops and blood flow is directed toward the inside of the body, away from the skin and the blood vessel will be contracted. Therefore the reflected amount of light in the blood vessel will be decreased. When the temperature of water is colder or immersion time is increased, the reflected amount will be more decreased. Fig. 6 shows the result after finishing immersion. In the room temperature, the measurement kept going about ten minutes. The first peak to peak value is 0.6V. The waveforms returned slowly to normal condition. The normal peak to peak value is 1.2V, which has about two times more than the initial values. In Fig. 6, we observe the blood vessel maintain vasoconstriction state for a while and also period characteristic of arterial pulse has continuously. Every subject has a little bit difference for vasoconstriction duration and velocity of recovery.

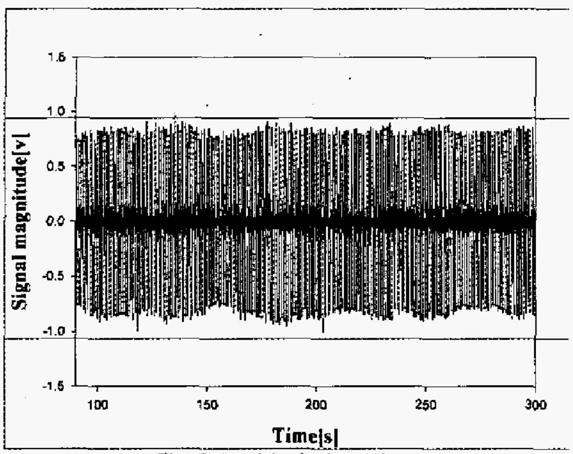

Fig. 5. Arterial pulse in steady state

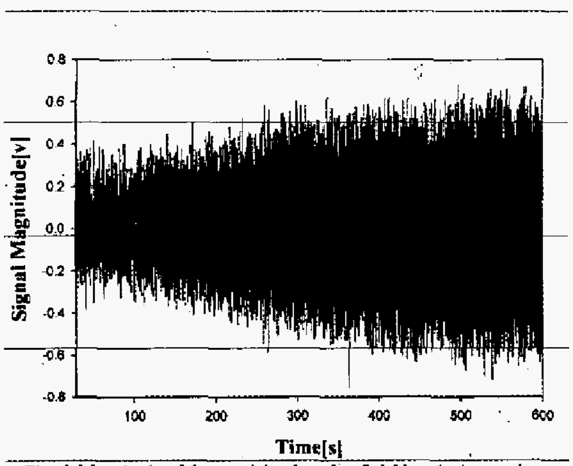

Fig. 6. Magnitude of the arterial pulse after finishing the immersion

IV. RESULT

In this system, LPF2, AGC, and VIC building feedback loop play important part in controlling optical magnitude of LED. Pulse width variation (PWV) generates two pulse signals. One provided to SAH is 130μsec pulse width and another supplied for VIC is 167 μsec pulse width. Two signals are synchronized each other. Supplied pulse frequency at PWV is 1.024 kHz. LPF1 can handle the pass band of the system and unnecessary noise signal from PD and SAH can eliminate. LPF1 has 0.2Hz to 10Hz frequency band width. If suitable HPF is used between LPF1 and AMP, DC offset that make gain control into difficult can be reduced.

The baseband can be simplified as excluding some devices such as SAH, LPF2, PWV, OSC and AGC. However these devices improve system S/N ratio and reduce power loss.

In this experiment, the arterial magnitude and shape is different according to subject. The magnitude of aBVP of old person is smaller than that of young person. The maximum and the minimum ratio and velocity returning to the original state are important values to check the blood vessel's age and the subject's health condition.

V. CONCLUSION

The arterial pulse has several characteristics and various information for parts of the body such as the spleen, stomach, lung, liver, and gallbladder [1]. Traditional Chinese medicine makes use of pulse analysis to diagnose such conditions. However because the pulse analysis is very difficult, the exact diagnosis is also difficult. We have to elucidate slow or fast, tense or tender, floating or sinking, large or small, empty or full of arteriolar vasoconstriction and vasodilatation.

Actually, it is difficult problem to detect and analysis the pulse signal even expert who has long experience. Therefore we make quantitative and standard measurement scheme.

Diversity tests are performed to analyze the arterial pulse such as cold pressure test (CPT) and pulse type classification by varying contact pressure. But there are problems to contact pressure on the test point. Pressure sensor affects the blood flow and pressure. Consequently the data including in the arterial pulse may be distorted. But the optical sensor using beam reflection does not affect the blood vessel. Also the sensor is useful for measurement on the all parts of the body.

The CDT will be useful for those who have a blood vessel disease and old people. We need to measure more subjects and diverse bodily shape and physical constitution.

VI. ACKNOWLEDGEMENT

The authors are appreciate for Laxtha Company for implementing the measured system.

REFERENCES

[1] Lu WA, Wang YYL, and Wang WK, "Pulse Analysis of Patients with Severe Liver Problems" IEEE Eng Med Biol Mag 18(1): 73 1999

[2] Y.Z Yoon, M.H Lee, K.S Soh, "Pulse Type Classification by Varying Contack Pressure" IEEE Eng Med Biol Mag 19(6):106-110 2000

[3] K. W Mun, K. S. Soh, "Chang of Arterial Pulse Shape During a Cold Pressor Test" Journal of the Korean Physical Society vol 40, No 2, February 2002, pp 289~292.

[4] Wang Lin YY, Chang CC, Chen JC, Hsiu H, Wang WK, "Pressure wave propagation in artery- A model with radial dilatation for simulating the behavior of a real artery" IEEE Eng. in Med. and Biol., 16(1): 51~56, 1997.

[5] Kanjilal. P. P, Palit. S, Saha. G, "Fetal ECG Extraction from Single-Channel Maternal ECG Using Singular Value Decomposition" IEEE Trans. Biomed. Eng., vol 44(1), 1997.

[6] J. H. Van Bemmel, "Detection of weak electrocardiograms by autocorrelation and cross correlation envelopes," IEEE Trans. Biomed. Eng., vol BME-15, PP.17-23, 1968.

[7] R. Pallas-areny, J. Colominus-balague, and F. J. Rosell, "The effect of respiration-induced heart movements on the ECG," IEEE Trans. Biomed. Eng., vol BME-36, PP. 585-590, 1989..

[8] S. M. S. Jalaleddine, C. G. Hutchens, R. D. Strattan, and W. A. Coberley, "ECG data Compression techniques- A unified approach," IEEE Trans. Biomed. Eng., vol 37, no. 4, pp. 329-343, 1990..

[9] Ali Khamene, Shahriar Negahdaripour, " A New Method for the Extraction of Fetal ECG from the Composite Abdominal Signal" IEEE Trans. Biomed. Eng., vol. 47, no. 4, april 2000.

[10] C. Li, C. Zheng, and C. Tai, "Detection of ECG characteristic points using wavelet transforms," IEEE Trans, on Biomed. Eng., vol. 42, no. 1, pp. 21-28, Jan. 1995.

[11] T. A. Reichert, R. L. Longini, J. Sl Crowley, and J. M. Yu, "A noninvasive extraction of the fetal electrocardiogram," Comput. Biomed. Res., vol. 10, pp. 1-7, 1977.