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Development of the device to detect *SPO_2 in the Field*

Yoshiaki KANAEDA, *Student Member, Tokai University, Japan,* Kazushige MAGATANI, *Member, Tokai University, Japan*

Abstract— **In case of disaster such as a severe earthquake, many sufferers will be generated at the disaster area. In this situation, we have a problem that sometimes rescuers are also injured by disaster. In order to avoid such damage, various kinds of rescue robots are being developed and used. Most of them are developed to remove debris and obstacles. Using these robots, we can find sufferers and rescue them in safety. However, rescue robots cannot asses a sufferer's condition at the disaster area. If some vital signs can be measured by a rescue robot, the efficiency of rescue operation will be greatly improved. Our objective of this study is the development of measurement methods that can assess sufferer's vital signs at the disaster area by a rescue robot.**

In this paper, we will talk about a developed method that can measure pulse and SPO_2. Most of SPO_2 measurement methods are using red and infrared ray that penetrate the skin. However, reflected rays are used to measure these vital signs in our method. Intensity of red and infrared ray is controlled automatically in order to measure vital signs stably. Using this method, these vital signs can be measured only by touching the sufferer's skin with a developed sensor. We think that this method will be powerful and useful to rescue sufferers at disaster area.

I. INTRODUCTION

In case of disaster such as a severe earthquake, many sufferers will be generated at the disaster area. In such situation, rescuers also expose themselves to danger, and sometimes rescuers are injured by disaster. In order to avoid such damage, various kinds of rescue robots are being developed and used. Most of them are developed to remove debris and make route to sufferers. Using these robots, we can find sufferers and rescue them in safety. However, rescue robots cannot assess a sufferer's condition at the disaster area. In other words, we cannot measure sufferer's vital signs using a rescue robot. Therefore, after rescue operation, we can assess body conditions of sufferers, and sometimes it is too late to save their life. If some vital signs can be measured by a rescue robot at the disaster area, the efficiency of rescue operation will be greatly improved. Our objective of this study is the development of measurement methods that can measure sufferer's vital signs and assess the sufferer's body condition at the disaster area by a rescue robot. We are now developing a SPO_2 measurement system and an ECG measurement system [1]. In this paper, we will talk about a developed method that can measure pulse and SPO_2.

SPO_2 (Saturation of Peripheral Oxygen) is one of the most important vital signs. This value means oxygen saturation level in arterial blood. Generally, the pulse oximetry method is used to measure SPO_2. In most case, SPO_2 is calculated using changing absorbance of the red and infrared ray that penetrates the skin. If we use penetrated rays, a sensor for SPO_2 has to be placed on a thin part of the body (for example, a fingertip or earlobe). A light source and a photo detecting device have to be placed one side and the other side of this part. Because of difficulty of sensor setting, it will be difficult for a rescue robot to measure penetrated rays at the disaster area. So, in our SPO_2 measurement system, SPO_2 is calculated using red and infrared rays that are reflected with the skin. A sensor of this system is consists of red and infrared ray LEDs and photo detectors for them. In our system, intensity of red and infrared ray is controlled automatically in order to measure SPO_2 stably. Using this method, SPO2 can be measured only by touching the sufferer's skin with a developed sensor. A changing of reflected ray amplitude indicates pulse wave, and pulse rate also can be measured by this pulse wave. I hope that this system operate in the field.

II. DETECTION

As mentioned earlier, SPO_2 means oxygen saturation level in arterial blood. SPO_2 is expressed as the following formula.

$$SPO_2 = \frac{HbO_2}{HbO_2 + Hb}$$

Where, HbO2 means the amount of oxy hemoglobin and Hb means the amount of de-oxy hemoglobin in arterial blood. In order to calculate SPO_2, the ratio of changing absorbance of the red (wave length is about 660nm) and infrared (wave length is about 900nm) ray is usually used. Because infrared ray is absorbed in de-oxy-hemoglobin and red ray is absorbed in oxy-hemoglobin. In this paper, changing of reflected red ray and infrared ray are called red pulse and infrared pulse respectively. Fig.1 shows examples of a red pulse and an infrared pulse. In this figure, yellow colored wave means an infrared pulse and red colored wave means a red pulse. Actually, SPO_2 is obtained as a ratio of a magnitude of a red pulse and a magnitude of an infrared pulse. To calculate SPO_2, following formulas are used.

$$\Delta A = \log(\frac{I}{I - \Delta I})$$

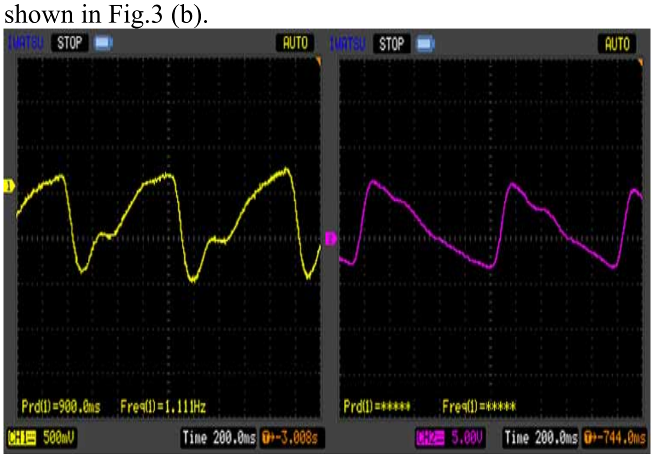
$$\Delta B = \log(\frac{L}{L - \Delta L})$$

$$\phi = \frac{\Delta A}{\Delta B}$$

$$SPO_2 = (\frac{Ia}{Ia + La}) \times \Phi \times 100 \cdots\cdots (1)$$

Where, I and L mean the maximum amplitude of an infrared pulse and a red pulse respectively. ΔI and ΔL mean the minimum amplitude of an infrared pulse and a red pulse respectively. Φ is the absorbing light constant. Ia and La mean the average of an infrared pulse and a red pulse respectively [2].

Fig.2 shows a block diagram of our SPO_2 measurement system. As shown in this figure, a sensor includes a red LED (wave length is 660nm), an infrared LED (wave length is 900nm) and photo diodes for each light source. Rays that are reflected with the skin are amplified and filtered with noises and then analog to digital converted. In this system, the red pulse and the infrared pulse are alternately measured every two seconds. This A/D convertor is included in the one chip micro processor (PIC 16F877) and the resolution of this convertor is 10bit. Digitized red and infrared pulses are analyzed and the intensity of each right source is adjusted so that the amplitude of pulses may become the best size. In our system, intensity of brightness of LED is controlled by adjusting the current that flows to the LED. A D/A convertor to adjust the current has 8bit resolution. Using this adjusting system, even if the sensor is put on thin clothes, we can obtain a pulse wave. SPO_2 is calculated in the PIC using the above mentioned formula, and calculated SPO_2 is shown in the seven segment display devices. Fig.3 (a) shows the developed SPO_2 measurement system. A sensor for this system is also shown in Fig.3 (b).



(a) Infrared pulse (b) Red pulse

Fig.1 Example of red pulse and infrared pulse

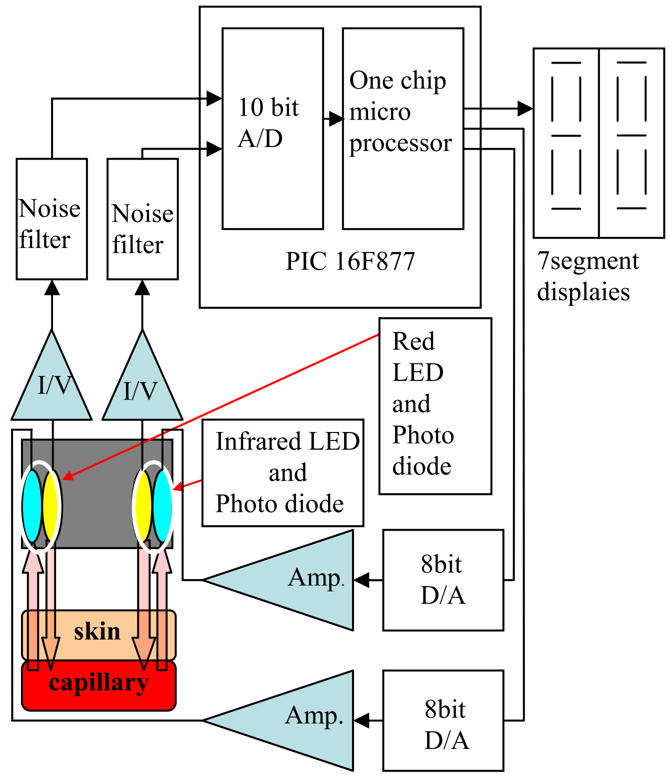
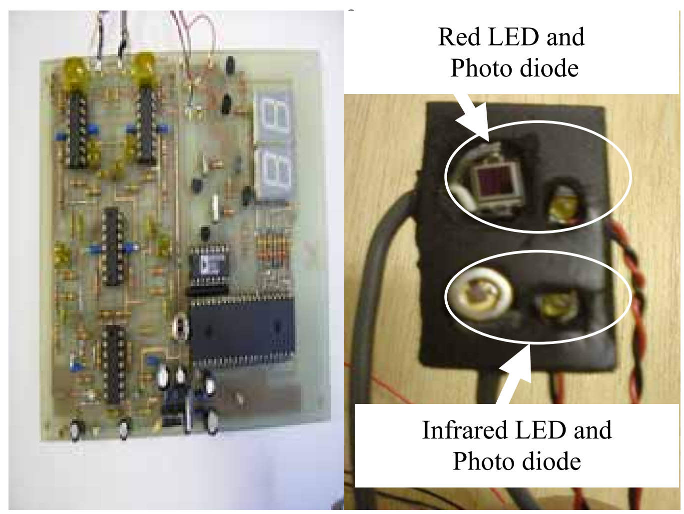


Fig.2 Block diagram of SPO_2 measuring system



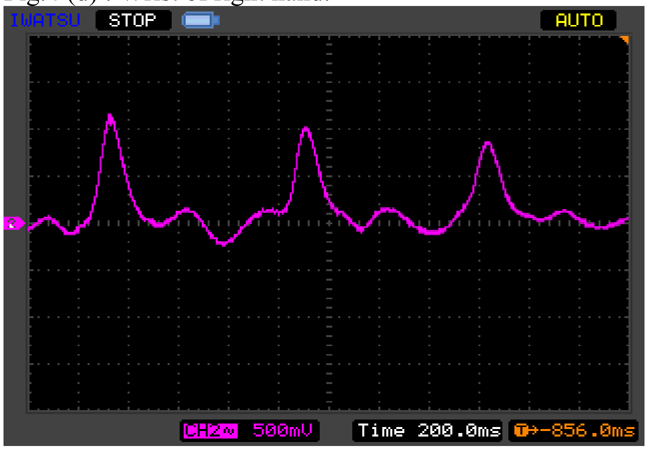
(a) (b)

Fig.3 SPO_2 detecting system and sensor for the system

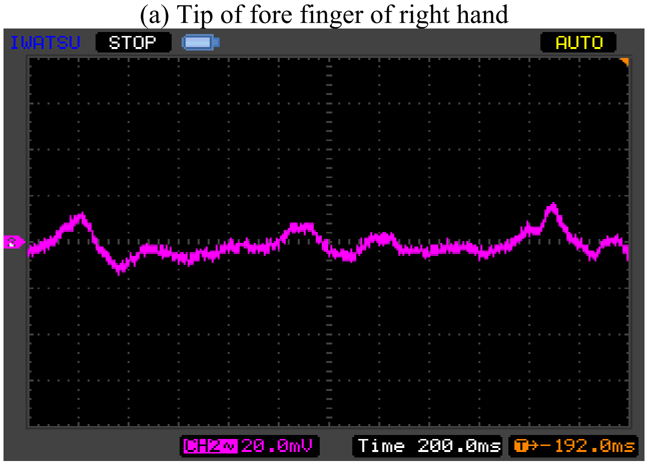
Experiment

A developed system was tested with three normal subjects. First of all, the measurement of the pulse was tried from various parts of the body. In this experiment, infrared ray was used as a light source. The results of this experiment are shown in Fig.4. In this figure, the measurement part is as follows.

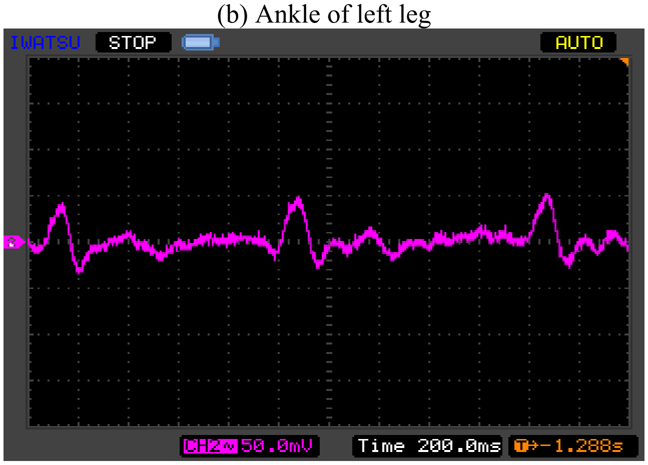
Fig.4 (a) : Tip of fore finger of right hand.
Fig.4 (b) : Ankle of left leg.
Fig.4 (c) : Neck.
Fig.4 (d) : Wrist of right hand.



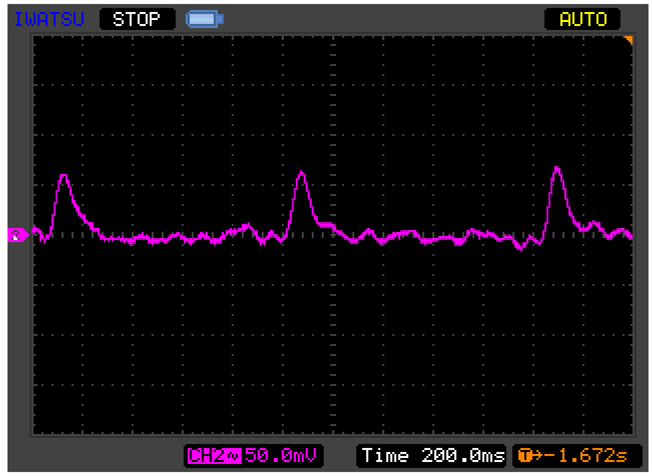
(a) Tip of fore finger of right hand



(b) Ankle of left leg



(c) Neck



(d) Wrist of right hand

Fig.4 Pulse that were measured from various parts of the body

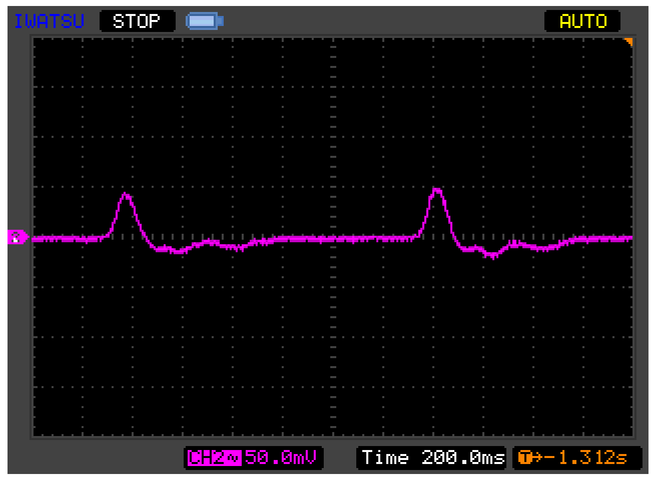


Fig.5 The pulse wave through one cloth

Considering the measurement SPO_2 at the disaster area, data cannot be necessarily obtained directly from the skin. So, the cloth was put on the tip of a finger, and the sensor was put on this cloth. An example of measured pulse wave under this condition is shown in Fig.5.

Using developed system, SPO_2 was measured from the tip of a fore finger of right hand. In this experiment, SPO_2 was measured at the same time with a pulse oxymeter (Nihon Koden Ltd. OVL-3100) as a reference data. The results of this experiment are shown in Table1.These subjects are healthy people

Table1 Measured SPO_2 values

Subject	Measured SPO2 by the pulse oxymeter (%)	Measured SPO_2 by the developed System (%)
A	98	99
B	96	97
C	97	96

Discussion

When the pulse wave is measured using red or infrared ray, it is said that the shape of pulse depends on the distribution of the capillary in the measurement part, and good pulse wave can be obtained in the part where a lot of capillaries are distributed. As shown in Fig.4, the case measured from the tip of a finger is the best. This result shows that this opinion is correct. However, in other places where the distribution of the capillary was a little, the pulse was able to be measured. These results show that the function to adjust intensity of brightness of LED works correctly. As shown in the formula that shows SPO_2, SPO_2 can be measured if the pulse can be measured. Therefore, it is thought that SPO_2 can be measured from places other than the tip of a finger. Considering the measurement SPO_2 at the disaster area, data cannot be necessarily obtained directly from the skin. In this case, a sensor will be put on the clothes. As shown in Fig.5, it is thought that SPO_2 can be measured through clothes if it is thin clothes. Therefore, this adjust function is useful to measure SPO_2 at the disaster area.

As mentioned earlier, the red pulse and the infrared pulse are alternately measured every two seconds in our system. As shown in Table1, most of measured SPO_2 value are larger than reference value. So using this hardware, amplified and filtered red and infrared pulse were analog to digital converted at the same time. SPO_2 were calculated using these data in a personal computer. The results of these calculations were very near the reference in all cases. In the personal computer, the same calculation as our system is done excluding A/D conversion, and it is understood that there is a problem in A/D conversion. So, we will solve this problem and improve the system in future.

III. CONCLUSIONS

Conclusion

In this paper, we talked about a developed system that can measure pulse and SPO_2. In our SPO_2 measurement system, SPO_2 is calculated using red and infrared rays that are reflected with the skin. This system was tested with normal subjects and evaluated. From the experiments, the function to adjust intensity of brightness of LED works correctly. And it was shown to be able to measure SPO_2 in many cases. Moreover, it was clarified that there was a problem in the analog to digital conversion software. Therefore, we've concluded that if this problem is improved, developed SPO_2 measurement system will be a very valuable one to support rescue operation at the disaster area.

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