Wearable EDA Sensor Gloves using Conducting Fabric and Embedded System

*Y. B. Lee, S. W. Yoon, C. K. Lee, M. H. Lee

***Abstract*—We developed wearable EDA sensor gloves using conducting fabric and embedded system. EDA(Electro-dermal Activity) signal is an electric response on the skin of the human body. There are SCL(Skin Conductance Level) and SCR(Skin Conductance Response) in EDA. Mostly, SCL consists of DC elements. On the other hand, SCR consists of AC elements. We use the relationship between the drowsiness condition and EDA signal. We made EDA sensors using conducting fabric instead of Agcl electrode for a more suitable wearable device. And we used an embedded system for EDA signal acquisition and processing instead of a personal computer, which is connected to the EDA sensor gloves through conducting fabric lines. Also, the embedded system is linked to a Notebook PC that shows the results of EDA signal processing analysis and gives proper feedback to the user. This system, for example, can be used in detecting and preventing drowsiness driving accidents for automobile drivers.**

***Index Terms*—Wearable Sensor Glove, EDA, Conducting fabric, and Embedded System.**

I. Outline

The total system is consisted of EDA sensor gloves, EDA measurement system, Embedded system and Notebook PC. In EDA sensor gloves, we located EDA sensor using conducting fabric for proper measuring EDA signal. There are two electrodes for measuring EDA signal. We connected EDA sensor gloves to EDA measurement system and embedded system through conducting fabric lines. We made the EDA measurement system and embedded system as Arm band type, because that type is comfortable for user just like arm-band type MP3 Player. EDA measurement system is analog circuit hardware that measures and filters EDA signal to make SCR, SCL signal. That system make AD conversion of SCR, SCL signal, and converted signal is transmitted to embedded system.

Embedded system make signal processing for SCR, SCL signal using embedded program and passed the signal processing result to Notebook PC. In Notebook PC, the user interface software shows the EDA signal processing result to user, and make feedback response such as drowsiness driving prevention alert.

Manuscript received April 3, 2006. This work was supported in part by Ministry of Information and Communication, Republic of Korea under Grant A1100-0501-0028. *Asterisk indicates corresponding author.*

*Y. B. Lee is with Department of Electrical and Electronics Engineering, Yonsei University, Seoul, Korea (e-mail: youngtiger@yonsei.ac.kr).
S. W. Yoon is with Department of Electrical and Electronics Engineering, Yonsei University, Seoul, Korea (e-mail: capysw@yonsei.ac.kr).
C. K. Lee is with Department of Electrical and Electronics Engineering, Yonsei University, Seoul, Korea (e-mail: micon78@yonsei.ac.kr).
M. H. Lee is with Department of Electrical and Electronics Engineering, Yonsei University, Seoul, Korea (e-mail: mhlee@yonsei.ac.kr).

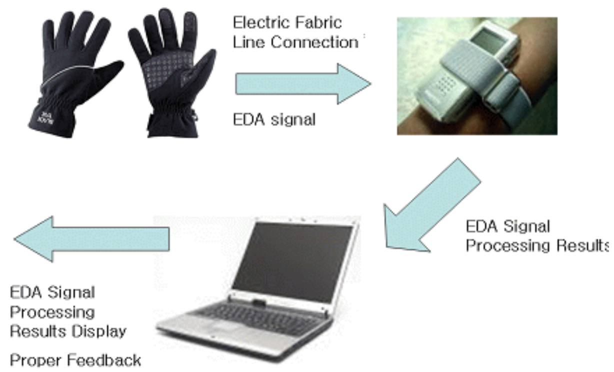

Fig. 1. Total System Outline

II. Hardware Design and Implementation

Figure 2 is total block diagram of EDA signal measurement system. The hardware is consisted of constant current generation circuit part, Instrumental amplifier part and ADC circuit part.

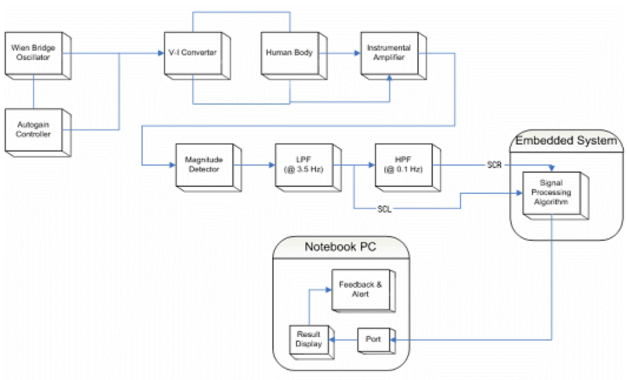

Fig. 2. EDA measurement system Block diagram

A. *Constant current generation circuit part*

Constant current generation circuit is consisted of Wien Bridge Oscillator, Auto-gain Controller and V-I Converter. Wien Bridge Oscillator makes resonance using unstable noninverting input characteristics. We make 20Hz alternating current voltage using this oscillator. Autogain Controller is the circuit that compensates oscillated alternating current. The signal caused by unstable noninverting channel is not stable. So we need to make oscillated signal to stable signal. Briefly speaking, if the magnitude of signal is bigger than threshold, it will be reduced, and the magnitude of signal is smaller than threshold, it will be amplified, and we can obtain constant voltage. V-I Converter is the circuit that translates input voltage to corresponding current. The dangerous parameter to our body is current, not voltage, so we must use constant current, not constant voltage.

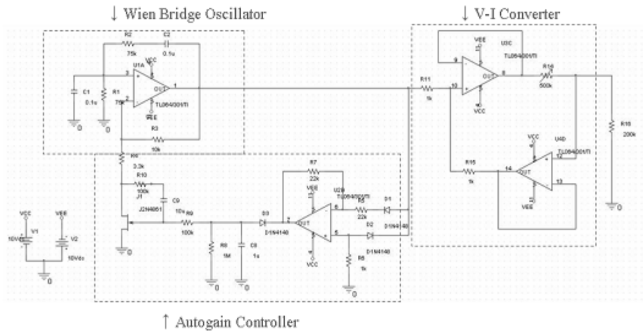

Fig. 3. Constant current generation circuit

B. *Skin impedance measurement circuit*

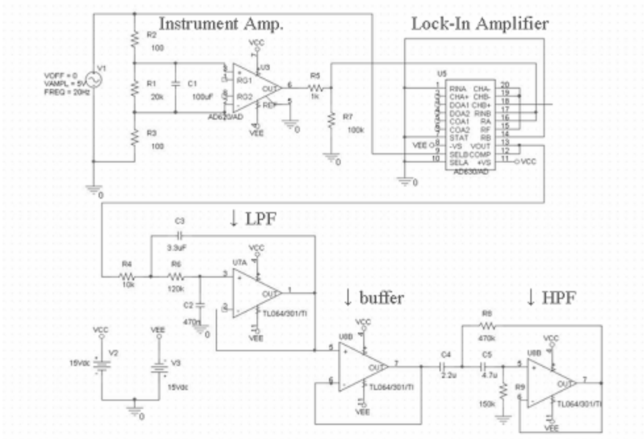

Fig. 4. Skin impedance measurement circuit

Figure 4 shows the skin impedance measurement circuit. We use AD620 as Instrumental Amplifier. AD620 is low price, low voltage instrumental amplifier, and high input impedance(10 GΩ), low offset voltage(50 μV max), low noise feature(0.28 μV p-p noise). AD630 is Lock-In Amplifier that prevents the phase difference noise, and 60Hz noise, and show the real time magnitude of skin impedance signal. Lock-in amplifier translate input signal to DC level signal for easy view. In filter part, we use 2nd Butterworth filter, and we connect 3.5Hz low pass filter and 0.3Hz high pass filter that classify SCR signal and SCL signal. Figure 5 is the picture of implemented system.

C. *A/D Conversion and monitoring*

For test of EDA measurement system, we use BIOPAC system for A/D Conversion. And we use MATLAB software to monitor skin impedance signal such as SCR, SCL signal. Figure 6 is measured SCL, SCR signal.

Using this method, we knew that this system is well working. So we made AD Converter circuit. Figure 7 is A/D converter circuit diagram. We use ADS7806 made in Texas Instruments for AD converter. ADS7806 is low power CMOS designed 12bit ADC. Skin impedance signal is very small signal, so we need high resolution. That is why we use 12bit ADC. And we use PIC16F84 made in microchip for controlling the ADC chip.

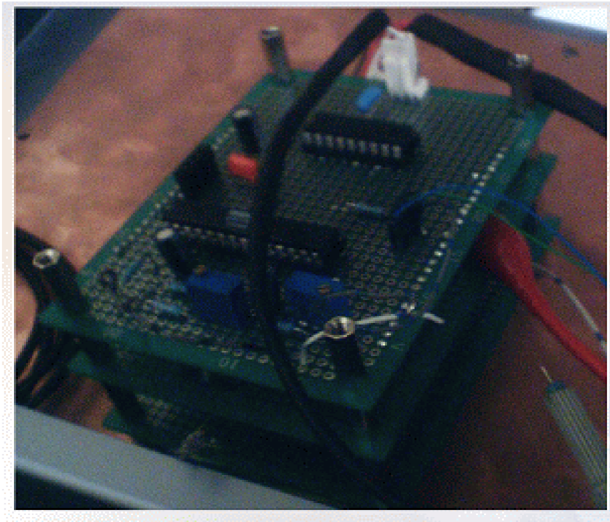

Fig. 5. EDA measurement system

III. EMBEDDED SYSTEM IMPLEMENTATION

We use embedded system based on Pxa270 Processor, Processor speed is 520MHz, and Power Supply IC is S1F81150. Flash memory is 64MB, SDRAM is 64MB. Ethernet chip is LAN91C111 and implement fully integrated IEEE 802.3/802.3u-100Base-TX/10Base-T Physical Layer. Serial port is UART for debugging port, USB port is USB 1.1 Host Support. I/O Board supports PCMCIA, Bluetooth, Stereo Audio, Camera Interface, IrDA interface. And the software specification of embedded system is based embedded LINUX OS. Bootloader is u-boot 1.2, Kernel is LINUX-2.6.9, Ramdisk is busybox-1.0, Supported device driver is serial port, MTD Flash support, Memory Management Unit, Ethernet Support, USB Host Support 1.1 Spec, LCD 16/18bpp display support, Touch Screen Support, APM & DVM/DFM Power Control support, PCMCIA support, Camera Interface, IrDA Support, Bluetooth Support, USB Client Support. Now, we completed embedded system initialization and installed device driver software and continued to make EDA signal processing algorithm.

We connected EDA signal measurement system to embedded system. And we made EDA signal monitoring software using TCP/IP communication on Notebook PC. Figure 9 is developed software screenshot.

IV. EDA SIGNAL PROCESSING ALGORITHM IMPLEMENTATION

After EDA signal measurement started, we have stable time for 5 minutes. And we calculate basal impedance using SCL average for 3 minutes. And we obtain Nz index that is SCL value divided by BI. And we define SCR revelation interval as IRI (Inter SCR Interval). This process repeated every 30 minutes while we measure EDA signal. We classify Awareness as 3 steps. That is Awake (Small), Sleepy

(Medium), and Sleep (Big).

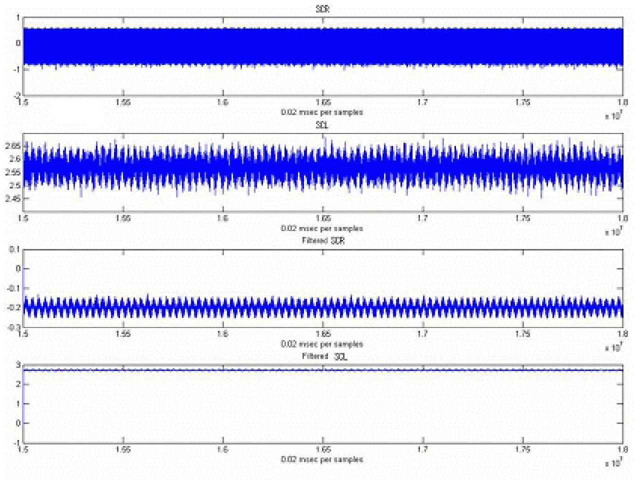
Fig. 6. SCL, SCR signal using BIOPAC and MATLAB

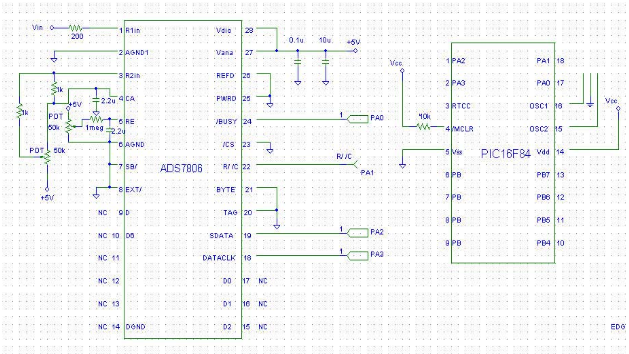
Fig. 7. AD converter circuit diagram

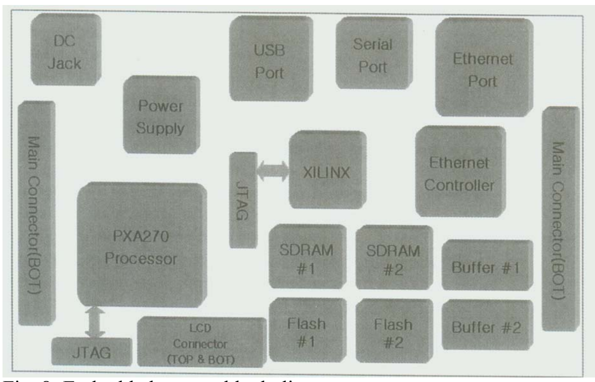

Fig. 8. Embedded system block diagram

Figure 11 is Awareness classification condition table. We will make EDA signal processing algorithm based on figure 10, 11.

V. EDA SENSOR GLOVES DESIGN

Figure 12 shows existing research example about Sensor glove that has various biosensors monitoring Skin potential, Skin temperature, Skin conductance, Skin blood flow.

Figure 13 is the design abstract of EDA sensor glove. We use high quality texture used in golf glove that gives comfort and good ventilation. And we make EDA sensor part using conducting fabric well-fitted to finger. We consider sensor glove's practical and artistic feature especially on conducting fabric line part and arm-banded pocket that contains embedded board. Figure 14 is EDA sensor glove picture.

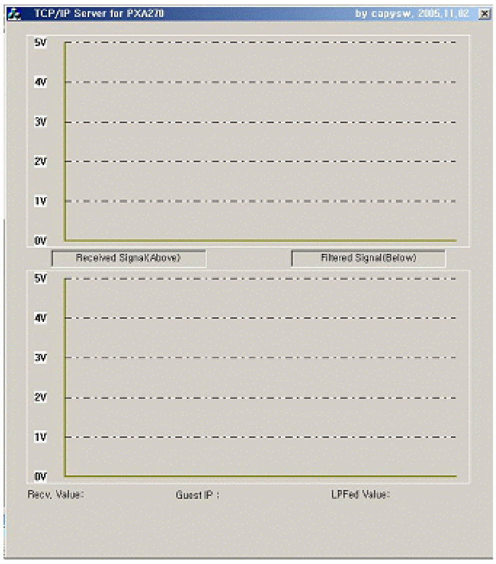

Fig. 9. EDA signal monitoring software

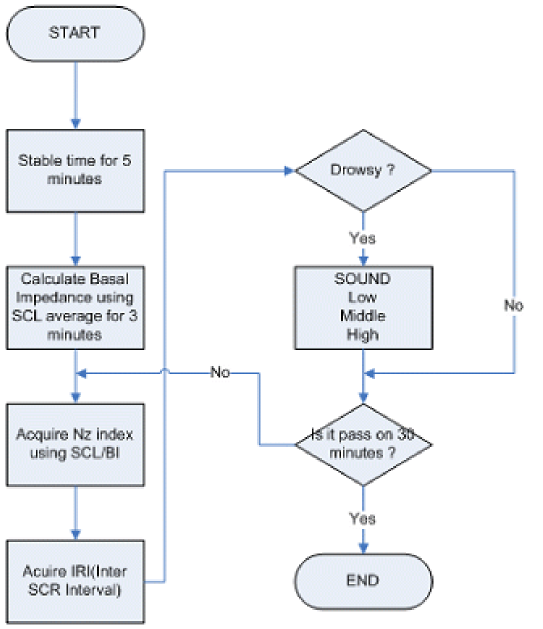

Fig. 10. EDA signal processing algorithm [2]

Since mid of 1990s, the wearable device design is focused on human-friendly design. And computing device becomes smaller, lighter. The development of smart texture is more important that combines sensor technology and texture manufacturing technology. And wearable device must be comfortable and easy to use. Now, Wearable device become nearly same to normal wear. Our design is also focused on user's utility and comfort that solves the electric wire problem, washability problem. Our wearable device use conducting fabric wire, so we can wash our sensor glove, and we consider the movement of arm, and we design the conducting fabric line not interrupting the movement of arm. And user can control the size of glove using Velcro tape to fit your hand.

Lastly, we design the pocket for glove and wire. That can be useful for mobility and keeping. And the separation board from glove is essential for washing, so we make it possible using button type.

		Nz(SCL/BI)		
		1.2<Nz<1.5	1.5<Nz<2.0	2.0≤Nz
IRI (sec)	IRI<60	Small	Small	Medium
	60≤IRI ≤90	Small	Medium	Big
	90≤IRI	Medium	Big	Big

·BI : Basal Impedance
·IRI : Inter SCR Interval
·Nz : SCL/BI

Fig. 11. Awareness classification condition table [2]

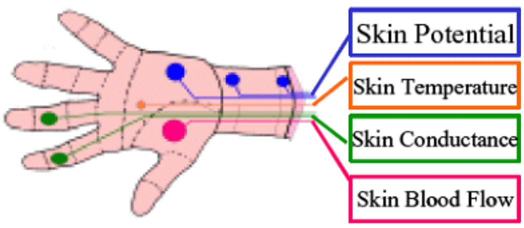

Fig. 12. Existing research example about Sensor glove [6]

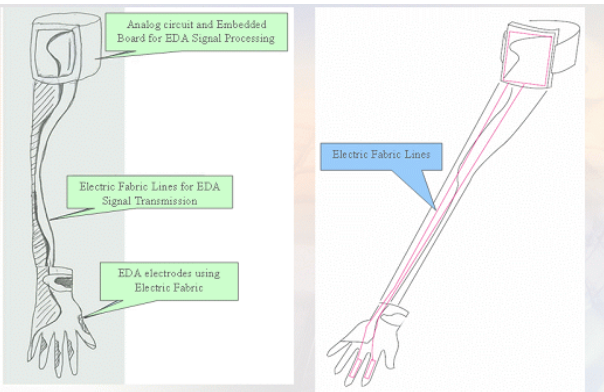

Fig. 13. EDA sensor glove Design

VI. Conclusion

We make EDA signal measurement system that obtains Skin impedance signal and monitoring SCL, SCR signal by filtering it. and we make EDA sensor using conducting fabric, connect EDA measurement system to embedded system and that gives many possibility to application such as EDA signal processing algorithm implementation and wearable device upgrading. And we design EDA sensor glove considering user's comfort and functionality. As future work, we will complete the EDA signal processing algorithm implementation. And using wireless communication module, our system send EDA signal processing result to outside display system, and give proper feedback to user.


Fig. 14. EDA sensor glove appearance

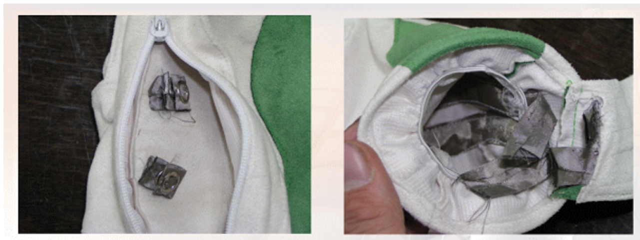
Fig. 15. Inner appearance of wearable Sensor Gloves

Acknowledgment

The authors thank financial and technical supports of Ministry of Information and Communication, Republic of Korea.

References

[1] H.W. Ko, W.G. Lee, G.K. Lee, "Arousal monitoring system using the change of skin impedance (1)", KOSOMBE Spring Conference, Vol.17, No.1, 1995

[2] H.W. Ko, Y.H. Kim, "Relationship Between Skin Impedance Signal, Reaction Time, and Eye Blink Depending on Arousal Level", Journal of KOSOMBE Vol.18, No.4, 1997

[3] Jennifer Healey, Rosalind Picard, "SmartCar: Detecting Driver Stress", Proceedings of ICPR'00, Barcelona, Spain, 2000

[4] F. Axisa, C. Gehin, G. Delhomme, C. Collet, O. Robin, A Dittmar, "Wrist Ambulatory Monitoring System and Smart Glove for Real Time Emotional, Sensorial and Physiological Analysis", Proceedings of the 26th Annual International Conference of the IEEE EMBS, San Francisco, CA, USA September 1-5, 2004

[5] Y.B. Lee, J.Y. Kim, C.K. Lee, M.H. Lee, "Automobile system for drowsiness accident prevention using EDA signal analysis", KOSOMBE Spring Conference, 2005