Study on User Interface for a Capacitive-Sensor Based Smart Device

Sun-IL Jung, Young-Chul Kim

Abstract

In this paper, we designed HW / SW interfaces for processing the signals of capacitive sensors like Electric Potential Sensor (EPS) to detect the surrounding electric field disturbance as feature signals in motion recognition systems. We implemented a smart light control system with those interfaces. In the system, the on/off switch and brightness adjustment are controlled by hand gestures using the designed and fabricated interface circuits. PWM (Pulse Width Modulation) signals of the controller with a driver IC are used to drive the LED and to control the brightness and on/off operation. Using the hand-gesture signals obtained through EPS sensors and the interface HW/SW, we can not only construct a gesture instructing system but also accomplish the faster recognition speed by developing dedicated interface hardware including control circuitry. Finally, using the proposed hand-gesture recognition and signal processing methods, the light control module was also designed and implemented. The experimental result shows that the smart light control system can control the LED module properly by accurate motion detection and gesture classification.

Keywords : capacitive sensor | electric field disturbance | EPS | NUI | PWM | motion detection | gesture recognition

I. INTRODUCTION

Most of the devices for information exchange and transferring have certain interfaces to accept human interaction. Through the interface, humans transmit inputs to the processing system to obtain and store various information. In recent research and development, means using the user's natural and intuitive actions as the input into the intelligent devices have been studied [1]. Also, the importance of interfaces that can be controlled and used in this way is emerging [2]. The NUI (Natural User Interface) evolved from the interface between human and information devices has been applied to various fields such as games, entertainment, lighting and TV control. Systems for recognizing a variety of human bio-signals, gestures, and monitors using smart sensors have been continuously developed as more advanced NUIs [3]. For convenient NUI implementation, it is very important in NUI implementation to recognize operation signals in a non-contact manner such that various actions can be recognized in remote without touching the sensor [4].

EPS among various capacitive sensors considered as one of the best candidates to non-contact mode motion or gesture recognition applications is a recently introduced state of art sensor technology that converts the surrounding earth's electric field disturbance or artificially created electric field around a human body or hand motion [5, 6]. In recent years, based on this principle, researches have been carried out to apply the body position or hand motion around the EPS to the indoor localization or motion recognition systems [7, 8, 9, 10, 11].

* This study was financially supported by Chonnam National University (Grant number: 2017-2886)
* This work was supported by the NRF of Korea grant funded by the Korea government(MSIT)(No. 2019 R1F1A1062829)
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Manuscript: 2019. 07. 31.
Revised: 2019. 09. 19.
Confirmation of Publication: 2019. 09. 28.
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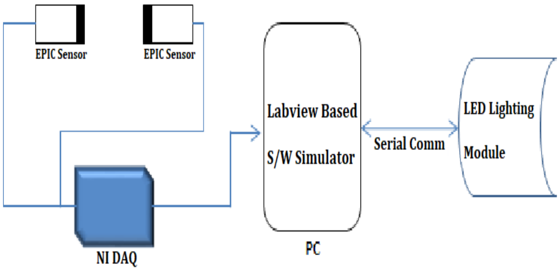


Fig.1. Configuration diagram for the entire system

In this paper, we proposed a system to control LED lighting by using the user 's hand motion by using EPS. In chapter 2, the configuration of the proposed EPS based smart lighting control system is discussed in Section 2. Section 3 describes the design of the driving and control circuits implementing the proposed lighting control module. Section 4 describes the test and measurement results of the proposed lighting control system. Finally, Section 5 describes the conclusion and future research directions.

II. SMART CONTROL SYSTEM BASED ON CAPACITIVE SENSORS

Figure 1 shows a block diagram of the typical smart control system, being capable of hand−gesture recognition based on the capacitive sensors. Preprocessing and detecting process of gesture signals are performed based on the data transmitted to the simulator.

Plessy, a UK manufacturer of EPIC sensors, has developed a CIB box−type device to measure changes in electromagnetic fields using EPIC sensors. However, since only two sensors can be connected to one box, It is impossible to use multiple sensors in one module apart. Also, it is difficult to induce a change to another part because it is only possible to monitor by continuous input signals [7].

In this study, we propose a scalable signal processing device to overcome this limitation, and it is possible to detect active hand−gesture signals through the threshold function, and also includes the attenuation function for undesired operation by using the average−value extraction method. The envelope of the signal was around 0.05V, and the SNR was improved to be about 8dB. The function of motion judgment is also plugged in. And there is almost no offset.

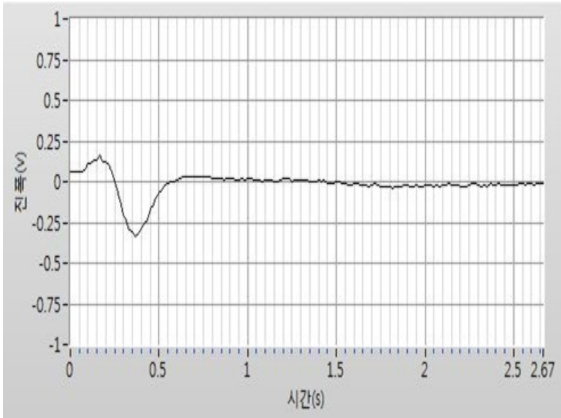


Fig.2.The motion signal obtained through the proposed signal processing method

Figure 2 shows the waveform of the motion signal obtained through the simulator implemented by the proposed signal processing method.

The proposed system shows characteristics such as SNR improvement, threshold voltage, and scalability to sensor input. Figure 3 shows that four different hand signals for lighting control are well separated, and the detection of the hand gesture and recognition results of motion are improved. The control system of the Non−contact method lighting by the hand motion applying the proposed signal processing system is smoothly controlled. Figure 3 shows a waveform showing several different hand gestures, while the right part shows the results of the motion classification.

In the algorithm implementation of the simulator, it is proved that the average value extraction method and the method of sensing using the threshold value can improve the data capacity and the execution speed in recognizing the hand gestures, and it is shown that the four operations are recognized properly.

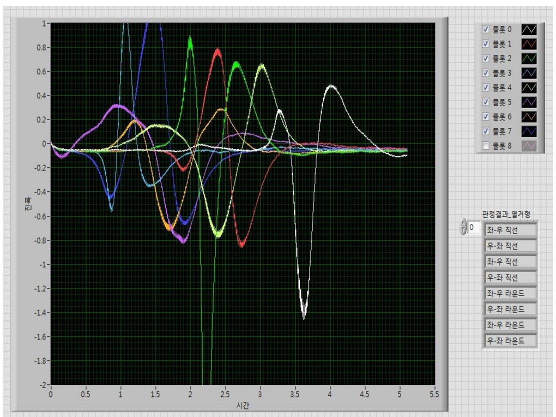


Fig.3. EPS signals produced by different hand gestures

III. DESIGN OF THE EPS-BASED CONTROL DEVICE

To verify the proposed EPIC sensor signal processing algorithm, a controller of LED lighting module was designed as a prototype of typical EPS-based smart device controller and made up as a processor system using Atmega128. A timer interrupt and a UART interrupt were used. The driver IC is used to drive the LED. Overall brightness and ON / OFF operation are controlled by the PWM signals corresponding to classified gestures. The EPIC sensor has been used to accept hand-gesture signals and to use them as the control signal of the interface. overall system performance as well as processing speed were improved.

III.1. Driver circuit design of an LED lighting module

The use of the driver IC is crucial for the stability of the system. In case of controlling the LED lighting by receiving gesture signals from the control circuit cooperated with NUI, the driver IC plays the main role in driving the LED. In this study, the driver IC of the LED lighting was fabricated and tested. The DW8410 is a multi-channel driver IC with four channels. Up to 40 LEDs can be driven by connecting 10 LEDs per channel in series. This number of drives is considered essential for backlight and general illumination.

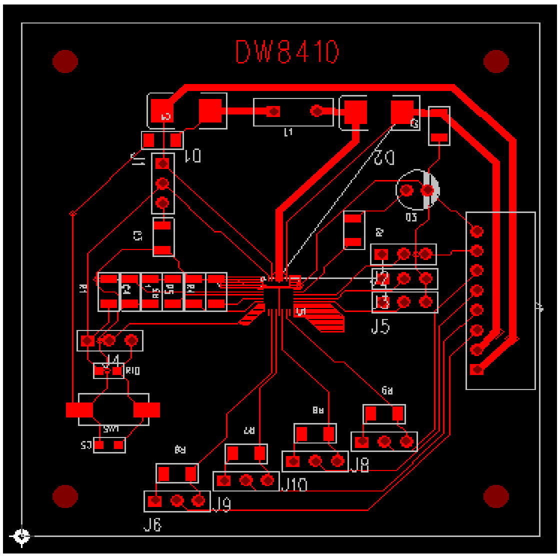


Fig.4. PCB layout for driver circuit

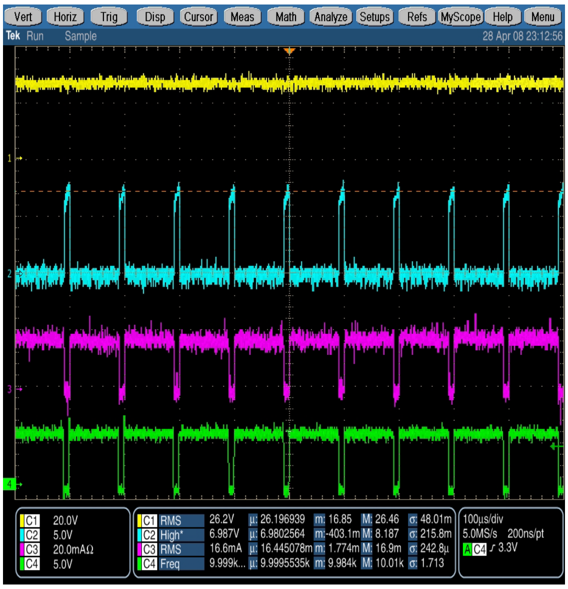


Fig.5. Measurement of operating waveform when duty of 90% of DWB410

There are FSET and ISET pins that can determine the frequency and current by connecting a resistor between GND and pin. The DIM pin has a 1-wire dimming function that can be adjusted in 32 steps. It also has SEL0 and SEL1 pins that determine the function to selectively turn on/off the applicable channel by selecting 4 channels of LED.

The DW8410 driver IC is considerably user friendly in terms of functionality and user friendliness. The circuit was implemented for comparison with other ICs using the DW8410 in which jumpers turn on/off each channel such that they can be selectively selected. The PWM signal line, which can receive the PWM signal from the outside, can be selected to select VCC or PWM. The PCB was designed and the results of the operation and the characteristics were measured. Figure 4 shows the PCB layout of the driver circuit using DW8421 The operational characteristics and functions of the controller were measured and tested correctly.

The DW8410 is packaged in TQFN type for effective heat dissipation. Figure 5 shows an example of a PWM signal which is externally applied using the DW8410. As shown in Figure 5, it can be seen that the waveform of the PWM-type current signal is well-behaved with the good sync.

III.2. Design of lighting module control circuit

In order to examine various kinds of driver ICs, a circuit that can generate by varying PWM signals was implemented using a micro controller. The period of the PWM can be changed by the setting process, or by the input of the switch. It is also designed to be compared with Supertex's HV9910. For convenience of users, communication part can be connected and used. The Atmel's Atmega128 was used as a micro−controller, which has an internal flash memory and is widely used in the industrial field.

Figure 6 shows the PCB layout of the LED−lighting module control circuits

It includes the designed micro−controller and peripheral circuits and is designed in a connector type to abe to be connected with other external driver ICs.

IV. IMPLEMENTATION OF A LED−LIGHT CONTROLLER

Figure 7 shows a control circuit diagram designed to drive LED lights using only two ICs. (a) is a circuit diagram of the LED module part and (b) is a circuit diagram of the driver IC part.

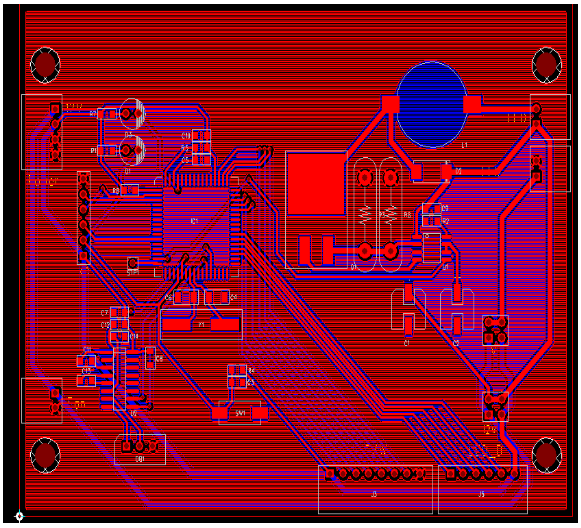
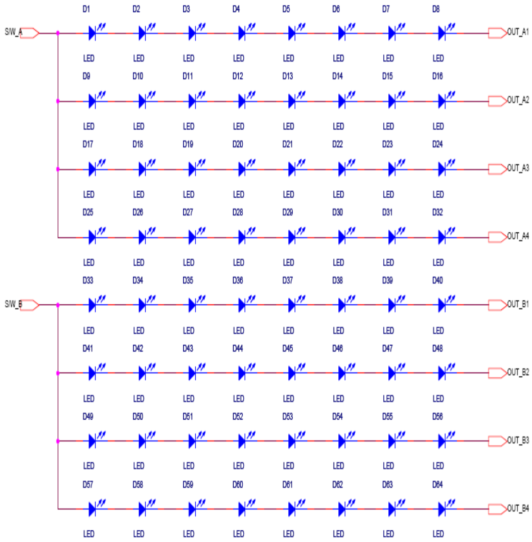
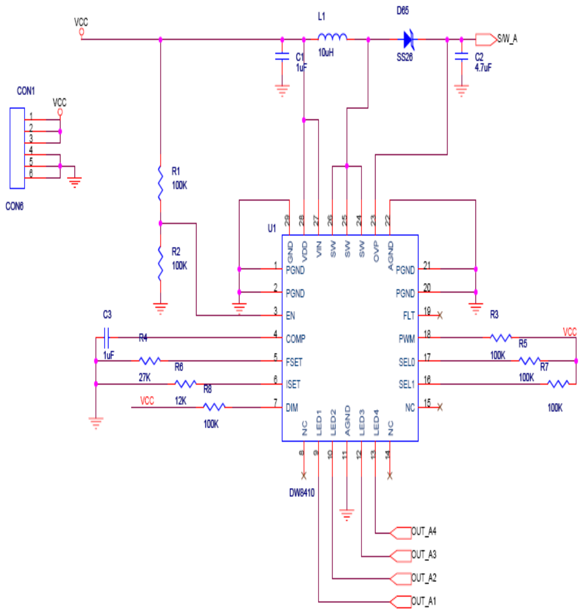


Fig.6. Control circuit PCB with a micro−controller

Two sensors were used to recognize and classify the movements of the four hand gestures. We digitized the given analog signals from the two sensors and extracted the characteristics of the signal generated by each gesture operation. We controlled LED lighting by classifying four hand gestures corresponding to commands to control the LED lighting unit. For communicating between the signal processing system and the LED−light controller, serial communication method was selected.



(a) Surface emitting LED module circuit



(b) IC circuit part driving the LED module

Fig.7. DW8410 surface LED module circuit

In the implemented system, the EPIC signal detecting and classification system transmits the recognized gesture command to the LED-light controller through the serial communication. In turns, the controller controlled the LED light module based on the data received.

Figure 8 shows our proposed, designed, and implemented EPIC based LED-light control system. Experiment and test results show that the system not only classified hand gestures correctly, but also controlled the LED lighting unit correctly and smoothly. The system consists of four parts. From left, it consists of an EPIC sensing unit, a signal detecting and processing unit, a LED controller, and an LED module.

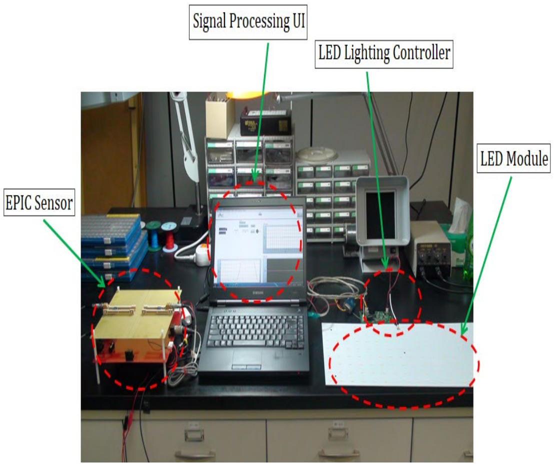


Fig.8. Configuration of the implemented LED-light controller.

V. CONCLUSION

In this paper, we implemented the LED lighting control system as a typical capacitive sensor based smart device, including HW/SW interface development. The interface is the key element in NUI implementation using EPS. Signal detection electronics were used to extract all EPS signals which were previously available only in limited forms. The extracted signals were able to be used with more freedom leading to performance improvement in the hand gesture recognition process. Our proposed and implemented system demonstrated the correct and smooth control of light-dimming and switch on/off. And also, faster recognition processing speed was achieved by using the interface circuit. We experimented with our proposed hand gesture recognition method, signal processing method, and LED lighting module. As a result, we could control the LED module with hand gestures. In this paper, we implemented a single target in a limited environment and did not consider multiple targets that additionally cause electromagnetic disturbances. Future research is needed to develop an NUI system capable of detecting the multiple gestures and the complementary modification of signal changes according to the external environment

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