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Development of a Sensing Module for Standing and Moving Human Body Using a Shutter and PIR Sensor

Ronnie O. Serfa Juan[1], Jin Su Kim[2], Yui Hwan Sa[3], Hi Seok Kim[4] and Hyeong Woo Cha[5*]

Cheongju University
[1]ronnieserfajuan@cju.ac.kr, [2]suzzang68@nate.com, [3]labiss1405@naver.com, [4]khs8391@cju.ac.kr and [5]hwcha@cju.ac.kr

Abstract

Advances in technology have led to the development of various sensing devices such as on-body and health-care monitoring that can integrate from different sources and can initiate actions or trigger alarms when needed. This paper developed a sensing module of standing and moving human body using a shutter and a pyroelectric infrared (PIR) sensor. The module consists of Fresnel lens, PIR sensor, interface circuit of the PIR, microcontroller unit (MCU), and light emitting diode (LED) as an alarm indicator. The principle for standing human body is to chop the thermal heat of human body utilized by the camera shutter. The human sensed signal is the controlling part of this algorithm, the detected interruption serves as its function. By merging the whole apparatus including the print circuit board (PCB), the developed product of this proposed sensing module can replace the commercially available detector. Experiment results show that sensing distance is about 7.0 meters with a sensing angles of around 110 degrees at room temperature. In these conditions, the sending ratio is 100% and the module's power dissipation is rated as 100 mW.

Keywords: *pyroelectric infrared sensor, sensor interface, chopping using shutter, standing body detector*

1. Introduction

In a rapid aging society, study shows that people who live alone, are twice as likely to have a heart attack or sudden cardiac death as those who live with someone. Receiving an effective and immediate CPR from another person can double or triple the chance of survival. There are increasing demands for ways ensuring healthier and more comfortable lifestyles. In order to achieve this goal, user-friendly operations are essential in keeping human sensations and conditions. Since human body generates infrared radiation and heat, an infrared motion sensor detector is a simple method to detect human body existence in space. This IR motion sensor detects infrared radiating from objects in its sensing area. Also, this sensor is suited to detecting the motion of people by their body temperature.

The pyroelectric infrared (PIR) sensor has high performance for IR detection at room temperature, and it does not need to use special and expensive cooling equipment like a photon-type detector [1]. Nowadays, pyroelectric devices are being implemented in human's daily life such as intrusion detection and smart usage of power consumption. Several studies were conducted in various applications, such as light sensing for buildings, traffic flow monitoring system, people's information collection, *etc.* [1-3]. However, in this case, detectors can be sensed only from moving human body because the

* Corresponding Author

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PIR sensor has a differential reaction. Therefore, the conventional detector using PIR sensor cannot detect a standing human body and its application is limited [4-5]. In general, there are 2 methods to detect a standing human body, they are the rotating PIR sensor like radar (rotation of PIR sensor) and chopping of infrared [6].

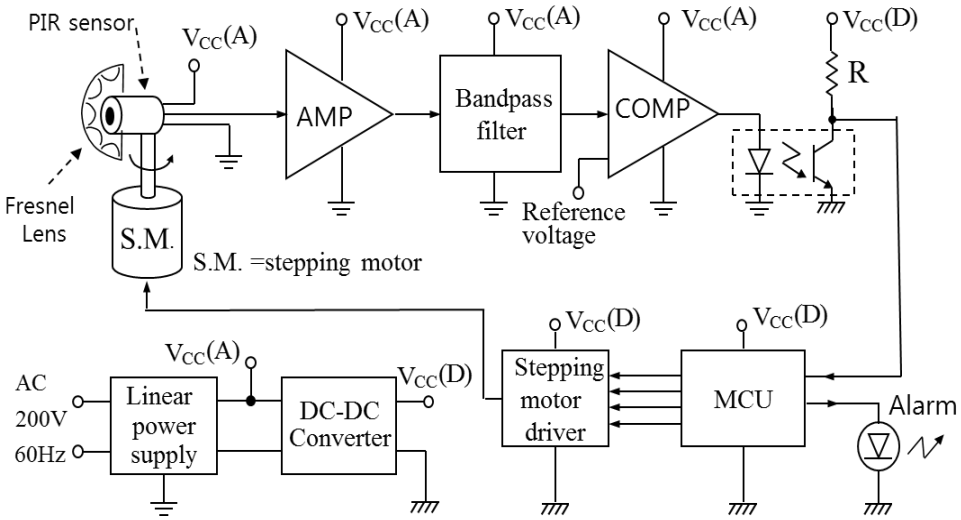


Figure 1. Block Diagram of the Proposed Sensing Module for Standing and Moving Human Body Using Rotation of PIR Sensor and Fresnel Lens

In Figure 1 shows the block diagram of our previous study. This system has a maximum detection distance of 6 meters and the sensing angle ranges between 0 to 180 degrees. However, the circuit implementation is complex and picks up large noise because of mixed circuit [6]. In this paper, a sensing module for standing and moving a human body using a chopping method was developed which consists of the following: a shutter, a Fresnel lens and PIR sensor [7]. The circuits and the control algorithm, which makes up the composition of the module was designed. Finally, the prototype was realized through experimental method, discussion of data, and results based on the proposed circuit's performance.

The rest of this paper is organized as follows. Section 2 describes the operational principle and module configuration. Then, Section 3 discusses the experimental results. Finally, Section 4 concludes this paper.

2. Operational Principle and Module Configuration

2.1. Circuit Design of Sensing Module

Figure 2 shows the block diagram of the proposed sensing module for a standing and a moving human body using a shutter method. The block consists of a shutter, Fresnel lens, PIR sensor, interface IC, MCU, and a LED alarm. The detecting principle of a moving human body is same as the convention method. However, the detecting principle of a standing human body has two steps. First (normal states), the shutter always opens, PIR sensor detects a temperature of a moving human body. If the PIR sensor detects the human body's temperature, the MCU outputs alarms, otherwise the shutter is always on an opened-state and MCU will not sound the alarm. While, the other step is the standing state that occurs after the detection of a moving human body. In this case, the MCU controls the algorithm of the shutter on opened-closed state alternately. This operation is analogous to the differential action characteristics of PIR sensor.

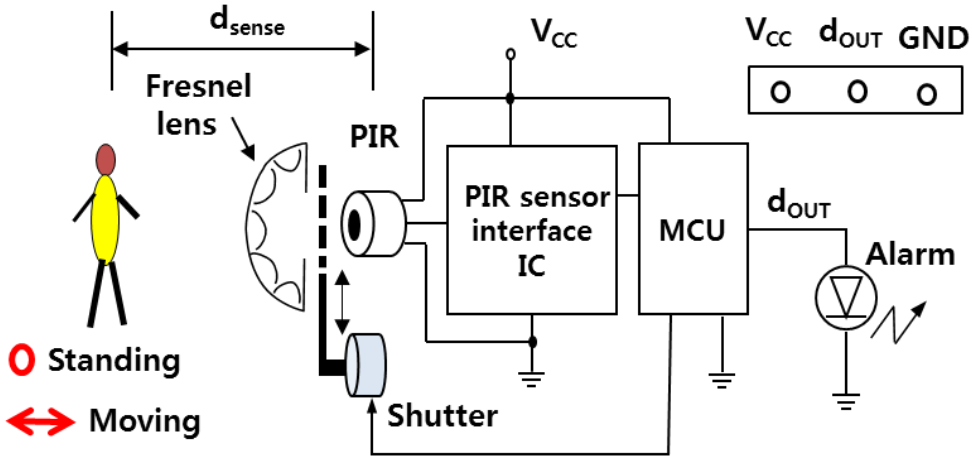


Figure 2. Block Diagram of the Proposed Sensing Module for Standing and Moving Human Body Using a Shutter

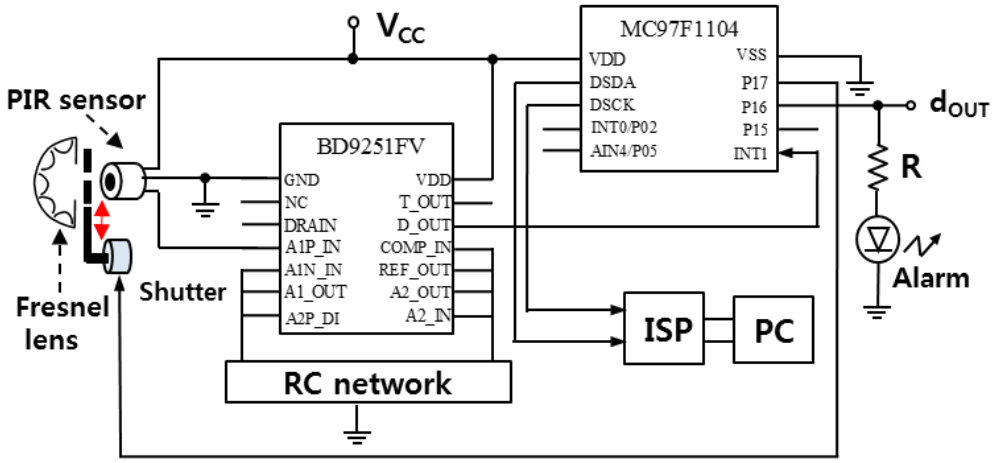


Figure 3. Circuit Diagram of the Sensing Module

Figure 3 shows the circuit diagram of the proposed sensing module. The circuit consists of interface IC chip (BD9251FV), MCU (MC97FI104), in-system program (ISP), and RC network. The BD9251FV act as an amplifier and band-pass filter for the output signal of PIR sensor. The MCU controls the shutter motor, alarm, and algorithm of the system. An 8-bit MCU with a minimum size of memory and chip was used. RC network is composed of resistors and capacitors in order to operate as an amplifier and filter. The ISP is an on-chip developed debugger firmware. This ISP can be removed optionally.

2.2. Mechanical Design of the Module

The shutter used in this proposed sensing module is shown in Figure 4. This shutter is commercially available and used in CCTV system. The shutter size is 3.4 cm by 2.0 cm. While the thickness and window diameter is 2.5mm and 10mm, respectively. This shutter operates on "on-state" at 3~5V_{DC} and "off-state" at 0V_{DC}. During "on-state", the shutter consumed about 20mA.

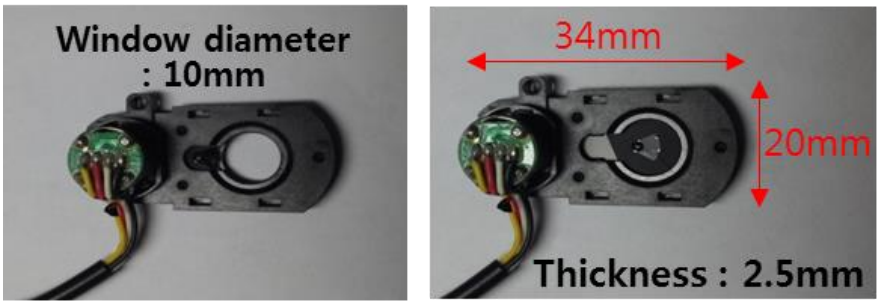


Figure 4. Shape of the Solenoid Shutter. Left : Shutter Motor is Opened. Right : Shutter Motor is Closed

The prototype module's size and actual object for sensing pipe is shown in Figure 5. To widen the detection angle, the distance between Fresnel lens and PIR sensor should be 7.5mm, while the distance for edge of sensing pipe from shutter should be 5mm. Figure 5(b) shows the "on" and "off" states of a shutter without Fresnel lens. Fresnel lens can be inserted easily for completing the sensing module. The sensing pipe was done through a 3D printer.

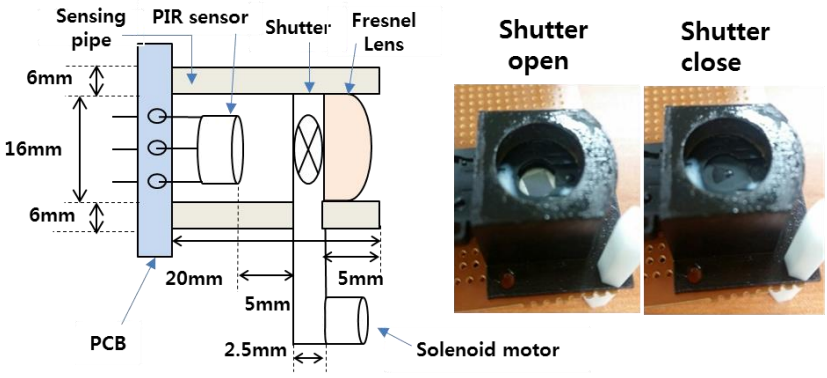


Figure 5. Design of Instrument for Sensing Pipe. (a) Size and (b) Actual Object Without Fresnel Lens

The final prototype sensing module detect standing and moving human body at room temperature as shown in Figure 6. The assembled prototype's size is 7mm (length) x 3mm (width) x 22mm (height). The LED was inserted as an alarm indicator in order to check the operation of the proposed prototype.

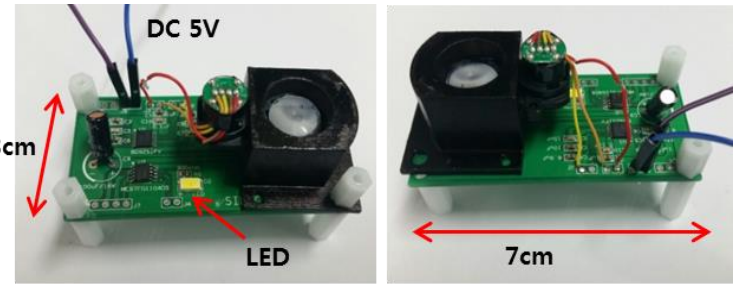


Figure 6. Final Prototype of Sensing Module for Standing and Moving Human Body

2.3. Sensing Algorithm

Sensing algorithm for standing and moving human body at room temperature is shown in Figure 7. The algorithm is consists of three steps: Starting point (normal states): detection 1 (temperature detection of moving human body), and detection 2 (temperature detection of a standing human body). During this step, hardware is initialized by MCU firmware, chopper is opened, while LED is in "off state", and the interruption of MCU enables the "on-state". Then, the next is detection 1: if human body was detected, LED will turn on and timer starts counting for 5 seconds, MCU will be interrupted that leads to off-state. Otherwise, it will return to the starting point. After 3 seconds, chopper will open, the timing delay will be 100msec, and the interruption of MCU will be enabled. Finally, if human body was detected at detection 2, it will return to detection 1. Otherwise, MCU will reset the timer after 2 seconds and will proceed to the initial step.

This algorithm, uses time delay of 100msec for MCU in order to reduce thermal noise between Fresnel lens and PIR sensor.

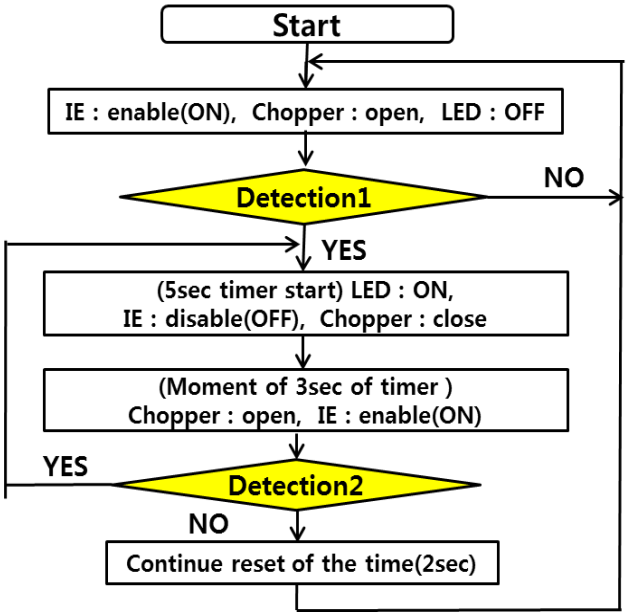


Figure 7. Control Algorithm of Sensing Module for Standing and Moving Human Body

3. Experimental Results and Discussion

Experimental method was used to determine the detection distance and angle of the final prototype shown in Figure 6. The components in prototype are the following: interface IC chip is BD9251FV [8], MCU is MC97FI104 [9], PIR sensor is RE431B [10], Fresnel lens is PF08-10W [11], and a solenoid shutter. The resistor and capacitor value used are the same RC network of the data sheet of BD9251FV. The supply voltage is DC 5V. The firmware was developed using OCD2 emulator, a debugger, and standard 8051 compiler [9].

Figure 8 shows the measurement environment for performance testing. The measured object for thermal of infrared was participated by a graduate student. The sensing module and measuring object are located above the fluorescent light, and it turns off and on, respectively. While the distance and angle detection were measured by following the movements of the student.

Figure 8. Measurement Environment of the Performance

3.1. Sensing Distance

Figure 9 shows the characteristic of sensing distance versus sensing result at the front side. The detection distance was measured by following the standing and movement of student in a testing environment as shown in Figure 8. The output voltage is D_{OUT} that supplies the power of LED during alarm state of the MCU. Noted that the proposed sensing module can be detected with a distance of 7.5 m for human body in standing and moving action. The detection ratio for this distance is 100%.

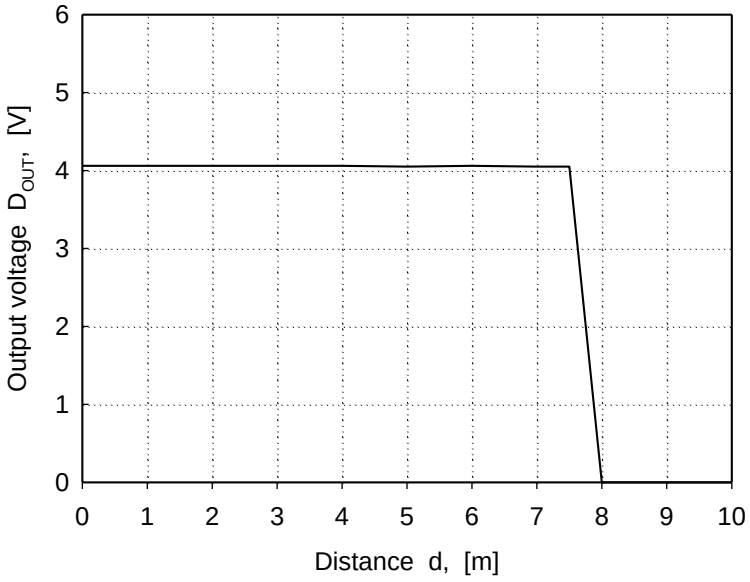
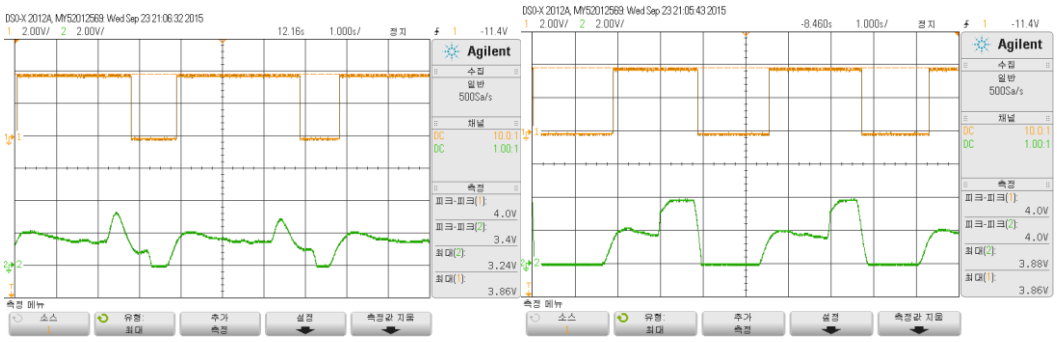


Figure 9. Measurement Graph of Sensing Distance at Front Side

Figure 10 shows the characteristic of signal output waveform for sensing distance of 2m and 7m at the front side. The upper and lower waveform are T_{OUT} and $A2\_{OUT}$ terminal of BD9251FV chip as it shown in Figure 3. From this results that maximum signal was obtained as 4V and 3.2V at sensing distance of 2m and 7m, respectively.



(a) (b)

Figure 10. Signal Output Waveform for Sensing Distance at Front Side Sensing Distance Were 2m (a) and 7m (b)

3.2. Sensing Angle

Figure 11 shows characteristic for sensing degree of an angle from -60^o to 60^o at the front side. Detection angle by following the standing and moving action of the student in the testing environment as shown in Figure 8 was measured. The distance is fixed at 7.0 meters. The output voltage D_{OUT} served as the LED supplied power. Note that the proposed sensing module can be detected between an angle of -55^o to 55^o at the front side of standing and moving action of the human body. From this distance and angle, the detection ratio was 100%.

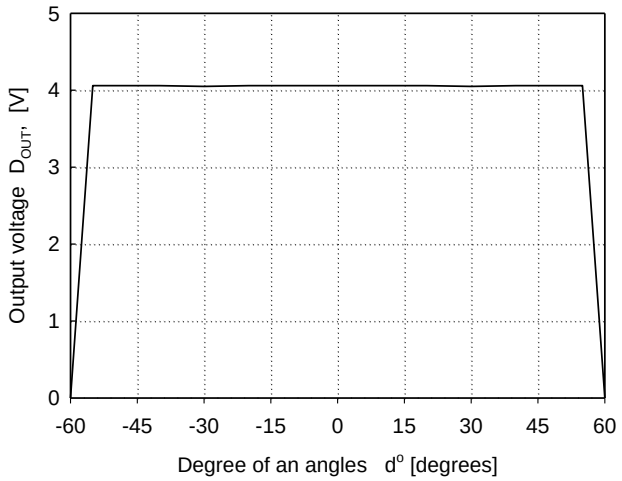


Figure 11. Measurement Graph of Sensing Angle

Figure 12 shows the characteristic of signal output waveform for sensing degree angle between -55^o and 55^o from the front side. The upper and lower waveform are T_{OUT} and $A2\_{OUT}$ terminal of BD9251FV chip is shown in Figure 3. From these results, we can identify that maximum signal is 2.8V at sensing distance of 7.0m. The final prototype is shown in Figure 6 has a power dissipation of 100mW with a supply voltage of 5V.

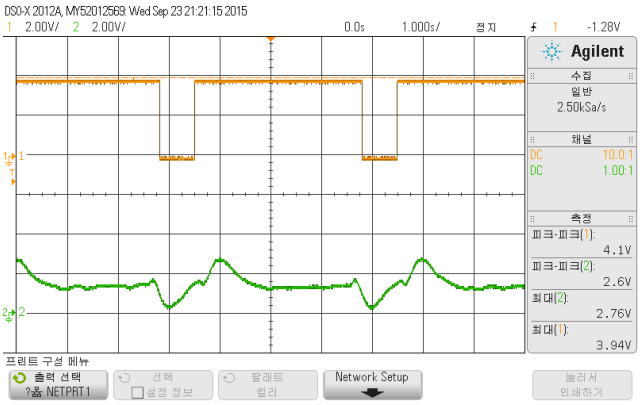


Figure 12. Signal Output Waveform for Sensing Angle of 55° from the Front Side at Distance of 7.0m

4. Conclusion

Sensing module for standing and a moving human body using a shutter and a PIR sensor was developed. The principle for a standing human body is chopped by utilizing the human body's thermal heat by the use of a shutter. The human sensing signal is the controlled part of the proposed algorithm the detected interruption serves as its function. Experiment results show that sensing distance is about 7.0 meters and sensing angles is around 110° at room temperature. In these conditions, sending ratio result is 100% and the power dissipation of the module is rated at 100mW. By merging the whole apparatus and PCB, the developed product sensing module can replace the commercially available detector for a moving human body.

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Authors

Ronnie O. Serfa Juan, received his BSc in Electronics and Communications Engineering from Technological University of the Philippines-Manila, and he earned his MSc in Information and Telecommunications Studies, majoring in Computer Systems and Network Engineering, at Waseda University in Tokyo, Japan in 1999 and 2007, respectively. He is currently working toward his PhD, majoring in Computer and Control, at CheongJu University in CheongJu City, South Korea. His research interests include radio frequency identification (RFID), advanced driver assistance system (ADAS) technology and Controller Area Network (CAN).

Jin Su Kim, received his BSc in Electronic Engineering from CheongJu University, in CheongJu-City, South Korea in 2015. Currently, on the same university, he's pursuing his Master Degree in Electronic Engineering, Major in Analog Circuit Design. Also, he's part of the team in doing research and development of Advanced Driver Assistance Systems (ADAS) and embedded Software-System on Chip (SW-SoC) for Smart automotive and self-driving car applications in Korea Evaluation Institute of Industrial Technology in Seoul, South Korea. Part of his works was awarded as one of the best paper in May 2015. His research of interest includes the development of Analog Circuit Designs, ISFET, Oscillator and other related Technology.

Yui Hwan Sa, received his BSc in Electronic Engineering from CheongJu University, CheongJu-city, South Korea, in 2015. He is currently working on his Master Degree in Electronic Engineering, Major in Analog Circuit Design on the same university. He is one of the team members in developing the Advanced Driver Assistance Systems (ADAS) and embedded Software-System on Chip (SW-SoC) for Smart automotive and self-driving car applications in Korea Evaluation Institute of Industrial Technology, Seoul, South Korea. His research of interest includes Comparator circuits and development of Analog Circuit Designs.

Hi Seok Kim, received his BSc, MSc and PhD in Electronic Engineering from Hanyang University in Republic of Korea in 1980, 1985 and 1987 respectively. He is currently a professor in the Electronic Engineering Department at CheongJu University in CheongJu City, South Korea. His research interests include digital video/audio system design, multi-view imaging, 3D image processing, and FPGA design. Dr. Kim has served as General Chair and a committee member of many Korean and international conferences, including the International SoC Design Conference and IEEE ISCAS. He is also one of the General Co-Chairs for APCCAS 2016.

Hyeong Woo Cha, received his Bachelor's degree and Master degree in Electronic Engineering from CheongJu University in 1989 and 1991, respectively. While he finished his Ph.D. in Electronic Engineering from Shizuoka University, Shizuoka, Japan in 1997. He is currently a Professor in Electronic Engineering Department under the Analog Circuit Design at CheongJu University in CheongJu City, South Korea. His research of interests includes sensor interface, LED driver circuits, current conveyer and op-amp applications. Dr. Cha has served CheongJu University in many positions like director of the innovation center for engineering education and for the industry academic cooperation foundation.