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Sewing-enabled electric button for smart fabric

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Abstract

A new button-shaped electrical device was developed for a smart fabric. This electric button can be sewn anywhere on the garment, similar to a traditional button fastener. t not only performs a decorative function but also makes the fabric suitable for use in Internet of Things (IoT) applications. It has metallic through-holes such that it can be fastened onto a fabric by conductive sewing threads. When threaded through metallic holes, the button can communicate with the external device by transmitting and receiving data. In addition, it adds specific functions by stacking a detachable application layer on the base layer. It is robust to frequent washing, and thus has excellent repeatability for use as an IoT device. The feasibility of the electric button was successfully demonstrated by its ability to identify the physical activities of walking and running, monitoring ambient temperature, and turning on LED lights.

Keywords : electric button, IoT device, smart fabric, conductive thread

1. INTRODUCTION

Textile-based wearable devices for smart fabrics have recently been developed [1–3]. These devices focus on implementing electrical functions rather than functioning as clothing accessories. Once they are fastened onto the garment, it is difficult to replace them. In particular, such devices have poor durability during washing [1–3]. In this study, we developed an electric button for a smart fabric. Traditionally, buttons are one of the most essential garment accessories that must be washable with clothing [4]. Our electric button is fastened to a clothing item using a conductive sewing thread. The proposed electric button has advantages in that it makes the fabric suitable for use in Internet of Things (IoT) applications and has washing durability and decorative functions similar to the traditional button. In this study, the electric button was used to perform specific functions, such as measuring physical activity, monitoring ambient temperature, and turning on LED lights.

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2. EXPERIMENTAL

2.1 Design of an electric button

The proposed button looks like a button in appearance and functions as an IoT device. Fig. 1 shows a conceptual diagram of an electric button. The electric button has a printed circuit board (PCB) and metallic through-holes. The PCB was designed to perform specific functions. Metallic through-holes were fabricated on the PCB surface to be sewn by conductive threads. Passivation materials, such as resin and silicon, sealed the PCB, exposing the metal pad around the through-holes. The exposed metal pad electrically connects the conductive threads to the integrated

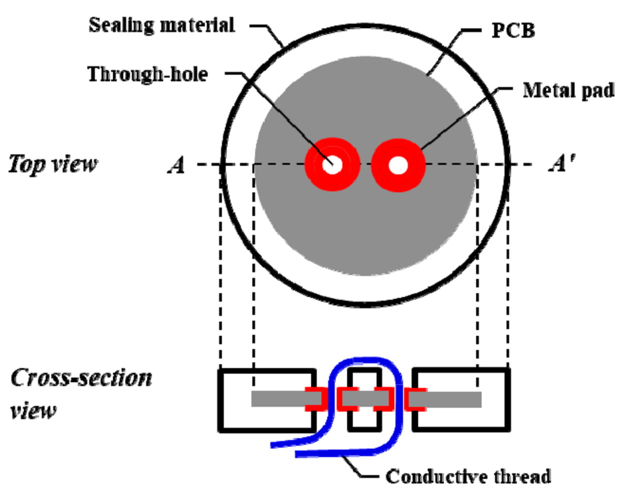


Fig. 1. Conceptual diagram of the electric button. The cross-section is the A-A′ line of top view.

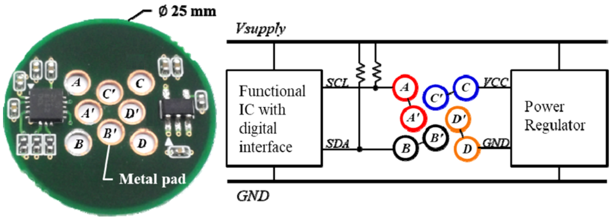


Fig. 2. (a) Photograph and (b) block diagram of the fabricated PCB.

components on the PCB. Thus, the electric button can transmit and receive electrical data while interfacing with external devices through the sewing threads.

2.2 Electrical connections for electric button

Figs. 2(a) and (b) display a photograph and block diagram of the fabricated PCB, respectively. The PCB has a circular shape with a diameter of 25 mm and eight metallic through-holes. The functional integrated circuit (IC) on the PCB is equipped with a digital interface, such as an inter-integrated circuit bus (I2C bus) [5]. This is because the digital interface works more robustly than the analog interface for long resistive sewing lines. Despite the voltage drop caused by the resistive sewing line, the power regulator provides stable power to the electric button. The eight through-holes for sewing threads are composed of four wiring pairs of the I2C clock (SCL, A-A′), I2C data (SDA, B-B′), power line (VCC, C-C′), and ground line (GND, D-D′). Here, A and A′ have electrically the same level because the thread sewed in through hole A is sewed out through hole A′ to fasten the button. The electrical levels of B, C, and D are the same as those of B′, C′ and D′, respectively. Four threads are required to operate the electric button. The PCB consumes a current of approximately 0.2 mA from a 3.3 V supply. Here, through-holes in the button must be tightly fastened with the conductive threads. If it is threaded loosely, contact resistance in line may change. Nevertheless, the proposed button is not affected by voltage drop due to the use of power regulator and digital interface lines.

Fig. 3 shows the fabrication mold for packaging the PCB in the shape of a button. First, the PCB was placed in the button cavity, and the top and bottom cases were joined together. The passivation material was injected along the inlet path to complete the button shape. The buttons were passivated using acrylonitrile–butadiene–styrene (ABS) resin and silicon material, as shown in Fig. 3(b). The metal pads were clearly exposed to sewing with a conductive thread.

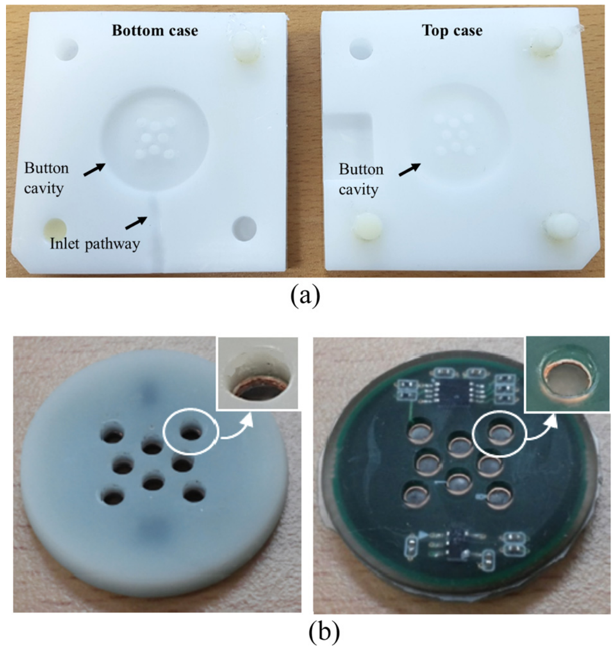


Fig. 3. (a) Button-shaped fabrication mold for packaging the PCB and (b) photos of fabricated buttons. Left and right buttons are made of ABS resin and silicon, respectively.

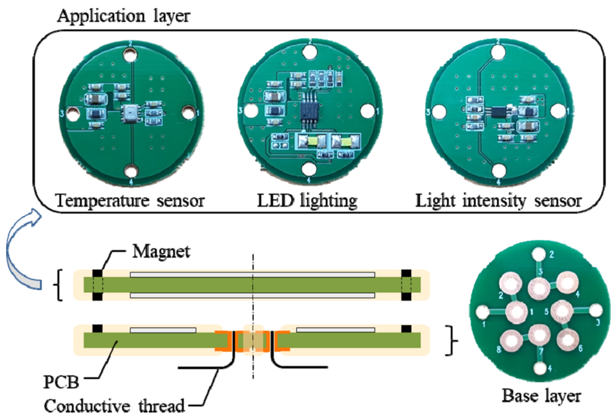


Fig. 4. Description of the stack button that consists of base and application layers.

2.3 Design of a stack button for adding functions

Unlike the single-layer button shown in Fig. 3, the stack button was developed to allow users to easily change the desired function. The stack button can add a specific function by stacking a detachable application layer on the base layer. The thread is sewn only on the base layer, and the base and application layers are connected using built-in magnets, as shown in Fig 4. Fig. 4 shows a conceptual diagram of a stack button and fabricated PCBs. First, the base layer is sewn to the garment with conductive thread, and then additional layers such as temperature sensors,

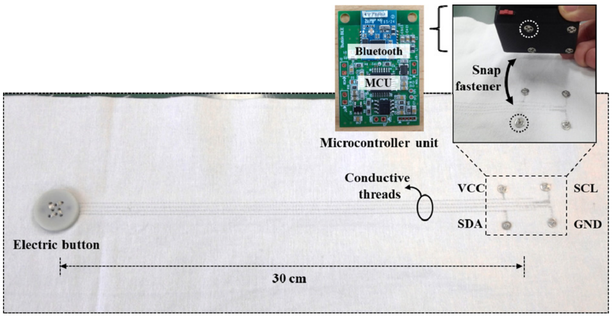


Fig. 5. Connection of the electric button to microcontroller unit on a cotton fabric using snap fasteners.

LED lighting, and light intensity sensors are combined to perform the desired function.

3. RESULTS AND DISCUSSIONS

3.1 Prototype experiment of the electric button

As a proof of concept, the electric button was sewn and fastened on a cotton fabric with conductive threads, as shown in Fig. 5. The conductive thread (ELITEX, Imbut GmbH, Germany) has a resistance of 50 Ω/m.

Electrical signals from the electric button were connected to the microcontroller unit using interlocking snap fasteners, as shown in the inset of Fig. 5. The top half of the snap fastener was attached to the bottom of the microcontroller unit, and the bottom half of the snap fastener was sewn on the fabric using a conductive thread. Four snap fasteners were connected to the VCC, GND, SDA, and SCL sewing lines from the electric button.

Fig. 6 shows the resistance in a variety of stitch patterns, such as single straight, multiple straight, zigzag, and multiple zigzag patterns. As expected, the patterns with repetitive stitches of multiple straight and multiple zigzags exhibited low resistance. In this study, considering the low current consumption of the electric button and the length of the sewing line being less than 1 m, the voltage drop due to the resistive sewing line is negligible.

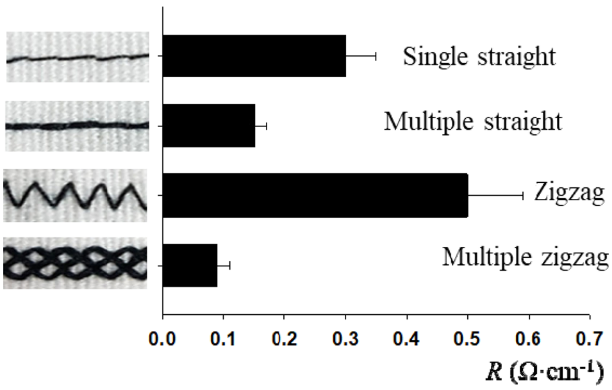


Fig. 6. Resistance in a variety of stitch patterns such as single straight, multiple straight, zigzag, and multiple zigzag patterns.

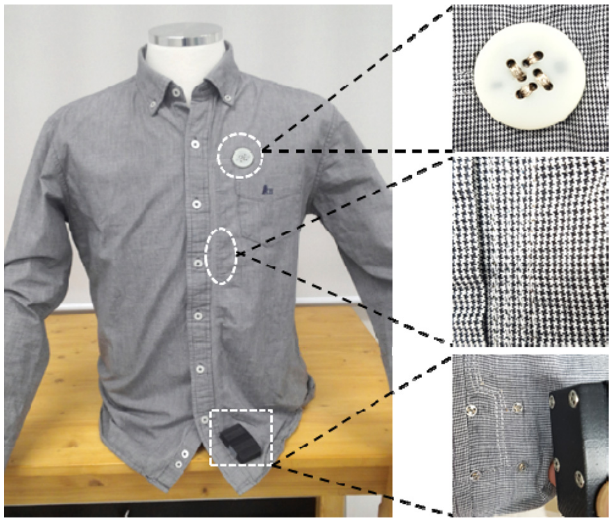
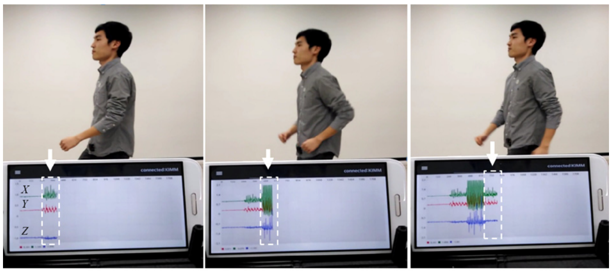


Fig. 7. Description of the electric accelerometer button fastened on clothing shirts.

3.2 Applications of the electric button

It was found that the electric button could measure physical activity by attaching it on clothing shirts. A button with an accelerometer (MMA8452Q, NXP Semiconductor, Netherlands) was used. In Fig. 7, an electric button was sewn on the left chest, similar to a traditional button fastener, and a detachable microcontroller unit was placed at the bottom of the clothing. Waterproof seam-sealing tape was attached to conductive threads to protect the sewing threads from moisture, such as sweat, and were isolated from the skin of the body. For commercialization, the conductive thread needs to be coated with an insulation material or repeatedly sewn over the signal line with a non-conductive thread. The microcontroller unit included a wireless communication module. Physical activities were confirmed through wirelessly transmitted signals when a participant walked, ran, and walked again, as shown in Fig. 8. The sewn electric button could successfully measure the physical activities of the wearer, which is comparable to the previous work [6].

The electric button can be washed with clothes just like traditional button fasteners. The electric button continued to work well even after washing and drying 10 times, which is in



(a) (b) (c)

Fig. 8. Physical activities of a participant captured via the electric button: (a) walking, (b) running, and (c) walking again.

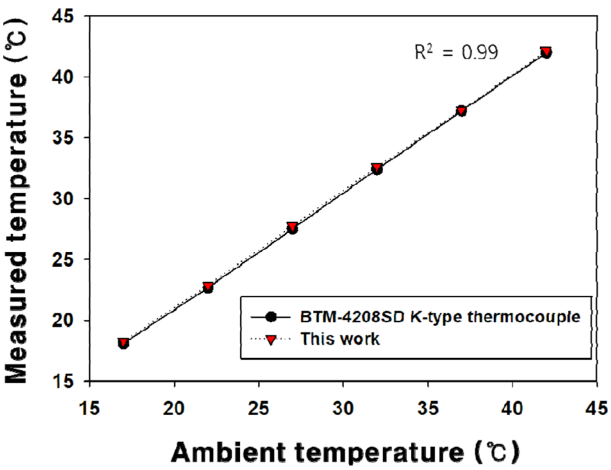


Fig. 9. Performance of the electric button as a temperature sensor.

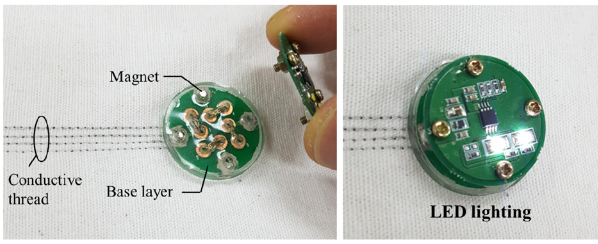


Fig. 10. Description of the electric button for LED lighting.

accordance with the washing durability standard of KS K ISO 6330.

To verify the performance of the electric button for temperature sensing, the measured temperature was compared with that of the reference equipment (BTM-4208SD, Taiwan). Fig. 9 shows the temperature measured by the button at various ambient temperatures. The temperature-sensing button used a commercial component of MCP9808 (Microchip Technology Inc., USA). The button had an accuracy effort of less than 1% compared to that of BTM-4208SD. Fig. 10 shows the successful operation of the button for LED lighting. It is expected that the LED button mounted on clothing can be used for pedestrian protection by turning it on in a dark environment.

4. CONCLUSIONS

A new electric device in the shape of a button was developed for smart fabric. The button was sewn with a conductive thread such that it could communicate with the external device. The PCB in the button has metallic through-holes that come in direct contact with the conductive threads. The specific functions of the electric button can be easily expanded by adding detachable application layers. When the electric button is sewn on for decorative purposes, like a traditional button fastener, it can identify the physical activity of the wearer, monitor ambient temperature, and turn on LED lights. The electrical considerations, such as power consumption and heat, can be neglected because the button in this paper has simple function such as LED lighting, but line resistance in the conductive thread can degrade the button's performance. Therefore, we investigated whether the line resistance could be sufficiently reduced by applying various stitch patterns. In this study, the electric components were successfully integrated into a button, demonstrating its potential as a wearable platform for IoT applications.

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