

Design of force measurement module for force touch screens

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Abstract: This paper presents a force touch technology that uses strain gauge sensors for next-generation 3D touch screens. We developed a force measurement module using strain gauges, and configured a system that was identifiable according to touch pressure, and tested the force measurement module. We found that the thickness of the base pad in the force measurement module is very important for touch sensitivity, and carried out thickness optimization of the base pad. We successfully conducted an experiment to display touch signals on a screen with various touch pressure and multi-touch testing. This study confirmed the possibility of applying to the force touch screen using the force measurement module.

Keywords: touch screen, force touch, 3D touch, strain gauge

Classification: Circuits and modules for electronics display

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1 Introduction

As mobile industry has been growing rapidly, 3D touch function is increasingly demanded for variety of 3D user interface. The new 3D touch function requires not only two-dimensional touch information but also touch force; the 3D touch function needs information on how much touch force is exerted to the screen. However, conventional touch screens normally detect the location of a touch within the two-dimensional screen area. Several touch sensing technology currently exist such as resistive, capacitive, infrared, and surface acoustic wave [1, 2, 3]. These technologies are not necessarily suitable for 3D touch function, so they need new force sensing technology. Various force sensing technologies have been researched for several fields such as robots, wearable machines, and mobile displays. For example, Apple introduced the new force sensing technology by introducing iPhone 6S in 2015 [4]. By placing capacitive sensors on the iPhone’s backlit module, the sensor detects microscopic changes in pressure by measuring the distance between the cover glass and the backlight of the sensor. When a user presses the iPhone screen, it will trigger pressure-sensitive ability that will open up menus or actions on the mobile phone. There are various other force sensing devices such as force sensing resistor, quantum tunneling composite, micro electro mechanical system (MEMS), and strain gauges [5, 6, 7, 8]. The force sensing resistor has a low price advantage, but has low reliability and precision. The quantum tunneling composite has a linear conversion characteristic which smoothly change from an electrical insulator to a metal-like conductor when placed under pressure. However, the material cost is high and the reliability is not yet complete. The MEMS has high precision and excellent temperature characteristics, but has disadvantages of high cost and thickness.

Strain gauges are a sensor to measure forces and are commonly used in commercial force sensors. It is already proven technology in the field of sensors and has a very cheap price. Using strain gauge sensors, we propose new force measurement module for force touch screens.

2 Proposed force measurement module architecture

Fig. 1(a) shows a cross-sectional view of the expected force touch screen which includes cover glass, display panel, air gap layer and force measurement module. The cover glass is a place where touching forces are applied, and acts to protect the display panel. When a touch is exerted on the cover glass, slight bending occurs in the cover glass and the display panel. As the air gap layer is reduced due to the

bending of the display panel, the magnitude of the touch force is measured by the force measurement module. Liquid crystal display (LCD) or organic light emitting diode (OLED) can be used for the display panel.

Fig. 1(b) shows block diagram of the proposed force measurement module which is divided into four sections: force detection unit, strain gauge amplifier, analog multiplexer, and data processing unit. The force detection unit uses touch sensors to detect any touch force on the display screen. Since the detected touch signal is very weak, it is amplified to a large signal through the strain gauge amplifier. The analog multiplexer is used to transmit touch data sequentially from multiple strain gauge amplifiers to the data processing unit. The data processing unit controls the analog multiplexer to receive data sequentially. The data processing unit transforms analog touch data into digital data, and calculates the touch coordinates and force.

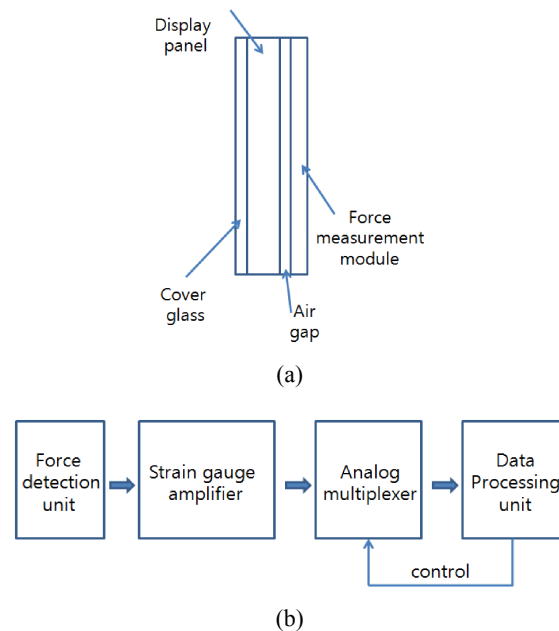


Fig. 1. (a) Cross-sectional view of a force touch screen. (b) Block diagram of the force measurement module.

Configuration of a force detection unit of the force measurement module is shown in Fig. 2(a). Using metal foil type strain gauges, the force sensor is constructed on a base pad. A number of strain gauges are arranged horizontally and vertically to form the force sensor. When a force is applied on the strain gauges, resistance of the sensor will be slightly changed. To detect the resistance change into a voltage, each strain gauge requires a voltage sensing circuit. The detected voltage (V_s) can be derived from Eq. (1) [9]:

$$V_s = V \left(\frac{R_2}{R_1 + R_2} - \frac{R_3}{R_3 + R_g} \right) \quad (1)$$

where R_g and V represent resistance of a strain gauge and input voltage, respectively. Resistance of each resistor (R_1, R_2, R_3) is 120 ohm, and the input voltage is set to 5 V.

Fig. 2(b) depicts a strain gauge amplifier which plays a role in amplifying the detected voltage (V_s) of the force detection unit. Variable resistor (VR_G) regulates amplification factor up to 2000, and another variable resistor (VR_O) adjusts offset voltage of the amplifier. Capacitor (C_F) acts as a low-pass filter to stabilize output voltage (V_{AMP}) whose maximum output voltage is designed to be 5 V. Since each strain gauge requires an individual strain gauge amplifier, gain adjustment between the amplifiers is essential.

Fig. 2(c) shows an analog multiplexer which selects multiple output voltages (V_{AMP}) sequentially and sends them to the data processing unit in Fig. 2(d). The selected input signal of the multiplexer is passed to the output (V_{MUX}). Also, multiplexer control signals consisting of 4 bits ($S0 \sim S3$) are controlled by the data processing unit.

As shown in Fig. 2(d), the data processing unit consists of analog-to-digital converter, force detection algorithm, and multiplexer control. As a microprocessor we used Atmega128 which includes a 10 bit analog-to-digital converter. In order to determine a magnitude of force being applied to a touch screen, we need digital

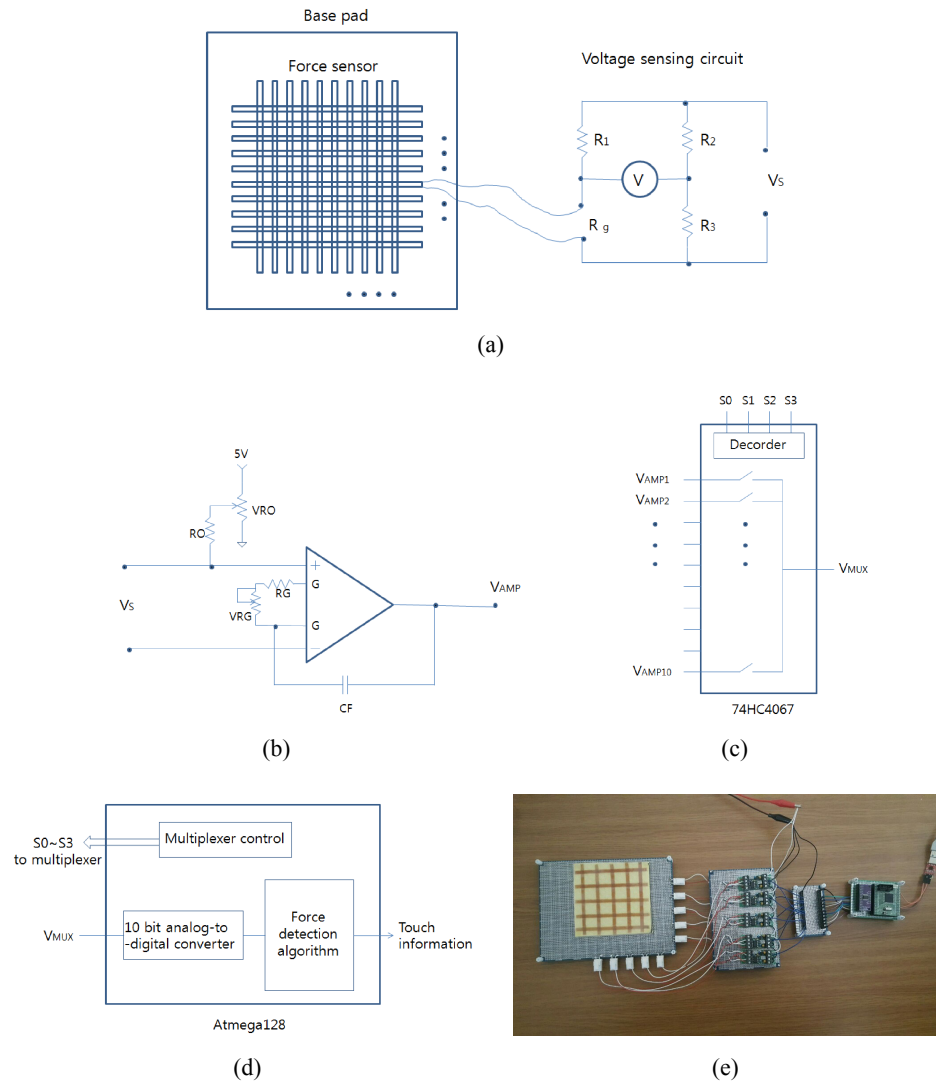
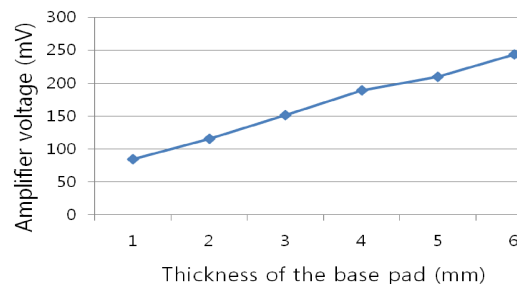


Fig. 2. Configuration of the (a) force detection unit. (b) strain gauge amplifier. (c) analog multiplexer. (d) data processing unit. (e) constructed the force measurement module.

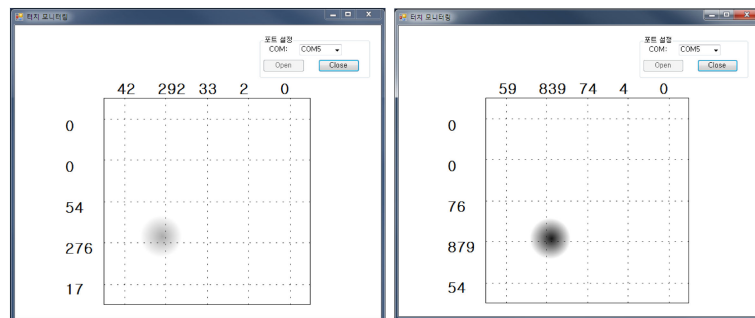
data for the data processing. The analog-to-digital converter transforms the analog multiplexer output (V_{MUX}) to digital data which is used for the force detection algorithm. Data is collected from the analog-to-digital converter sequentially and the median value of the data is calculated on the horizontal axis and on the longitudinal axis respectively. The force detection algorithm calculates the touch coordinates and force strength and allowed them to appear on a screen. In particular, multi-touch algorithm for force touch screen is employed [10]. The constructed force measurement module is shown in Fig. 2(e).

3 Experimental results

The key point in force sensing depends on the sensitivity of the force sensor, which is mainly dependent on the thickness and material of the base pad in the force detection unit. To identify the sensitivity of the force sensor, silicon rubber plates were used as the base pad material. In Fig. 3(a) we show the effect of the thickness

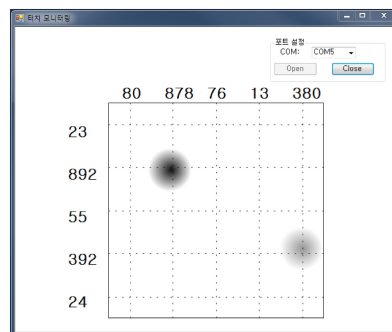


(a)



(b)

(c)



(d)

Fig. 3. (a) Output voltage of the strain gauge amplifier as a function of thickness of the base pad. (b) test with a weak touch. (c) test with a strong touch. (d) test with a multi-touch.

change of the base pad on the output voltage of the strain gauge amplifier. It was found that the strain gauge amplifier voltage increases linearly as the thickness of the base pad increases as shown in Fig. 3(a). The reason is that the resistance value of the metal foil type strain gauge is varied by the touch force of the horizontal direction rather than the touch force in the vertical direction. In other words, the thicker the thickness of the pad, the better the touch sensing is. However, if the thickness is too large, it is likely to cause strain on the strain gauge to cause damage to the strain gauge. Therefore, the thickness of the pad was moderately determined by 4 mm.

To test the performance of the force measurement module, a graphic user interface system has been configured to display the touch force on a screen. The system displays the outputs of five strain gauges in horizontal direction and in vertical direction, respectively. Output values are distinguished according to the touch pressure up to a maximum of 1024. Fig. 3(b) and (c) show the test results with a weak touch and a strong touch. It is noticed that the touch position is marked by a concentration difference depending on the touch pressure. In addition, in the case of multi-touch, two touch points are shown in Fig. 3(d) to show that the different touch pressure is displayed simultaneously.

4 Conclusion

We developed the force measurement module using strain gauges for a force touch screen, and carried out a successful experiment with various touch pressure and multi-touch testing. We have identified and optimized the thickness of the base pad and the touch sensitivity of the force measurement module. As a future study, we need research to reduce the number of strain gauge amplifiers for a small size product and cost reduction.

Acknowledgments

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