Surveys on the Stylus Technologies for Capacitive-Type Touch Systems

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Abstract

In this paper, the surveys on the stylus technologies for capacitive-type touch systems (CTSs) are presented. The stylus technologies are classified into the passive and active stylus depending on the battery integration. To explain two types of the stylus, the architecture of CTS with the stylus is firstly explained. Afterward, the operation principles of the passive, which have a capacitive-type (C-type), an electromagnetic resonance type, and an electrically coupled resonance type, and a C-type active type styli are described.

Author Keywords

Active stylus; capacitive-type passive stylus; electromagnetic resonance (EMR) type passive stylus; electrically coupled resonance (ECR) type passive stylus

1. Introduction

The capacitive-type touch systems (CTSs) are widely used in various applications such as a mobile phones, a tablet PCs, an automotives, and an interactive whiteboards due to their durability, high sensitivity, and multi-touch capability (1-3). Especially, the more a high-end CTSs are needed in these applications, the more the stylus in the CTS is demanded to express the various expressions with high sensitivity (1-13).

As shown in Table 1, the stylus can be classified into the passive and active stylus without and with the battery integration, respectively (3). Among the several types of passive styli, the capacitive type (C-type) is dominantly used with the CTS because of its small thickness and weight, and the low fabrication cost, but it can express the only coordinate of stylus with a low sensitivity. The electromagnetic resonance (EMR) type (3,6-7) stylus can express the pressure and tilt angle with a high resolution and sensitivity, but it requires an additional EMR sensor under the display panel, which increases the power consumption, fabrication cost, weight, and thickness of the CTS. The electrically coupled resonance (ECR) type stylus can express the pressure without an additional sensor, but it can represent only a pressure expression with a low resolution (8-9). The C-type active stylus (10-13) can represent the various expressions such as the pressure and tilt angle with a high resolution, but it needs a high thickness, high power consumption, and fabrication cost of the stylus because of the additional circuit and battery.

This paper presents the surveys of stylus technologies for the CTSs. Section 2 explains the architecture of the CTS with stylus. Sections 3 and 4 describe the passive and active stlyi, respectively. Finally, the conclusion is given in Sections 5.

2. Architecture of CTS with Stylus

Fig. 1 shows the architecture of the CTS, which includes the touch sensor, analog front-end IC (AFE IC), and digital processor, with the stylus,. When the AFE IC sends the excitation signal (V_{EXT}) to the touch sensor, V_{EXT} is converted into the charge signal (Q_S) due to the capacitance between transmitter (TX) and receive (RX) electrodes. At the same time, the stylus changes the amplitude of Q_S through the capacitances between stylus, and TX and RX electrodes ($C_{STY,TX}$ and $C_{STY,RX}$). The AFE IC digitizes the Q_S and transfers the digital data to the digital processor. The digital processor extracts the digital data to the touch data, and transfers it to the host PC. The host PC then calculates the touch coordinate and sends it to the display panel to show the various expressions of the stylus. According to the types of stylus, the multiplexer can be used to change the sensing direction (3,8-13).

Table 1. Types of stylus.

Types	C-type passive stylus	EMR-type passive stylus	ECR-type passive stylus	C-type active stylus
Battery	No	No	No	Yes
Form factor of stylus	Thin and light	Thin and light	Thin and light	Thick
Additional sensor	No	Yes or No	No	No
Fabrication cost	Low	High	Low	High
Sensitivity (SNR)	Low	High	Middle	High
Pressure (resolution)	No	Yes (High)	Yes (Low)	Yes (High)
Tilt (resolution)	No	Yes (High)	No	Yes (High)

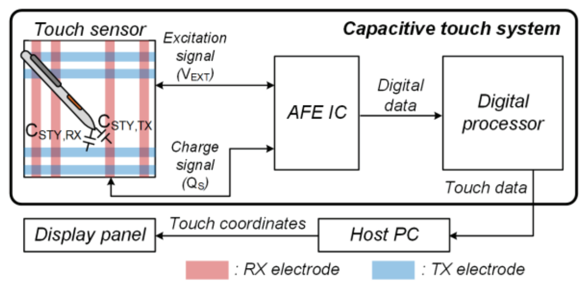


Figure 1. System architecture of CTS with stylus.

3. Passive-type stylus

3.1 Capacitive Type (C-type)

The C-type passive stylus has been widely used in the CTS because of its small thickness and weight, and the low fabrication cost (3). Figure 2 shows the conceptual diagram of the C-type passive stylus. When the stylus moves from point A or C (between two RX electrodes) to point B or D (on the RX electrode), respectively, the capacitance variation increases because the C-type passive stylus changes more amplitude of Q_S. In addition, when the stylus tip is enlarged, it also changes more the amplitude of Q_S between the stylus tip and touch sensor, resulting in an increase in the capacitance variation.

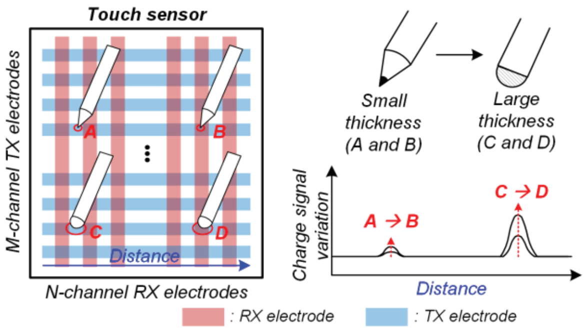


Figure 2. Conceptual diagram of C-type passive stylus.

Thus, the C-type passive stylus depends on the thickness of the tip and electrode pitch of touch sensor. When the tip thickness is decreased, it absorbs less Qs from the touch sensor, resulting in a small capacitance variation, and thereby it is hard to detect the stylus coordinate. Therefore, to maximize the capacitance variation of touch sensor, a large thickness tip is conventionally used for the C-type passive stylus (4-5).

3.2 Electromagnetic Resonance (EMR) Type

For various expressions such as the pressure and tilt angle, the EMR-type passive stylus has been adopted for mobile devices (6-7). Figure 3 shows the conceptual diagram of the EMR-type passive stylus and its sensing system. The sensing system consists of the EMR sensor with magnetic coils, EMR switch, and EMR excitation and readout circuits. In the EMR-type passive stylus, the equivalent circuit can be drawn using the tank inductor (L_{TANK}), tank capacitor (C_{TANK}), and pressure-sensitive capacitor ($C_{PRESSURE}$), button capacitor (C_{BOTTON}), and button switch. When the EMR excitation circuit is connected with the EMR sensor through the switch, the stylus absorbs the magnetic field, which is generated from the magnetic coils in the EMR sensor, through the L_{TANK} and combination of capacitors (C_{TANK}+$C_{PRESSURE}$+C_{BUTTON}). According to the pressure of stylus and button, the value of the combination of capacitors are changed because the values of $C_{PRESSURE}$ and C_{BUTTON} is adjusted, respectively. After then, the stylus converts the magnetic field to a radio frequency (RF) signal and sends the RF signal back to the EMR sensor as a stylus signal (V_{STY}) having different V_{STY} frequency (f_{STY}) according to the pressure and button as an Equation 1.

$$f_{STY} = \frac{1}{2\pi\sqrt{L_{TANK} \times (C_{TANK} + C_{PRESSURE} + C_{BUTTON})}} \quad (1)$$

In addition, to extract the coordinate of stylus efficiently and accurately, the two-step sensing method is used. During the first step sensing period, the coordinate of stylus is roughly determined. When the coordinate of stylus is detected, the coordinate is accurately extracted by driving the additional magnetic field and sensing V_{STY} during the second step sensing period. The EMR-type stylus can express the pressure and tilt angle with a narrow tip, but it needs the additional EMR sensor, which needs higher power consumption, thickness, and fabrication cost. In addition, the sensitivity of the EMR stylus depends on the magnetic coil's density and uniformity in the EMR sensor. Therefore, the magnetic coils is necessary to place with even and dense in all EMR sensor area.

3.3 Electrically Coupled Resonance (ECR) Type

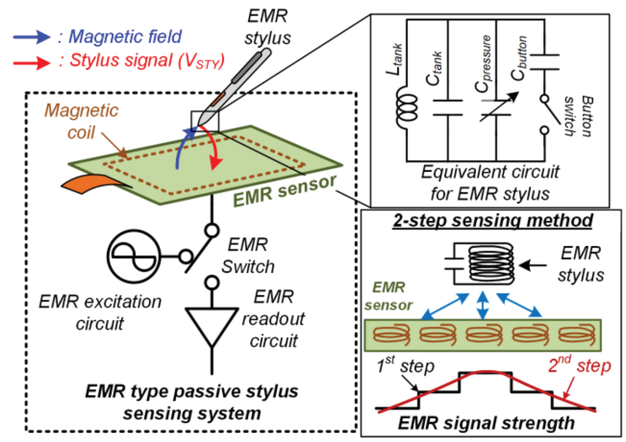


Figure 3. Conceptual diagram of an EMR-type passive stylus and sensing system.

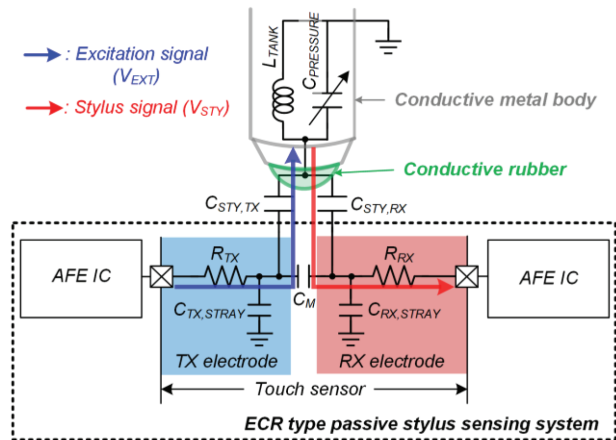
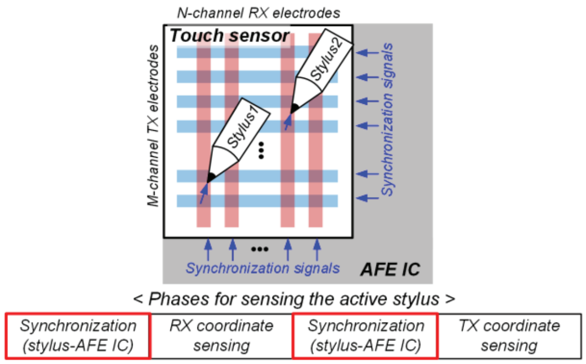


Figure 4. Conceptual diagram of an ECR-type passive stylus and sensing system.

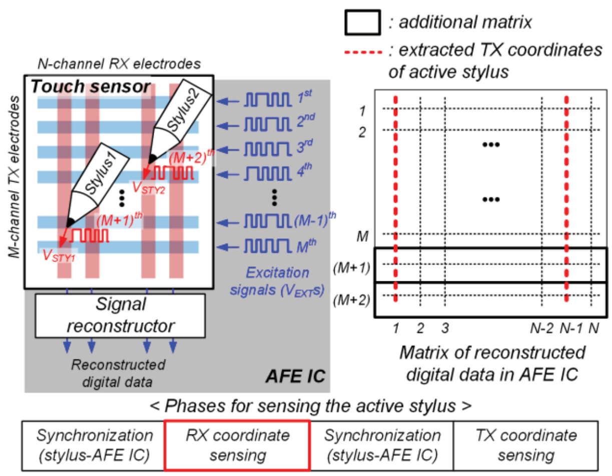
To express the pressure without the additional sensor, the ECR-type passive stylus was introduced (8-9). Figure 4 shows the conceptual diagram of the ECR-type passive stylus and sensing system. The ECR-type passive stylus consists of the conductive rubber and the conductive metal body including L_{TANK} and $C_{PRESSURE}$. When the AFE IC sends the V_{EXT} to the touch sensor, the stylus absorbs the V_{EXT} through the $C_{STY,TX}$. It then converts the absorbed V_{EXT} to the resonance signal and transmits the resonance signal to the touch sensor as a V_{STY} with a frequency of an Equation 2.

$$f_{STY} = \frac{1}{2\pi\sqrt{L_{TANK} \times C_{PRESSURE}}} \quad (2)$$

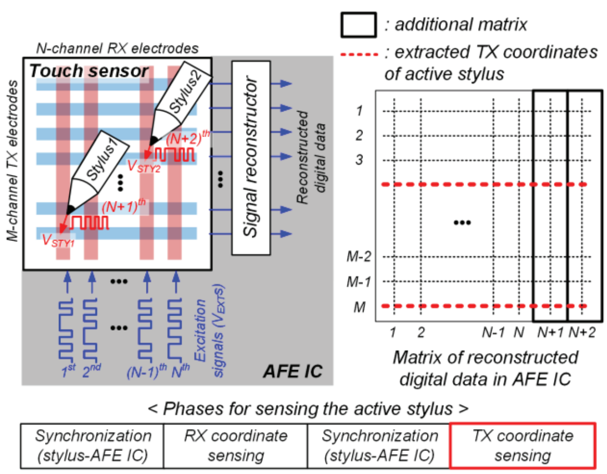
The AFE IC senses the V_{STY} through the $C_{STY,RX}$. The pressure of the ECR-type passive stylus can be expressed using a different frequency of V_{STY} by changing the $C_{PRESSURE}$ as described in Equation 2. The ECR-type passive stylus does not need an additional sensor, thus it achieves a low power consumption and fabrication cost, and small thickness of the CTS. However, because the values of $C_{STY,TX}$ and $C_{STY,RX}$ are small due to the small tip, the ECR-type passive stylus cannot absorb the enough V_{EXT} through the touch sensor, and thus it has a low sensitivity. Moreover, the ECR-type passive stylus can



(a)



(b)



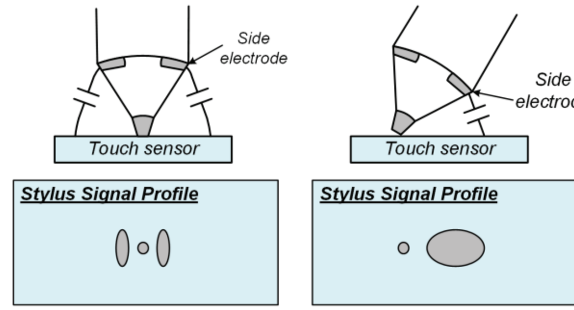
(c)

Figure 5. Conceptual diagram of active stylus and sensing system: (a) synchronization phases, (b) RX coordinate sensing phase, and (c) TX coordinate sensing phase.

express the pressure only.

4. C-type Active-type Stylus

To express the pressure and hovering with high sensitivity, the active stylus was firstly adopted in the CTS with the parallel driving method (PDM) (10). As shown in Figure 5(a), to synchronize the timing between the active stylus and AFE IC, the active stylus absorbs the synchronization signals from the AFE IC before the RX and TX coordinate sensing phases. Figure 5(b) shows the RX coordinate sensing phase. The two active styli send the two V_{STYS} (V_{STY1} and V_{STY2}) to the touch sensor. At the same time, the AFE IC emits the V_{EXTS} to M-channel TX electrodes in parallel. When the AFE IC receives the V_{STY1}, V_{STY2}, and M-V_{EXTS}, it generates the N×(M+2) matrix digital data, and reconstructs this matrix to digital data through the signal reconstructor. Then, the AFE IC extracts the RX coordinates of the two active styli. Figure 5(c) shows the TX coordinate sensing phase. After the second synchronization phase, the sensing direction of AFE IC is changed from RX electrode to TX electrode. When the two styli and AFE IC send V_{STY1} and V_{STY2}, and N-V_{EXTS} to the touch sensor, respectively, the AFE IC sense these signals and reconstruct them as the (N+2)×M matrix digital data using the signal reconstructor. Finally, the AFE IC extracts the RX and TX coordinates of the two active styli.

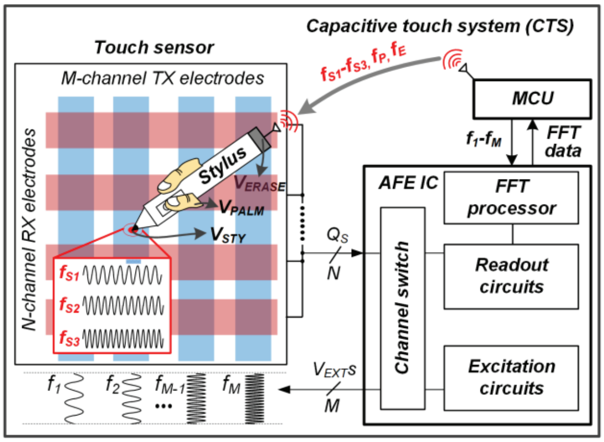


(a) (b)

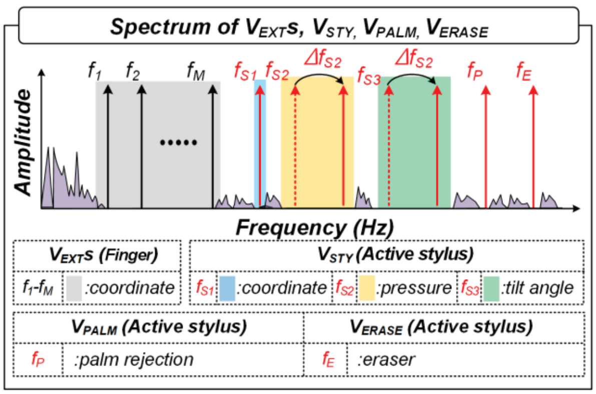
Figure 6. Principle of the tilt expression of the active stylus: (a) without and (b) with the tilt angle.

Figure 6 shows the principle of the tilt expression of the active stylus. To express the tilt angle, the side electrodes are added at the side of stylus (11). Due to the side electrodes, the AFE can detects the capacitance variation between side electrodes and touch sensor. Without the tilt angle, three profiles of V_{STY} can be extracted in the CTS as shown in Fig. 6(a) because of two side electrodes and tip. With the tilt angle, the two profiles of V_{STY} are extracted in the CTS along with the direction of the tilt. According to the capacitance profiles and their dimensions, the CTS can extract the tilt angle of active stylus. Although the active stylus can express the pressure, tilt, and hover height with high sensitivity, the additional synchronization phases are needed for synchronizing between stylus and AFE IC.

To remove the synchronization phases, the CTS and active stylus adopt the multiple-frequency driving method (12-13). Figure 7 shows the conceptual diagrams of the CTS with the active stylus and operational principle. As shown in Figure 7(a), the MCU allocates the frequencies of f_1-f_M (frequency of V_{EXTS}) and f_{S1}-f_{S3}, f_P, and f_E (f_{S1}: coordinate, f_{S2}: pressure, f_{S3}: tilt angle, f_P: palm rejection, and f_E: eraser) in the low noise region for the high sensitivity, and sends them to the AFE IC and active stylus, respectively, without synchronization phases. When the active stylus senses the pressure and tilt angle, it changes the f_{S2} and f_{S3} to $f_{S2}+\Delta f_{S2}$ and $f_{S3}+\Delta f_{S3}$, respectively, and sends the V_{STY} having f_{S1}-f_{S3} to the touch sensor. To realize the palm rejection, the active stylus sends the V_{PALM} with f_P to the touch sensor through the side electrode and human body (13). In addition, to perform



(a)



(b)

Figure 7. Conceptual diagram of (a) the CTS and active stylus using the MFDM, and (b) its operational principle.

the erase operation, the active stylus sends a V_{ERASE} having f_E to the touch sensor via the conductive eraser (13). As shown in Figure 7(b), when the AFE IC senses the frequencies of Δf_{S2} and Δf_{S3}, the MCU can extract the pressure and tilt angle of the active stylus. In addition, when the AFE IC senses the frequencies of f_P and f_E, the MCU identifies the presence of palm and eraser, respectively (13). Therefore, the active stylus can express the pressure, tilt angle, and eraser without the synchronization phases (12-13). Although the active stylus can express the pressure, hovering height, and tilt angle with a high sensitivity, it has a high thickness, high power consumption, and high fabrication cost because of the additional circuit and battery in the active stylus.

5. Conclusions

This paper presents the survey of stylus technologies for the CTSs. The stylus technologies are classified into passive and active styli depending on the battery integration. To explain two types of styli, the architecture of CTS was firstly explained. After then, the operation principles of passive, which has the C-, EMR-, and ECR-types, and the C-type active stylus are described for the CTSs with the operational principles, advantages, and disadvantages. The passive stylus should be researched more to achieve high sensitivity with the thin and light, and low fabrication cost. The active stylus should be researched to have small thickness and weight with having a various expressions.

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