Sharp Force Touch for On-Screen User Interface in LCD and Foldable OLED Display Application

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Abstract

We describe ultra-high sensitive force sensor on flat display that can detect and differentiate between feather touch and press touch or tapping. The proposed unique sensor pattern design and pressure-sensitive material enables ultra-high force sensitivity, multi force detection (10 points). The minimum force that can be detected is 25g with cover film and 300g with thick cover glass. The proposed technology provides on-screen user interface with extremely good performance for automotive application. Moreover, with integrated force function, we can realize "error-free input", "adaptive input" and "any object input" interface on flat display.

1. Introduction

Recently, the trends of the cockpit in the automotive industry have undergone major changes. As shown in Fig. 1, from the viewpoint of cockpit trends, an integrated center console adopting a flat design has become the mainstream. This novel center console includes displays for meters, center information and co-driver.

Figure 1. Trend of cockpit.

From the viewpoint of HMI (Human Machine Interface), the integrated center console with a flat design eliminates the mechanical button placement and expands the user interface on the display. However, the current on-screen user interface has some of issues. The current user interface using conventional capacitive touch panel are prone to typos, and the interface is not ergonomic. As consequence, usability of conventional center information display is still low and the on-screen user interface is still far from being what the user expects.

We describe the target regarding user interface for automotive application. Exceptionally ergonomic on-screen user interface with usability performance as good as mechanical buttons and as user friendly is strongly required for automotive products. This can be achieved by additional force function that enables to distinguish the difference between “Feather Touch” and “Press or Tap” (Fig. 2).

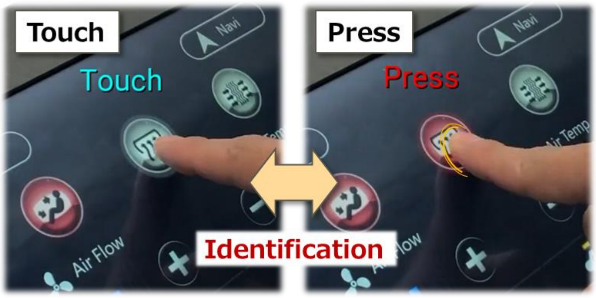


Figure 2. Concept.

Recently, intensive work on display-integrated force touch sensor to realize on-screen user interface have been reported. In the past years, different kinds of sensing methods have been studied to develop high-performance force sensors as Capacitance [1, 2, 5, 7], Piezoresistivity [4], Piezoelectricity [6]. The performance of the force sensor is required to be equal to or higher than that of a mechanical button. Sensitivity, key force less than 60g, and multi-touch are required. In the conventional technology, panel bending capacitive sensing methods used in iPhone [1] or pressure sensitive elements at module frame have difficulties to increase sensitivity and support multi-touch. Our technology achieves the same performance as the mechanical keyboard with a key force of 25g or less, a key entry of 5 times per second and multi-touch with cover film. Furthermore, our proposed technology achieves the same performance as the mechanical buttons with a key force of 300g or less for automotive application with thick cover glass.

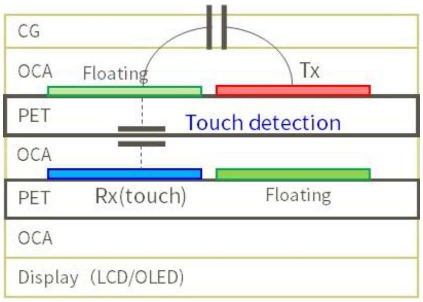
In this paper, we present the force touch technology for on-screen user interface in LCD and OLED display application. Our prototype realizes the on-screen user interface with extremely good usability and glove input on flat display.

2. Force Touch Technology

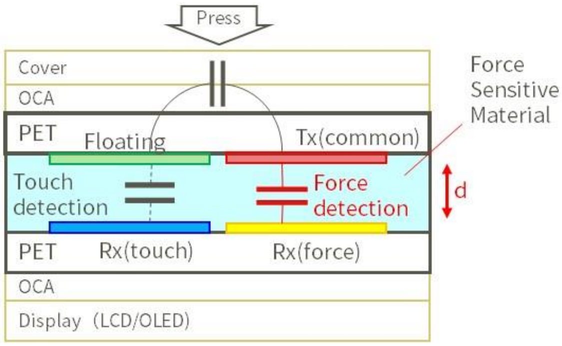
2.1. Sensor Structure

Fig.3 shows the advantage of ***<u>s</u>harp <u>f</u>orce <u>t</u>ouch(SFT)*** technology compared with the projected capacitive touch panel. In the conventional capacitive touch panel, the finger is detected by the change of the capacitance between Tx (transmitter electrode) and Rx (receiver electrode). In the proposed technology, additional electrodes for force-sensing is arranged on the same layer with the touch receiving electrode and directly under the transmitter electrode.

The force signal is measured by change in the thickness of the pressure sensitive layer and detected at the same time as touch detection. The stack-up structure is same as that of conventional touch panel but our unique sensor pattern design and pressure-sensitive material enables to simultaneously detect the touch and pressure signals.



(a) Conventional capacitive TP



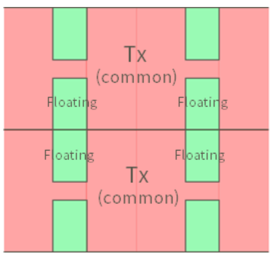
(b) Sharp Force Touch

Figure 3. Details of the cross section structure.

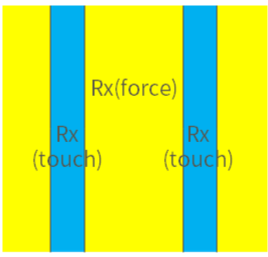
In our previous work [6], the sensor had a three-layer structure in which the force electrode and the touch electrode were arranged in separate layers. The presented new structure has realized thinner, higher transparency and sensitivity. Compared with conventional capacitive touch panel, this technology realizes both the force and touch detection at the same time without additional layer.

2.2. Sensor Pattern

Fig. 4 shows the novel force touch sensor pattern for automotive products. For automotive application, an active stylus is not required. Therefore, the area of the force electrode are maximized to achieve much higher force sensitivity. The sensor pattern is designed based on the rectangle pattern. In the first layer, the Tx (transmittance) electrodes and floating electrodes are arranged next to each other.



(a) First layer



(b) Second layer

Figure 4. Sensor patterns of Sharp Force Touch.

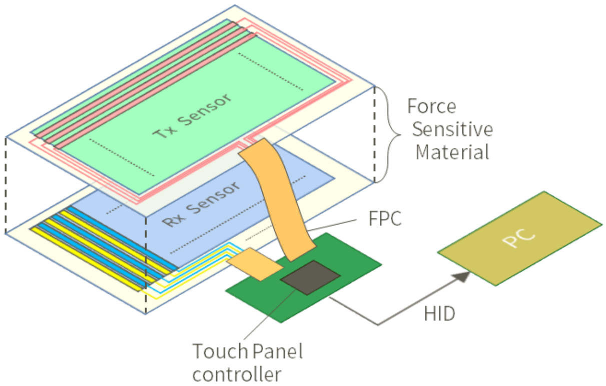
In the second layer, the Rx (Touch) electrodes are arranged in the direction perpendicular to the Tx electrode, and next to it, the Rx (Force) electrode is arranged so as to be overlapped with the Tx electrodes. By sensing the electrical signals between crossed Tx electrodes and Rx (Touch / Force) electrodes, touch and force detection can be realized with high resolution.

Also, since the added electrodes for force detection does not affect the electrode for touch, finger touch detection is done in same way as conventional capacitive touch panel.

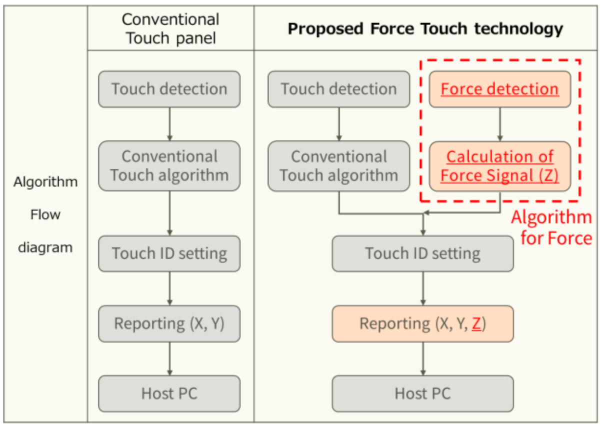
2.3. Sensor System and Algorithm

Fig. 5 shows the sensor system and algorithm for ***Sharp Force Touch***. The touch sensor has 48 Touch Rx, 48 Force Rx and 27 Tx electrodes. For touch and force sensing, the all electrodes were interfaced to a converter board circuitry comprising in-house touch controller IC (SHARP IC).

Understandably, algorithm of conventional Touch IC is slightly modified so that Force features can be reported to the Operating System and used for different application. The change in algorithm is very minimal. Differently from the conventional touch algorithm, data acquired from Force Touch sensor are devised into 2 maps; one map displays touch feature and the other displays force feature. The two maps are correlated and merged to assign force features to their touches. Beside that the rest of touch algorithm pipeline is kept intact. Force features are also added in HID (HID=Human Interface Device) report.



(a) System diagram



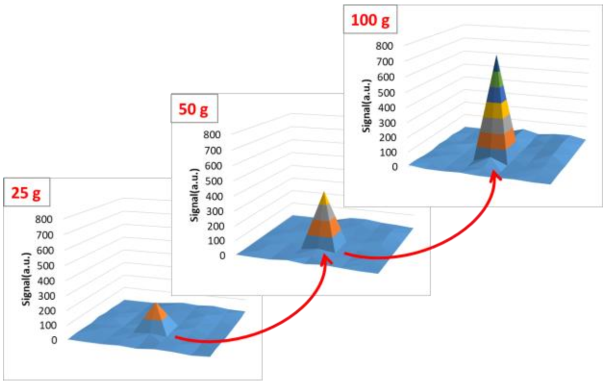
(b) algorithm

Figure 5. Sensor system and algorithm for Force Touch.

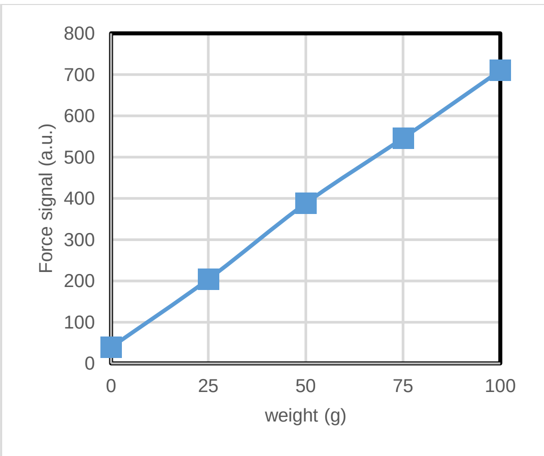
3. Results and Discussions

3.1. Force Sensitivity

Fig. 6 shows the evaluation results of force sensitivity. The pushing jig is hemisphere with r = 8 mm and the Shore A hardness of 20, and pushing weight is 0 g to 100 g. You can see that the force map has a clear peak when force is applied. Since this force signal rises linearly with the force increasing, the level of the force can be easily detected. The minimum force that can be detected is 25g with cover film, which realizes one half of 50g that the mechanical keyboard responds to key-input. Our prototype using our unique sensor pattern design and pressure-sensitive material has increased 10 times the sensitivity from 250g to 25g compared to our previous work [6]. Furthermore, the novel rectangle sensor pattern realized 3.2 times higher force sensitivity than previous diamond pattern [7].



(a) 3D Map of force detection.



(b) Quantitative evaluation of force detection.
Figure 6. Results of Force Sensitivity.

3.2. Touch and Force Detection

FIG. 7 shows the result of 3D Map when pressing on the display with three fingers, and the finger-to-finger distance is 18 mm. The proposed force touch technology detects touch and force signal at the same time, and Fig. 6 shows the touch map and the force map. As a result, the three well-separated peaks can be detected on the touch map and force map respectively. The touch map and force map signals are integrated by a dedicated algorithm, and the position and force of each finger can be detected with high resolution.

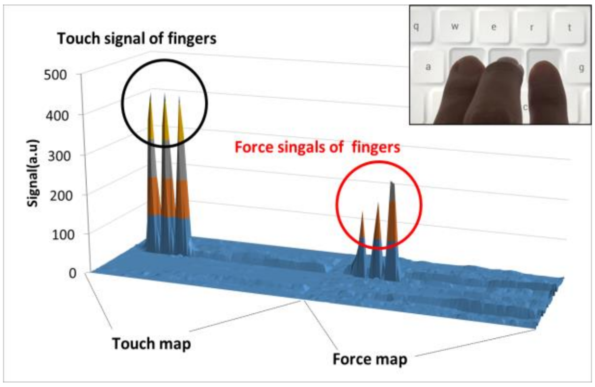


Figure 7. Results of touch and force sensing performance.

3.3. Prototype

The curved force touch display has been fabricated and the performance experimentally verified. Specifications of the prototype are shown in Table 1. The display size is 10.1”, in-house touch controller IC is used, force sensitivity is 25g with cover film, key entry is 5 times/sec, multi-touch 10 points is available, report rate is 120Hz, level for force is 512 levels and haptics function is available. To verify and demonstrate the usability and the user experience in each application, these prototypes were fabricated. Figure 8, 9 and 10 show the 10.1 inch prototype.

Table 1. Specifications of prototype.

	10.1” Curved Force Touch Display	
Display	Size	10.1” LCD
	Resolution	1,024 x 600 (WSVGA)
	Curvature	R500 mm
	LCD mode	IPS
	Backplane	IGZO TFT
Touch Panel	Number of sensors	48 x 27
	Number of terminals	96 x 27 (Rx(touch):48, Rx(force):48, Tx:27)
Force	Sensitivity	25 g
	Key entry	5 times/sec
	Multi touch	10 point
	Report rate	120 Hz
	Separation	12 mm
	Level for force	512 levels
Haptics	Actuator	Solenoid
	Acceleration	3.75G (Max.)

3.3.1. Error-free Input

Figure 8 shows the 10.1 inch prototype. Our force touch technology enables to search by “feather touch” and select by “press”. Therefore, SFT technology does avoid touch errors and reduces distraction. On a flat screen integrated with the tactile sensation and sound feedback, SFT allows user to find position of buttons by “feather touch” and select by “press”. Therefore, SFT enables blind input operations and provide touch sensation similar to mechanical button. SFT realizes accurate and tactile operation without erroneous input.

3.3.2. Adaptive Input

Furthermore, SFT sensitivity is linearly proportional to the pressing load. Therefore, for example, user can adjust press strength to his comfort. The control button can also be applied to various setting adjustments such as volume, temperature and screen brightness. Figure 9 shows navigation application. "Slide using feather touch" is move, "Press" with one finger is zoom in, "Press" with two fingers is zoom out. The unique gesture functions enable error-free and tactile flat-interface.

3.3.3. Any Object Input

Furthermore, since SFT can calculate touch coordinates using only force signals, SFT enables input operations with non-conductive objects in addition to fingers and conductive stylus. Users can operate with any object. SFT enables pen input with a non-conductive stylus and operation with a very thick glove for automotive application. (Fig. 10)

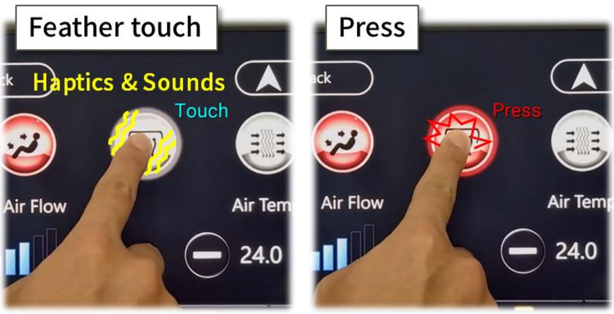


Figure 8. Error free input

Figure 9. Adaptive input

Figure 10. Any object input (Eraser)

4. Conclusion

We describe ultra-high sensitive force sensor on flat display that can detect and differentiate between simple touch and press touch or tap touch. The proposed unique sensor pattern design and pressure-sensitive material enables ultra-high force sensitivity, multi force detection (10 points). The minimum force that can be detected is 25g with cover film and 300g with thick cover glass. The position of the button can be detected by "feather touch" with the tactile sensation and sound feedback, and the force touch technology enables to select by "Press". Therefore, the proposed technology enables blind input operations and provide touch sensation similar to mechanical button.

The force function realizes the advantage of analog feeling such as mechanical buttons on the flat panel. Furthermore, new functions can be assigned to force function. The proposed technology enables glove input for rugged PC application, on-screen console button and joystick on miniature mobile computer for work at maintenance sites and factory lines. Our force touch technology can be applied not only to Automotive application but also to Industrial application such as miniature mobile computer and rugged PC.

Acknowledgements

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