A Robust, Continuous Capacitive Slider Control for Cooktops

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Abstract

We introduce a continuous capacitive slider controller for consumer electronics. Rather than using a series of discrete proximity pickups, this controller uses only two distributed receive electrodes. A feed-line shielding scheme limits sensitivity to finger rolling and misplacement. This system has been demonstrated to work well through glass ceramic, and is proposed as a continuous slider to control the burner heat of a flat cooktop.

1. Introduction

Capacitive touch controllers are very old, dating back to elevator buttons from the middle of the last century [1]. As the associated electronics became simpler, capacitive touch controls have migrated into many other appliances, from electronic music keyboards to personal music players. Touch controllers are especially appropriate to cooking surfaces, where they can be placed beneath a flat nonconductive plate that can be easily cleaned [2]. Accordingly, they are extensively applied in flat glass ceramic cooktops, where one typically sets the burner heat by repeatedly hitting increment or decrement buttons to arrive at a desired continuous value. While this works adequately, it lacks the intuitive appeal of a continuous knob or slider that analog controls use. Although a continuous slider can be approximated by an array of closely-spaced discrete buttons, this paper describes a simple system that uses only three patterned electrodes to make a capacitive slider that robustly detects finger position beneath a glass ceramic surface.

2. Electrode Geometry

Figure 1 shows the geometry of the electrode that is placed beneath the cooktop. The top drawing shows

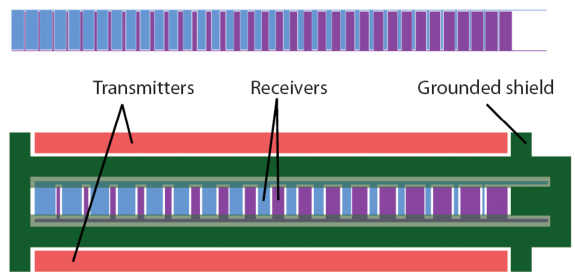

Figure 1: Interweaved pair of tapered pickup electrodes (top) and full electrode arrangement with transmit electrode and shielding (bottom)

the pickup electrodes – they are tapered in a complementary fashion [3] such that the average capacitive coupling intercepted by a finger placed over each electrode varies linearly (and oppositely) with position along the electrode's axis. A finger at left induces more signal on the top electrode than a finger at right, which induces more signal on the bottom electrode. Using an interdigitated geometry reduces sensitivity from moving the finger up and down, orthogonally to the sensitive axis. It was noted in practice that the feed lines at the upper and lower edges of the electrodes would give a noticeable bias when the finger rolled up or down – accordingly, these feed lines were shielded by a overlaid grounded guard electrode, as depicted in the lower figure (the feed lines can also run along a trace on a printed circuit layer beneath the electrodes, to which they couple with vias, eliminating the need for feed traces on the top layer and the large shield).

This sensor works in shunt mode [4], where an AC signal capacitively coupled from a transmit electrode surrounding the structure (Fig. 1) is absorbed by a nearby finger or extended object. The intrinsic coupling between the pickup electrodes and the transmit electrode is lowered by the presence of a finger in close proximity to the sensor, producing a drop in the induced pickup signal.

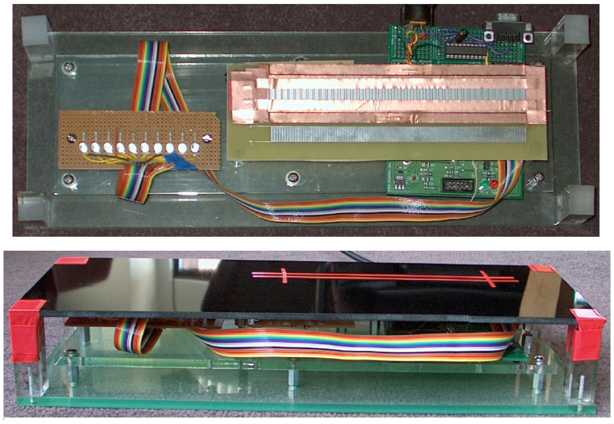

Figure 2: Complete slider demo - overhead view without glass ceramic cover (top) and side view (bottom)

3. Implementation

The receive electrodes were implemented as current-sensing pickups by conditioning each with a transimpediance amplifier followed by a passive filter and a full-wave envelope detector. A microcontroller digitized these signals into 12 bits, low-pass filtered them with an IIR filter to remove noise, and produced a 50 kHz, 3V square wave that was applied to the transmit electrode. A finger is "detected" when the sum of both pickup signals drops below 95% of its quiescent value, upon which the finger position along the slider is calculated by normalizing the difference between the pickup signals by their sum.

The electrode of Fig. 1 was 6 inches long and 0.5" wide, and the smallest fingers are .008" wide, while the largest are 0.15" wide. The transmit electrodes are 0.25" wide, and separate the sensing electrodes from the transmit electrode (plus force the sensed electric field lines to pass up over the glass), as depicted in Fig. 1. The ground is extended over the feed electrodes by an insulated spur of copper tape. More details are given in [5].

4. Results

The electrode assembly was mounted just below a 0.125" thick pane of glass ceramic from a cooktop assembly, as shown in Fig. 2, which shows the entire setup including all electronics, microcontroller, LED bargraph, and electrodes (note that only the upper set of electrodes, visible in the top photo and enclosed by copper tape, were used). The 95% detection threshold on the sum signal reliably indicated the presence of a finger when it was just touching the glass, whereupon this system tracked finger position smoothly, with a sensitivity better than 1 mm across the full sensor range, and displayed excellent robustness to finger roll. Since spillage of conductive or dielectric liquid, such as salty water, increases the net coupling of the transmit signal to the pickup electrodes, it works in a fashion opposite to a finger, hence can easily be detected and ignored. The microcontroller directly drives a 10-LED bargraph beneath the glass ceramic to give direct visual feedback, and outputs the raw data to a serial port for further analysis. Figure 3 shows the demo tracking finger position (the red tape on the glass ceramic only serves to visually indicate the slider position) and a video clip is available online [6].

10. References

[1] Bruns, W.H., "Control for Electronic Circuit," US Patent No. 2525769, October 17. 1950.

[2] Gould Jr., R.R., "Domestic Range Control and Display System," US Patent No. 3819906, December 26, 1972.

[3] Baxter, L.K., *Capacitive Sensors*, IEEE Press, New York, 1997.

[4] Paradiso, J.A. and Gershenfeld, N., "Musical Applications of Electric Field Sensing", *Computer Music Journal*, 21(3), 1997, pp. 69-89.

[5] Paradiso, J.A., et al, "Sensing Systems for Glass Ceramic Cooktops," Responsive Environments Group Technical Report, MIT Media Laboratory, July 18, 2003.

[6] See: http://www.media.mit.edu/resenv/Cooktops

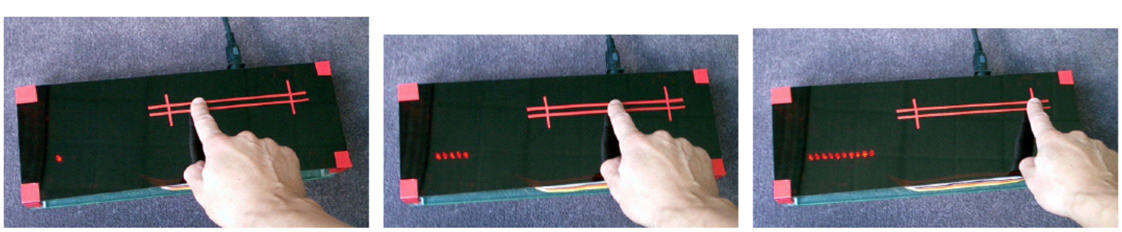

Figure 3: Slider demo tracking a fingertip –sensed finger position is plotted on the LED bargraph at right