Energy Efficient Solution Approach to Capacitive Touch Sensors using Noise Immunity and Comparative Work

Savita Gahlot, Rakesh Gill

***Abstract*— Touch sensing devices giving best application to the world in matter of digitalization as well as power consumption. No matter we are using resistive touch or capacitive touch but this touch is far better in comparison of manual buttons. The switches which operates manually need similar power supply for respective functions. The life of the resistive switches are better as compared to capacitive touch but the switches used through capacitive touch has better immunity to noise. This paper has a aim to compare all the characteristics and present useful outcome for the future researchers in matter of touch sensors. This paper contains various formation method of the device as well as improved method through oscillator results. The paper presents well compared result for both the touch available in market with the research.**

***Index Terms*— capacitive sensitivity layer formation mapping touch data data process.**

I. INTRODUCTION

There are so many excellent reasons to use I pad or other touch devices as musical controller among them edibility continuous gesture recognition and direct relationship between image and touch input. However no touch screen device can replace the tactile feedback of traditional instruments. Tactile feedback is crucial in keyboard performance since pianists generally play by feel rather than by screen. This paper presents a system of capacitive multi touch sensing which attaches with the surface of physical keyboard. Each key contains sensor pads and a controller which measures the location and contact area of protocol on the key surface. The complete system, consisting of upto 8 octaves, communicates with a computer by USB. The touch measurement transform the keyboard into a continuous multidimensional control surface, mechanical input device with current device. Thus sensor electrodes is being designed in various flexible manners which includes its shape and layout of these sensor. electrodes can be approaching to appealing, modern product designs with enhanced applications. Such a wide range of elements can be mounted with touch sensor electrodes: easy buttons and keyboards, circular sliders or linear sliders, transparent touch elements on displays or even buttons on wooden top. As the sensor electrodes are fabricated inside the device, no openings are necessary. Then cost-effective and ideally suited for rough environments and he housing is more robust where dust and moisture could creep into element.

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In case of medical applications or devices used in clean environments like in the food industry or in hygienic matters the capacitive touch control enables hygienic prevention. If we focus our approach for the matter of reliability then these mechanical switches or any such button may be with moving parts is limited to a life time after that they may get heated and worn out for unreliability. In such a case if we use less of moving parts, capacitive touch is much more applicable. However for more stressed elements, the surface response overlay cover material of the touch electrode has to be considered. As a plastic we may use Glass or acryl which will be better. Isolated buttons, single switches even metal can be used, not for complete front covers only to as the sensor pads must be isolated from individuals. For the tactile feedback to user the most positive aspect of moving parts in conventional push buttons or switches to the consumer. By touching a surface, the consumer does not "feel" if the press button was triggered. Which can be compensated by using acoustical or, a bit more complex vibration feedback optical. In many cases, machines, home appliances and electronic devices have to be controlled by us. We are familiar with switches, keyboards, knobs, push buttons, slider controls and appliances controlling devices. On time, always a new species of control elements joins the electronic industry to the appliance. The initialization of such a device started in consumer products like mobile phones and MP3 players but now moves to each of the electronic device. Such a change is called as a touch sensors which is replacing the manual mechanical switches.

II. CAPACITIVE SENSING

Capacitive touch sensing allows high-precision tracking of a user's finger motion with no electrical contact between user and device. A conductive plate forms a capacitor with the surrounding free space and ground layers. Objects which are conductive or have a substantially different dielectric constant than air, when brought into proximity with the plate, will change its capacitance [8]. Capacitance values are typically measured either by charging the plate to a known voltage and measuring discharge time in an RC circuit, or by measuring its frequency response in a resonant circuit. The capacitance of a single sensor can be read as a continuous value which roughly corresponds to the proximity and size of nearby objects. To measure position, an array of discrete sensors are required. Sensors are measured one at a time, with the remaining sensors tied to ground.

A finger touch will activate several adjacent sensors, from which a centroid value (weighted average) can be calculated. Because the sensor values are continuous, position resolution can far exceed the number of sensor elements in the array. Though more complex to implement than resistive position sensors, capacitive sensing has the advantage of requiring no finger pressure (indeed no contact at all) to operate. With certain sensor configurations, multi-touch capability is also in the favour of system, where resistive sensors are limited to at most one or two points of contact. Capacitive sensing can be combined with existing pressure (after touch) keyboard systems, and unlike after touch, both pressed and un pressed keys can be read.

A. Surface Coating

The initial design of the TouchKeys [5] used a thin plastic laminate on top of the circuit board. The intention was to more accurately simulate the look and feel of the traditional keyboard. Many types of plastic were tested, including polypropylene, PETG, Delrin, acrylic, teon, nylon and polycarbonate and similar things. Enamel and epoxy paints were also tested. Experimentally, it was found that the laminate could be no thicker than 0.5mm on the black keys, and that on the front of the white keys, even a laminate of 0.25mm reduced performance in the two-dimensional sensor area. Unexpectedly, many pianists indicated that the raw soldermask coating of the circuit board (an insulating layer applied during fabrication) produced a better feel than the various compositions , many of which were felt to be too sticky on the fingers port. The copper sensor pads are slightly raised with respect to the etched parts of the circuit board, so the keys have a texture that was initially thought to be a drawback. However, some pianists observed that ivory keys also have a textured surface, which is not a problem in performance. The next design revision will use white and black soldermask to maintain the standard look of the keyboard. In general, the designer can optimize any three of the following quantities at the expense of the fourth: sensor pad size, coating thickness, measurement speed and measurement resolution. The size of the TouchKey pads are constrained by the geometry of the keys, and speed and resolution were prioritized over coating thickness.

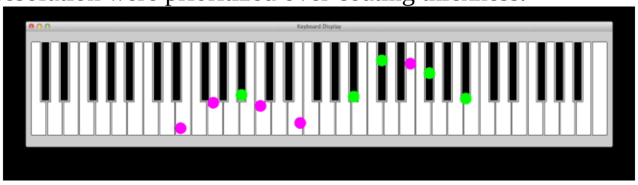

Figure 1: Real-time display of touch position.[13]

B. Data Aggregation

The controller on each key is responsible for scanning all the sensors in sequence, calculating up to three centroid shape and position, and transmitting this data trough the I2C to different controller. Such octave controller aggregates the data from an octave of keys and routes it to a \host" controller which communicates to a computer via USB [5]. The host microcontroller implements a USB serial device. MIDI, even in its native USB implementation, is ill-suited for TouchKey data since controls are limited to 7 bit resolution (compared to 10 bits or more for touch position data) and Control Change messages are channel-wide rather than especial to each note. The serial data is unpacked by the computer into OSC messages which can in turn be dynamically mapped to MIDI. The mapping is discussed in the next section. The software provides a real-time visualization.

III. MAPPING TOUCH DATA

Open Sound Control is the native output of the TouchKey system, with messages for the following actions:

- Touch onsets and releases. Distinct from MIDI note onsets and releases, this indicates when touched or left the key surface.
- Shifting of the place and the area of contact for every finger touch.
- Pinch and slide and pinch gestures involving two or three or more.
- For all data sheet the raw data frame and size for touch frames.
- The complete control system consists of touch data correlated with MIDI data from the underlying keyboard. This gives a picture of both activity on the key surfaces as well as physical key motion. Where the keyboard supports aftertouch, a form of three-dimensional sensing is available on pressed keys. Each OSC messages are tagged with a MIDI note number so a synthesis program can easily correlate touch sensor and keyboard data.

IV. SINGLE VERSES PAIRED SENSOR PAD DESIGNING

The interleaving of the sensors is required to keep the shift of both inputs as equal as possible, given the uncertainty of finger placement on the sensor. If possible, the areas of the two sensor elements should be equal, and approximately the size of ½ a single sensor. While this does increase the size of the sensor, it allows for more sensitivity on the paired sensor. Note the spacing between the two elements of a paired sensor should also be as large as possible to prevent interaction between the elements when the single sensors attached to each side are activated. The decode logic for a shared button system starts by testing each frequency value against two touch thresholds, one for single sensor function, and a small threshold for combined operation. The outcome of the setests are then passed through a search protocol which finds for paired shifts, first, and then single shifts. If a paired shift is discovered, the button is considered detected and the single shift test is skipped. If a paired shift is not detected, then the single shift test is performed and any press conditions detected are reported. If more than two shifts beyond the paired threshold are detected, then a Fault condition is asserted and the decoding routine is terminated.

Figure 2 : Single versus paired sensor pad design[12]

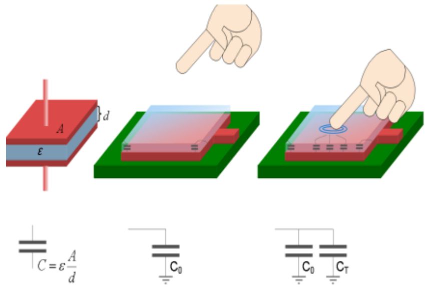

Figure 3: Touch Sensor Principle: untouched sensor pad with parasitic capacitance C0, touched sensor pad with additional touch capacitance CT.[14]

A. Application specific standard protocol

Such a system consists of 2 devices: the system host controller and a slave which handles the capacitive touch sensing in hardware. The usage of a ASSP is even more flexible as the first implementation class with general purpose microcontrollers since existing applications must not be modified significantly. Just an interface, like a serial I2C is required to connect the devices. The disadvantage of a ASSP solution is the additional component which generates cost and requires PCB area. Putting the additional resources into perspective which are required for software solutions (many GPIO pins, Flash memory for the library, etc., maybe even a bigger device is necessary) the cost adder for the ASSP may be less significant. The performance of an ASSP is much better than other solutions, especially when several sensor channels are required. Of course a dedicated hardware implementation offers faster response times than software algorithms. Also the current consumption balance tends to be lower with an ASSP. Another advantage is the easy and fast integration. Sensing pads are connected directly to one pin of the device, no additional external components have to be dimensioned. As the reliable operation comes in hardware, the designer can concentrate on the application. The development effort is lower compared to software methods.
Fujitsu's FMA1127 is an example for an ASSP solution. It is connected to any host Microcontroller via an I2C interface. The delay to digital capacitive sensing method is implemented and achieves short latencies in the range of 200µs. The average active current consumption for 12 channels is around 120µA.

B. Dedicated Capacitive touch using microcontroller peripherals

Some microcontrollers feature special hardware modules for capacitive touch sensing. These modules reduce software development effort and increase performance. They are a compromise between purely software based and more hardware focused ASSP solutions.

V. TOUCH SCREEN

The lack of mechanical components enables the implementation of capacitive touch based control elements on LCD panels. As the sensing pads are placed above the display, the user can touch directly onto the screen. Thus it is possible to generate context dependent, virtual buttons and other user friendly, intuitively control elements. Usually the sensing pads are made of a thin layer of Indium Tin Oxide (ITO) which is deposited on a glass or transparent foil. ITO is conductive and optically transparent at the same time. However for increased conductivity, the ITO film thickness has to be increased which has a negative impact on transparency. I.e. thicker, better conductive layers become slightly visible. The sheet resistance of a typical ITO layer is in the range of some hundreds of Ohms/square. Depending on the track layout, the series resistance between a sensing pads and the connector can reach tens of kOhms.

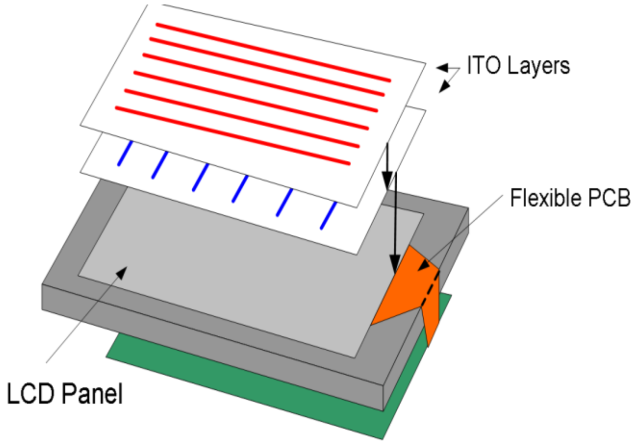

Figure 4: Capacitive touch screen with matrix arrangement [14]

For some touch screen applications, several discrete sensing areas on the screen, e.g. 10 or so, are sufficient while for other applications, the position of the finger must be determined in a higher resolution, e.g. 640 x 480 positions or higher. In the 1st case a layout with one ITO layer is sufficient to form the sensing pads. In the 2nd case, two isolated layers ore more are necessary to form a matrix. In such an arrangement one touch activates two channels: one row and one column. In both cases it is possible to apply interpolation techniques to increase the resolution as described above. Due to the different requirements, many vendors provide dedicated products for button/slider implementations on one hand and touch screen applications with high resolution on the other hand.

Figure 5 Capacitive touch screen with discrete sensing pads, consisting of one ITO layer [14]

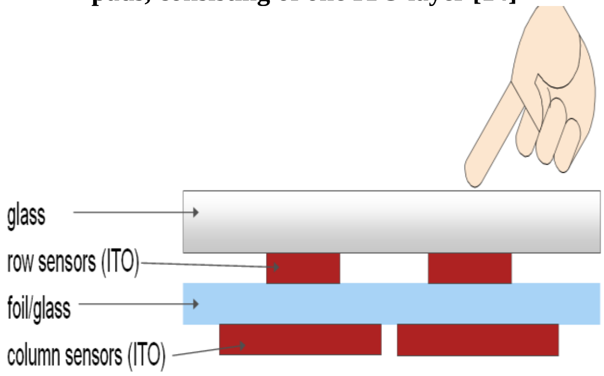

Figure 6 High resolution capacitive touch screen with matrix arrangement, consisting of two ITO layers [14]

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Resistive touch screens are used for a longer time than capacitive solutions because of the simpler control circuits. Two conductive planes, also made of ITO material, are separated by tiny spacers. The upper layer is deposited on a flexible foil. Pressure leads to a contact between the two conductive layers. In pressed state, the layers form a voltage divider. By evaluating the voltages at this divider, a control circuit determines the position of the contact. In two steps 1st the X and 2nd the Y coordinate is calculated. Resolutions up to 2000 to 4000 steps per dimension are possible. The major weak point of this approach is the flexible foil. It wears out over time, it is sensitive to physical stress and the optical characteristics are inferior to glass. Frequently used resistive touch screens may look dull after a while and show scratches. Capacitive touch screens feature a robust glass cover and have a much higher endurance. Thus the surface of a capacitive touch screen looks premium and lasts longer. A second advantage of capacitive touch screens is the ability to detect multi touches. This opens new applications like scaling or rotating pictures by moving two fingers over the screen.

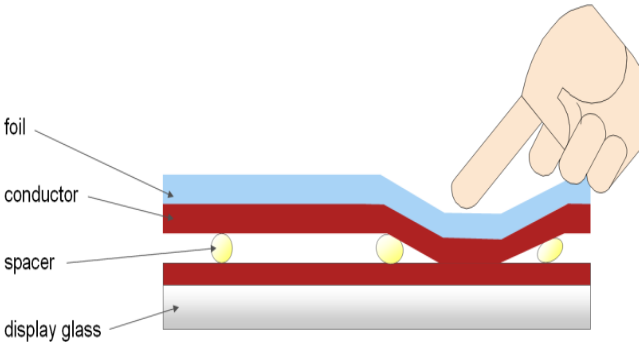

Fig7: Layout of a resistive touch screen with flexible foil as upper layer [14]

A) Comparison with a system already in market

In an effort to give an impression on the power usage of this module compared to others on the market a comparable module has been found. The QT100A from Quantum Research Group is a single capacitive touch button on an IC and is marketed as using 128 µA on average over time with a 3V power supply resulting in a power usage of 384µW. When touched it sets its one bit output low for the duration of the touch. Its internal threshold is adjusted over time to compensate for changes from the environment. This units behaviour is then the same as the one in this paper and should be a good benchmark for the power consumption. The capacitance in the node is also something that is hard to affect from the point of view of a system designer. This is more a characteristic of the physical system.

B) Difference in method used in touch device

The main method of decreasing power usage in the oscillator is to maximize the resistance in the RC-circuit, with or without reducing the capacitance to keep the frequency constant. As can be seen the power is inversely dependent on the size of the resistor. The resistance should then be minimized for a specification effort to minimize the power dissipated in the resistor.

$P(t)=i_r(t)\, v_r(t)$.

VI. CONCLUSION

The formation of capacitive touch is much complex as compared with resistive but the immunity and response is far better than resistive. The touch saves energy consumption at great extend such a device is prefer for reduced energy operation. This paper satisfy the aim to illustrate all the chartersics and process of formation. The paper present the comparative noise immunity solution well with the oscillator used in the capacitive touch sensors. The paper includes the comparative study for the classical switches with resistive and capacitive performance.

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