AN12082

Capacitive Touch Sensor Design

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Application note

Document information

Info	Content
Keywords	LPC845, Cap Touch
Abstract	This application note describes how to design the Capacitive Touch Sensor for the LPC845 Cap Touch Interface.

Revision history

Rev	Date	Description
1.0	20171031	Initial revision.

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1. Introduction

In a Capacitive Touch System, the changed in capacitance when touched is converted from charging time to count in the microcontroller.

The LPC microcontroller uses the mutual capacitance method, where a transmitting electrode and a receiving electrode are used to generate an electromagnetic field, and changes in the electromagnetic field between these nodes are detected.

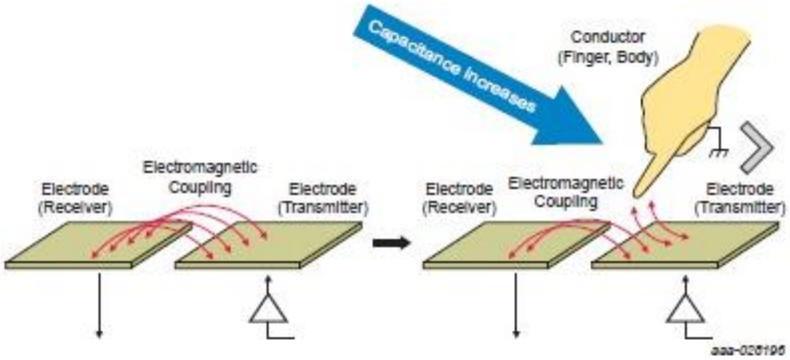

Fig 1. Mutual Capacitive Touch

A pulse is applied between the transmitting and receiving electrode to generate an electromagnetic field. When a finger comes into close proximity, part of the electromagnetic field moves to the finger where the decrease in electromagnetic field strength is detected by the electrodes. The capacitance is detected and captured, and recognized as a finger presence.

Mutual capacitance is less noise sensitive and has less reliance on electrode characteristics of the finger. When liquid that comes into contact with the operating surface, it has little effect on the electromagnetic field. Thus, this method can be used even in environments where the operating surface is likely to get wet. Mutual capacitance is harder to use for proximity, but also has fewer false positives.

2. Touch Sensor Design

Capacitive Touch sensor design relies on the sensor and the electrodes connected to it. The electrode's geometry, size, material, thickness, and layout affect touch sensor measurements.

2.1 Basic Theory

Touch sensor is based on the parallel plate capacitor model in which the variation of the capacitance C is directly proportional to the area A of two parallel plates times the dielectric constant k of the object between them. The capacitance C is inversely proportional to the distance d between the plates.

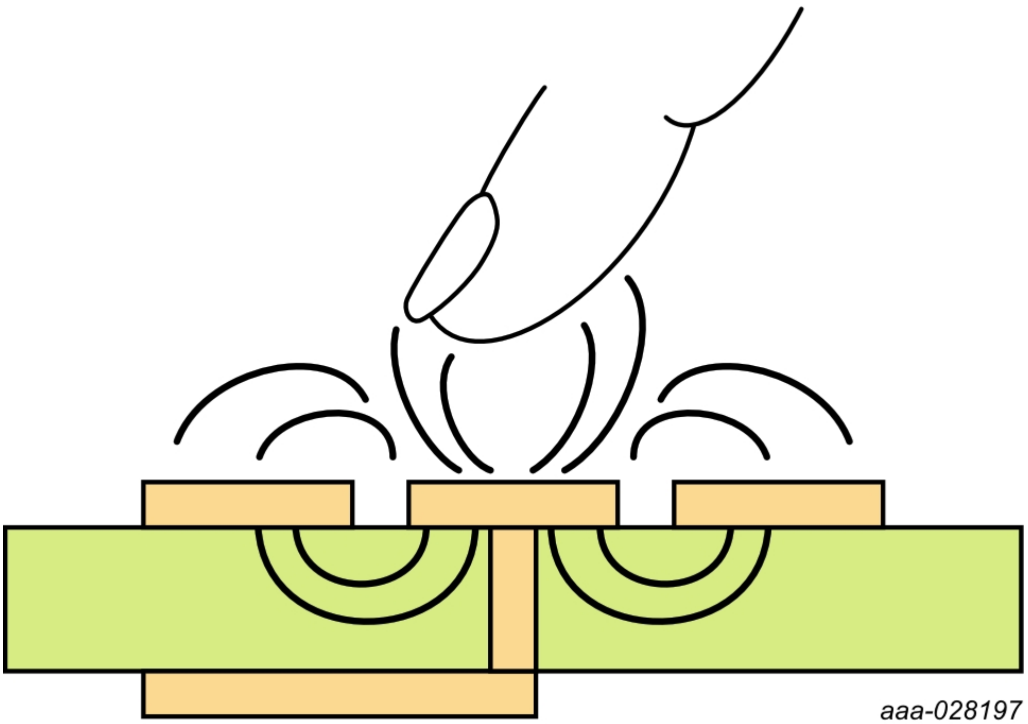

Fig 2. Basic PCB Capacitor

$C = (k\varepsilon o A) / d$
C is the capacitance in farads (F).
A is the area of the plates in square meter
d is the distance between the plates in meter (m)
k is the dielectric constant of the material separating the plates
εo is the permittivity of the free space (8.85 × 1012 F/m)

2.2 Equivalent Circuit

In the LPC Cap Touch interface, the mutual capacitor can be modeled as follows:

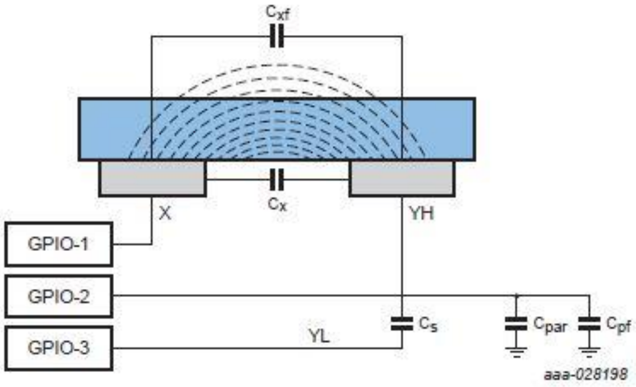

Fig 3. Capacitance model

Cpar : Parasitic capacitance when NOTouch
Cpf (Delta C): Parasitic capacitance of YESTouch (finger)
Cx : NOTouch Capacitance
Cs : Measurement capacitor to take over the charge in Cx

Depending on the sensor design (one layer versus two layer), the model changes slightly.

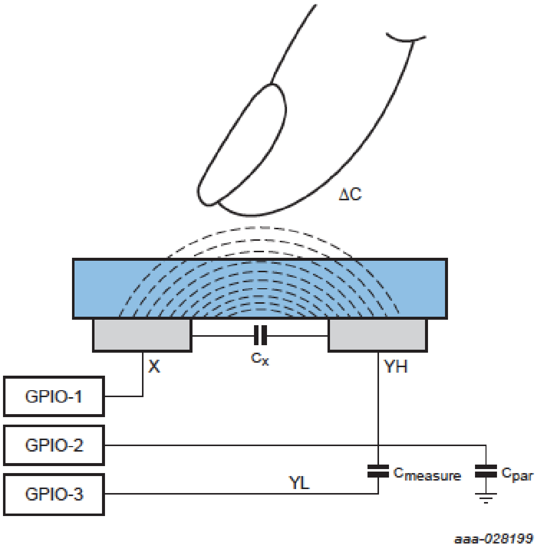

Fig 4. One Layer Sensor

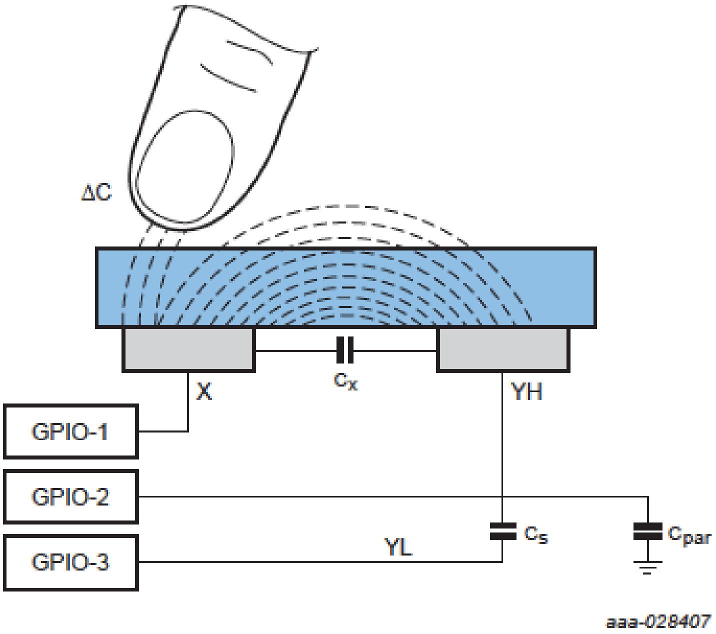

Fig 5. Two Layer Sensor

The sensor characteristics will determine the SW detection details. See the Applications note on SW for Cap touch.

2.3 Sensor design

The Cap Touch peripheral support the following types of sensor design.

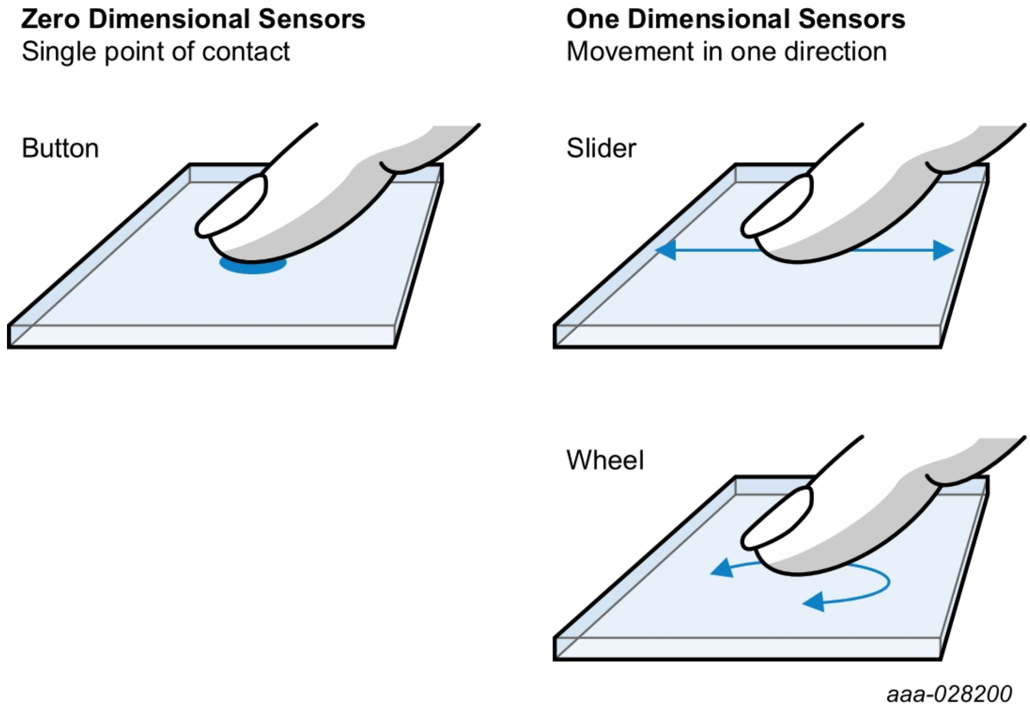

Fig 6. Zero and One Dimensional Sensors

Having good sensor layout determine how well the Cap touch system will work. It is important to keep the sensor design consistent to get good Touch/No Touch results.

2.3.1 Planar Design

In planar construction, both sensor electrodes and traces are on the same plane. The capacitor is formed with the electrodes and with air and the sensor Front panel material acting as dielectric. Note both Zero and One dimensional sensors can be constructed in Planar Design.

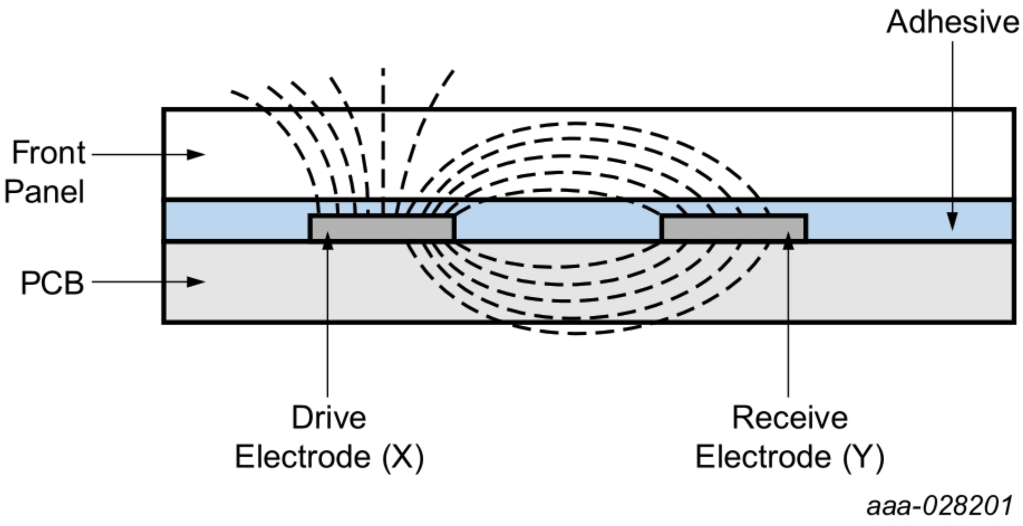

Fig 7. Planar Sensor

Field propagation heavily depends on the overlying Front panel as most of the coupling field flow to horizontal. Therefore make sure the sensor is firmly attached to the front panel (no air bubble, gaps, etc) to avoid unit-to-unit variations.

Example of Button planar sensor:
This is commonly used for Button sensor design where the interdigitated of X and Y electrodes form an interlocking fingers.

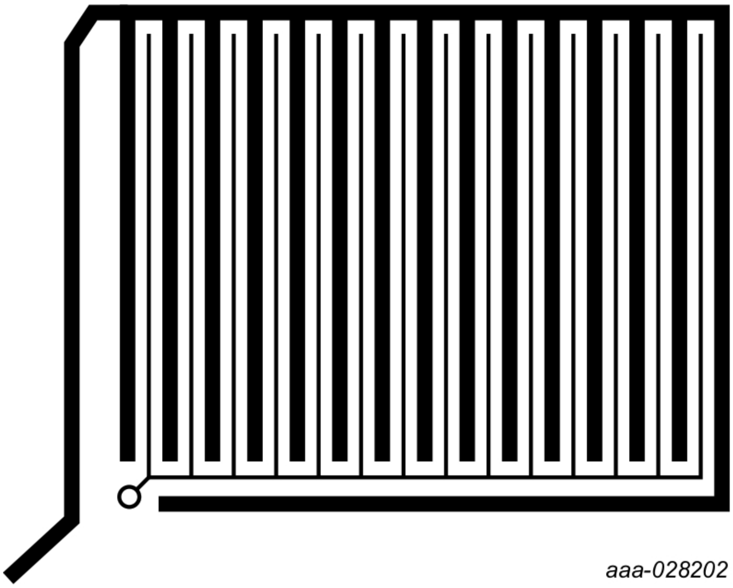

Fig 8. Button Planar Sensor

Placement of adjacent buttons should have a minimum spacing of 10mm sensor edge to edge, to reduce cross coupling. For applications which require Gesture recognition using 9 buttons, placing Capacitive Touch sensors with <5mm spacing is necessary.

2.3.2 Slider and Wheel Design

Sliders are used for control requiring gradual adjustments. Examples include lighting control (dimmer), volume control, graphic equalizer, and speed control. A slider is constructed using an array of Cap Touch sensors called segments that are placed adjacent to one another. Actuation of one segment results in partial actuation of physically adjacent segments.

One layer slider

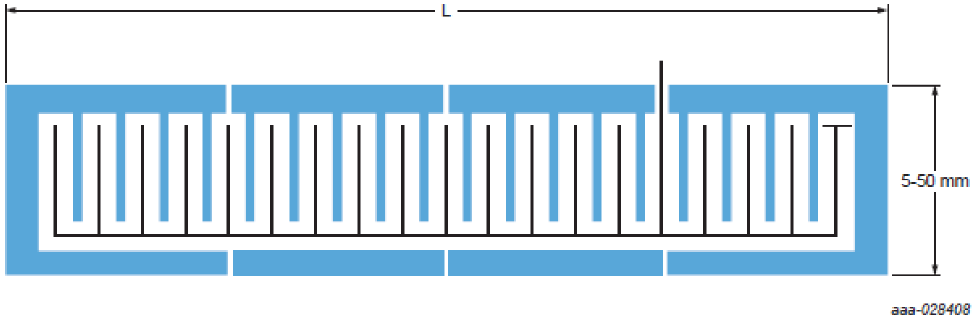

Fig 9. **Slider Planar Sensor**

Here’s one linear slider design (Two layers)

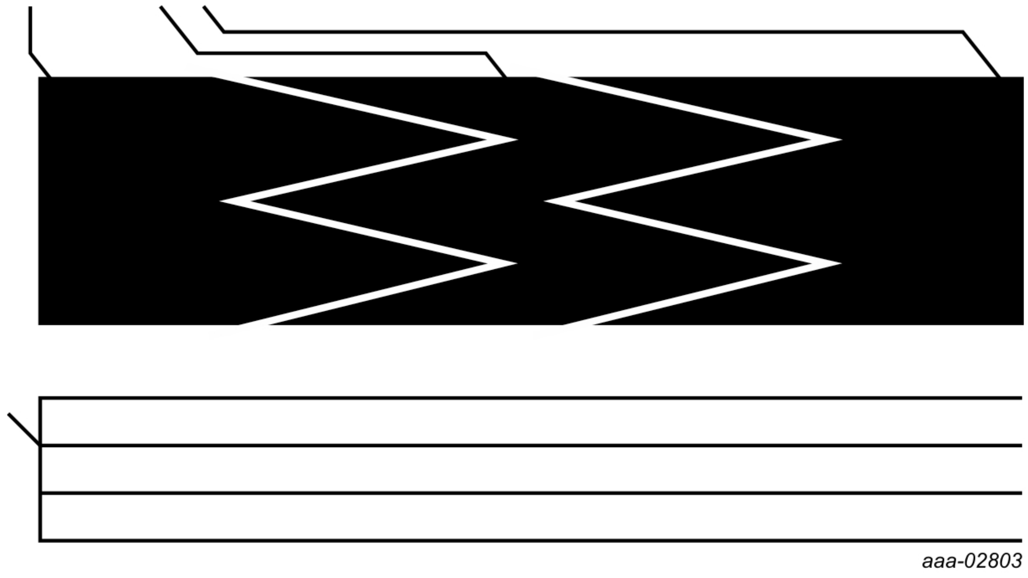

Fig 10. Slider Sensor Design (Two Layers) with 3 Sensor Inputs

In a linear slider, each Cap Touch sensor is connected to one slider segment. A zigzag pattern (double chevron) as shown in Figure 11 is recommended for slider segments.

The sequence of each Cap Touch should be sequential to ensure proper scanning. CAPTX1 ->CAPTX2 ->CAPTX3 (or CAPTX2->CAPTX3->CAPTX4)

Two layer Wheel (medium to larger wheel)

Dividing the circle into 6 zones give 60 degrees coverage for a wheel diameter size >30mm. The “wave” sensor design breaks across the wheel providing more gradual detection as the finger moves from one sensor to another.

In this configuration, when the finger is on the sensor and move, at least one of the adjacent sensors threshold count will change to reflect the direction of the movement indicating the finger’s position in the circle.

To have a group of similar capacitances and interference during touch, it is suggested to move the sensor traces greater than one finger spacing (>10mm) away from outer circle circumference.

The sequence of each Cap Touch should be sequential to ensure proper scanning. CAPTX1 ->CAPTX2 ->CAPTX3 -> CAPTX4 ->CAPTX5-> CAPTX6

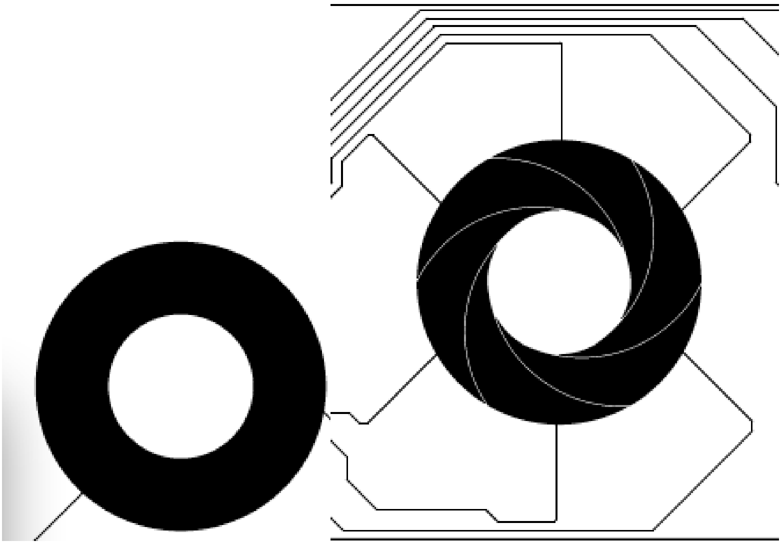

Fig 11. Wheel Sensor Design (Two Layers) with 6 Sensor Inputs

One Layer Wheel

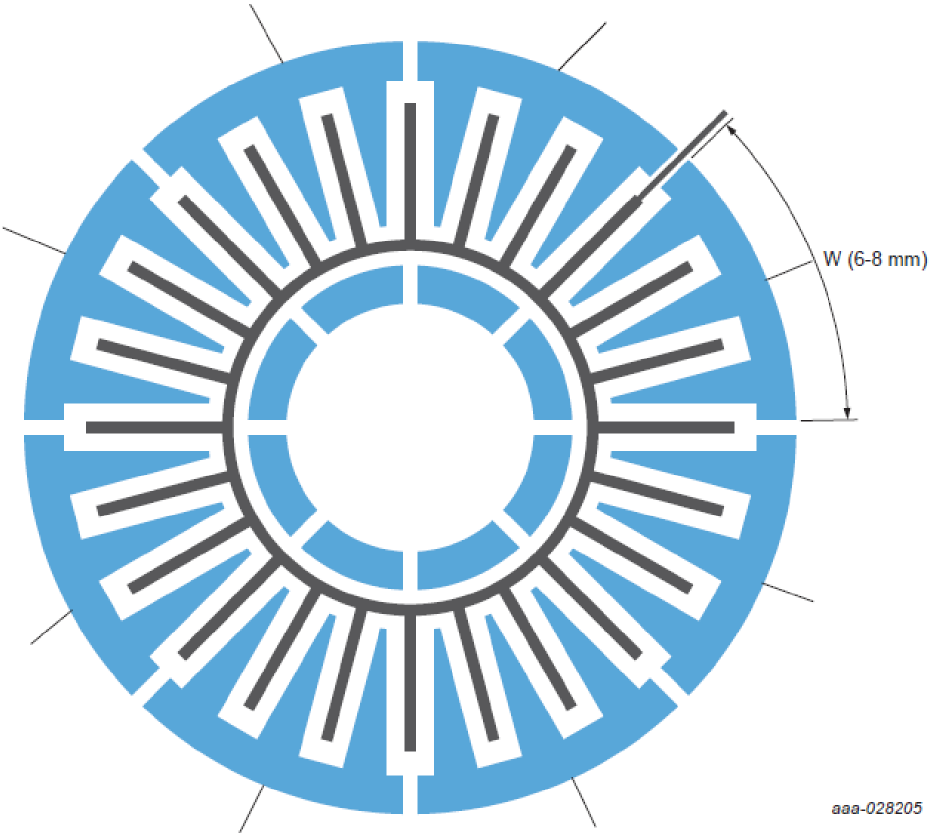

Fig 12. Wheel Planar Sensor

2.3.2.1 Routing of Cx and YH Signals from Sensor to Microcontroller pin

As the signals are routed, take care to minimize the finger's influence over the traces.

For the single plane sensor, it is a good practice to make the Cx signals on the bottom layer, while YH signal on the top layer. In multilayer board, Ground and Supply layers underneath the sensor should be avoided.

3. Cap Touch understanding

NXP's touch sensing works on the principle of Switched Capacitor Integration circuit as shown in Fig-13
drawings: add Cpar, Change A to two input comparator w another input tied to a resistor ladder, remove "Fig 4"

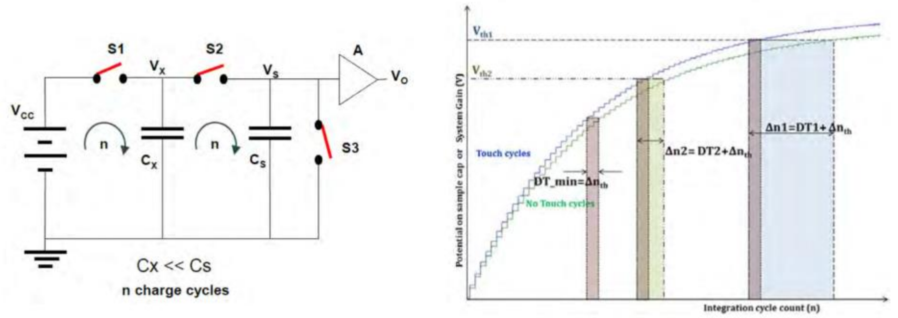

Fig 4. Switched Capacitor Integrator

Fig 13. Switch Capacitor Model

It consists of two capacitors (Cx-Sensor and Cs -integration capacitor) controlled by switches S1 and S2, switched in non-overlapping fashion. When S1 is closed Cx charges to Vcc. Then S1 is opened and S2 is closed. This results in transfer of charge stored in Cx to Cs||Cpar until both are at same potential.
This is named as **one charge cycle** where the charge that is first stored in Cx is shared with Cs by alternate switching of S1 and S2.

The value of Cs is chosen to be very large compared to Cx, so that multiple charge cycles will be integrated onto Cs. Consequently increases the voltage of Cs. After Cs is charged to a threshold voltage, it is translated into Count, which is reported to the CPU and then discharged using S3. One complete charge cycle of Cs form **one integration cycle**.

3.1 Touch Occurs

When a finger touches Cx, it adds Cf (delta C) from finger to Cx. As S1 is turn ON, Cx + delta C are charged to Vcc, in this case, the energy stored in Cx + Cf (delta C) > Cx (No Touch)

Note: the Cs will also increase by Cf (delta C). The additional Cf (delta C) charges up the integration capacitance faster.

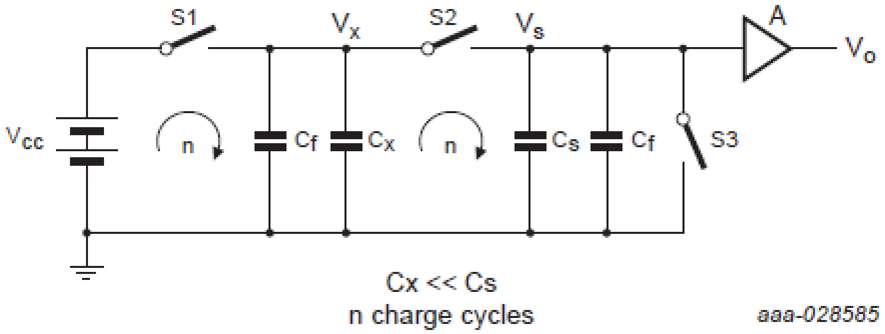

Fig 14. Switch Capacitor Model for Touch

During S2 ON cycle, the Cx (with finger touching) will transfer more energy to the integration cap, compared to the No Touch cycle, resulting in faster charging, less Counts. The user will observe a reduction in Counts for the Cx Touch. At the same time, for the remaining Cx which do not have finger touching, the effective Integration Cap has been increased, resulting in much faster charge transfer, resulting in much less Counts than the Cx with finger touching.

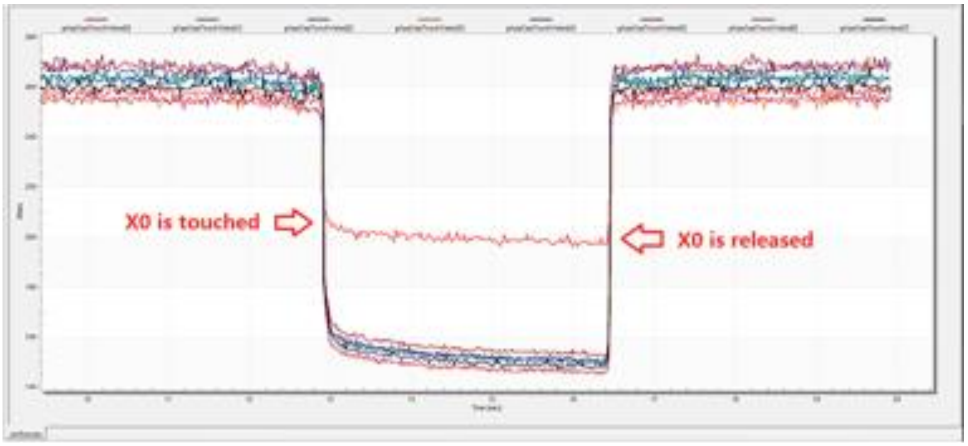

Fig 15. Integration Count Waveform

This method is more accurate than pure RC charge and/or discharge cycles.
The longer time for one integration cycle imply noise is more likely to be balanced out.

3.2 Cap Touch Implementation in LPC845

There are up to 9 Cap Touch Sensor input Xn in the LPC845 Cap Touch module.

Each Cap Touch Sensor input perform charging/discharging/transferring charge accumulation between X and Y plates to an external integration cap used for measurement.

Note: Xn refers to each electrode plate (point) and Y refers to the common measurement point (so finger correspond to each measured X).

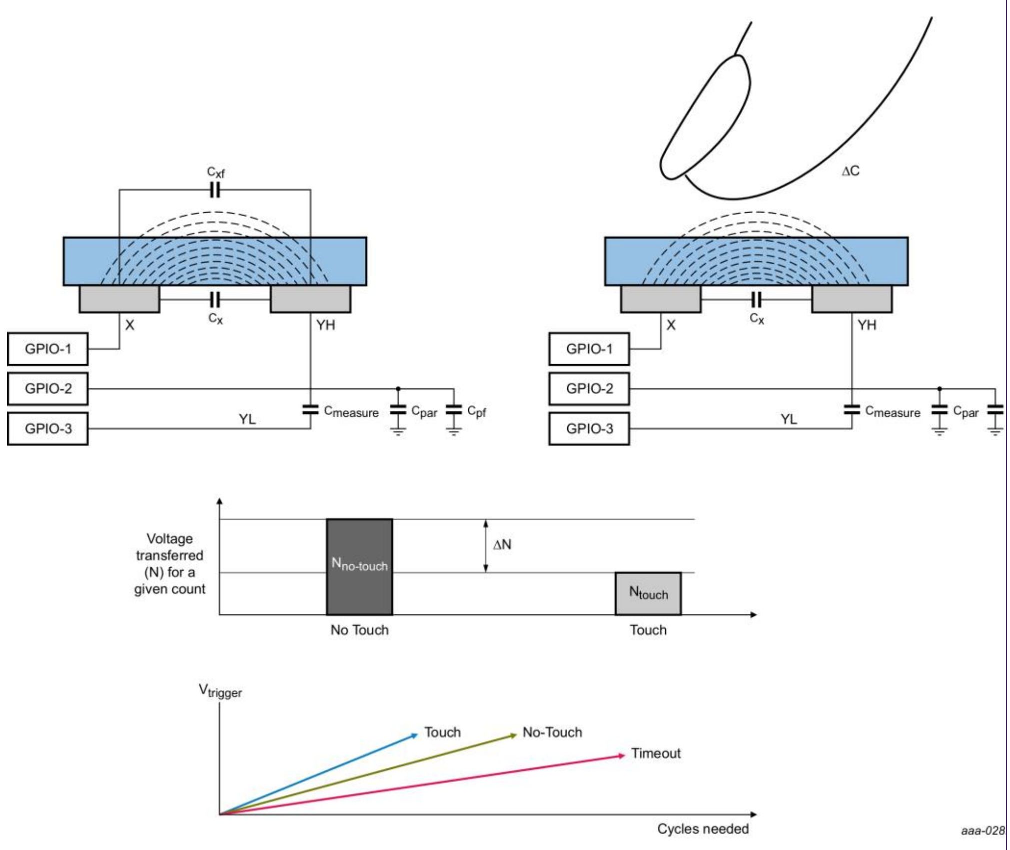

Fig 16. Touch versus NO Touch

The time needed to get the Integration Cap (Cs) voltage to the trigger point determines it is likely touch or partial touch. The amount of time will be reported back as Number of Integration Cycle Counts. When it takes too long to charge the Integration Cap (during No-Touch cycle), the Number of Counts will exceed TOUT setting, which results in Timeout flag.

The software upper layer code will handle interpretation of results, filtering, and gestures (if used). In addition, the upper level software handle the Sensor design: buttons, slides, pads, etc) and configuration. The inner loop only takes measurements in the multiple of the charge cycle. Read the Cap Touch Example Code Bundle for each sensor type implementation.

4. Conclusion

This application note discussed the LPC84x Cap Touch implementation and the Cap Touch Sensor design consideration to have a good cap touch sensing operation.

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