AN2733

S-Touch™ PCB and layout guidelines

Introduction

The aim of this application note is to provide guidelines for the construction and the layout of different types of printed circuit boards (PCB) for the implementation of S-Touch™ capacitive devices: the FR4 and flexible PCBs or the ITO panel.

Various substrate materials are available for different PCB design construction.

Among the substrate materials currently available in the market, the FR4 is the most common. FR4 is a glass fiber epoxy laminate and the PCBs can have one or several layers. Given a limited size of the touch module, the 1-layer PCB implementation is not always possible, whereas the four-layer and the 2-layer PCB are more common.

For applications requiring a very compact form factor, the flexible PCB can be used.

The capacitive touch module on top of the display unit requires a transparent sensor electrode and traces which can be implemented using an indium tin oxide (ITO) layer on glass/plastic panel.

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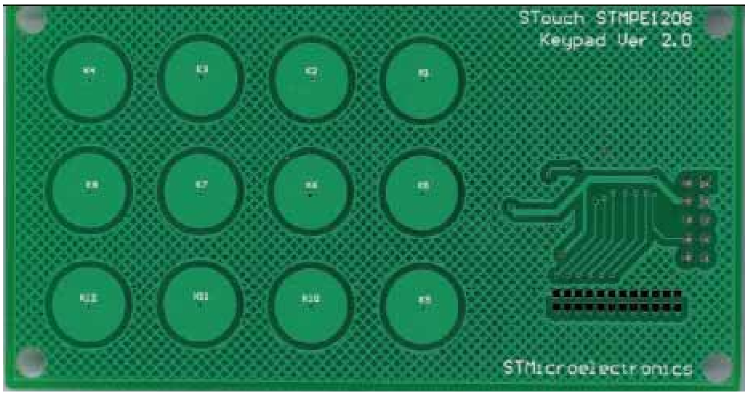
1 PCB design and layout

This section provides some guidelines on the design and layout related to several types of PCBs.

Figure 1. FR4 electrode construction

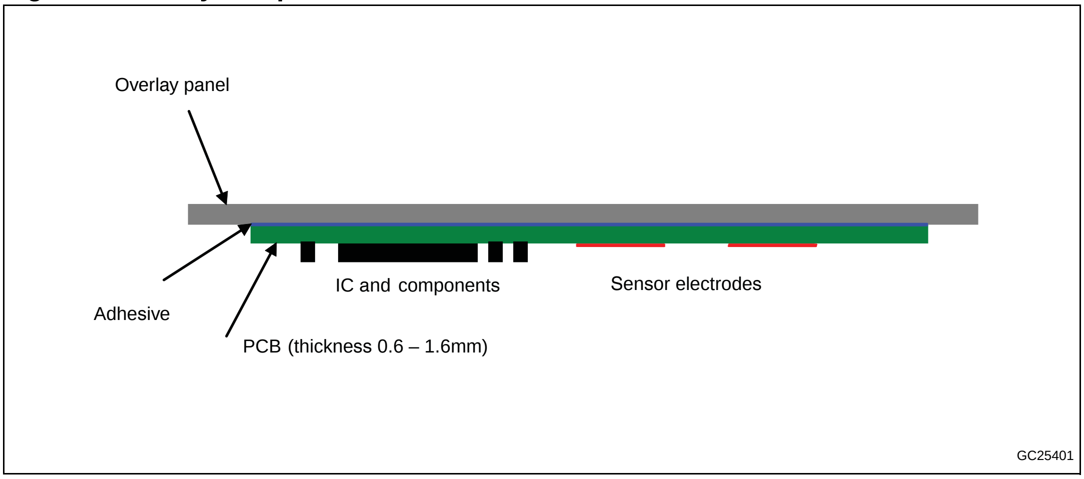


1.1 1-layer PCB construction

A capacitive touch module can be designed in a single-layer FR4 PCB of standard thickness (1.6 mm). The electrode and all the components are at the same side of the PCB. The other side of the PCB is attached to the overlay panel. The field senses through the PCB, adhesive layer and overlay panel to the finger.

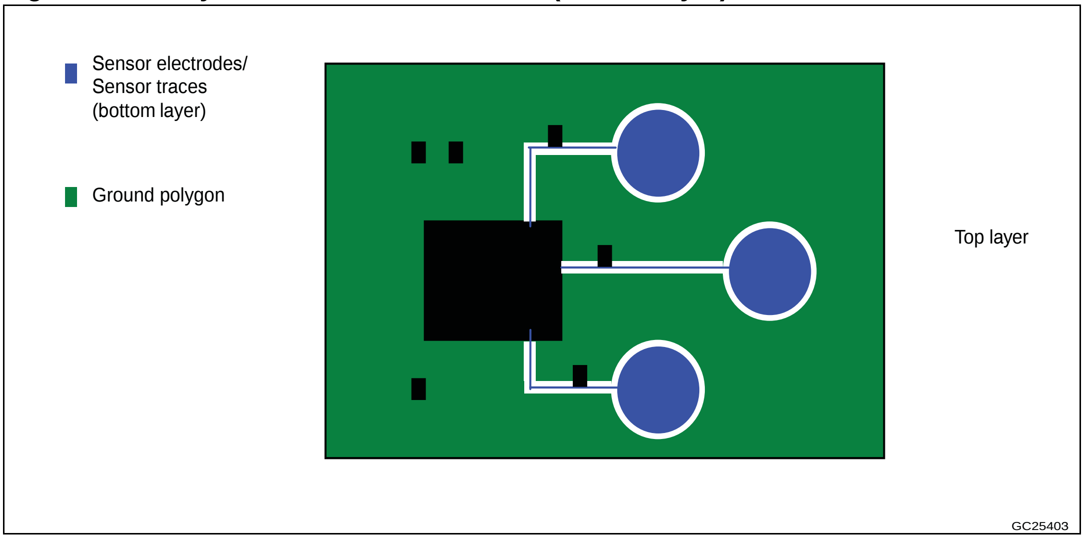
A 1-layer PCB provides a cheaper solution compared to touch modules using more than one layer. However, the touch module using a one-layer PCB can only be implemented if there is enough area on the PCB for the routing of the signals. Since the sensor electrode is placed at the bottom of PCB, the sense field passes through the PCB and overlay panel before reaching the finger. In this case, the maximum overlay panel thickness is reduced due to the additional thickness of the PCB.

Figure 2. 1-layer capacitive touch module



The S-Touch™ controller, the passive components and the sensor electrodes are located at the bottom of the PCB. The void area at the bottom layer can be filled with mesh ground polygons. The mesh ground construction will be explained in a separate section.

Figure 3. 1-layer PCB cross section area (bottom layer)



1.1.1 Design rules

Layer 1 (*top layer*) design rules

- Only the bottom layer is used and the top layer is empty. Non conductive adhesive is to be applied on the top layer to attach the PCB to the overlay panel.

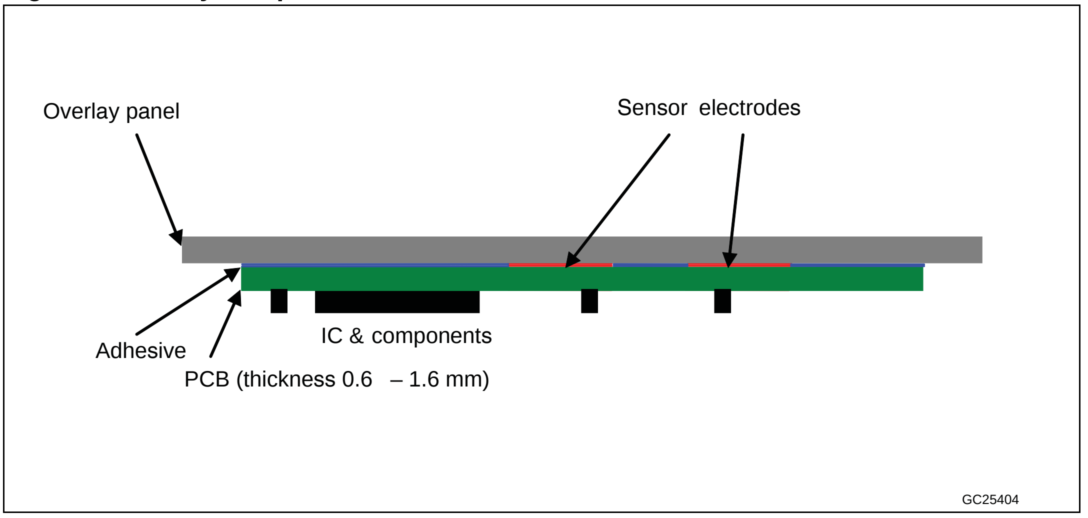
Layer 2 (*bottom layer*) design rules

- The void area can be filled with a mesh ground polygon (recommended 6 mils track width, 30 mils grid size).
- The distance between the sensor electrodes and the ground polygon should be at least 0.75 mm.
- The distance between the sensor signal traces and the ground polygon should be at least twice the trace width.
- Maximize the distance between one sensor electrode/trace to the others in order to minimize crosstalk. If possible, place ground polygon to separate sensor traces/electrodes.
- For good sensitivity it is recommended to have 10 x 10 mm sensor area. It is still possible to utilize a sensor area smaller than this, but with reduced sensitivity. However it is recommended that the sensor size not bigger than 15 x 15 mm. If the sensor size is increased beyond this size, sensitivity will not increase but the susceptibility to noise will increase.
- The sensor signal traces do not need to be of the same length. Input tuning capacitors are used to balance input capacitance between the channels. However, if there is enough space on the PCB, a balancing between the sensor input traces length can be done (sensor electrode size is uniform). In the later case, only a reference tuning capacitor should be added in order to adjust all of the sensors' impedance values to be in the centre of dynamic range.
- Any clock, data or periodic signal should not be routed side by side with the sensor signal traces. As much as possible these signals should be routed perpendicular with respect to the sensor signals. If they have to be run in parallel, route them on different cross section area of PCB.

1.2 2-layer PCB construction

In the 2-layer PCB construction, the S-Touch™ controller IC and other components are placed at the bottom layer of the PCB. The sensor electrodes are placed on the top layer.

Figure 4. 2-layer capacitive touch module



The tuning capacitor of each sensor channel can be placed directly underneath the sensor electrode itself. However it is recommended to place the S-Touch™ controller IC at the bottom layer area where there is no sensor electrode on top. The void area on the top and bottom layers can be filled with mesh ground polygon.

Figure 5. 2-layer PCB cross section area (top layer)

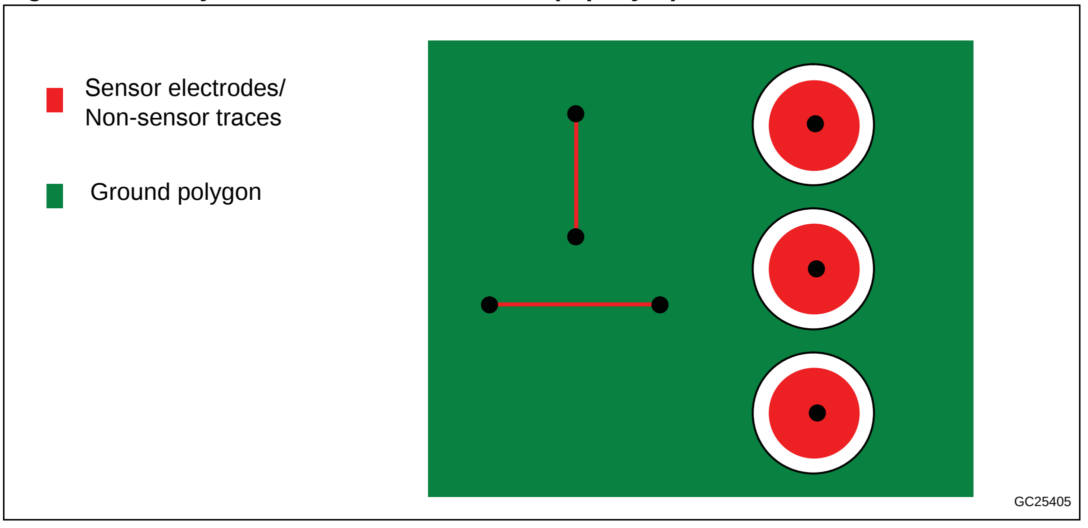
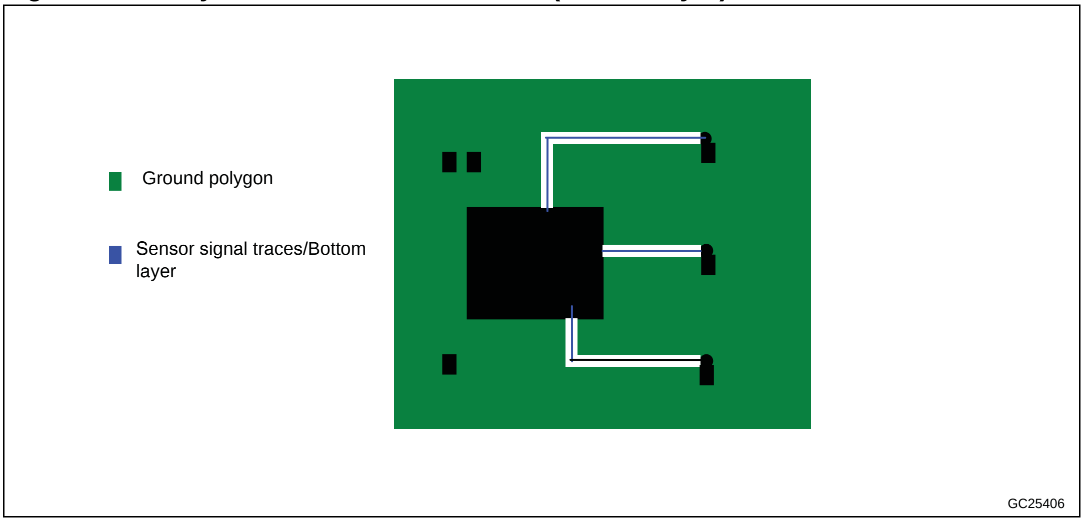


Figure 6. 2-layer PCB cross section area (bottom layer)



1.2.1 Design rules

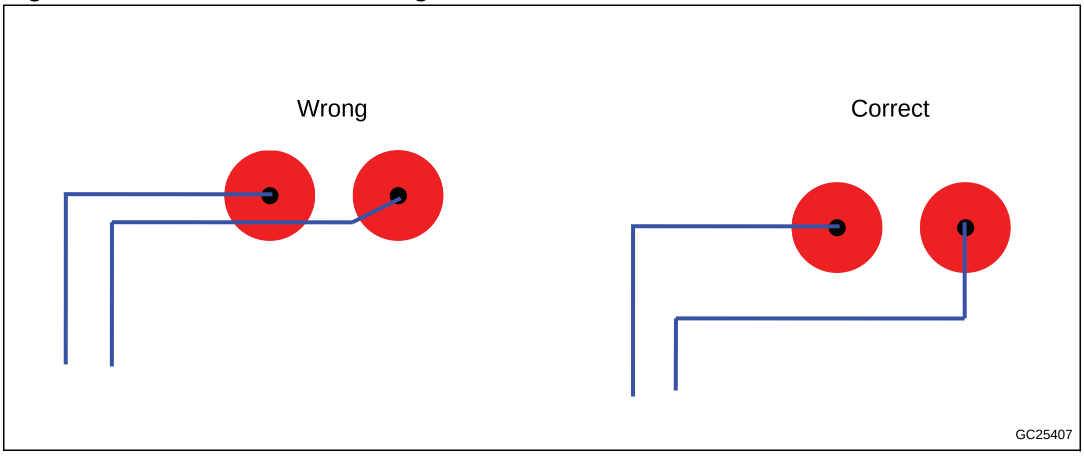
Layer 1 (*top layer*)

- The sensor electrodes are on the top layer of the PCB (top side of PCB is to be attached to the overlay panel). For good sensitivity it is recommended to have 10 x 10 mm sensor area. It is still possible to utilize sensor area smaller than this, but with reduced sensitivity. However it is recommended that the sensor size not bigger than 15 x 15 mm. If the sensor size is increased beyond this size, sensitivity will not increase but susceptibility to noise will increase.
- The void area can be filled with ground polygon (6 mils track width, 30 mils grid size).
- The top layer can be used to route signal traces with the exception of sensor signal traces. As much as possible, sensor signal traces are to be routed at the bottom layer.
- The distance between sensor electrodes and the ground polygon should be at least 0.75 mm.

Layer 2 (*bottom layer)*

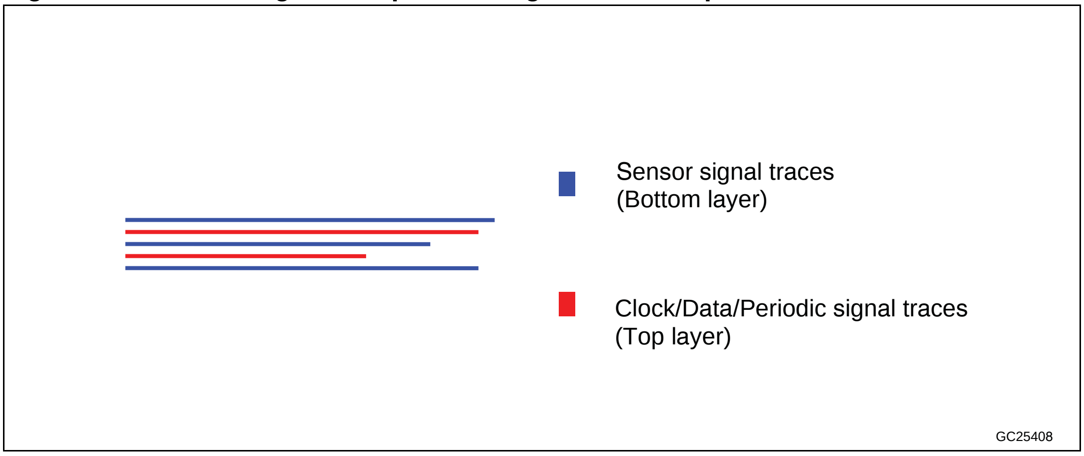
- The S-Touch™ controller IC and passive components are to be placed at bottom layer.
- Sensor signal traces are to be routed on the bottom layer. Sensor signal traces of a particular channel should not be routed underneath the sensor electrode of other channels.

Figure 7. **Sensor traces routing underneath the electrode**



- The void area can be filled with ground polygon (6mils track width, 30 mils grid size).
- The distance between sensor signal traces and ground polygon should be at least twice the trace width.
- Maximize the distance between one sensor electrode/trace to the other in order to minimize crosstalk. If possible, place ground polygon between two sensor traces/electrodes.
- Sensor signal traces do not need to be of the same length. Input tuning capacitors are used to balance input capacitance between channels. However if space of PCB allows, balancing sensor input traces length can be done (sensor electrodes size is uniform). In the later case, only reference tuning capacitor should be added in order to adjust all of sensor impedance values to be in the centre of dynamic range.
- Any clock, data or periodic signal should not be routed side by side with the sensor signal traces. As much as possible these signals should be routed perpendicular with respect to the sensor signals or they should be routed on different area of PCB.
- If clock, data, or any periodic signal traces should run in parallel proximity to sensor signal traces, they should be routed in different layer and should not overlap. Keep the section where the signals running in parallel as short as possible.

Figure 8. **Sensor signal and periodic signal traces in parallel**



1.3 4-layer PCB construction

The four-layer PCB construction is the most common as compared to the one or two-layer stack-up. Mainly this is due to the fact that the most of the electronics systems are designed in a compact form factor thus providing a restricted space on the PCB area. It offers the best performance in space limited applications as compared to single or double layer PCB.

Figure 9. 4-layer capacitive touch module

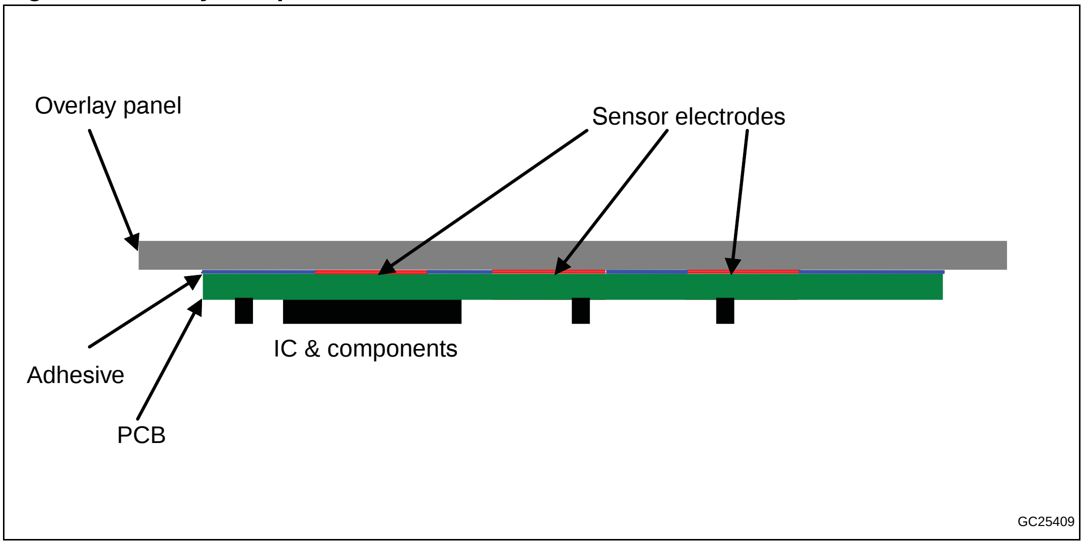
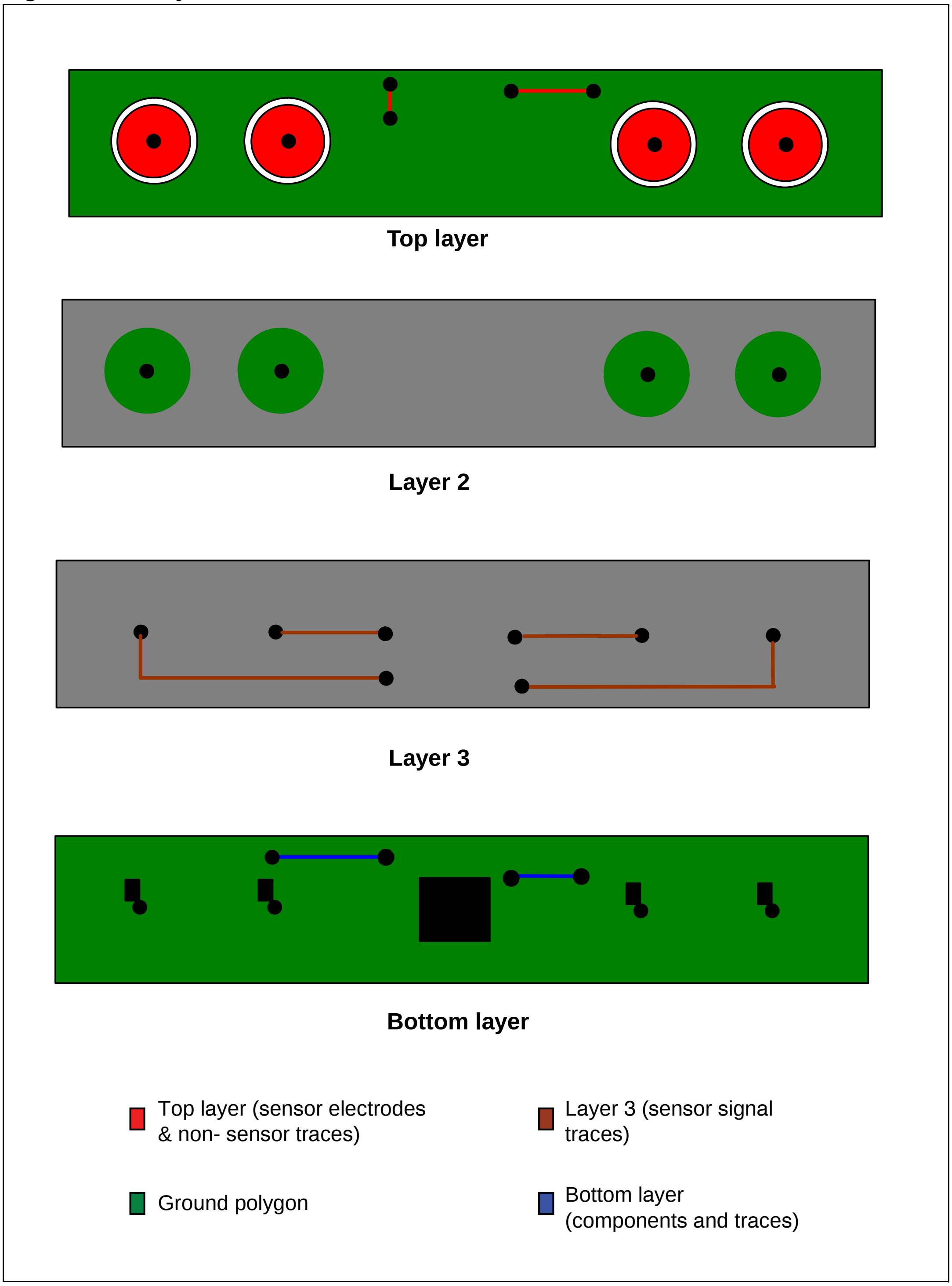


Figure 10. 4-layer PCB cross section area



1.3.1 Design rules

Layer 1 (*top layer*)

- The sensor electrodes are placed on the top layer. For good sensitivity it is recommended to have 10 x 10 mm sensor area. It is still possible to utilize sensors area smaller than this, but with reduced sensitivity. However, it is recommended that the sensor size is not bigger than 15 x 15 mm. If the sensor size is increased beyond this size, the sensitivity will not increase but susceptibility to noise will increase.
- Void areas can be filled with ground polygons (6 mils track width, 30 mils grid size).
- The top layer can be used to route signal traces with the exception of sensor signal traces. As much as possible, sensor signal traces are to be routed at layer 3.
- The distance between sensor electrodes and the ground polygon should be at least 0.75 mm.

Layer 2 (*mid layer 1*)

- A partial ground polygon is placed on layer 2 to shield the sensor electrodes from traces on layer 3 and bottom layer. The partial ground polygon shape can be of the same size as the sensor electrode that is shielded. Other cross section areas on layer 2 can be left empty.
- No traces are to be routed on layer 2 underneath the sensor electrodes. Exception to this rule applies to static signals (power lines) that can be routed directly underneath the sensor electrodes if there is not enough space to route them on other layers.

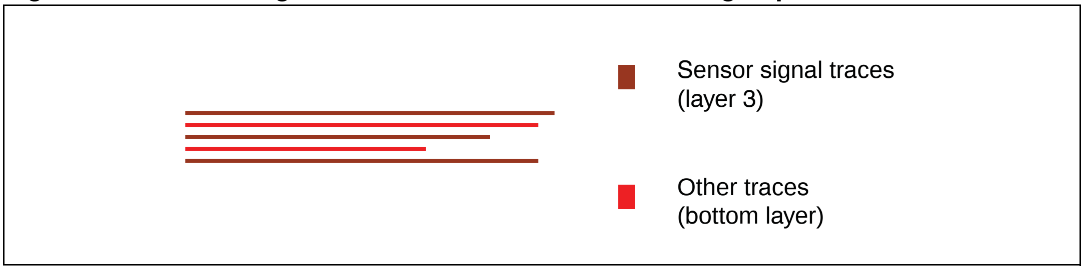
Layer 3 (*mid layer 2*)

- Sensor signal traces are to be routed on layer 3. Via hole connects from sensor electrode on top layer to sensor signal traces on layer 3. The traces are then routed on layer 3, and then connected by via holes to bottom layer. The signals are then connected to touch controller IC through a short trace at the bottom layer.
- Sensor signal traces need do not to be of the same length. Input tuning capacitors are added to balance input capacitance between channels. However, if the space of the PCB allows, balancing sensor input traces length can be done (sensor electrodes size should be equal). In the later case, only reference tuning capacitor should be added in order to adjust all the sensor impedance values to be in the centre of the dynamic range.
- Other traces can also be routed on layer 3 when there is not enough space on the bottom layer. However these traces should not be routed side by side to sensor signal traces.

Layer 4 (*bottom layer*)

- The S-Touch™ controller and the passive components are to be placed at the bottom layer. Communication signals and other traces (ex. LED signal traces) are to be routed in this layer.
- Non-sensor signal traces on bottom layer should be routed on area that is not overlapping with the sensor signal traces on layer 3. If the PCB cross section area to route sensor signals at layer 3 and non-sensor signals at the bottom layer are overlapping, the traces should not be routed on top of one another (no overlapping).

Figure 11. Sensor signal traces and other traces running in parallel



1.4 Ground polygons

On the previous sections that explain in details about 1, 2, and 4-layer FR4 PCB, the ground polygons are used to fill void cross section areas of the PCB. Ground polygons shield the touch module from external noise sources and also stabilize the inherent capacitance of sensor lines.

However, there are a few precautions regarding the use of ground polygons. These precautions stems from the fact that ground polygons increase the sensor inherent capacitance and also increase the susceptibility of detecting a false trigger due to water drop.

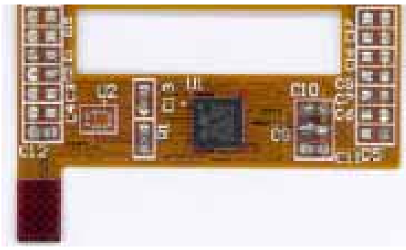
Guidelines on the use of ground polygons:

1. It is recommended to have mesh ground polygons instead of solid ones. 20% mesh ground polygon is recommended (6 mils track width and 30 mils grid size). The ground polygon angle should be set to 45°.
2. Sensor to ground polygon clearance should be at least 0.5 mm. 0.75 mm is recommended.
3. Sensor signal traces to ground polygon clearance should be at least twice the size of the traces width.
4. For the 4-layer PCB described in this application note, if the sensor signal traces routed at layer 3 run longer than 10 cm, it is recommended not to have a ground polygon at the bottom layer to minimize capacitive loading on the long traces.
5. If a partially conductive material is used for the overlay panel, it is recommended not to have ground polygons on the top layer.
6. For capacitive sense systems operating in a wet environment, it is recommended not to have ground polygons on the top layer.

1.5 Flex PCB construction

Flex PCBs can be implemented in as single or double conductive layer. Void areas around components and traces can be filled with ground polygons.

Figure 12. Touch module on flex PCB



The layout rules described in the section related to the FR4 layout also apply to the flex PCB layout.

1.6 ITO PCB construction

Traces and electrodes of ITO are etched on substrates such as polyester (PET) film, polycarbonate or glass to form a capacitive panel.

Buttons, matrix of buttons, and touch pad functions can be implemented on a transparent capacitive panel using ITO construction.

Normally, the ITO panel is either implemented in the single or double-layer construction. For the touch sense matrix configuration, a double-layer ITO is required.

Figure 13. Single-layer ITO on glass

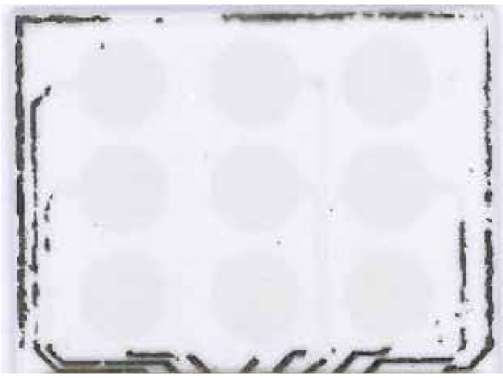
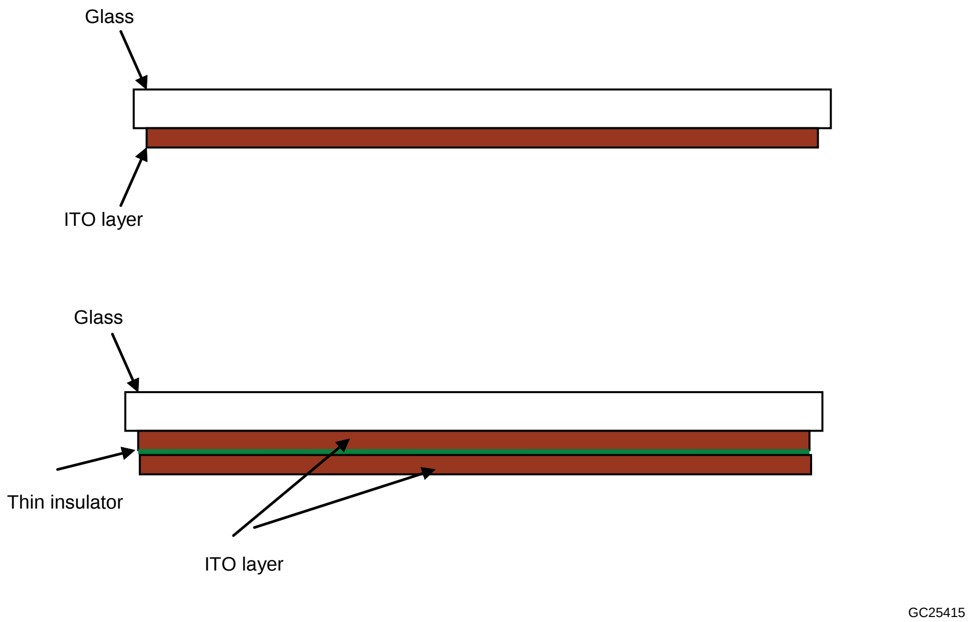


Figure 14. Single and double-layer ITO construction



Sensor electrodes and traces etched on ITO have finite sheet resistance that might affect the sensitivity of the system. However if the sheet resistance is not too high (up to a few hundred Ω/□) it will not cause any problem.

2 Sensor's basic function description and guidelines

A capacitive sensor electrode is a conductive pad used for the measurement of finger capacitance. It is connected to sense input of the S-Touch™ controller IC.

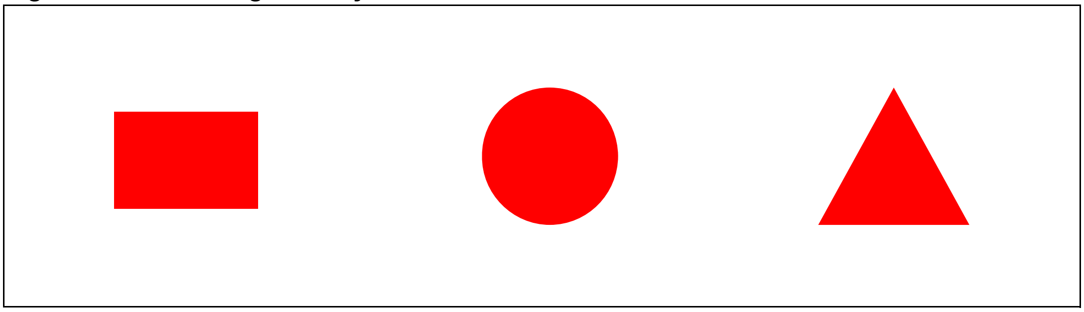
There are various shapes and sizes of sensor electrodes geometry for different functionalities and applications.

2.1 Button

The button has the basic function of detecting the finger's presence.

The S-Touch™ controller IC measures the capacitance of the button electrode. If a finger is in close proximity of a button, the capacitance measured exceeds certain values of predefined threshold and the finger presence is detected.

Figure 15. Button geometry



Any shape of buttons can be implemented such as square, round, triangle or others. Given a limited area of PCB, the button shape is designed so as to maximize the usage of the area to achieve better sensitivity.

For a 2-3 mm of acrylic plastic overlay, the recommended sensor size is a square with minimum 10 x 10 mm dimension. However, the size should not be larger than 15 x 15 mm because if it is larger than this, sensitivity is not improved but noise susceptibility is worsened.

2.2 Slider

The slider function is used to detect the finger movement along one dimensional direction. One example of its application is for volume control. There are two ways to implement the slider function: touch status and ratiometric slider.

The Touch status slider is implemented by placing square shape buttons in close sequence.

Figure 16. Touch status slider implementation

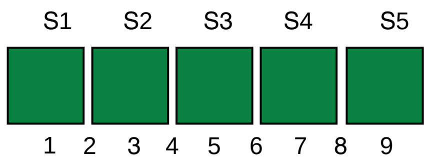


Table 1. Touch status slider implementation

Position	Sensor ON
1	S1
2	S1, S2
3	S2
4	S2, S3
5	S3
6	S3, S4
7	S4
8	S4, S5
9	S5

The finger's position along the sensor strip is determined by checking sensors status that is ON. In the example above, five sensors can be used to detect 9 positions. If S1 and S2 are ON at the same time, it means the finger position is on step 2.

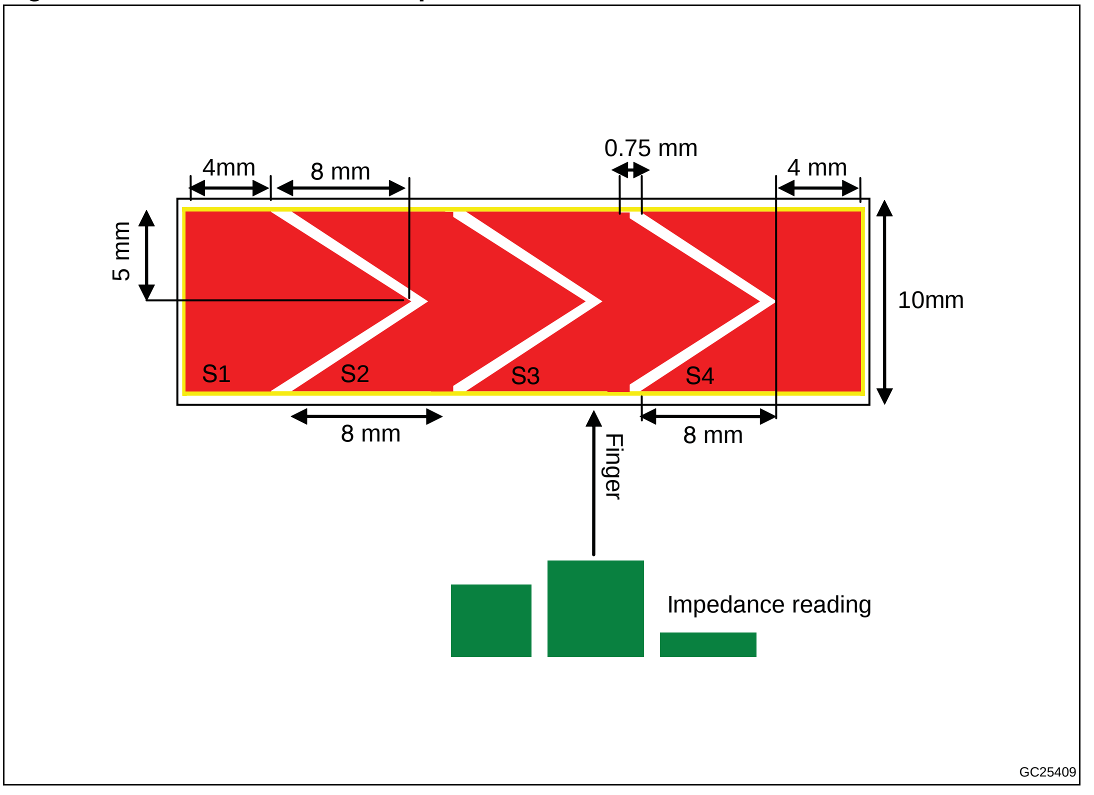
For the 2-3 mm of acrylic plastic overlay, a minimum sensor size of 10x10 mm is recommended. The gap between any two adjacent sensors should not be greater than 1 mm in order to make sure that when the finger is located exactly at the gap, the two sensors turn on simultaneously. The recommended value for the gap between each slider sensor is 0.75 mm.

The advantages of the touch status slider are its simple implementation and good stability in the presence of noise. However, if a large number of positions is required, this method cannot be implemented as it would require many sensor channels.

Another implementation is the ratiometric slider. Instead of checking the touch status of each sensor along the strip, this method determines the finger location based on the exact amount of capacitance measured for each sensor. After measuring the exact amount of capacitance of each sensor, a ratiometric calculation is performed to determine the exact location of finger.

For proper ratiometric calculation, finger touch on any portion of the slider should induce capacitance change on two or more sensor channels. Thus it is important that sensors geometry overlap each other outside their edges.

Figure 17. Ratiometric slider implementation



A finger touch in the above position, induces a capacitance increase on three sensor electrodes. The amount of capacitance increase is different for each sensor because the area covered by the finger is different. The raw capacitance data of the sensors is then processed to get the exact finger location.

The S-Touch™ devices that are available at the time of writing this application note do not have the capabilities to process the raw capacitance data and output to the host the exact location of finger. The device only reads the capacitance data and output them to the host. The host will then process the data to determine the exact location. S-Touch™ devices with internal processing capabilities are currently under development.

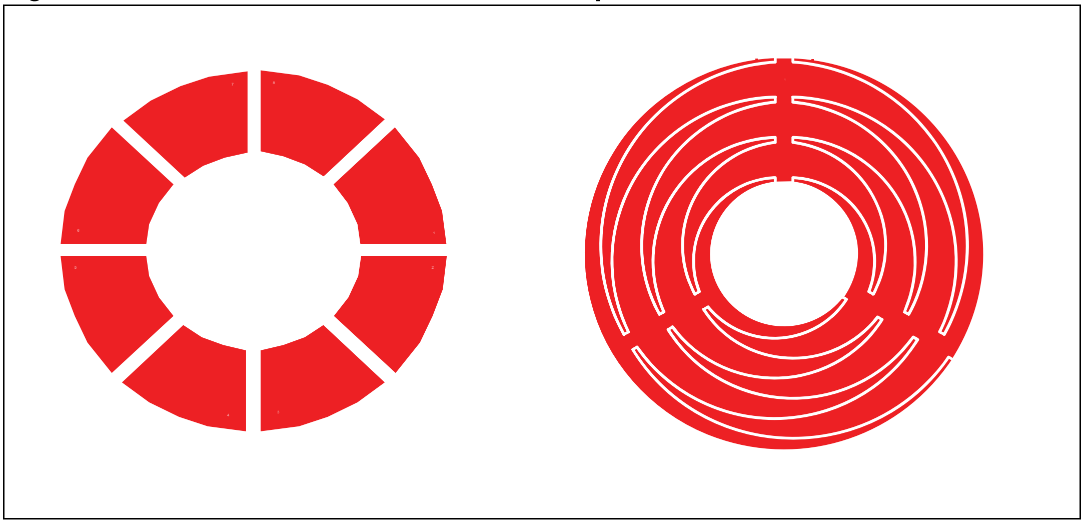
The relative and absolute position slider implementations are possible with the methods explained above.

2.3 Rotator

As with the slider, a rotator can be implemented based on the touch status or ratiometric concept.

The touch status rotator determines the finger location by checking the status of each sensor of the slider. In ratiometric rotators, the finger location is determined by measuring the exact capacitance increase due to the finger presence. A finger scrolling on the rotator causes a capacitance increase on a few electrodes. The increase of capacitance on the electrodes is then calculated to give the exact location of the finger.

Figure 18. Touch status/ratiometric rotator implementation



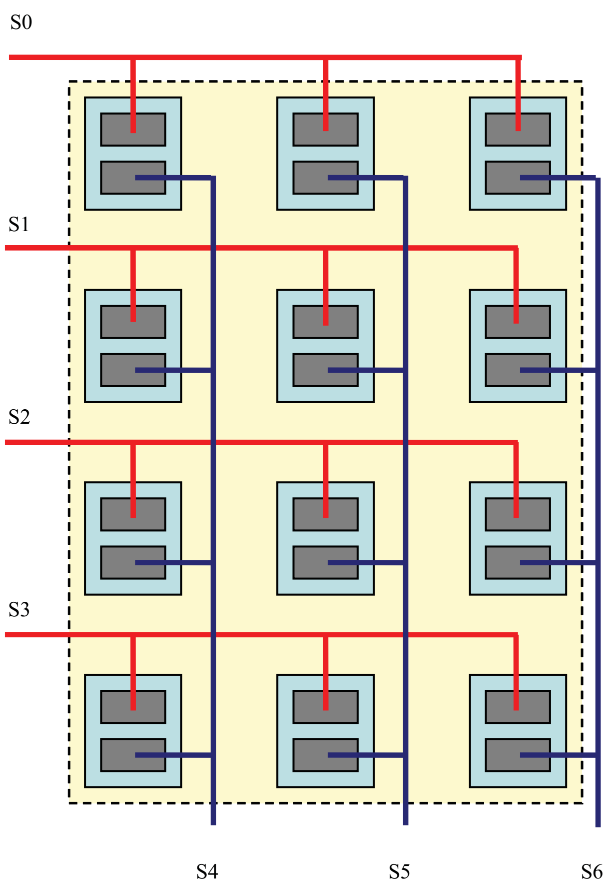
The finger detection's stability along the rotator is a factor of resolution and number of sensor inputs. For high resolution rotators, more sensor electrodes might be required instead of only three sensors as shown in *Figure 18* for the ratiometric implementation.

2.4 Matrix

2.4.1 Matrix keypad

The number of sensor electrodes connected to a single device can be increased beyond its sensor input channels by implementing matrix keypad configuration.

Figure 19. Key matrix configuration



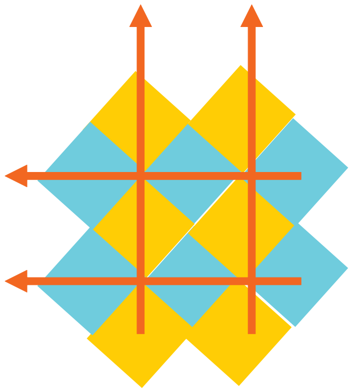
The keys are arranged as rows and columns. A finger touch on the sensor electrodes will activate two status bits on the touch byte register, one bit for the row and the other one for the column. A simple decoding is performed by the host to determine the active key based on the touch byte data.

At the time of writing this application note, S-Touch™ devices' sensing mechanism is not based on force and sense method. The key matrix explained above only allows single finger touch. A two-finger touch is still possible provided that the two keys are located on the same row or column. S-Touch™ devices with a new method that is capable of detecting multiple-touch are in development.

2.4.2 Matrix touchpad

A two dimensional capacitive sensing user interfaces can be implemented by a matrix configuration.

Figure 20. Touchpad implementation



The sensor channels are grouped as rows and columns. Rows and columns electrodes (cells) are arranged in interleaving pattern. The size of the cells should be designed so that when a finger touch is detected, a few cells are covered by the finger. Proper overlapping of cells is important to obtain good finger resolution.

A finger touch on the pad increases the capacitance on the row and column inputs. Processing the raw capacitance data will yield the exact location of the finger.

There are many different patterns that can be used in a touchpad application. Two examples are the diamond and hexagonal pattern.

3 Other considerations

By following some basic PCB and layout guidelines, a reliable capacitive sensing application can be achieved.

Other important PCB design considerations:

- No floating plane/pad on PCB. Void areas on PCB can either be filled with ground polygon or left empty.
- The PCB should be designed such that tuning reference capacitor value is less than 30 pF (this value is determined during hardware tuning stage). If it is higher than this value, some basic layout changes should be done such as by reducing density of ground polygon, widening the distance from sensing input trace/electrode to ground polygon, reducing the width of sensor signal traces, or even removing ground polygon entirely. If maximum sensing input capacitance is greater than 30 pF, tight tolerance tuning capacitors might be required.
- Minimize inherent capacitance differences between sense input channels to within 15 pF (this difference can be determined during hardware tuning stage). If it exceeds 15 pF, re-layout should be done to minimize the difference by reducing the mismatch in trace length and sensor electrode size.
- Place series resistors on I^2C SDA and SCL lines in order to filter noise disturbances that can be introduced from wire harness connecting the main board to touch module or from power supply noise that might distort I^2C signals.

4 Revision history

Table 2. Document revision history

Date	Revision	Changes
09-June-2008	1	Initial release.

STMicroelectronics group of companies

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