Application Note

Capacitive Touch Sensing Layout Guidelines

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1 Introduction

The purpose of this application note is to provide guidelines for the layout of capacitive touch sensing modules based on the Semtech products.

1.1 SX864x Family Overview

The SX864x family provides ultra low power, fully integrated solution for capacitive touch buttons, slider and wheel applications with up to 12 sensors. Unlike many capacitive touch solutions, the SX864x family features dedicated capacitive sense inputs (that requires no external components) in addition to 8 general purpose I/O ports (GPIO). Each GPIO is typically configured as LED driver with independent PWM source for enhanced lighting control such as intensity and fading.

The SX864x family includes a capacitive 10 bit ADC analog interface with automatic compensation of the environment parasitic capacitance up to 100pF. The high resolution capacitive sensing supports a wide variety of touch pad sizes and shapes and allows capacitive buttons to be created using thick overlay materials (up to 5mm) for an extremely robust and ESD immune system design.

The SX864x family incorporates a versatile firmware that was specially designed to simplify capacitive touch solution design and offers reduced time-to-market. Integrated multi-time programmable memory provides the ultimate flexibility to modify key firmware parameters (gain, threshold, scan period, auto offset compensation…) in the field without the need for new firmware development.

The SX864x family supports the 400 kHz I²C serial bus data protocol and includes a field programmable slave address. The tiny 5x5mm (SX8643, SX8644, SX8645) and 4x4mm (SX8646, Sx8647, Sx8648, SX8649) packages makes it an ideal solution for portable, battery powered applications where power and density are at a premium.

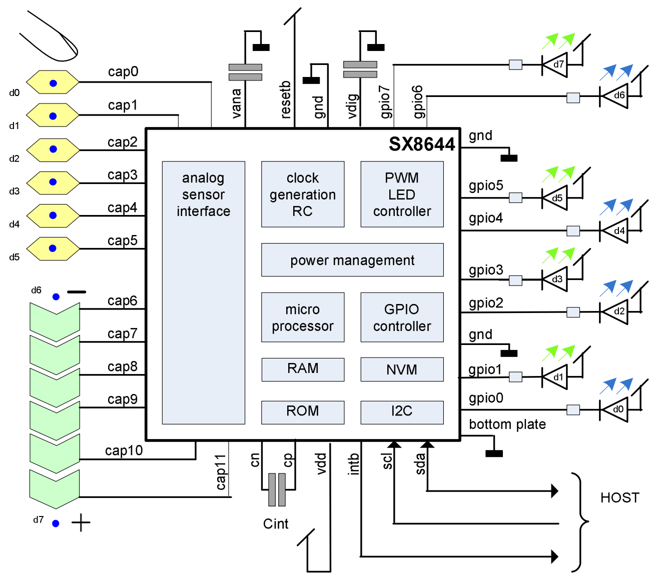

Figure 1: SX8644 Typical Application

1.2 Capacitive Sensing

Capacitive sensing is the art of measuring a relatively very small variation of capacitance in a noisy environment.

To illustrate the principle of capacitive sensing we will use the typical simplest button implementation below but the same basic laws apply to more complex capacitive structures like sliders or wheels.

Figure 2 shows cut view and top view of a typical capacitive button implementation. The sensor connected to the SX864x is a simple round copper area on top layer of the PCB. It is usually surrounded by ground for noise immunity (see § 2.3). For obvious reasons (design, isolation, robustness …) the PCB is stacked behind an overlay which usually consists in the housing of the complete system (notebook, TV, monitor, cell phone, etc) .

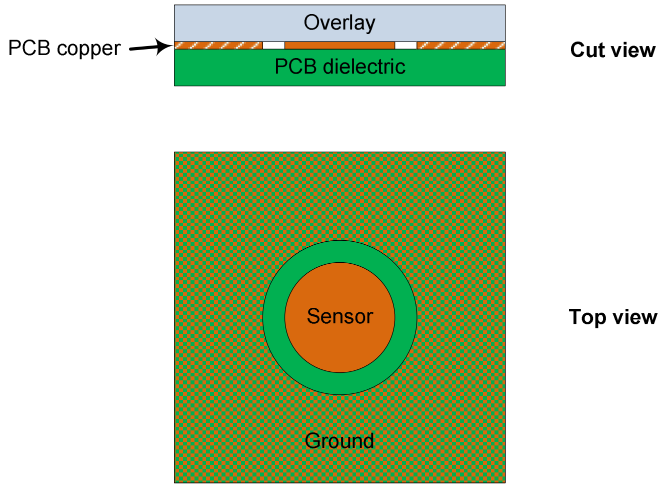

Figure 2: Typical Capacitive Button

When no conductive object, like a finger, is close the sensor only sees an inherent capacity value C_{Env} created by its electrical field's interaction with the environment, especially with ground areas.

When a conductive object, like a finger, approaches the sensor the electrical field around the sensor will be modified and the total capacitance seen by the sensor increased by the finger capacitance C_{Finger}.

This phenomenon is illustrated in Figure 3 below.

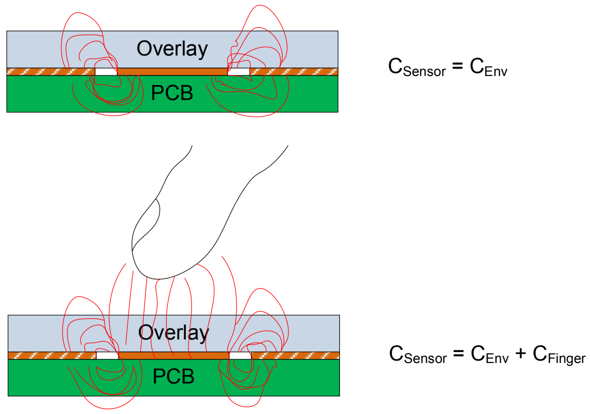

Figure 3: Finger Proximity Effect on Electrical Field and Sensor Capacitance

The challenge of capacitive sensing is to detect this relatively small variation of C_{Sensor} (C_{Finger} usually contributes for a few percent only) and differentiate it from environmental noise.

For this purpose, Semtech products integrate an auto offset compensation mechanism which dynamically removes the C_{Env} component to extract and process C_{Finger} only.

C_{Finger}, like any capacitance can be expressed in the formula below :

$$C_{Finger} = \frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{d}$$

A is the common area between the two electrodes hence the common area between the finger and the sensor, typically $1cm^2$ for an adult finger.

d is the distance between the two electrodes hence the overlay thickness, typically 1-3mm. Overlay thickness is a compromise between mechanical/ESD robustness (the thicker the better) and power consumption (if too thick the sensitivity may need to be increased to be able to sense C_{Finger} properly).

ε_0 is the free space permittivity and is equal to 8.85 10e-12 F/m (constant)

ε_r is the dielectric hence overlay permittivity when finger is touching. Typical permittivity of some common overlay materials is given in table below. Higher ε_r allows reducing power consumption and/or increasing overlay thickness.

Overlay Material	Typical ε_r
Glass	8
FR4	5
Acrylic Glass	3
Wood	2
Air	1

From the discussions above we can easily feel that the most robust and efficient design will be the one that minimizes C_{Env} value and variations while improving C_{Finger}. The following paragraphs will provide the necessary layout guidelines to reach this objective while maintaining power consumption as low as possible.

2 General

2.1 *SX864x Chip*

a) Strong ground connection on bottom exposed pad and ground pins

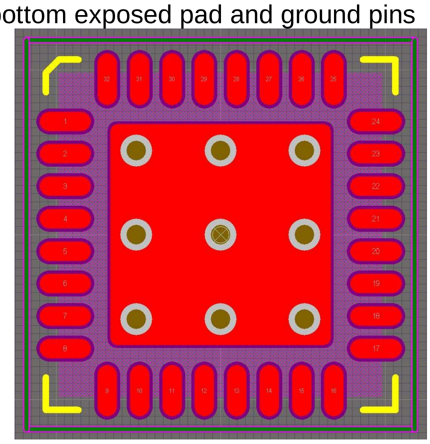

Figure 4: SX864x 5x5mm Recommended Footprint

b) VANA, VDIG, VDD decoupling capacitors must be placed as close as possible to their associated pin
c) Integration capacitor Cint (see *Figure 1*) must be placed as close as possible to the chip and as far as possible from noisy signals

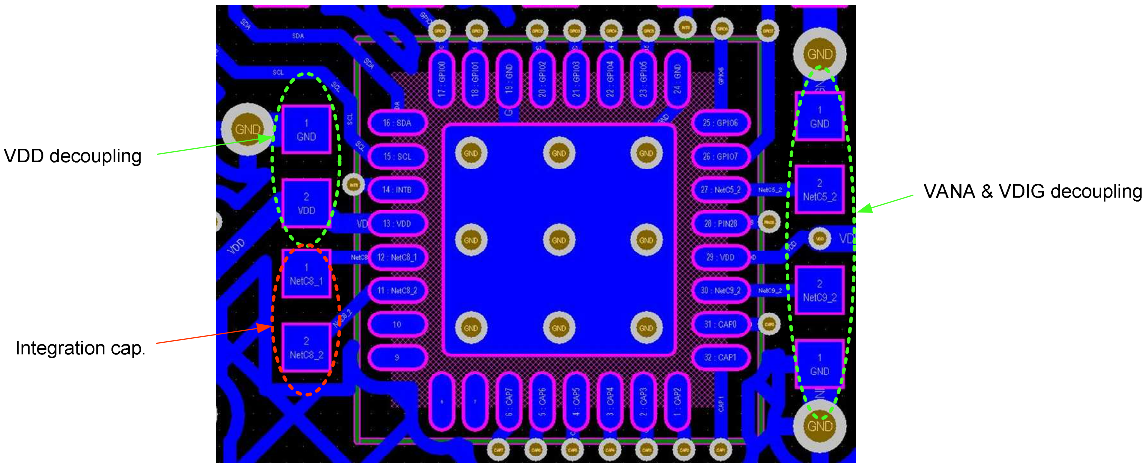

Figure 5: Integration and Decoupling Capacitors Recommended Placement

2.2 *Connections to CAPx Sensors*

a) 0.2 mm trace width is recommended
b) Minimum 0.2mm clearance between CAPx traces, recommended 0.5mm or above. CAPx are sensed serially by SX864x, non-sensed CAPx are internally tied to ground hence the clearance requirement.
c) Connections must be as short and direct as possible.

d) Preferably not to be routed on top layer to reduce potential finger coupling (must only be maximized on the CAP sensors, not on the traces)
e) Vias number must be reduced to the minimum.
f) CAPx signals should be routed as far as possible from noisy signals (LEDs, etc) and ideally on different layer or isolated by ground.
g) Noisy signals should not be routed below CAP sensors, if needed they must be isolated with ground layer.

2.3 Ground Considerations

a) 0.5 to 3mm recommended clearance with CAP sensors. Low values maximize noise immunity while high ones minimize power consumption.
b) Below 0.5mm clearance is possible but increases significantly ground coupling hence requiring higher sensitivity setting and higher consumption.
c) Above 3mm clearance is possible but doesn't reduce significantly ground coupling while reducing noise immunity.
d) Both top and bottom layers should be filled with hatched ground (typ. 20 %) to improve noise immunity while keeping DC cap low.

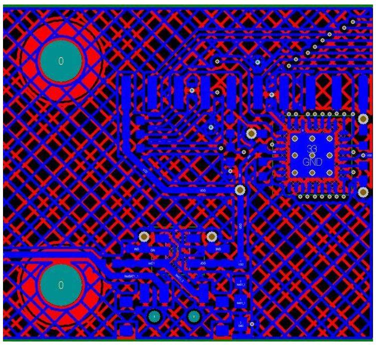

Figure 6: Hatched Ground Example (Red = Top; Blue = Bottom)

3 Buttons

3.1 Introduction

Similarly to the mechanical buttons they intend to replace, touch buttons provide ON/OFF information i.e. respectively button touched or not touched by the finger.

Each touch button is associated to its dedicated capacitive sensor.

Please refer to SX864x datasheets [1] for detailed touch buttons operation.

3.2 Shape

a) Round is best while oval or square with round corners are also acceptable
b) Any other shape with acute angles is not recommended
c) Possibility to put a hole for reverse mount SMD LED in the middle (will reduce a little bit the sensor surface, can be compensated with higher sensitivity setting or bigger sensor)

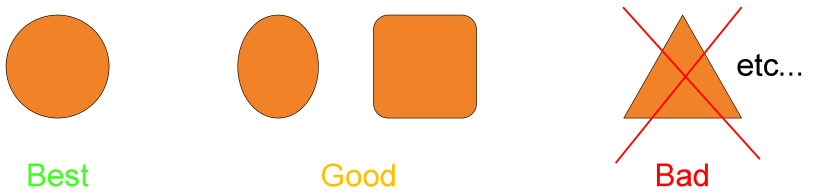

Figure 7: Button Shape Recommendations

3.3 Size

a) 1cm diameter is recommended
b) Above 1.5cm diameter is useless due to finger tip surface
c) Below 1cm is possible at the expense of higher sensitivity setting hence higher consumption

3.4 Pitch

a) 1.5cm is recommended as minimum
b) Below 1.5cm is possible but reduces user friendliness and improves the risk of side touch effects.

3.5 Examples

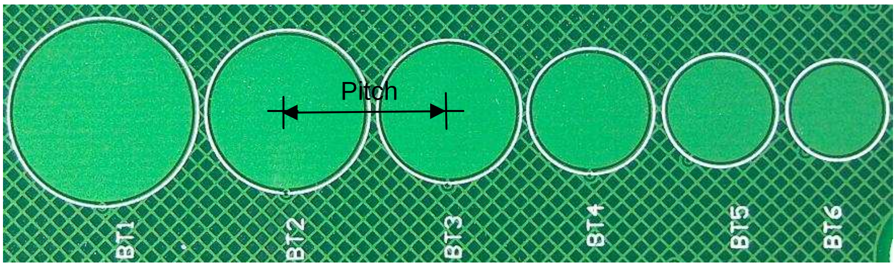

Figure 8: Example of Buttons without LED Hole

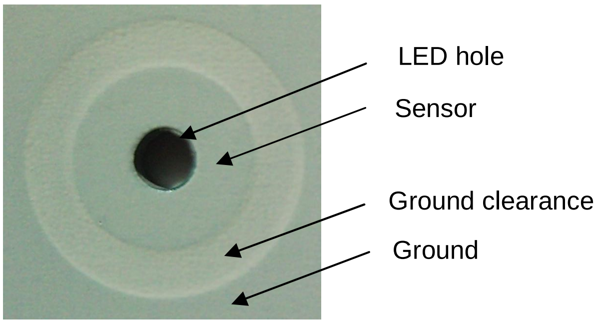

Figure 9: Example of Button with LED Hole (covered by white silkscreen)

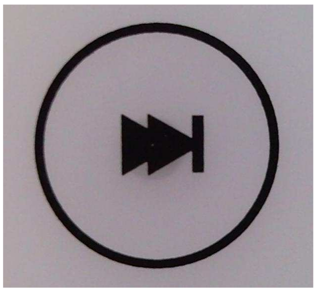

Figure 10: Example of Button Overlay with Pictogram

4 Slider

4.1 Introduction

Similarly to the mechanical sliders they intend to replace, touch sliders monitored by Semtech products provide of course the position information but also an ON/OFF state (i.e. respectively slider touched or not touched by the finger) as well as movement information (move-up or move-down).

Each touch slider is made by several capacitive sensors placed back to back on the PCB.

For good position resolution a slider usually requires interpolation (i.e. number of positions not limited to the number of sensors) which requires a layout ensuring that the finger always touches at least 2 sensors.

Please refer to SX864x datasheets [1] for detailed touch sliders operation.

4.2 Shape

4.2.1 Slider

a) Straight shape is usually recommended for better user friendliness but other shapes are also possible
b) Mechanical guide on overlay improves user friendliness and robustness especially for exotic shapes

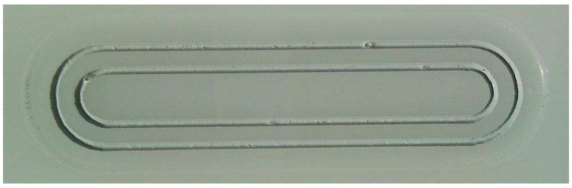

Figure 11: Example of Slider Overlay Guide

4.2.2 Sensors

a) Rectangular shape implies a lot of sensors to ensure interpolation (max half surface of finger per sensor)
b) Chevron shape is recommended as it provides good interpolation with relatively low number of sensors

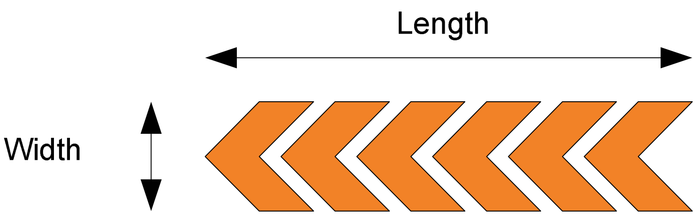

Figure 12: Slider Shape Recommendation

4.3 Size

4.3.1 Slider

a) 1cm recommended width
b) Above 1.5cm width is useless due to finger tip surface
c) Below 1cm width is possible at the expense of higher sensitivity setting hence higher consumption
d) The number of sensors depends on the length required and resolution targeted

4.3.2 Sensors

a) The smaller the better, typically below 0.5cm^2 recommended (half surface of finger)
b) Bigger is possible but requires more complex layout (more interpolation required to ensure good resolution)

4.4 Pitch

a) The smaller the better to maximize interpolation
b) Ground clearance recommendations apply (see §2.3)

4.5 Example

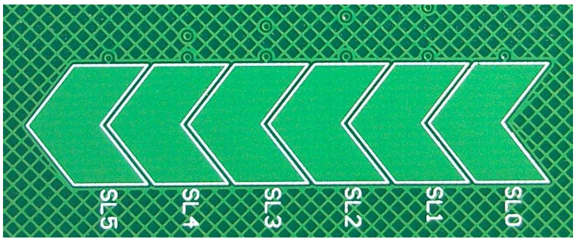

Figure 13: Example of Slider

5 Wheel

5.1 Introduction

A wheel can be seen as a slider with round shape, as such it has similar layout constraints and also provides position, ON/OFF, and movement information.

Each touch slider is made by several capacitive sensors placed back to back on the PCB.

Similarly to a slider, a wheel usually also requires interpolation but because of its “infinite length” nature, the position precision requirement is usually not as critical as for a slider. (movement detection may be more important)

Please refer to SX864x datasheets [1] for detailed touch wheels operation.

5.2 Shape

5.2.1 Wheel

a) Round is usually recommended for better user friendliness but other shapes are also possible
b) Mechanical guide on overlay improves user friendliness and robustness especially for exotic shapes

Figure 14: Example of Wheel Overlay Guide

5.2.2 Sensors

a) Rectangular shape implies a lot of sensors to ensure interpolation (max half surface of finger per sensor)
b) Chevron shape is the best but may be complex to design inside a wheel
c) Whirl shape is recommended as it gives a good compromise between the number of sensors required and layout complexity

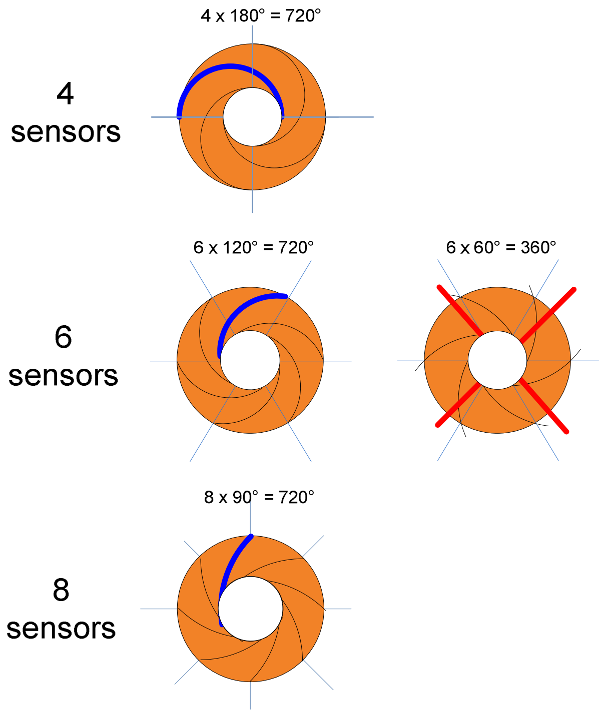

Figure 15: Wheel Shape Recommendation

5.3 Size

5.3.1 Wheel

a) 1cm recommended width
b) Above 1.5cm width is useless due to finger tip surface
c) Below 1cm is possible at the expense of higher sensitivity setting hence higher consumption
d) The number of sensors depends on the wheel diameter required and the resolution targeted

5.3.2 Sensors

a) The smaller the better, typically $1cm^2$ recommended for whirl shape (see below)
b) Bigger is possible but requires more complex layout (more interpolation required)

5.4 Pitch

a) The smaller the better to maximize interpolation
b) Ground clearance recommendations apply (see §2.3)

5.5 Examples

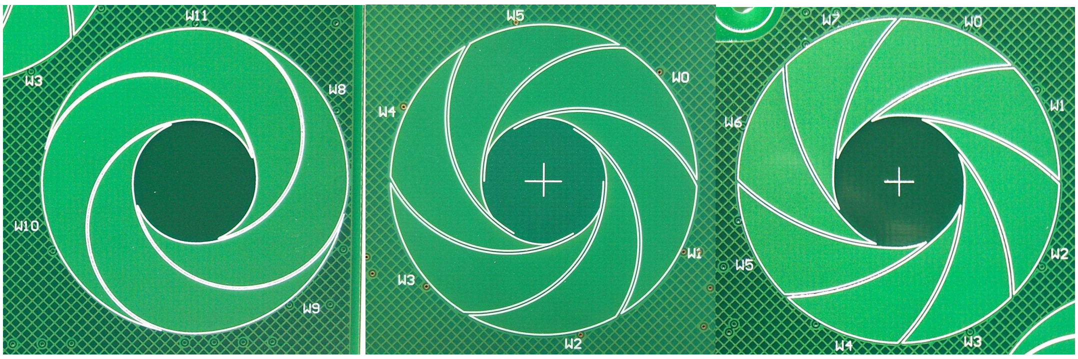

Figure 16: Examples of Wheels (4, 6 and 8 sensors)

6 References

- [1] SX864x Datasheets
- [2] SX864xEVK User's Guide

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