AN3431
Application note

How to design a PresSense pressure touch button

Introduction

Traditional capacitive touch sensing solutions offer several advantages such as reduced cost and no mechanical moving parts. The simple mechanical design of capacitive touch sensing systems facilitates sealing water off devices while simultaneously maintaining a very professionnal look and feel. There are however, some limitations. Such limitations can be addressed by capacitive sensing technology but, in a different form called press to sense technology (PresSense).

The advantages of PresSense over traditional capacitive sensing implementations are as follows:

- Water does not affect the measurements of PresSense capacitive sensing devices whereas traditional capacitive sensing devices, with sensors that may be susceptible to water/other contaminants, must follow special design considerations.
- PresSense capacitive sensing devices present no problems for users with gloves.
- PresSense capacitive sensing devices can have a metallic finish whereas traditional capacitive sensing devices cannot.
- PresSense capacitive sensing devices have a higher radio frequence (RF) immunity.
- False detections are significantly reduced in PresSense capacitive sensing devices as a small force is required for an actuation.

This application note describes how to design a PresSense touch sensing solution using electrodes and a metal layer.

Typical applications that are best suited for the PresSense series include:

- Stoves
- Waterproof housing
- Microwave ovens
- Industrial applications
- Kitchen appliances
- Waterproof keypads

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1 Principle of operation

In both traditional and PresSense capacitive sensing technologies, the change in capacitance caused by the user is measured by a sensor. In traditional capacitive sensing technology, the sensor pad forms one side of a parallel capacitor and the user's finger forms the other side. If the user brings his finger closer to the pad, the distance (d) between his finger and the sensor pad decreases according to *Equation 1*. Consequently, the capacitance (C) increases.

Equation 1: Parallel plate capacitor

$$C = \xi_R \xi_0 (A / d)$$

Where ε_R = relative permittivity, ε_0 = vacuum permittivity, and A = area.

In PresSense technology, the concept of the parallel plate capacitor still applies, except that the second plate is not the finger of the user but a conductive material with a fixed potential suspended over the sensor pad. When a user applies a force to the conductive material above the sensor pad, a slight local deflection is created in the material. Consequently, the distance (d) between the two plates alters.

The conductive material, used as a top cover, must be kept at a fixed potential. In some cases, the external metallic part of the system must be connected to earth for safety reasons. The conductive top cover can be connected to earth but, in this case, the electronic touch sensing must be referred to earth.

Figure 1 shows a cross section of a typical PresSense button when it is unpressed.

Figure 1. PresSense technology: cross section of an unpressed button

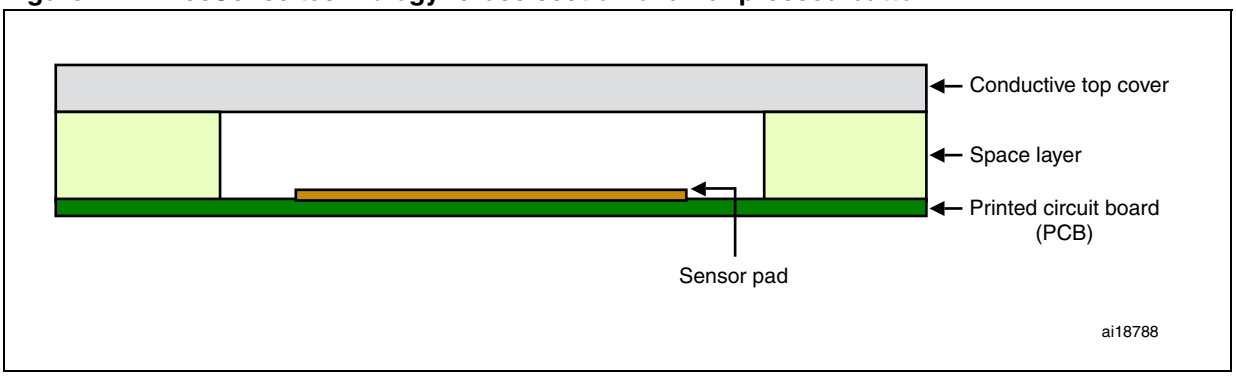
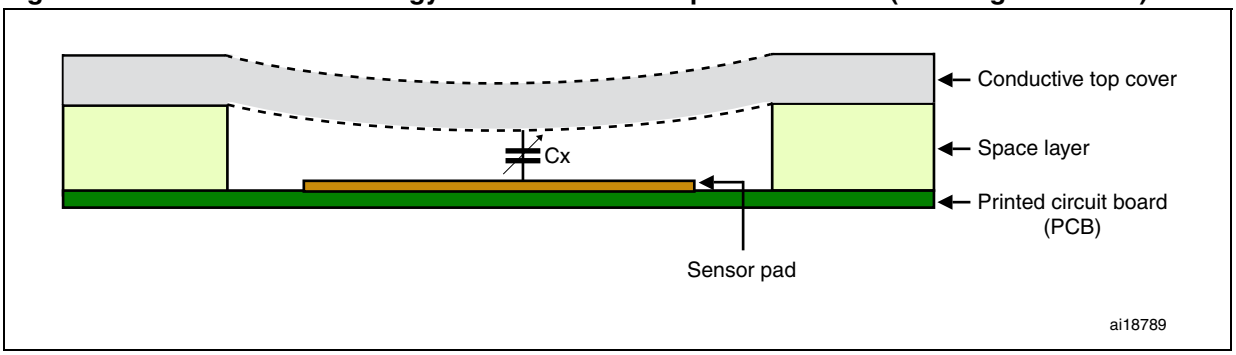


Figure 2 shows a cross section of a typical PresSense button when it is pressed.

Figure 2. PresSense technology: cross section of a pressed button (showing deflection)

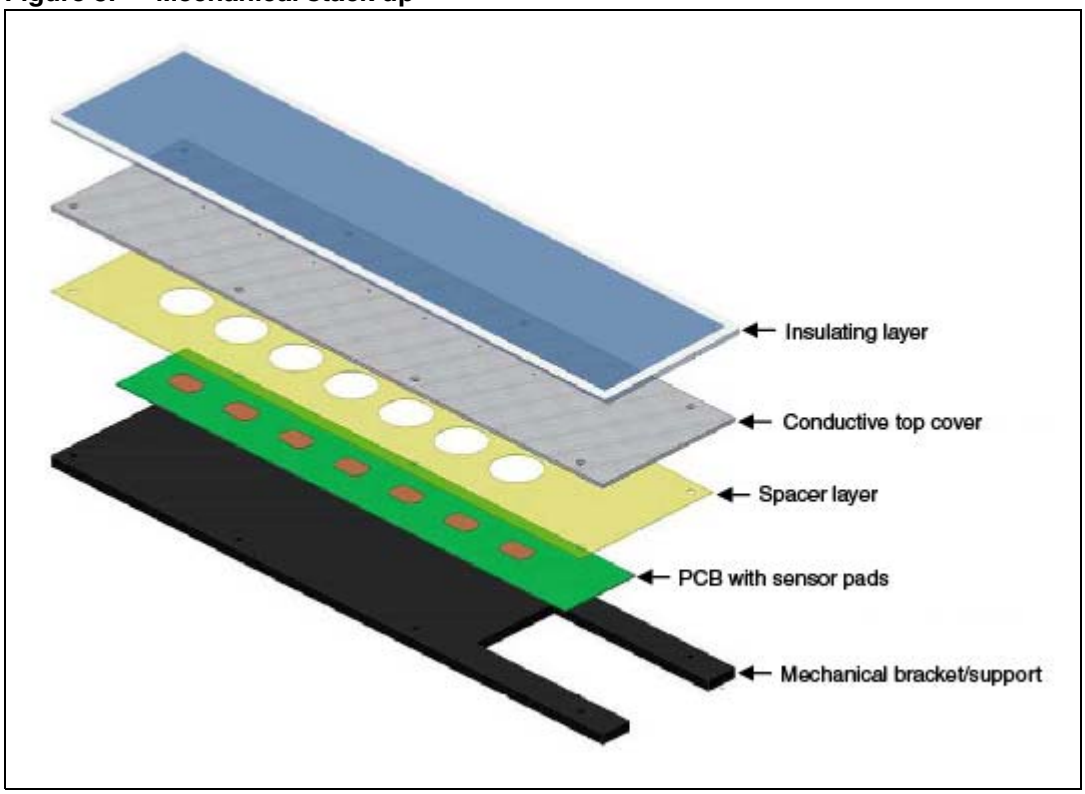


2 Mechanical construction considerations

2.1 Stack up

The mechanical stack up is shown in *Figure 3*. The conductive top cover is normally metal. An insulating layer may be added without modifying the behaviour of the PresSense buttons. The middle layer is a spacer with cut-outs to allow for the deflection of the top cover at predetermined positions. The bottom layer is the PCB with the sensor pads as copper pours. An additional mechanical bracket/support layer can be added.

Figure 3. Mechanical stack up



The parameters that impact touch and detection are:

- The insulation layer material and thickness
- The top cover material and thickness
- The thickness and the hole size of the spacer
- The size of the sensor pad and the routing of the touch sensing signals
- The mechanical construction and the rigidity of the overall touch module.

2.1.1 Insulating layer

The designer can add an optional insulating layer to improve electrostatic discharge (ESD) protection (if the conductive top cover is driven by an MCU pin) and/or to enhance the look of the application. This layer can simply be glued onto the top cover and has limited impact on the behavior of the touch module.

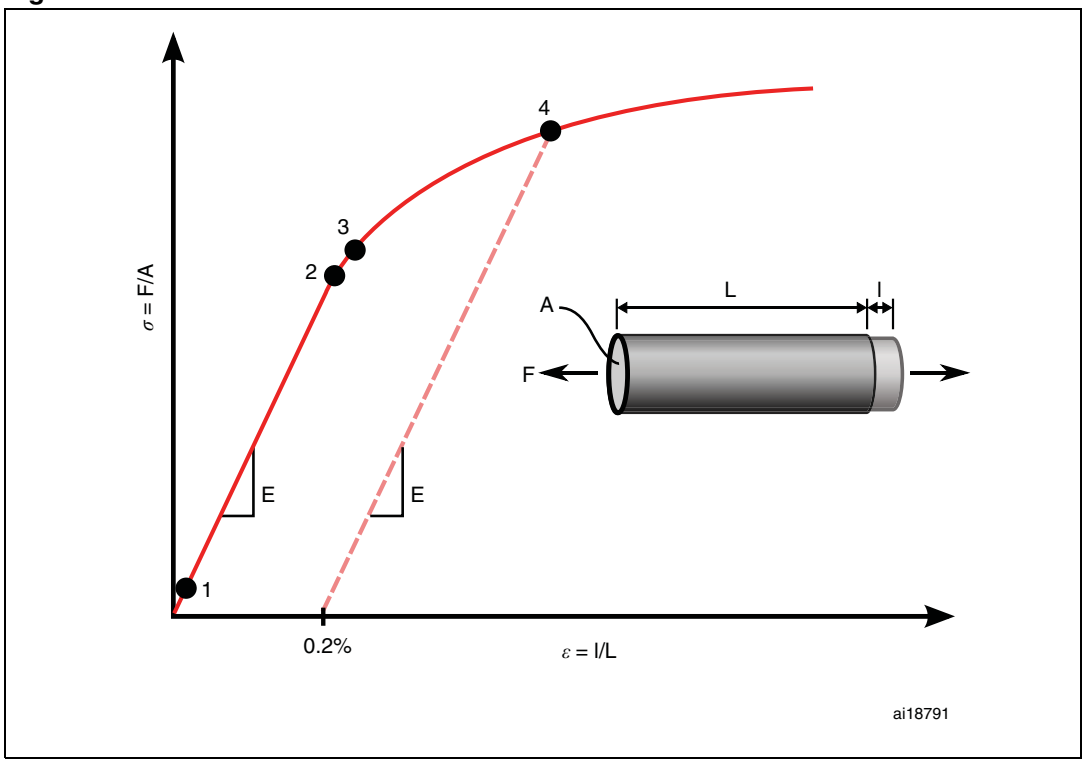
2.1.2 Conductive top cover

The conductive top cover should be designed so that it has a measurable non-permanent deflection when pressed in the desired sensor area.

For any material sample, it is possible to represent graphically the relationship between stress (forces which deform a body) and strain (the relative deformation itself). *Figure 4* demonstrates the relationship between stress and strain. The first part of the curve is linear (according to physical laws). Here, the ratio between stress (σ) and strain (ε)[(a)] is called Young's modulus (E). An additional parameter, the elastic limit (1), must also be taken into account. This applies when the material becomes permanently deformed if the stress applied is too high.

a. In this mechanical context, "ε" does not relate to the permittivity but, to the strain (a strain is a normalized measure of deformation representing the displacement between particles in the body relative to a reference length).

Figure 4. Stress-strain curve



1. Legend
   1: True elastic limit (crystallographic defect movement), which occurs for a very low stress
   2: Proportionality limit
   3: Elastic limit (yield strength, $_y$), above this stress, a permanet deformation occurs
   4: Offset yield strength, usually defined as ε = 0.2 %
   : Engineering stress
   ε: Engineering strain
   A: Undeformed cross-sectional area
   F: Uniaxial load
   L: Underformed length
   l: Elongation
   E: Young's modulus

The conductive top cover should be chosen so that the physical properties of the material (its type and thickness) allow enough elongation when applying a force (stress) but, should not cause a permanent bend (i.e. the stress should not exceed the elastic limit).

The top cover is usually a metal but, can also be a conductively coated material or plastic. The most common metal for light touches (80-150 g) is Aluminium. *Table 1* shows Young's modulus and the yield strength for several common materials.

Table 1. Young's modulus and yield strength of common materials

Material	Young's modulus -E- (GPa)	Yield strength -σ_y- (MPa)
Aluminium	69	95
Steel	200	250 to 1650
Copper	100 to 128	70
Polycarbonate	2.6	70
Titanium	105 to 120	730

It can be seen from *Table 1* :

- Aluminium has a very favorable ε and σ_y. Aluminium is also widely available as it is the most abundant metal in the earth's crust.
- The other listed metals can also be used, but the higher force required should be considered. Designing with stringent design parameters can still yield a soft touch on these metals.
- Polycarbonate is a very workable plastic which is used as an electronic component and construction material, in automotive, aircraft and security components, and in niche applications.

2.1.3 Spacer layer

The spacer layer is used to create an air-gap between the top cover and the sensor pad on the PCB. When a user presses the top cover (above the sensor pad area), the slight deflection of the overlay material into the air-gap increases the capacitance measured. Although the thickness of the spacer layer is the main design consideration, it is also important to consider the material. A rigid material, such as FR-4 or a nondeformable plastic, should be used for the spacer layer so that it does not deform with the top cover if a force is applied on the overlay material. A rigid spacer layer also keeps the PCB secure.

The deflection required in the overlay material should be at least 2-5 %. This yields a 0.9-2 % change in the capacitance of the button (deflection is not linearly equivalent to change in capacitance due to parasitic capacitances). A larger deflection is better because it yields a higher signal-to-noise ratio (SNR).

Spacer layer recommendations

- The recommended spacer layer thickness is 0.1-0.5 mm.
- The spacer layer can be a nondeformable plastic film with holes over the buttons.
- The conductive top cover can have blind holes above the sensor pads. This also decreases the cost of spacer layer manufacturing, fitting and adhesion, as it is directly incorporated into top cover. For example,
  - 0.7 mm Aluminium with 0.2 mm deep blind holes above sensor pads
  - 1 mm plastic/perspex with 0.2-0.5 mm blind holes above sensor pads
- The holes in the spacer layer are recommended to be at least 110-130 % of the button size. This increases the area which is deflected towards the sensor pad, in essence, increasing the change in capacitance.

2.1.4 PCB layer

The PCB layer can be made with an extra mechanical tier over the top routed tier. The PCB can be 0.1-0.5 mm thick with cut-out/blind holes above the sensor pads. This decreases the cost of the spacer layer manufacturing, fitting and adhesion, as it is directly incorporated into the PCB.

2.1.5 Mechanical bracket/support layer

This layer can be added to ensure that the module does not bend or move when a force is applied to a button. To get a stable and robust solution, only local deflection over the button is permitted.

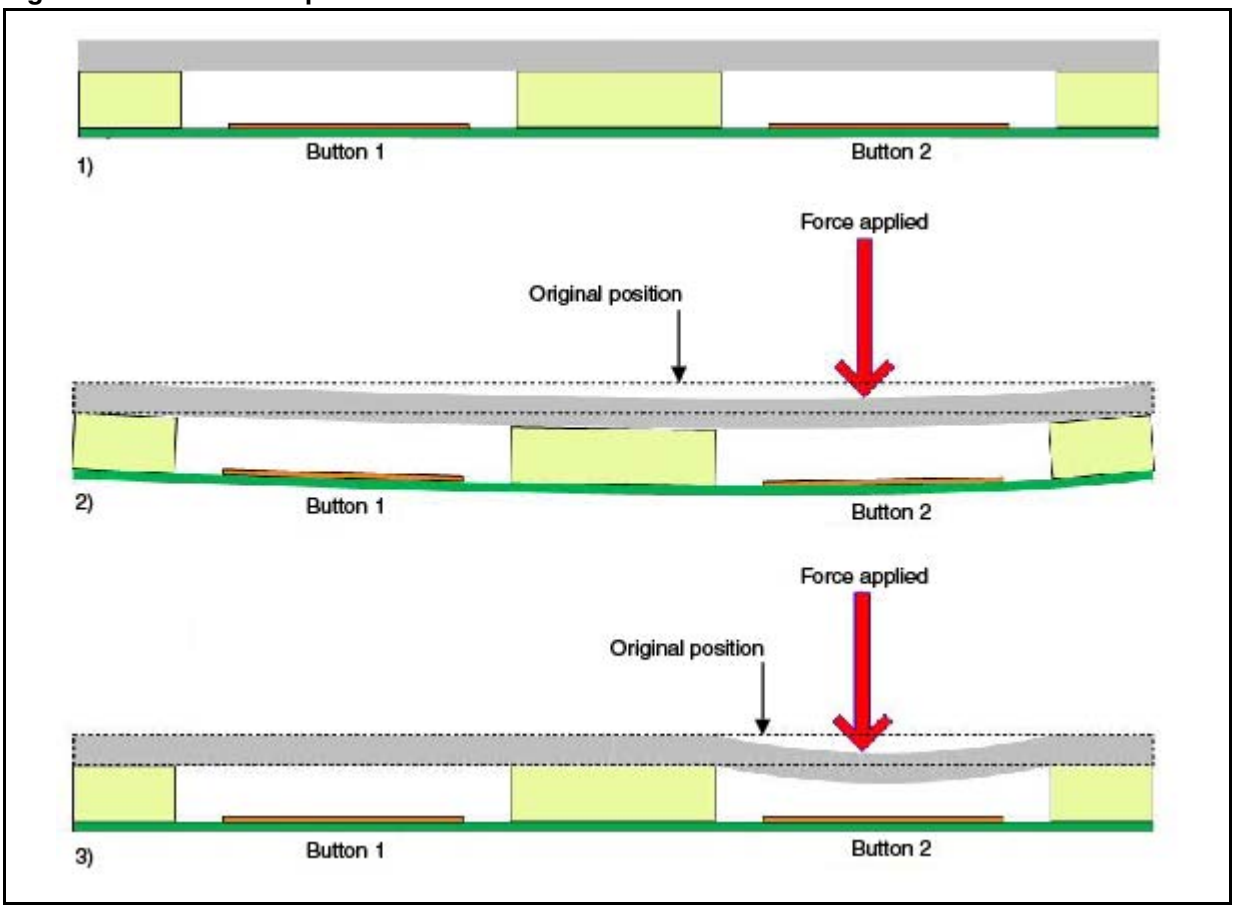
2.2 Application rigidity and adhesion of layers

The PresSense should be in a neutral position where no points on the back of the PCB should be stressed. The PCB should have uniform pressure across the system and should not be allowed to deform/move if a force is exerted onto the conductive top cover.

It is strongly recommended to have a backing support of rigid insulating material pressing the PCB uniformly against the spacer layer.

Figure 5 (part 2) shows 'mechanical problem 1' where the system deforms when a force is applied.

Figure 5. Mechanical problem 1



1. No force applied
2. Force applied (incorrect movement)
3. Force applied (correct movement)

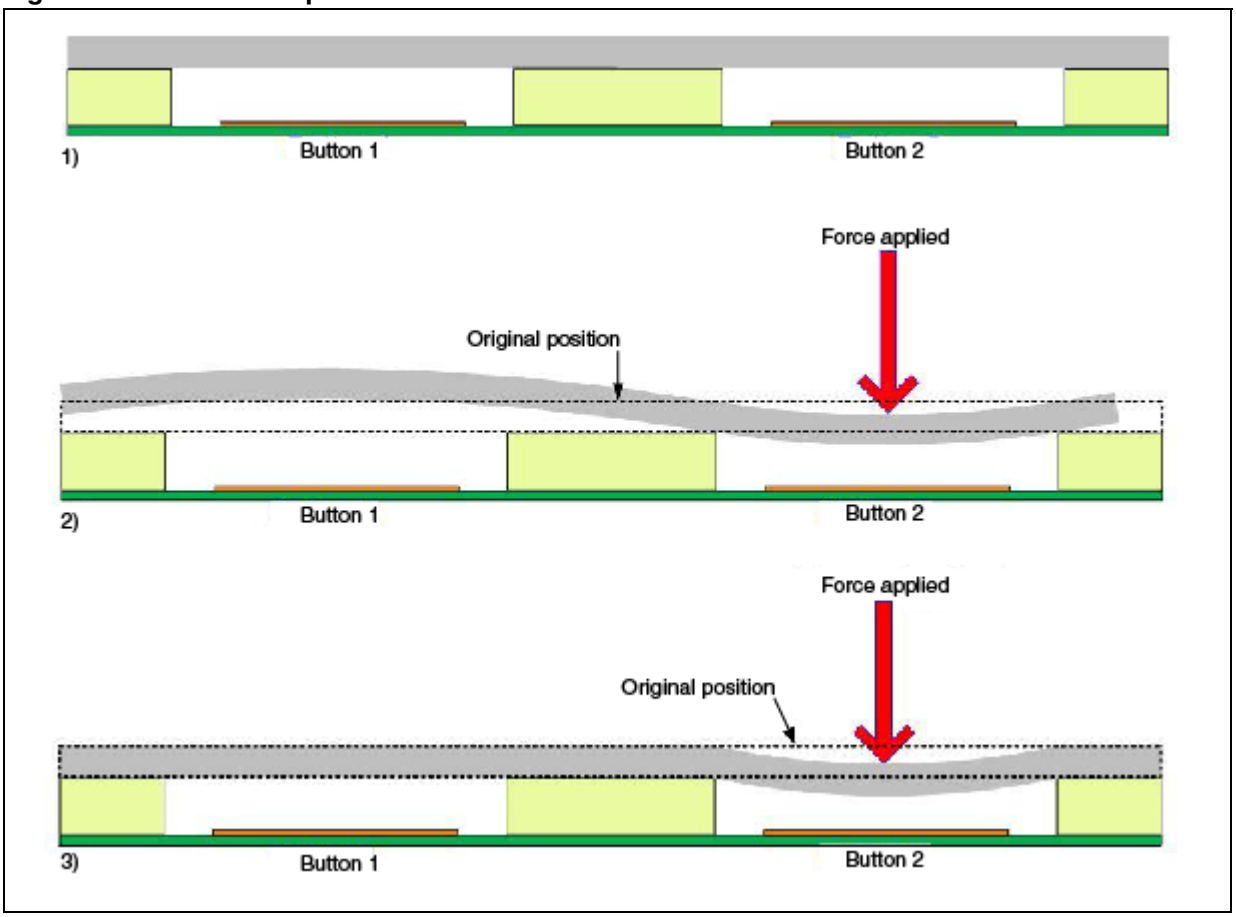
Table 2. Mechanical problem 1 analysis

Possible mechanical problems in *Figure 5*	Electrical consequences
Spacer layer not made from nondeformable material - entire system deforms downwards.	Increased capacitance on buttons 1 and 2 with possible false detection on both
Mechanical support behind PCB is not in a neutral position - whole structure (conductive top cover, spacer layer, and PCB layer) deforms downwards.	

A nonelastic adhesive should be used, together with a backing support material, to merge the different layers (conductive top cover, spacer layer, and PCB layer) together permanently.

If the conductive top cover is too stiff and the adhesive is elastic, it may cause ‘mechanical problem 2’ (see *Figure 6*, part 2). In this situation, if a force is exerted to button 2, the conductive top cover over button 1 may lift.

Figure 6. Mechanical problem 2



1. No force applied
2. Force applied (incorrect movement)
3. Force applied correct movement

Table 3. Mechanical problem 2 analysis

Possible mechanical problems in *Figure 6*	Electrical consequences
Adhesive did not create a permanent adhesion between layers - consequently, conductive top cover layer deforms	Increased capacitance on button 2 due to touch and decreased capacitance on button 1(1)
Adhesive layer is too elastic and conductive top cover is too stiff	
Buttons are too close to each other	

1. Decreased capacitance on button 1 causes a latch-on effect on this button when the force is no longer exerted to button 2. This is due to a reference adaptation.

2.3 Size of the sensor pads

An area of at least 80 mm^2 (absolute minimum size) and up to 160 mm^2 is recommended for the sensor pads. The size of the sensor pads is a very important consideration because the greater their size, the more sensitive they are. Sensor pads can be square (with round edges) or round.

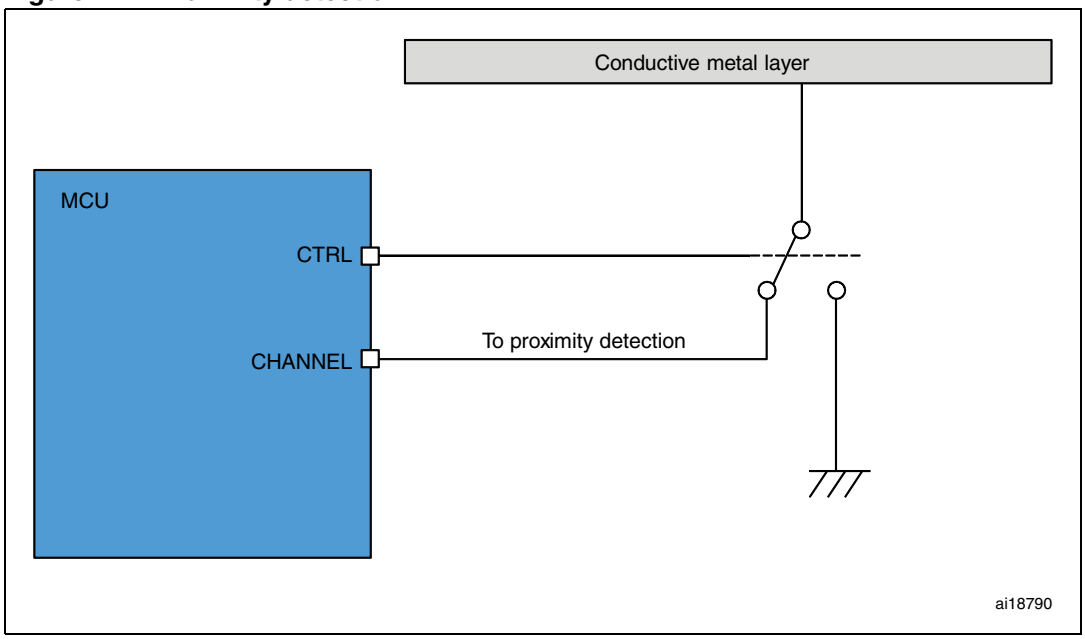
The button spacing of the sensor pads should be designed so that a force applied on one button, should not have an effect on an adjacent button.

3 How to combine proximity detection with PresSense[b]

A proprietary technique exists which detects proximity events as a user approaches. The big advantage of this technique is that backlighting can be illuminated as the user approaches even before the actual touch event. This unique feature is implemented in PresSense capacitive sensing technologies with limited external components.

For proximity event detection the conductive metal cover is connected to a capacitive sensing channel of the touch sensing microcontroller device. The connection is shown in *Figure 7*. After proximity detection has taken place the metal layer is grounded and a touch can be detected. If no touch occurs after a given amount of time or if the detection of the touch ends, the connection is switched back to the proximity detection.

Figure 7. Proximity detection



b. This technology is patent pending.

4 Implementation example

Figure 8 shows a single PresSense button designed using an STM8T142 device. The top cover is made of an aluminium sheet 0.6 mm thick with a 0.2 mm blind acting as the spacer layer. The sensor is 10 mm in diameter.

Figure 8. Single channel PresSense switch with metal top cover

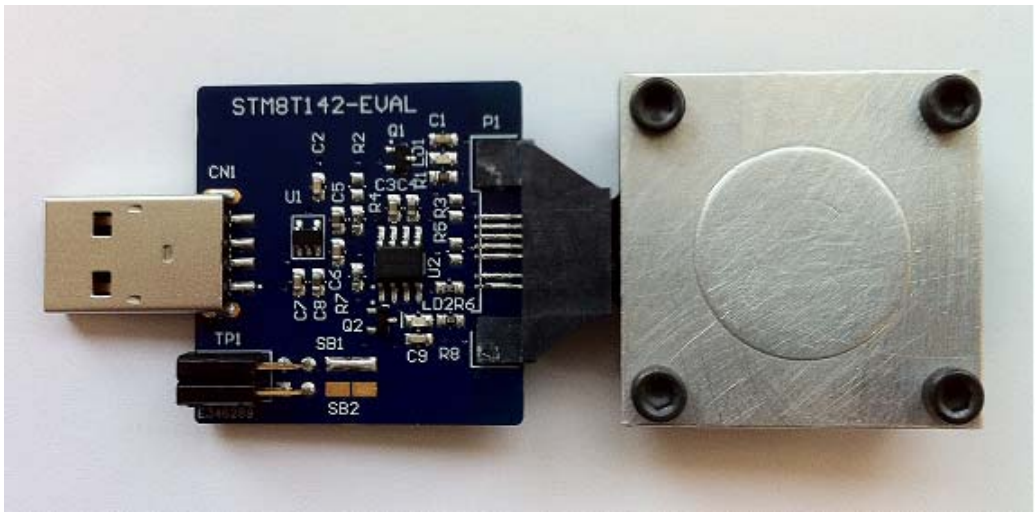
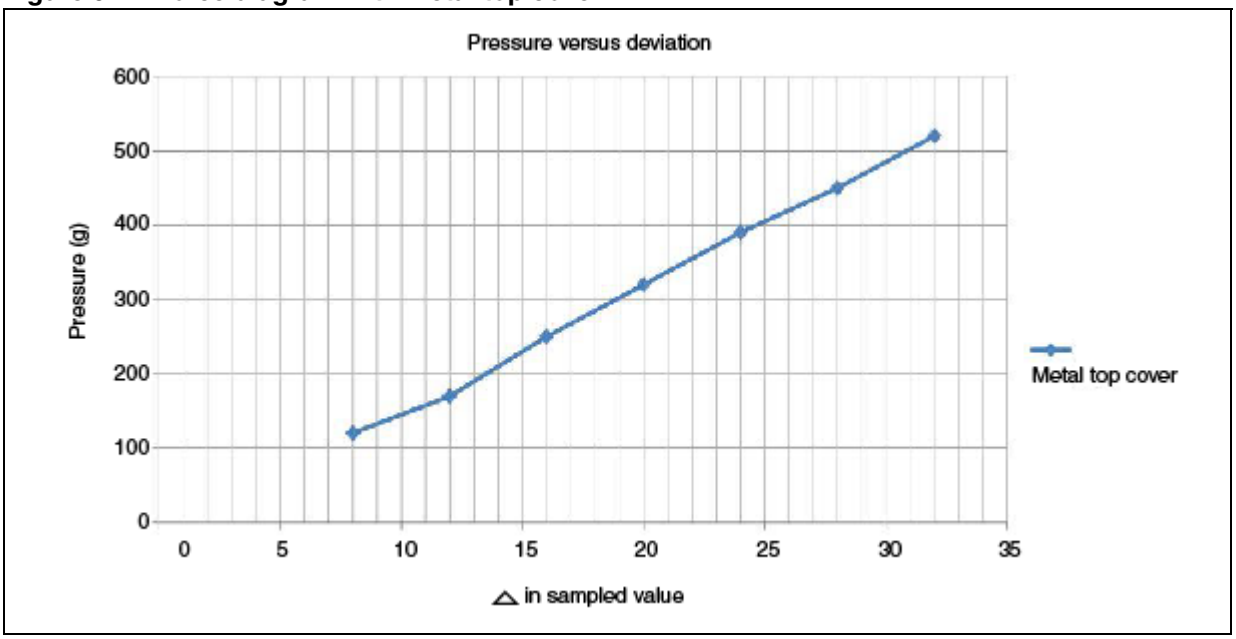


Figure 9 shows the amount of pressure needed to flex the top cover. Flexing of the top cover results in a change in the capacitance reflected in the sampled value. A typical sample consists of 900 charge cycles. In the most sensitive setting a deviation of 8 in the sampled value constitutes a touch.

Figure 9. Force diagram with metal top cover



1. 1 Netwon (N) is equivalent to about 100 g.

5 Conclusion

The deformation of the metal layer which leads to a touch detection depends on several parameters which are summarized in *Table 4*.

Table 4. Mechanical parameters and recommendations

Mechanical parameters	Recommendations
Top cover material type	Aluminium
Top cover material thickness	0.7 mm
Spacer thickness	0.1 mm to 0.5 mm
Sensor size	80 mm^2 to 160 mm^2
Hole size	110 % to 130 % of the button size
Force applied	Roughly between 1 N and 10 N

Other factors influence how the buttons affect each other including the elasticity of the top cover material or how well the top cover and spacer layers are merged with the adhesive. Such factors can also be reduced by placing the buttons at least half the diameter of a button away from each other.

6 Revision history

Table 5. Document revision history

Date	Revision	Changes
23-Sep-2011	1	Initial release.

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