
Guidelines for designing touch sensing applications with surface sensors

Introduction

This application note describes the layout and mechanical design guidelines used for touch sensing applications with surface sensors.

Capacitive sensing interfaces provide many advantages compared to mechanical user interfaces, like the ones listed below:

- Modern look and feel
- Easy to clean
- Waterproof
- Robust

Capacitive sensing interfaces are more and more used in a wide range of applications. The interface is based on surface sensors that are made of small copper foils. The sensor acts as a capacitor that is alternatively charged and discharged. The capacitor value depends on the presence of the user finger as well as the sensor design. This application note introduces various sensor designs and recommendations to achieve optimum performances, keeping in mind that none of the sensor elements should interfere with each other.

This document provides simple guidelines covering the three following main aspects:

- printed circuit board (PCB)
- overlay and panel materials
- all other items in the capacitive sensor environment

[Table 1](#) lists the microcontrollers concerned by this application note.

Table 1. Applicable products

Type	Applicable products
Microcontrollers	STM32F0 Series, STM32F3 Series, STM32L0 Series, STM32L1 Series, STM32L4 Series, STM8L Series, STM8AL Series

Contents

1	Capacitive sensing technology in STMicroelectronics	6
1.1	Charge transfer acquisition principle	6
1.2	Surface capacitance	6
2	Main capacitive sensing guidelines	8
2.1	Overview	8
2.2	Construction	8
2.2.1	Substrates	8
2.2.2	Electrode and interconnection materials	9
2.2.3	Panel materials	11
2.2.4	Mechanical construction and PCB to panel bonding	12
2.2.5	Metal chassis	13
2.2.6	Air gap	13
2.2.7	Transfer of an electrode from PCB to the front panel	14
2.3	Placing of LEDs close to sensors	14
2.4	TC versus FT I/O	14
2.5	Power supply	16
3	Surface sensor design	17
3.1	Touchkey sensor	17
3.2	Touchkey matrix sensor	18
3.3	Linear sensor	19
3.3.1	Normal patterned linear sensor	20
3.3.2	Interlaced patterned linear sensor	21
3.4	Rotary sensor	21
3.4.1	Normal patterned rotary sensor	22
3.4.2	Interlaced patterned rotary sensors	22
3.4.3	Rotary sensor with central touchkey	23
3.5	Specific recommendations	24
3.5.1	LEDs and sensors	24
3.5.2	Driven shield	25
3.5.3	Using electrodes separated from the PCB	28
3.5.4	PCB and layout	29

	3.5.5	Component placement	31
	3.5.6	Ground considerations	31
	3.5.7	Rotary and linear sensor recommendations	32
4		Conclusion	33
5		Revision history	34

List of tables

Table 1. Applicable products 1

Table 2. Potential application problems with flex PCB placement 10

Table 3. Dielectric constants of common materials used in a panel construction. 11

Table 4. Document revision history 34



List of figures

Figure 1.	Equivalent touch sensing capacitances	7
Figure 2.	Example of capacitive sensor construction	8
Figure 3.	Clear ITO on PET with silver connections	9
Figure 4.	Silver printing on PET	10
Figure 5.	Flexible PCB (FPC)	10
Figure 6.	FR4 (2-sided epoxy-fiberglass)	11
Figure 7.	Typical panel stack-up	13
Figure 8.	Examples of cases where a LED bypass capacitor is required	14
Figure 9.	TC I/O	15
Figure 10.	FT I/O	15
Figure 11.	Typical power supply schematic	16
Figure 12.	Sensor size	17
Figure 13.	Recommended electrode size	17
Figure 14.	Simple matrix implementation	18
Figure 15.	Mono electrodes design	19
Figure 16.	Half-Ended electrodes design	19
Figure 17.	Dual electrodes design	19
Figure 18.	Normal patterned linear sensor with 5 channels / 6 electrodes (half-ended electrodes design)	20
Figure 19.	Interlaced linear touch sensor with 3 channels / 4 electrodes (half-ended electrodes design)	21
Figure 20.	Normal patterned rotary sensor with 3 channels / 3 electrodes	22
Figure 21.	Interlaced patterned rotary sensor with 3 channels / 3 electrodes	23
Figure 22.	Back-lighting touchkey	24
Figure 23.	PCB 3D top view	24
Figure 24.	PCB bottom view	25
Figure 25.	STM8L1xx driven shield example using the charge-transfer acquisition principle	26
Figure 26.	STM32L driven shield example using the charge-transfer acquisition principle	27
Figure 27.	Printed electrode method showing several connection methods	28
Figure 28.	Spring and foam picture (both are not compressed)	29
Figure 29.	Track routing recommendation	30
Figure 30.	Ground plane example	32
Figure 31.	Hatched ground and signal tracks	32

1 Capacitive sensing technology in STMicroelectronics

STMicroelectronics offers different capacitive sensing technologies for STM8 devices and STM32 microcontrollers based on Arm^{®(a)} cores.



The technology covered by this application note is based on the charge transfer acquisition principle and is supported by all microcontrollers listed in [Table 1](#).

1.1 Charge transfer acquisition principle

The surface charge transfer acquisition is a proven, robust and efficient way to measure a capacitance. It uses a minimum number of external components to operate with a single ended electrode type. This acquisition is designed around an analog I/O group which is composed of four GPIOs. Several analog I/O groups are available to allow the acquisition of several capacitive sensing channels simultaneously and to support a larger number of capacitive sensing channels. Within a same analog I/O group, the acquisition of the capacitive sensing channels is sequential.

One of the GPIOs is dedicated to the sampling capacitor (C_S). Only one sampling capacitor I/O per analog I/O group must be enabled at a time.

The remaining GPIOs are dedicated to the electrodes and are commonly called channels. For some specific needs (such as proximity detection), it is possible to simultaneously enable more than one channel per analog I/O group.

The surface charge transfer acquisition principle consists of charging an electrode capacitance (C_X) and transferring a part of the accumulated charge into a sampling capacitor (C_S). This sequence is repeated until the voltage across C_S reaches a given threshold (V_{IH} in our case). The number of charge transfers required to reach the threshold is a direct representation of the size of the electrode capacitance. When the electrode is “touched”, the charge stored on the electrode is higher and the number of cycles needed to charge the sampling capacitor decreases.

1.2 Surface capacitance

A capacitance is modified when a finger gets close to a sensing electrode.

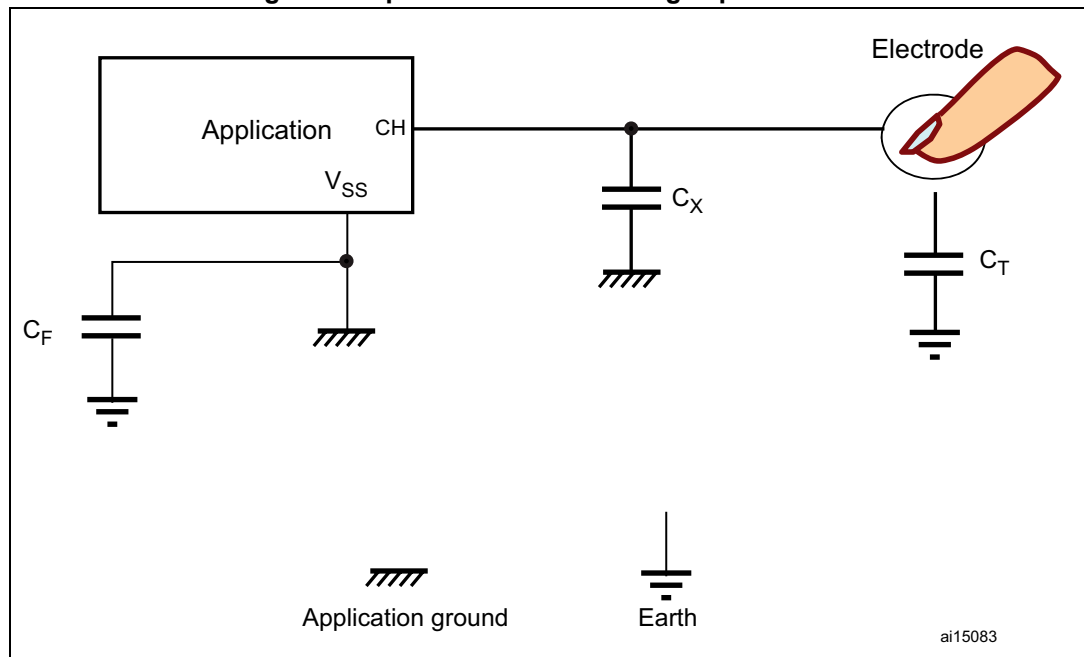
The return path goes either through:

- a capacitor through the user's feet
- a capacitor between the user's hand and the device
- a capacitor between the user's body and the application board through the air (like an antenna)

a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

Background

Figure 1. Equivalent touch sensing capacitances



C_X is the parasitic capacitance of the electrode.

C_X is composed of two capacitances: the first one refers to earth, which is not significant and can be ignored, and the second one refers to the application ground, which is dependent on the PCB or the board layout. This latter parasitic capacitance includes the GPIO pad capacitance and the coupling between the electrode tracks and the application ground. The PCB and board layout must be designed to minimize this parasitic capacitance.

C_F is the feedback capacitance between earth and the application. Its influence is important in surface capacitance touch sensing applications, especially for applications which do not feature a direct connection to earth.

C_T is the capacitance created by a finger touch and it is the source of the useful signal. Its reference is earth and not the application ground.

The total capacitance measured is a combination of C_X , C_F and C_T where only C_T is meaningful for the application. So we measure C_X plus C_T in parallel with C_F , which is given by the formula:

Equation 1

$$C_X + \frac{1}{\frac{1}{C_T} + \frac{1}{C_F}}$$

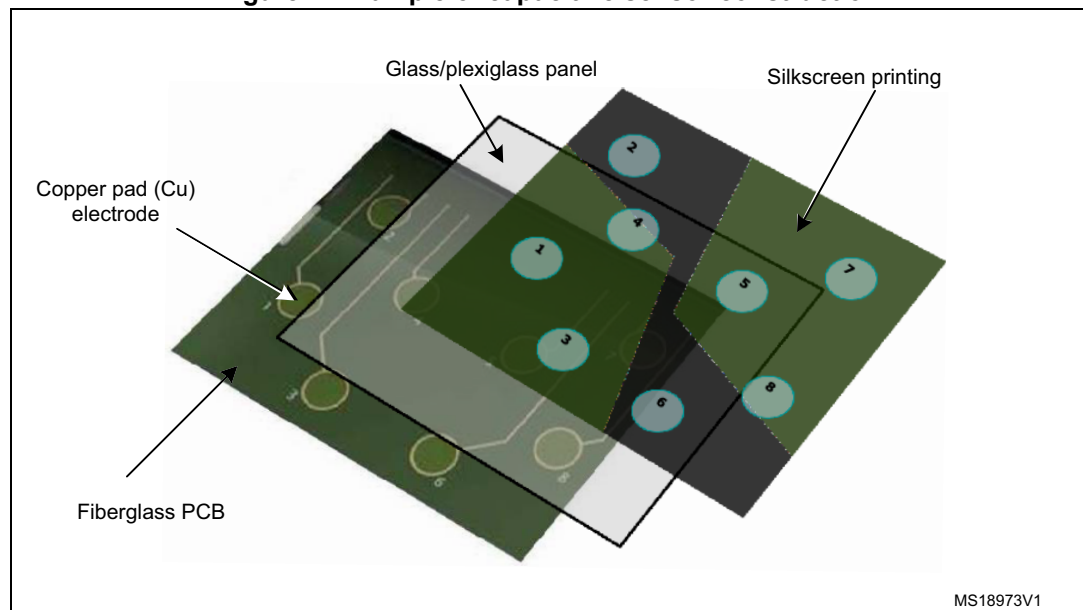
2 Main capacitive sensing guidelines

2.1 Overview

A surface capacitive sensor is generally made up of the following different layers:

- a fiberglass PCB
- a set of electrodes made of a copper pad
- a panel made of glass, Plexiglas, or any non-conductive material
- a silk screen printing

Figure 2. Example of capacitive sensor construction



2.2 Construction

2.2.1 Substrates

The substrate is the base material carrying the electrodes.

A substrate can be chosen among any non-conductive material, in practice, PCB materials (e.g. FR4, CEM-1), acrylics like polyethylene terephthalate (PET), or polycarbonate can be used. Glass is also an excellent material for this purpose.

In many cases, the substrate which is used in electronic application works also well for capacitive sensing. Special care is required to avoid materials which can retain water contained in the atmosphere (e.g. hygroscopic material such as paper based). Unfortunately, this would modify ϵ_R (relative permittivity) with environmental conditions.

It is not recommended to directly set the substrate against the front panel without gluing it by pressure or by bonding. Some moisture or air bubbles may appear between them and cause a change on the sensitivity. Indeed, if the substrate and the panel are closely linked together, it avoids a varying sensitivity loss which is hard to predict (when the air bubbles

are greater than 2 mm diameter). Hence, the way used is to strongly glue them all mechanically or with a suitable bonding material.

It is possible to construct sensors that do not rely on a substrate. These are described in this document under separate sections ([Section 2.2.7](#), [Section 3.5.3](#) and [Section 3.5.4](#)).

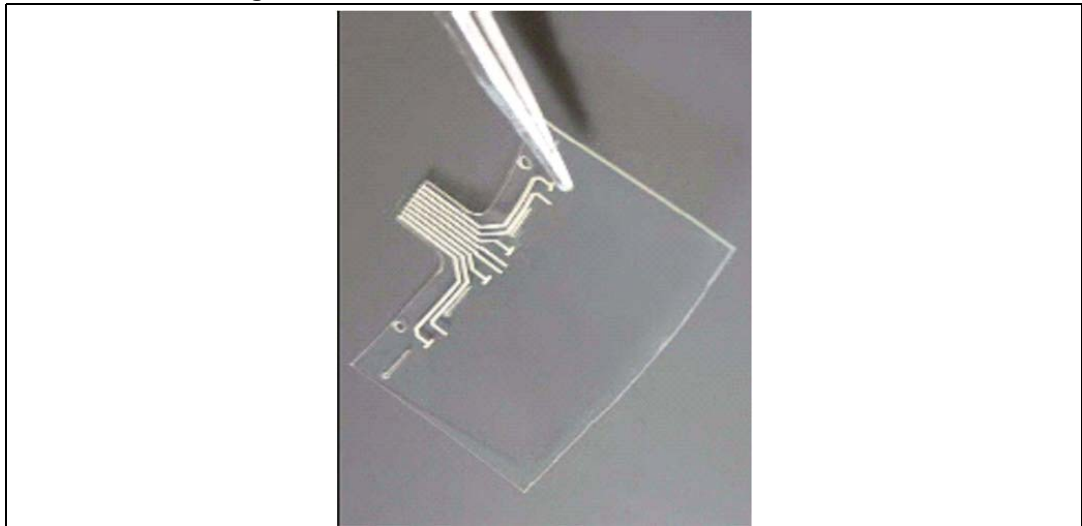
2.2.2 Electrode and interconnection materials

Generally, an electrode is made with the following materials: copper, carbon, silver ink, Orgacon™ or Indium Tin Oxide (ITO).

The resistance to electric current of a material is measured in ohm-meters (Ωm). The lower this degree of resistivity the better, as well as a good RC time constant. That is why interconnections are made with low Ωm material. A printed silver track at 15.9 $\text{n}\Omega\text{m}$ that is 100 mm long, 0.5 mm wide and 0.1 mm thick (so the area is 0.05 mm^2) has a resistance of 32 $\mu\Omega$.

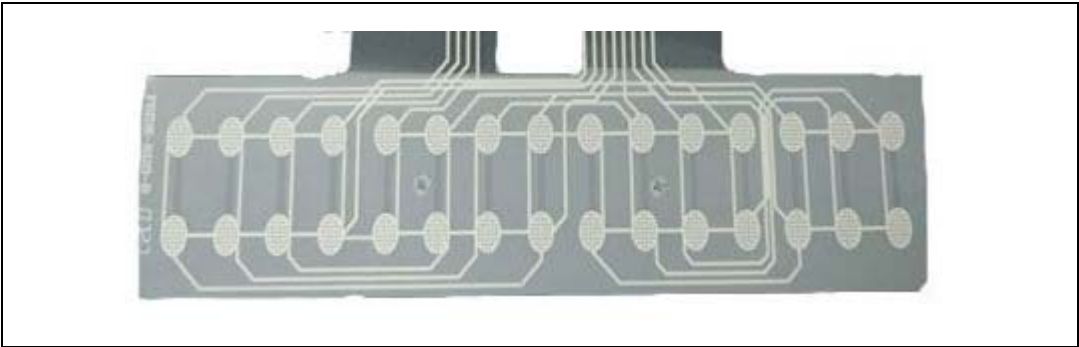
About metal deposition, another well-known approach is to consider the Ω/\square ^(a) of a material. For instance, you can compare silver and ITO (which is about 10 times greater) and deduce which material is well suited for the connections.

Figure 3. Clear ITO on PET with silver connections



a. Pronounced "Ohms per square" and also called sheet resistance; if you know this constant (given by the manufacturer) and how many squares are put in series, you can deduce the overall resistance of the line.

Figure 4. Silver printing on PET

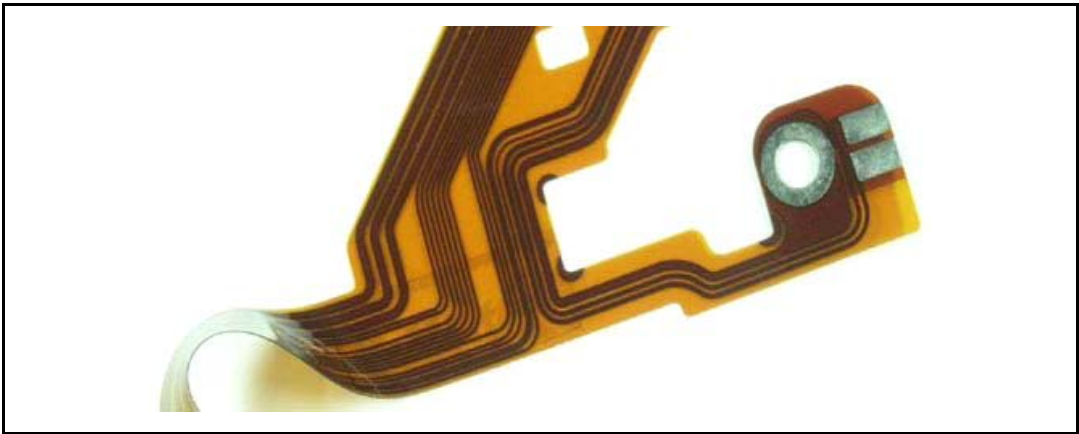


More and more applications need a flex PCB or FFC/FPC^(a) to interconnect circuitry; it is suitable, provided that the overall application is mechanically stable. Furthermore, the FPC tracks are part of the touch sensor. So if the flex moves a little bit, even a few micrometers, the capacitance to its surroundings definitely changes and may be significant, causing false touch detections or drops in sensitivity. Putting the flex in close proximity to a metal chassis or other signals, or on top of noisy circuitry, can cause problems as well (loss of sensitivity or spurious detection).

Table 2. Potential application problems with flex PCB placement

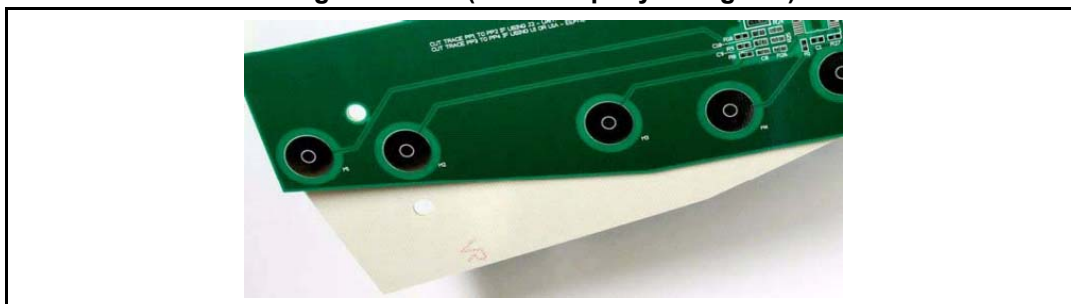
When the flex PCB is in close proximity to...	...the following can occur.
...the ground or to a metal chassis connected to the ground.	...the sensitivity is reduced.
... a floating metal object or to a floating metal chassis	... the object or the chassis conducts the touch to the electrode
... a source of noise	... the acquisition is strongly perturbed and so the touchkey becomes non-usable

Figure 5. Flexible PCB (FPC)



a. FFC = Flat flexible conductor, FPC = Flexible printed circuit

Figure 6. FR4 (2-sided epoxy-fiberglass)



2.2.3 Panel materials

You can choose the panel material which best suits your application. This panel material **must not** be conductive. The material characteristics impact the sensor performance, particularly the sensitivity.

Dielectric constant

The panel is the main item of the capacitor dielectric between the finger and the electrode. Its dielectric constant (ϵ_R) differentiates a material when it is placed in an electric field. The propagation of the electric field inside the material is given by this parameter. The higher the dielectric constant, the better the propagation.

Glass has a higher ϵ_R than most plastics (see [Table 3](#)). Higher numbers mean that the fields propagate through more effectively. Thus a 5 mm panel with an ϵ_R of 8 performs similarly in sensitivity to a 2.5 mm panel with a relative epsilon of 4, all other factors being equal.

A plastic panel up to 10 mm thick is quite usable, depending on touchkey spacing and size. The circuit sensitivity needs to be adjusted during development to compensate for panel thickness, dielectric constant and electrode size.

The thicker a given material is, the worse the SNR. For this reason, it is always better to try and reduce the thickness of the front panel material. Materials with high relative dielectric constants are also preferable for front panels as they help to increase SNR.

Table 3. Dielectric constants of common materials used in a panel construction

Material	ϵ_R
Air	1.00059
Glass	4 to 10
Sapphire glass	9 to 11
Mica	4 to 8
Nylon	3
Plexiglass	3.4
Polyethylene	2.2
Polystyrene	2.56
Polyethylene terephthalate (PET)	3.7
FR4 (fiberglass + epoxy)	4.2

Table 3. Dielectric constants of common materials used in a panel construction

Material	ϵ_R
PMMA (Poly methyl methacrylate)	2.6 to 4
Typical PSA	2.0 - 3.0 (approx.)

Sensitivity

A useful parameter to consider with panel material and thickness (T) is the electric field equivalent vacuum thickness T_V .

Equation 2

$$T_V = \frac{t}{\epsilon_R}$$

where t is the thickness of the dielectric.

T_V is the thickness of vacuum with an electric field conduction equivalent to that of the material. The smaller it is, the easier the field can reach through. Panels with the same T_V make touchkeys with identical sensitivity. This works for both directions of course and may be used to evaluate the touch sensitivity from the back side of the application.

For a panel built from a stack of different materials, it is possible to add the vacuum equivalent thickness of each layer:

Equation 3

$$T_{V(STACK)} = \sum T_{V(layers)}$$

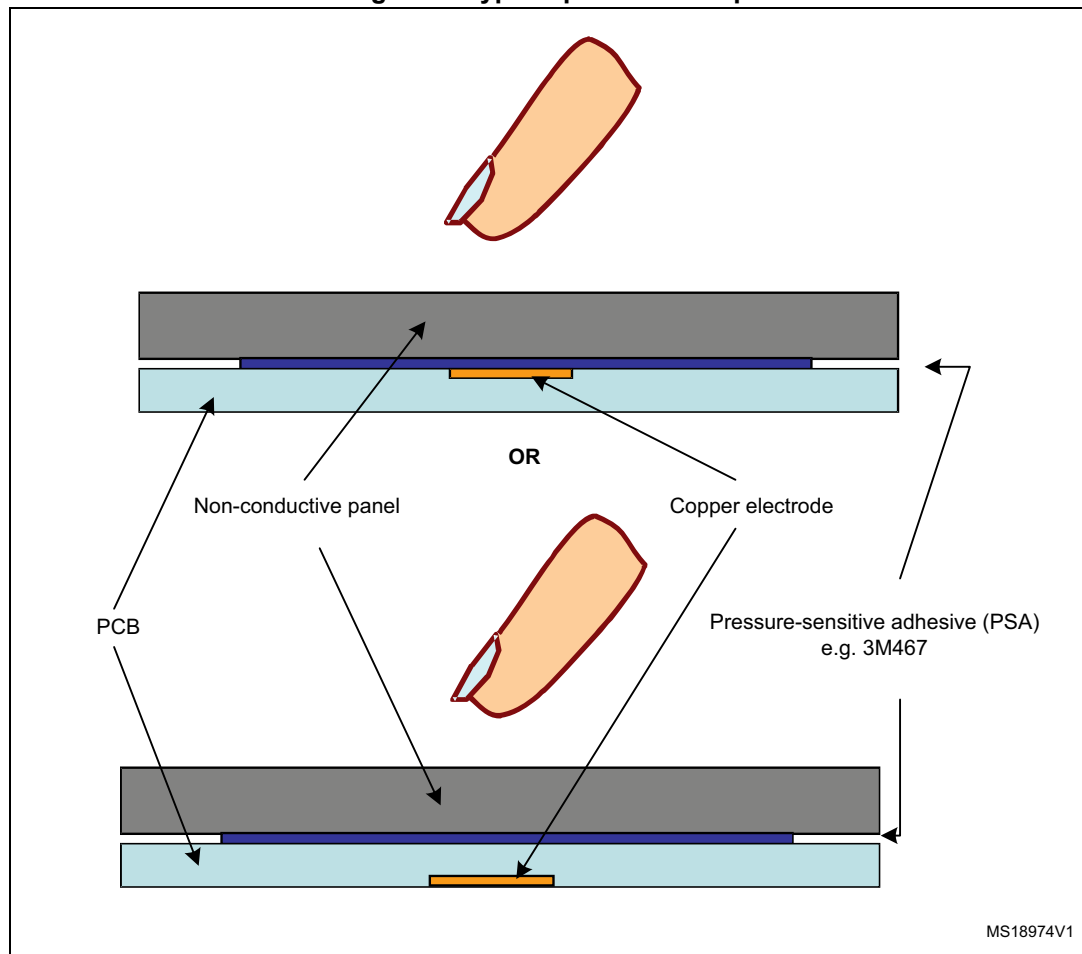
Each material has an influence on the sensitivity. So the equation can be used when, for example, the electrodes are on the bottom surface of the PCB substrate, then the thickness and ϵ_R of the substrate are also factors of the global sensitivity.

2.2.4 Mechanical construction and PCB to panel bonding

In order to ensure stable touch detection, the PCB must always be at the same place on the panel. The slightest variation, even as small as 100 microns, may lead to differences in the signal which can be detected. This must be avoided to ensure the integrity of the touch detection. The panel and other elements of the device must not be moved, or only as little as possible, by the user's finger. To avoid this kind of problem, glue, compression, co-convex surfaces can be used to mechanically stabilize the PCB and the panel very close together.

In the list of the different ways to achieve this, we can put: heat staking plastic posts, screws, ultrasonic welding, spring clips, non-conductive foam rubber pressing from behind, etc.

Figure 7. Typical panel stack-up



Normal construction is to glue a sensor to a front panel with pressure sensitive adhesive (PSA). 3M467 or 468 PSAs work very well.

2.2.5 Metal chassis

A metal chassis behind a touch sensor is a good path to the ground and tends to reduce the sensitivity of the touch response in case there is a significant area of overlap. Such a metallic surface must never be electrically floating as it makes the whole product unstable in terms of touch detection. This is also applicable for any conductive decorative feature close to the sensor.

Metal chassis and decorative items must be grounded or connected to the driven shield (see [Section 3.5.2: Driven shield](#)) if it is implemented.

Metallic paints can be an issue if they contain conductive particles. Low particle density paint is recommended.

2.2.6 Air gap

Due to its dielectric constant, air can be used as an isolator. An air gap reduces the touch sensitivity when it is in the touch side stack. However, in some conditions, air can be useful to reduce the ground loading in the non-touch side stack. Such ground loading can be due

to the metal chassis or an LCD. For instance, when designing a touch-screen solution, an air gap of 0.5 mm to 1 mm between the LCD and the touch sensor is recommended. Air gaps also help to reduce the sensitivity of the back side of a portable device.

2.2.7 Transfer of an electrode from PCB to the front panel

It is possible to use a conducting cylinder or a compressed spring to achieve a transfer of an electrode from a PCB to the front panel. Please refer to [Section 3.5.3](#) or [Section 3.5.4](#) for further information.

2.3 Placing of LEDs close to sensors

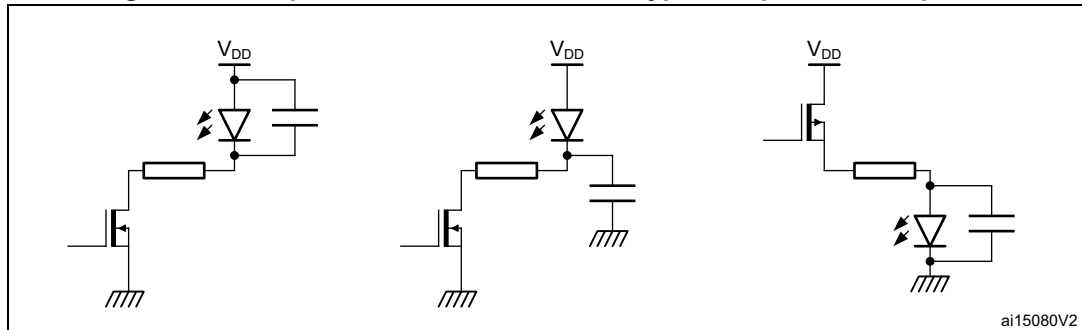
Light-emitting diodes (LEDs) are very often implemented near capacitive sensor buttons on application boards. The LEDs are very useful for showing that the button has been correctly touched. When designing application boards with LEDs, the following considerations must be taken into account:

- LEDs change capacitance when switched on and off
- LED driver tracks can change impedance when switched on and off
- LED load current can affect the power rail

Both sides of the LEDs must always follow the low impedance path to ground (or power). Otherwise, the LEDs should be bypassed by a capacitor to suppress the high impedance (typically 10 nF).

The examples of bypass capacitors for the LEDs using a driver ([Figure 8](#)) can also be applied to transistors.

Figure 8. Examples of cases where a LED bypass capacitor is required



2.4 TC versus FT I/O

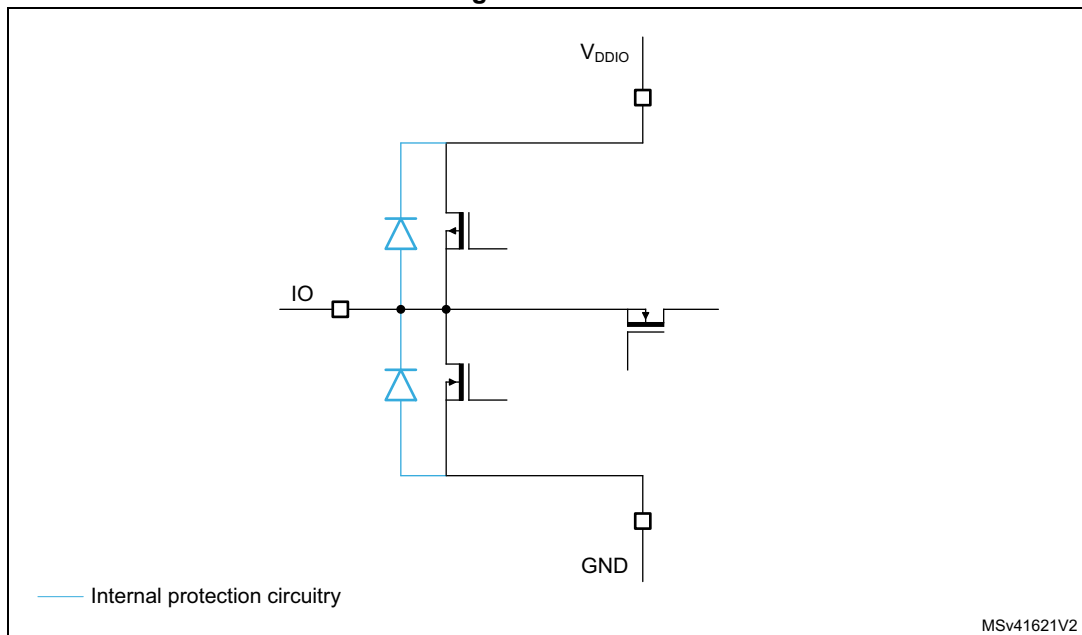
TC and FT I/O structures are slightly different:

- FT: 5 V tolerant I/O
- TC: 3.6 V compliant I/O.

On a TC I/O, there is an internal clamping diode connected to V_{DD} , see [Figure 9](#).

Thanks to this diode, when an EMC stress occurs, the level of the noise is clamped to V_{DD} . As a consequence, channels implemented on TC I/O show a better noise immunity.

Figure 9. TC I/O

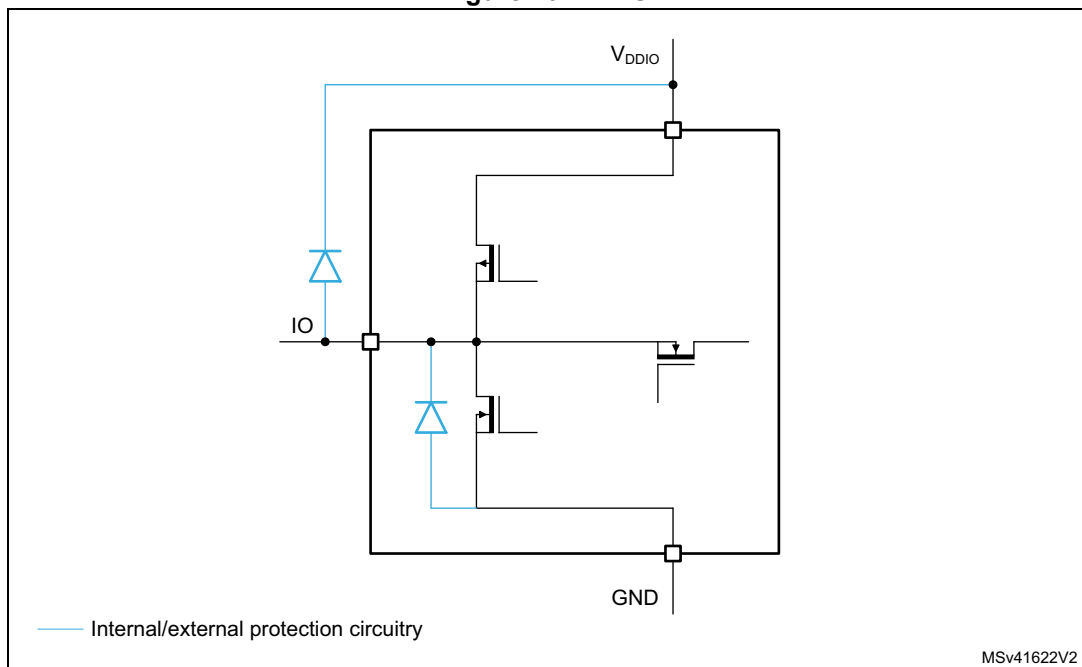


With FT I/O, it is possible to reach the same noise immunity level than with TC I/O, by adding an external Schottky diode, see [Figure 10](#). A Schottky diode with a low capacitance (< 5 pF) must be selected such that the reduction of the channel sensitivity remains insignificant.

Recommended external STMicroelectronics Schottky diode:

- BAR 18 / BAS70-04 06 ($C_{max} = 2$ pF).

Figure 10. FT I/O



2.5 Power supply

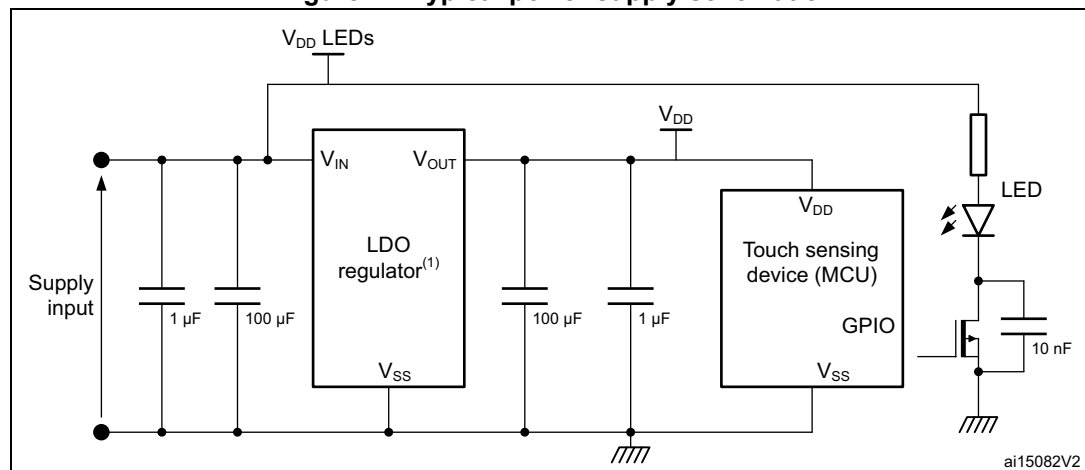
For devices without a touch sensing dedicated regulator, it is strongly recommended to use an external voltage regulator to power the device only.

The voltage regulator must be chosen to provide a stable voltage without any ripple. The actual precision of the voltage is not important, but the noise rejection feature is critical. This voltage is used to drive C_X and is also used as a reference when measuring the sampling capacitor (C_S). Any variation of this voltage may induce measurement variations which could generate a false touch or a missed touch. For instance, a ± 10 mV peak to peak variation on V_{DD} limits the resolution of linear sensor or rotary sensor to 4 or 5 bits.

The voltage regulator should be placed as far as possible from the sensors and their tracks.

The voltage regulator also acts as a filter against noise coming from the power supply. So, it is recommended to power any switching components, such as LEDs, directly from V_{DD} and not from the regulated voltage (see [Figure 11](#)).

Figure 11. Typical power supply schematic



1. Typical voltage regulator LD2980 can be used.

3 Surface sensor design

3.1 Touchkey sensor

A touchkey can be either touched or untouched by the user. So the information that is managed by the microcontroller is a binary one (e.g. '0' for untouched and '1' for touched).

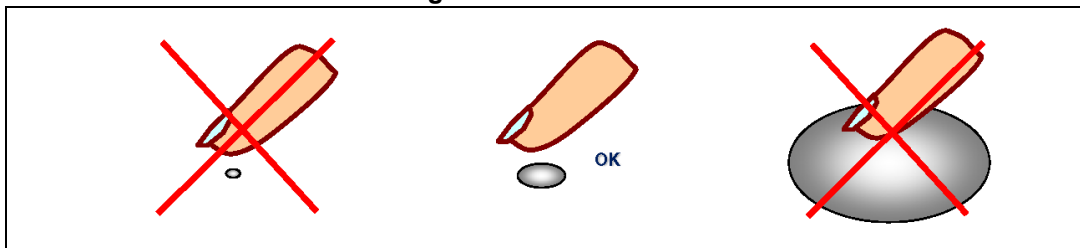
The sensor can be any shape, however it is recommended to use round or oval as these shapes are the simplest. The libraries and hardware cells automatically compensate for capacitance differences, but the acquisition time and processing parameters can be optimized if the electrodes have similar capacitance. For this reason, it is recommended to use the same shape for all electrodes. The touchkeys can be customized by the drawing on the panel.

When designing touchkey sensors, two parameters must be taken into account:

- the object size to be detected
- the panel thickness

Regarding object size (see [Figure 12](#)), it is recommended to design a sensor in the same range as the object to be detected. In most cases, it is a finger.

Figure 12. Sensor size



Regarding panel thickness, the touchkey must be at least four times as wide as the panel is thick. For example, a panel which is 1.5 mm thick and has no immediately adjacent ground layer, must have a touchkey sensor which is at least 6 mm in diameter if the touchkey sensor is round, or have a 6 mm side if the touchkey sensor is square (see [Figure 13](#)). There are sensitivity issues if dimensions lower than these values are used.

Figure 13. Recommended electrode size



As shown in [Equation 4](#), a capacitor is used to detect the finger touch. The capacitor is proportional to the size of the electrode. Increasing the electrode area allows the capacitor to be maximized, but increasing the electrode size above the size of a finger touch only increases the parasitic capacitance and not the finger touch capacitance, resulting in lower relative sensitivity. Refer to [Section 3.5.4: PCB and layout](#). There is also a problem of relative sensitivity: when the electrode size is increased, C_T stops increasing while C_X keeps growing. This is because the parasitic capacitance is directly proportional to the electrode area.

Equation 4

$$C_T = \frac{\epsilon_R \epsilon_0 A}{d}$$

where:

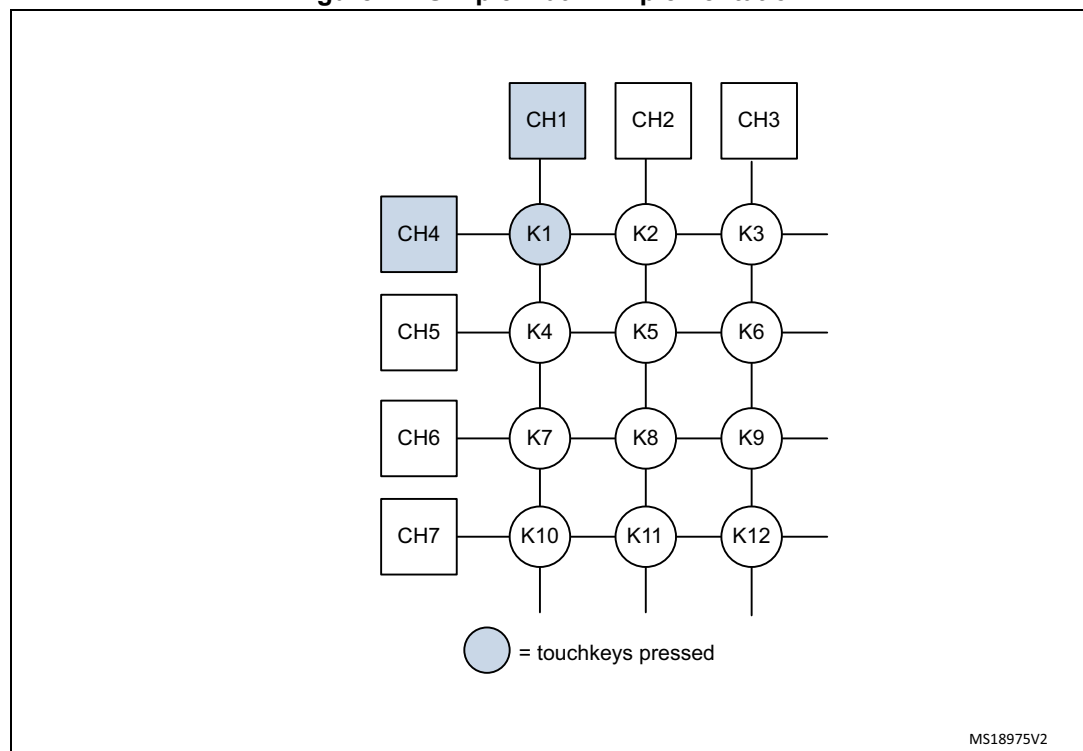
- C_T is the touchkey capacitance.
- A is the area with regard to the electrode and the conductive object.
- d is the distance between the electrode and the conductive object (usually the panel thickness).
- ϵ_R is the dielectric relative permittivity.
- ϵ_0 is the vacuum permittivity.

3.2 Touchkey matrix sensor

To extend the number of touchkeys, it is possible to implement the touchkey using a matrix arrangement.

For further information, please refer to the application note *Guidelines to increase the number of touch sensing touchkeys* (AN3236).

Figure 14. Simple matrix implementation



Hardware recommendations:

- Touching one touchkey may induce sufficient capacitance change on other channels
- Special care must be taken to avoid
 - Imbalanced electrodes
 - Columns and lines electrodes tracks too close in the user touchable area

3.3 Linear sensor

A linear sensor is a set of contiguous capacitive electrodes connected to the device and placed in a single axis line. The number of electrodes is dependant of the desired size and resolution of the sensor.

The electrodes can be arranged in three different ways:

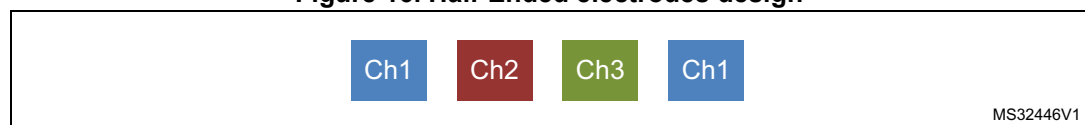
- **Mono electrodes** design: each channel is associated to only one electrode (see [Figure 15](#)).

Figure 15. Mono electrodes design



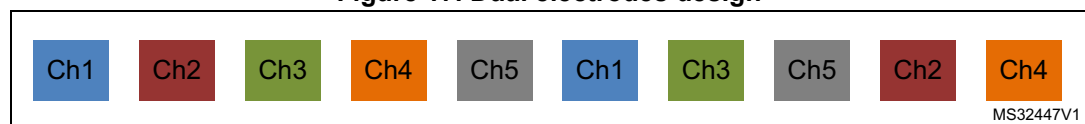
- **Half-ended electrodes** design: the first and the last electrodes are connected to the same channel (usually the first one) and their width is half the width of the other electrodes. This is to ensure that all the electrodes capacitance are identical (see [Figure 16](#)).

Figure 16. Half-Ended electrodes design



- **Dual electrodes** design: all the electrodes are duplicated and interlaced together (see [Figure 17](#)).

Figure 17. Dual electrodes design



The half-ended and dual electrodes designs are used to increased the touch area of the sensor.

On top of that, there are two manners to design the electrodes pattern on the PCB:

- Normal pattern (see [Figure 18](#)).
- Interlaced pattern (see [Figure 19](#)).

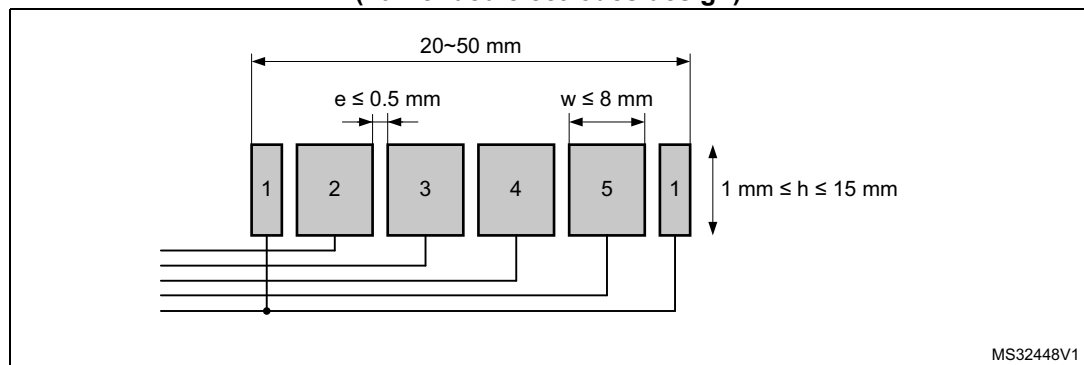
These two patterns are described in more details below.

Note: *For optimum performance of a linear or rotary sensor, all channels of such a sensor must be acquired simultaneously, therefore selected I/Os must belong to different analog I/O groups. Refer to the product datasheet for more information regarding I/O groups and available capacitive sensing GPIOs.*

3.3.1 Normal patterned linear sensor

With a normal patterned half-ended linear sensor (see [Figure 18](#)), the linearity is limited due to the ratio square width versus finger touch area. To improve the linearity, to get a smoother transition between items and to increase the resolution, it is recommended to use an interlaced patterned electrodes design with crisscross teeth as shown in [Figure 19](#).

Figure 18. Normal patterned linear sensor with 5 channels / 6 electrodes (half-ended electrodes design)



1. Legend: e is the gap between two sensor electrodes, h is the height of the sensor electrode, and w is the width of the sensor electrode.

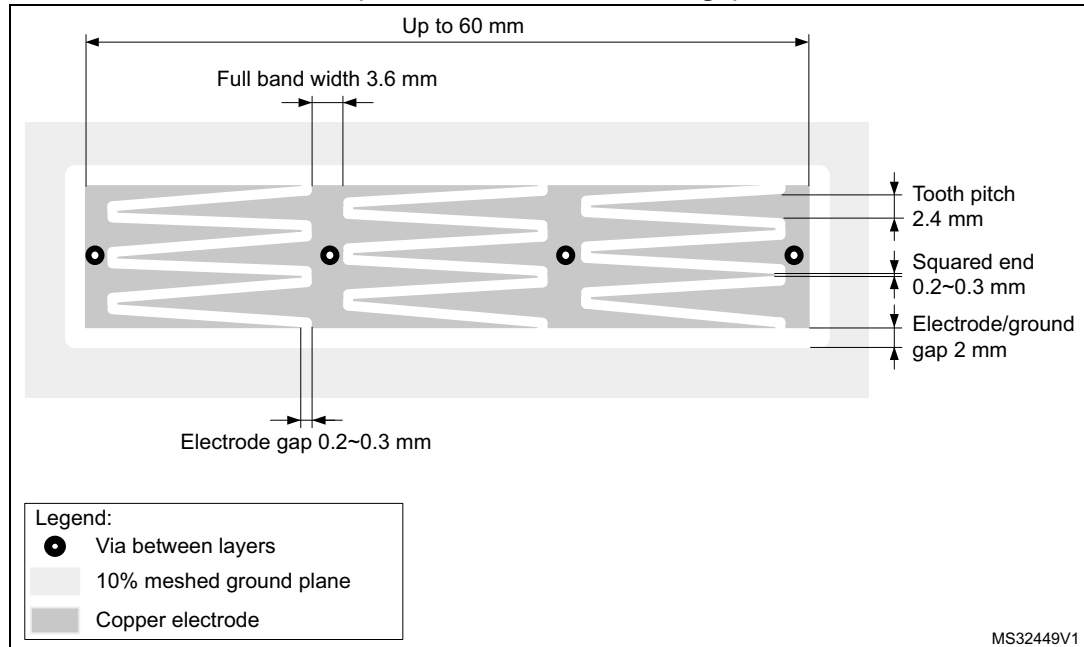
The size of the square electrode and gap between electrodes are valid irrespective of the number of electrodes.

To get larger linear sensors, the number of electrodes can be increased to eight.

3.3.2 Interlaced patterned linear sensor

When using the charge transfer acquisition principle, it is possible to use only three channels thanks to the higher resolution achieved.

Figure 19. Interlaced linear touch sensor with 3 channels / 4 electrodes (half-ended electrodes design)



1. The teeth of the interlaced linear touch sensor must be perfectly regular.

3.4 Rotary sensor

A rotary sensor is a set of contiguous capacitive electrodes connected to the device and placed in a circular way. The number of electrodes depends on the size and the resolution of the sensor.

The electrodes can be arranged in two ways:

- mono electrode design (same as the half-ended electrode design)
- dual electrode design.

Like for the linear sensor, there are two options for designing the electrode pattern on the PCB:

- normal pattern
- interlaced pattern.

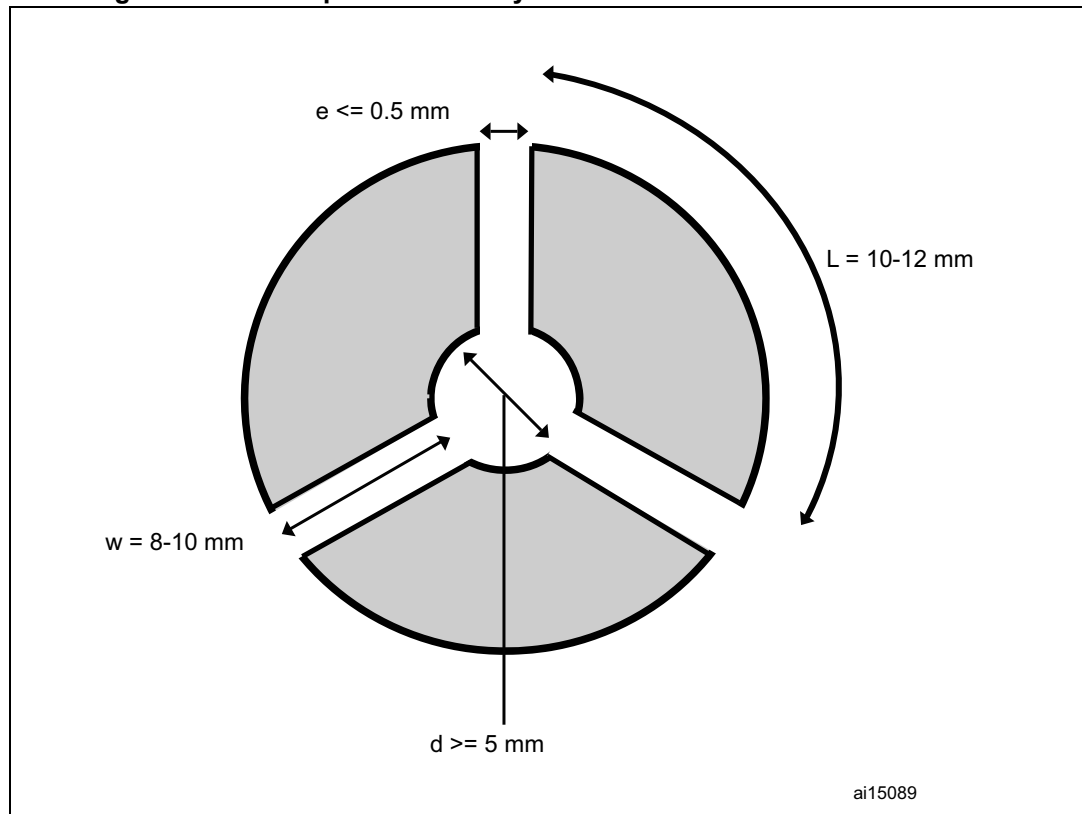
These two patterns are described in more details below.

A rotary sensor can also have a touchkey placed in the center.

Note: *For optimum performance of a linear or rotary sensor, all channels of such a sensor must be acquired simultaneously, therefore selected I/Os must belong to different analog I/O groups. Refer to the product datasheet for more information regarding I/O groups and available capacitive sensing GPIOs.*

3.4.1 Normal patterned rotary sensor

Figure 20. Normal patterned rotary sensor with 3 channels / 3 electrodes



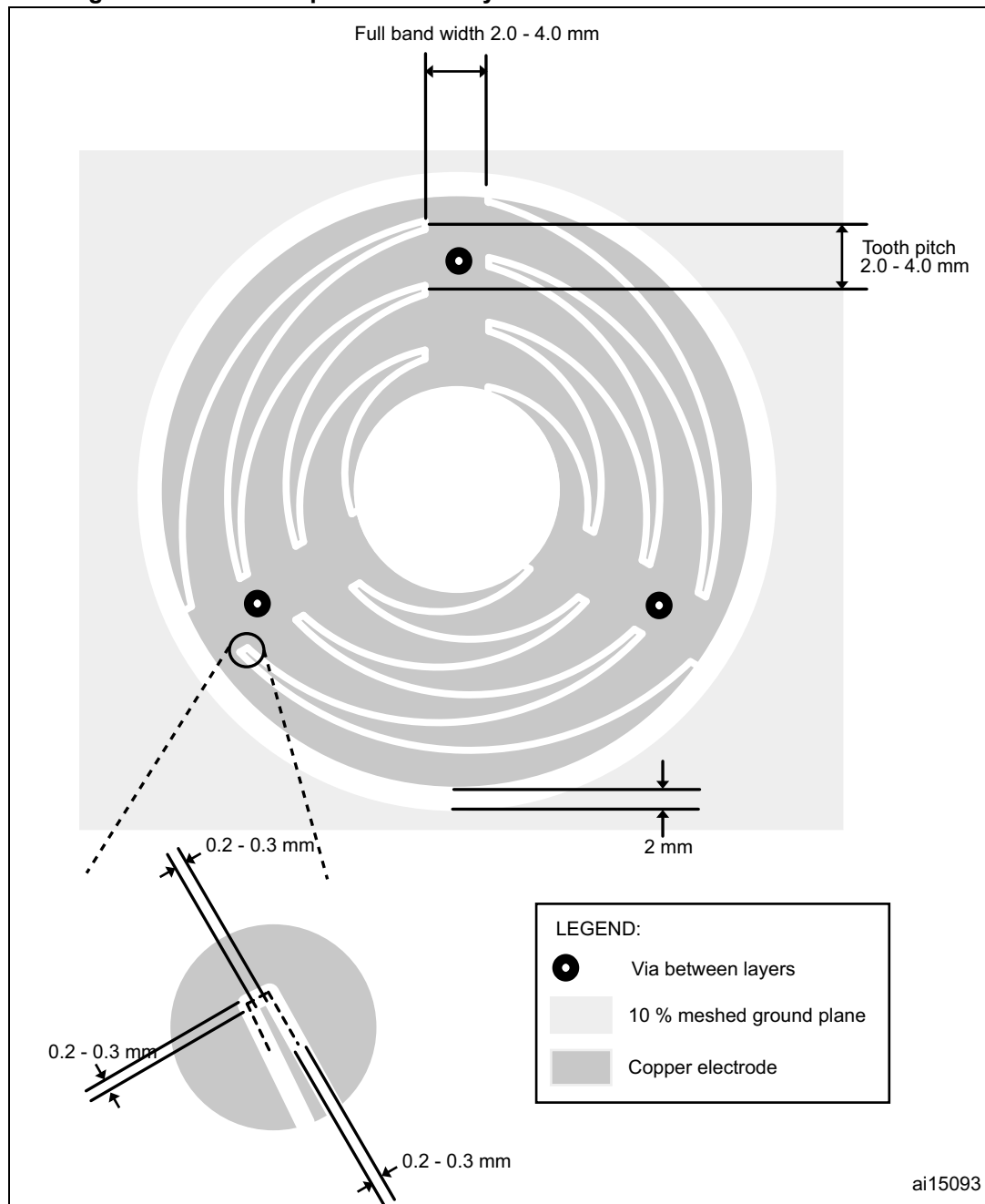
1. Legend: d is the diameter of the center, e is the gap between two sensor electrodes, w is the width of the sensor electrode, L is the length of the external perimeter of the sensor electrode.

The dimensions d , e , w , and L of the three-electrode scheme above can also be applied for five and eight electrodes, thus giving a bigger rotor.

3.4.2 Interlaced patterned rotary sensors

Like for the linear sensor, the size of the rotary sensor can be increased by using the interlaced pattern design.

This allows a smoother transition and a higher sensitivity. To cover a large range of sizes, more teeth are added inside the rotary touch sensor rather than increasing the size of an individual tooth.

Figure 21. Interlaced patterned rotary sensor with 3 channels / 3 electrodes

3.4.3 Rotary sensor with central touchkey

It is possible to locate a touchkey in the center of a rotary sensor. This touchkey has a lower sensitivity compared to other single touchkeys. To reduce the loss of sensitivity induced by the center touchkey on the rotary sensor, it is recommended to place the center touchkey and rotary sensor electrodes on the same acquisition bank. The pattern of the central touchkey must be as symmetrical as possible so that the loading effect on the rotary sensor is also symmetrical.

3.5 Specific recommendations

3.5.1 LEDs and sensors

In some cases, a hole needs to be inserted in the sensor electrode to create a back-lighting touchkey (see [Figure 22](#), [Figure 23](#) and [Figure 24](#)). This is a very common solution which does not involve a sensitivity dip in the middle of the sensor electrode as the electric field tends to close over above the hole. As the sensor area decreases, there is a corresponding decrease in sensitivity.

Figure 22. Back-lighting touchkey

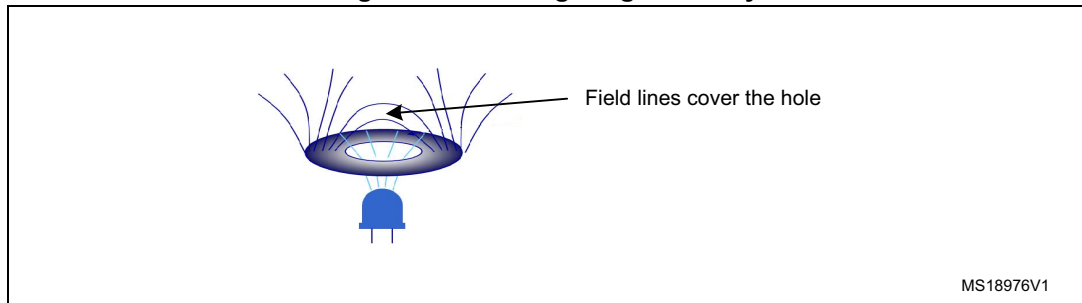


Figure 23. PCB 3D top view

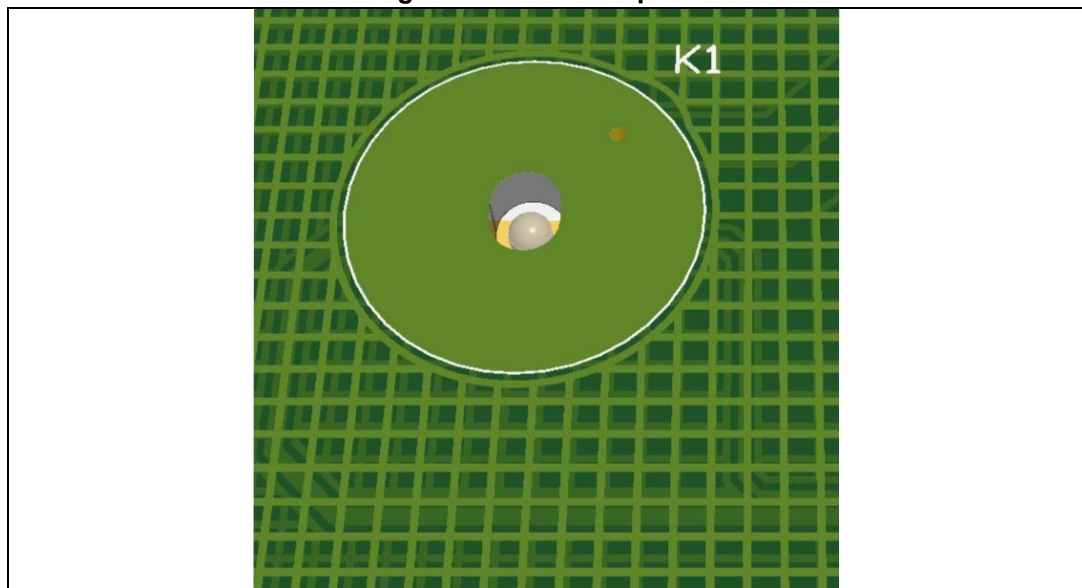
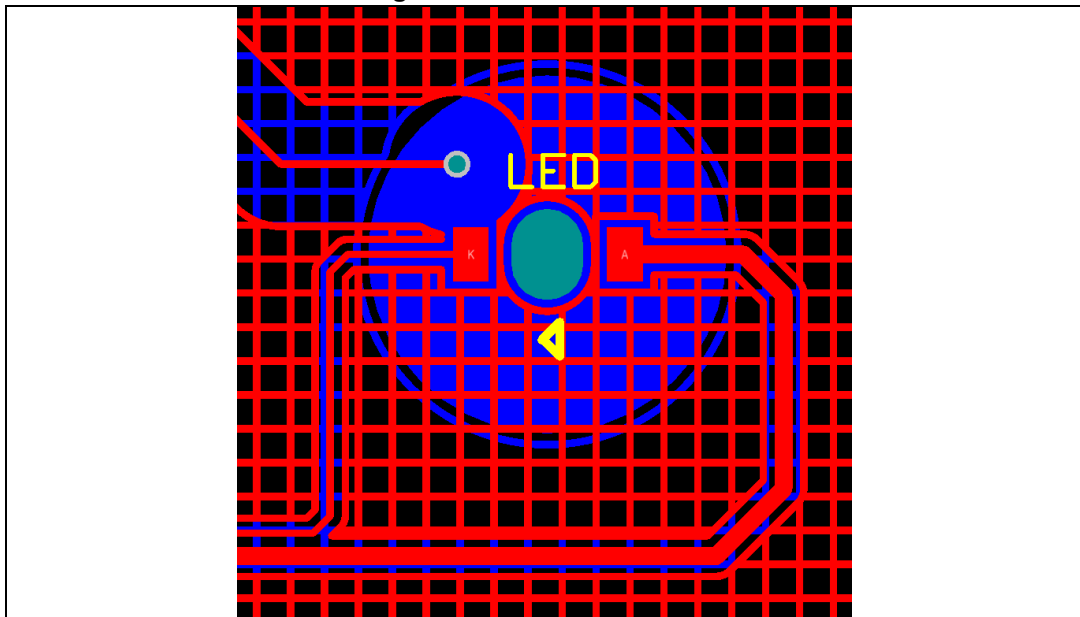


Figure 24. PCB bottom view



3.5.2 Driven shield

The principle of a driven shield is to drive the shield plane with the same signal as the electrode.

There are several advantages to using a driven shield instead of a grounded shield:

- The parasitic capacitance between the electrode and the shield no longer needs to be charged. This cancels the effect on the sensitivity.
- A driven shield is useful for certain applications where shielding may be required to:
 - Protect the touch electrodes from a noise source
 - Remove touch sensitivity from the cable or track between the electrode and the sensing MCU.
 - Increase system stability and performance when a moving metal part is close to the electrode.

If the design is done by using the charge transfer acquisition principle to have an efficient shield, its waveform must be similar to that of the touchkey. Here are some guidelines for achieving this (refer to [Figure 25](#) and [Figure 26](#)):

- The Cs/Cx of the shield should be in the same range as the Cs/Cx of the touchkeys.
- Using $Cs_{shield} = k.Cs_{key}^{(a)}$ usually gives good results.
- The Cs of the shield does not need to be a high grade capacitor. Any type should work.
- The noise/ESD protection resistor may be mandatory on the shield because it may be exposed to ESD. In order not to modify the pulse timings, the Rs_{shield} should be in the range of Rs_{key}/k .

a. $k = (\text{shield area})/(\text{electrode area})$

Figure 25. STM8L1xx driven shield example using the charge-transfer acquisition principle

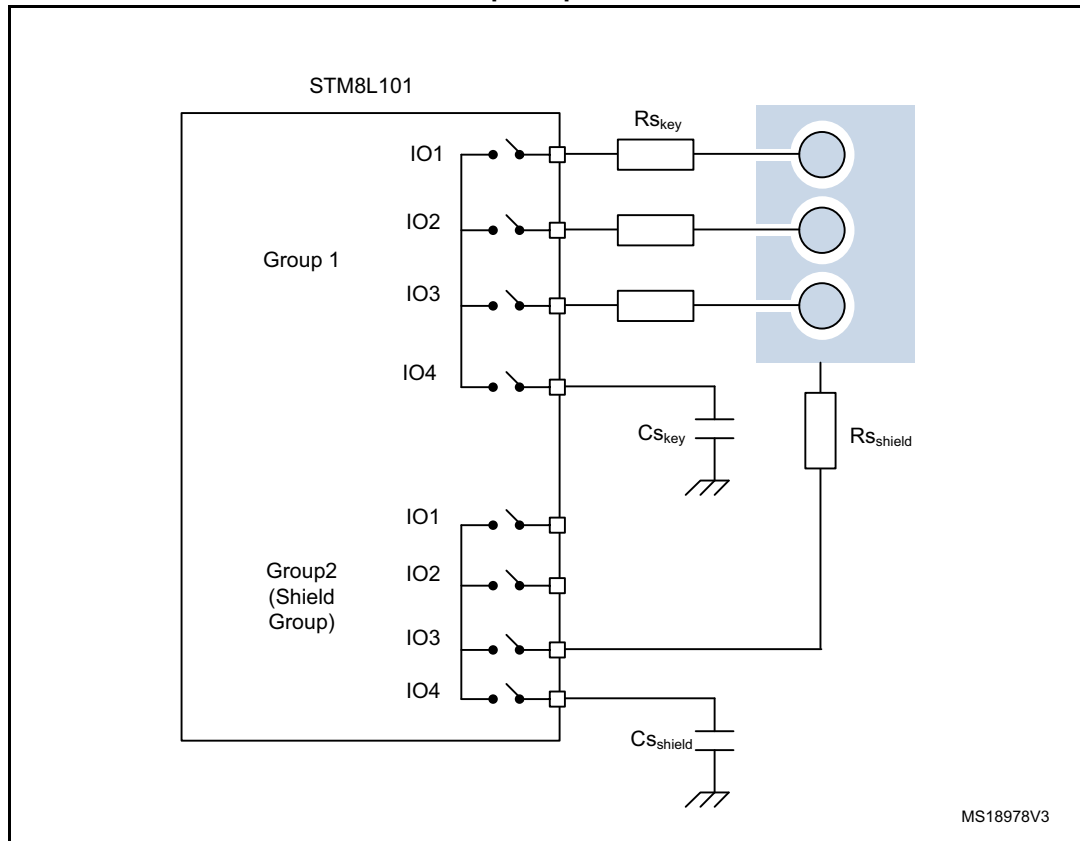
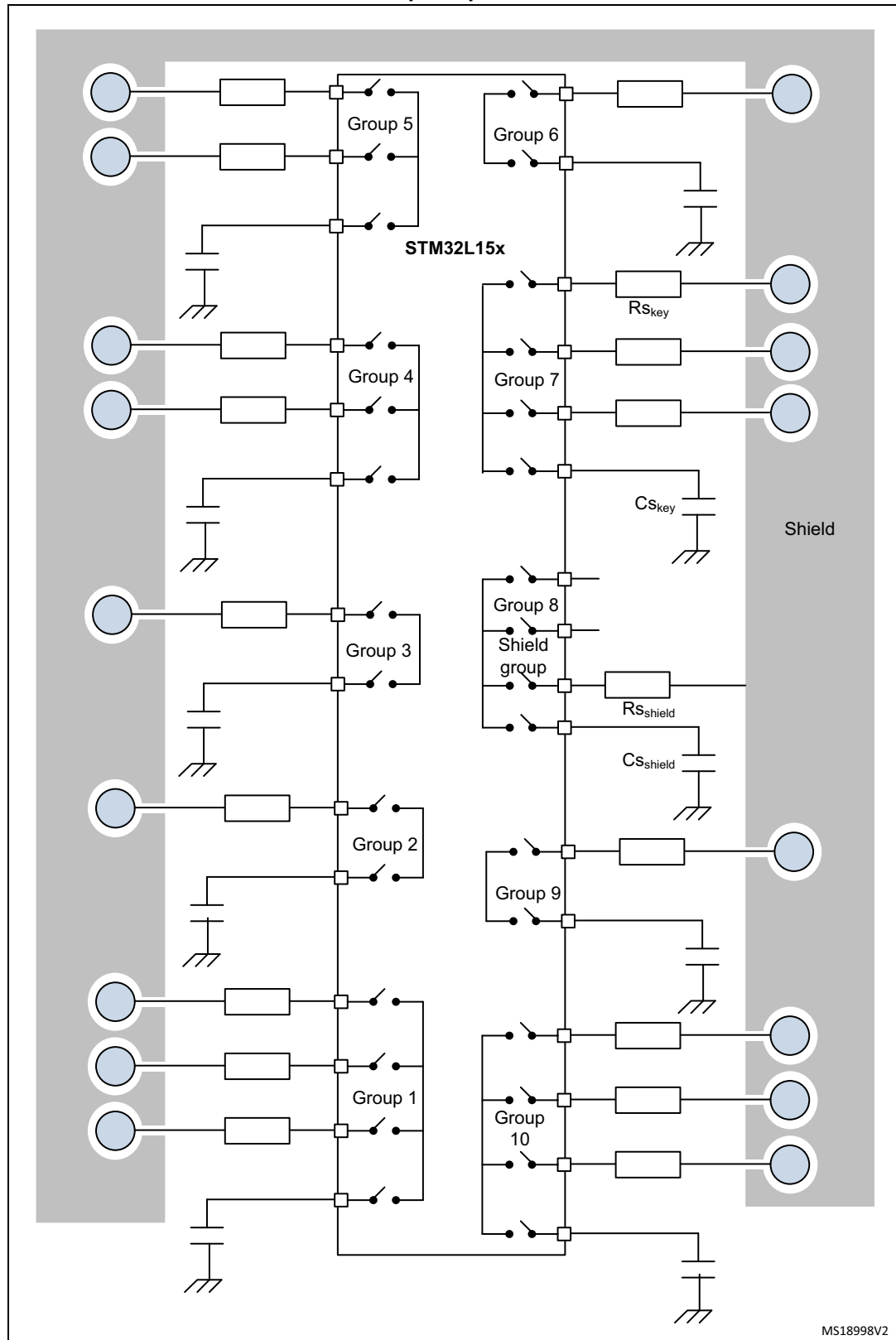


Figure 26. STM32L driven shield example using the charge-transfer acquisition principle



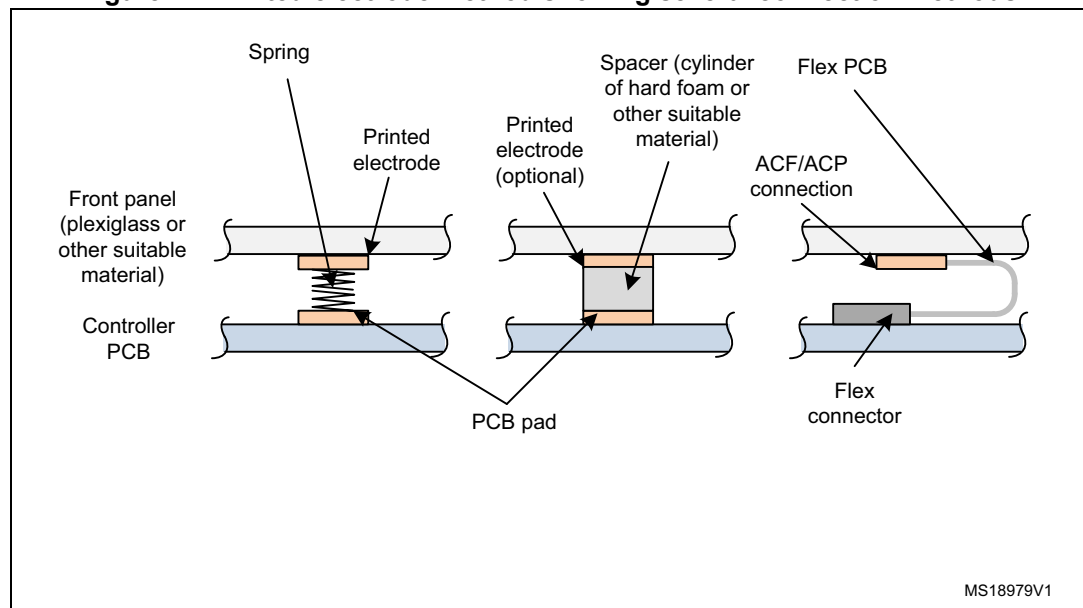
3.5.3 Using electrodes separated from the PCB

It is possible to use surface electrodes which create a sensitive area on the bottom surface of the panel and are not close to the PCB.

One option is to print an electrode array on the inner surface of the front panel. In this case, the electrode shape rules are as described in [Chapter 3.1](#), and the materials are as described in [Chapter 2.2.2](#). The sensors can be connected using spring contacts, conductive foam or rubber, or a flex tail attached using ACF/ACP ^(a)(see [Figure 27](#)).

Remember that, with this technique, the area where the interconnection is made is touch-sensitive too.

Figure 27. Printed electrode method showing several connection methods



a. ACF/ACP = Anisotropic conductive film/Anisotropic conductive paste

Figure 28. Spring and foam picture (both are not compressed)



3.5.4 PCB and layout

Sensor track length and width

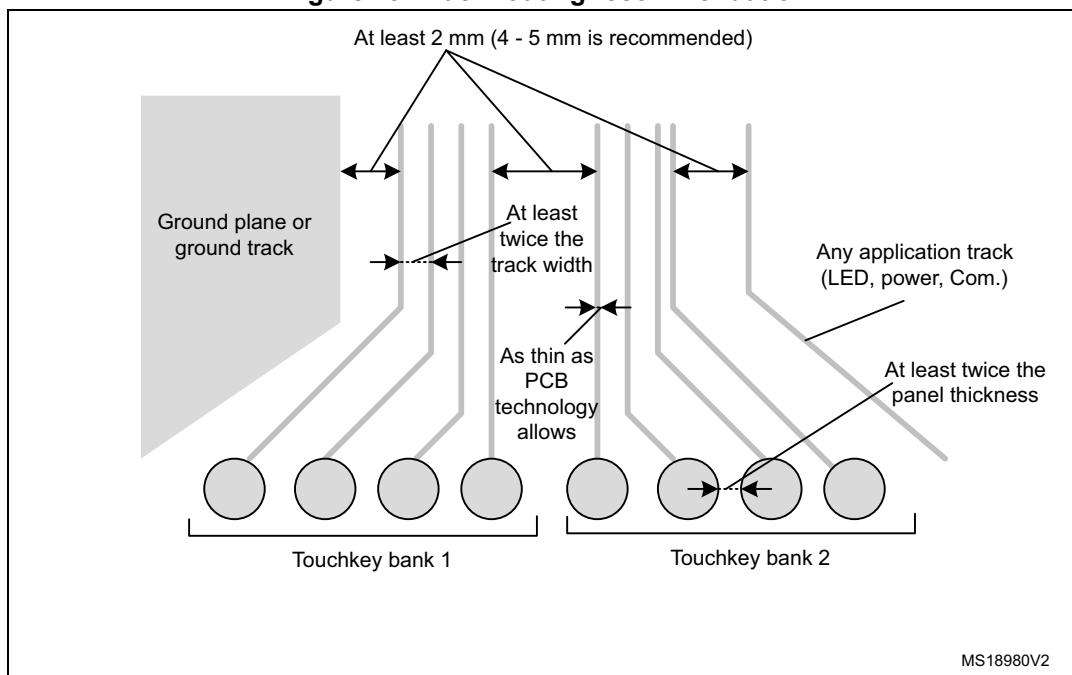
The parasitic capacitance of a track depends on its length and its width. Besides that, a long track can create an antenna effect which may couple noise. So, the main rule to keep in mind is that the shorter and thinner the track is, the smaller the parasitic capacitance.

It is recommended to route the tracks as thin as the PCB technology allows and shorter than 10 cm for standard or flexible PCBs.

Sensor track routing

The main goal, when laying out the PCB, should be to minimize the interactions between elements or, if they cannot be minimized, to make them uniform for all capacitive elements.

Although the touch sensing controller algorithms, used to acquire touchkey, linear sensor and rotary sensor signals, take into account that the capacitance of each array is different, it is good practice to keep things as balanced as possible.

Figure 29. Track routing recommendation

Electrode banks

A set of electrodes that are driven simultaneously during the acquisition is called an acquisition bank.

This set of electrodes and tracks interact less with each other and can be routed closer. Typically, a spacing of twice the track width is sufficient.

For electrodes not belonging to the same bank, coupling must be avoided, a spacing of at least 2 mm is required and 4 to 5 mm is recommended (see [Figure 29](#)).

Electrode spacing

To avoid cross detection on adjacent electrodes, it is recommended to keep a gap of at least twice the panel thickness between electrodes (see [Figure 29](#)).

Interaction with other tracks

To avoid creating coupling with lines driving high frequency signals, it is recommended to cross the sensor tracks perpendicularly with the other tracks. This is especially true for communication lines, where it is forbidden to route them in parallel with the sensor tracks. To avoid such a configuration, the pins of the microcontroller must be selected and grouped by function. When it is possible, all the sensor pins are consecutively distributed on one or several sides of the microcontroller package (the pins are then used as GPIOs like the LED drivers and communication lines).

It is strongly recommended to dedicate the pins to be used as sensors and not to share them with other features. Sharing tracks produces parasitic capacitance due to re-routing of the sensor tracks, and impacts the sensitivity.

3.5.5 Component placement

To reduce the sensor track lengths, it is recommended to place the microcontroller very close to the sensor electrodes. It is also recommended to center the microcontroller among the sensors to balance the parasitic capacitance and to put a ground layer above it.

The ESD protection resistors must also be placed as close as possible to the microcontroller to reduce the track length which could drive ESD disturbance directly to the microcontroller without protection. These ESD resistors must be selected according to the acquisition method recommendations.

3.5.6 Ground considerations

Ground plane

It is recommended to route the sensors and the ground on the same layer while the components and other tracks are routed on the other(s) layer(s).

When a multilayer PCB is used, both sides of the PCB are commonly grounded to improve the immunity to noise. Nevertheless, the ground has an effect on the sensitivity of the sensor. The ground effect is to increase C_X , which reduces the sensitivity as the ratio C_T/C_X decreases. So, to balance between noise immunity and sensitivity, it is recommended to use partial grounding on both sides of the PCB through a 15% mesh on the sensor layer and a 10% copper mesh for the opposite side with the electrodes and tracks.

Ground around sensor

When the ground plane is on the same layer as the sensor, it surrounds the sensors. To avoid increasing C_X , it is recommended to keep a gap between the sensor and the ground.

This gap size must be at least 2 mm (4-5 mm recommended) and must also be respected with any noisy application track or power supply voltage.

There are two different cases:

- distance to GND and power supply voltage, shorter distance is possible, but impacts significantly the touchkey sensitivity
- distance to noisy signal, the detection may completely stop working in case the distance is not respected

Special care must be taken to balance the ground around the sensors. This is particularly true for a rotary or linear sensor (see [Section 3.5.2: Driven shield](#)).

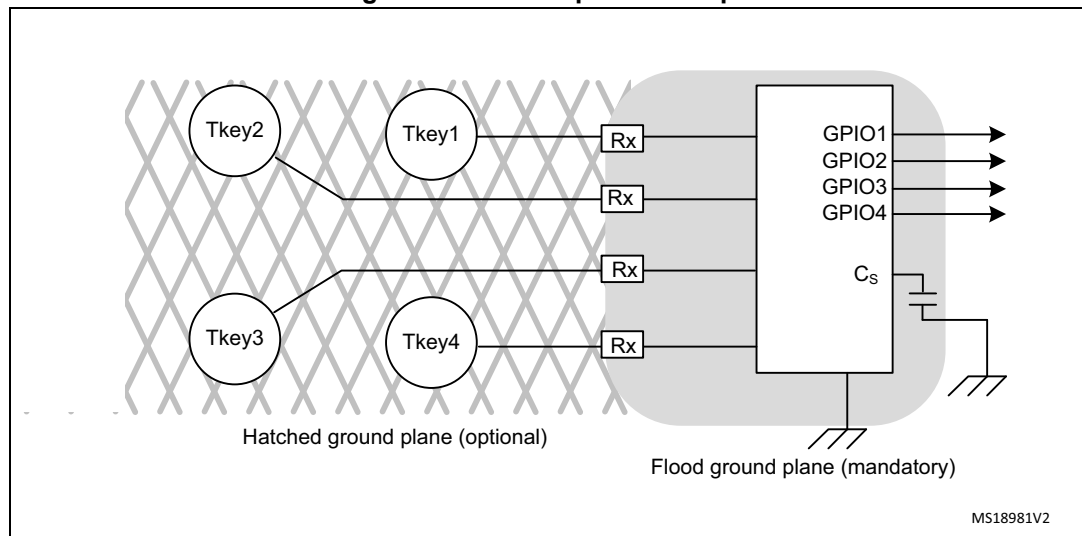
Caution: Floating planes must never be placed close to the sensors.

Ground plane example

A full ground plane is mandatory below the MCU up to serial resistors (see [Figure 30](#)).

- It must cover the tracks between the MCU and the serial resistors
- It must cover the sampling capacitors

Figure 30. Ground plane example

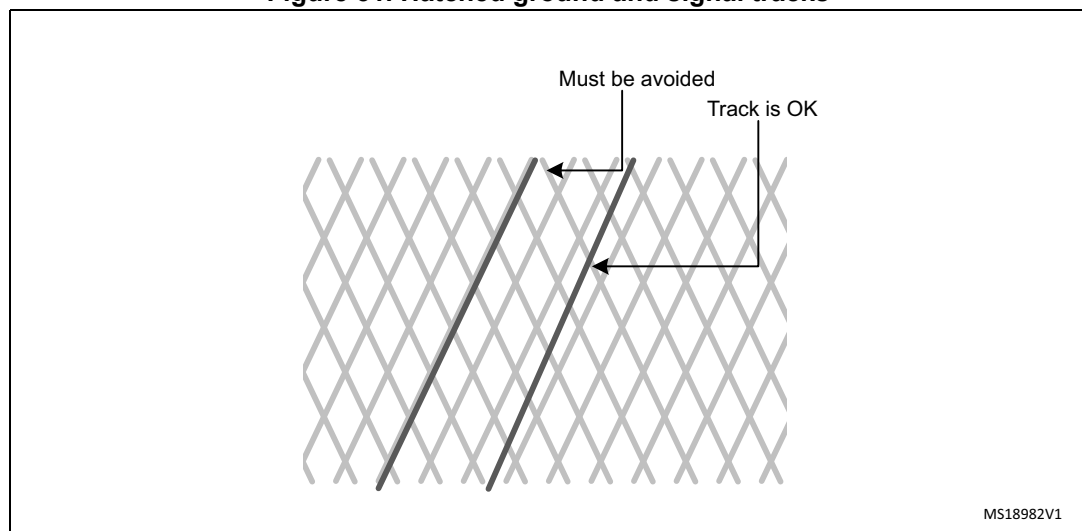


Hatched ground plane

Here are some guidelines for satisfactorily designing an application with a hatched ground plane (see [Figure 31](#)):

- The signal track should cross the ground lines as little as possible
- The signal track should never follow the ground lines

Figure 31. Hatched ground and signal tracks



3.5.7 Rotary and linear sensor recommendations

Given that the sensitivity must be very high in order to be able to detect the position most accurately, neither the power plane nor any application signal should run under a rotary or linear sensor.

4 Conclusion

The layout and design of capacitive sensing boards usually present conflicts between all signals present on the application. This document should be used as a general guideline for resolving all issues. When the guideline recommendations cannot be followed, tests should be performed to validate the implementation and verify the sensitivity and robustness of the impacted channel.

To summarize, the layout of a touch sensing application should reduce the ground coupling to a minimum and use short clean wires as far as possible from other potential interference sources.

5 Revision history

Table 4. Document revision history

Date	Revision	Changes
30-Sep-2013	1	Initial release.
02-Nov-2016	2	Updated Table 1: Applicable products . Added Section 2.4: TC versus FT I/O . Updated Figure 8: Examples of cases where a LED bypass capacitor is required . Updated Figure 9: TC I/O . Updated Figure 10: FT I/O . Updated Figure 11: Typical power supply schematic .
28-Jun-2017	3	Updated Section 2.4: TC versus FT I/O .
30-Aug-2018	4	Specific note added in Section 3.3: Linear sensor and Section 3.4: Rotary sensor .

IMPORTANT NOTICE – PLEASE READ CAREFULLY

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2018 STMicroelectronics – All rights reserved