
Chipsmall
深圳市津利帝科技有限公司
Geelead Technology Limited
Chipsmall
采购部

# Touch Sensors

# Design Guide

## Table of Contents

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## *Section 4*

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## *Section 5*

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## *Section 6*

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## *Appendix A*

# *Getting Started*

Start by reading the introductory sections in Section 1, paying particular attention to:

- Section 1.2 “Self-capacitance and Mutual-capacitance Type Sensors”
- Section 1.3 “Dimension Groups”
- Section 1.4 “Some Important Theory”

Next, read the general advice on sensor design in Section 2:

- Section 2.1 “Charge Transfer”
- Section 2.2 “Components”
- Section 2.3 “Materials”
- Section 2.4 “Nearby LEDs”
- Section 2.5 “Electrostatic Discharge Protection”

Now use the flow diagram below to determine which further sections in this design guide are relevant to your project.

**Type of Sensor**

What type of sensor are you designing (how many dimensions does it have; see Section 1.3)?

**Key**

The sensor has zero dimensions (a single point of contact)
Go to “Zero Dimensions” on page viii

**Slider or wheel**

The sensor has one dimension (linear movement along one axis)
Go to “One Dimension” on page ix

**Touchscreen**

Two-dimensional sensors are not covered by this guide. For information on designing two-dimensional sensors, please contact Atmel’s Touch Technology Division.

## Zero Dimensions

**Charge-transfer Technology**

? Which charge-transfer circuit technology does the sensor use?

- **One direct connection to the sensor controller chip (e.g. QTouch)**

  ▶ The circuit is a self-capacitance circuit (see Section 3)

  **Location of Electrodes and Traces**

  ? How are the electrodes located with respect to the related circuitry (traces, LEDs and other components)?

  - **The electrodes and traces are fabricated on the same plane of the substrate**

    ▶ The design is planar  
    Read Section 3.2 “Planar Construction”

  - **The electrodes are located on the panel’s surface and the rest of the circuitry is on a separate circuit board**

    ▶ The design is non-planar  
    Read Section 3.3 “Non-planar Construction”

- **Two connections (X transmit line and Y receive line) to the sensor controller chip (e.g. QMatrix)**

  ▶ The circuit is a mutual-capacitance circuit (see Section 4)

  **Location of Electrodes and Traces**

  ? How are the electrodes located with respect to the related circuitry (traces, LEDs and other components)?

  - **The electrodes and traces are fabricated on the same plane of the substrate**

    ▶ The design is planar  
    Read Section 4.2 “Planar Construction”

  - **The electrodes are located on the panel’s surface and the rest of the circuitry is on a separate circuit board**

    ▶ The design is non-planar  
    Read Section 4.3 “Non-Planar Construction”

## One Dimension

**Charge-transfer Technology**

Which charge-transfer circuit technology does the sensor use?

**One direct connection to the sensor controller chip (e.g. QTouch)**

The circuit is a self-capacitance circuit (see Section 5.1)

**Introduction and General Advice**

Read Section 5.1 “Introduction”
Read Section 5.2 “General Advice”

**Go To**

Go to “One Dimension: Self-capacitance Sensors” on page x

**Two connections (X transmit line and Y receive line) to the sensor controller chip (e.g. QMatrix)**

The circuit is a mutual-capacitance circuit (see Section 6.1)

**Introduction and General Advice**

Read Section 6.1 “Introduction”
Read Section 6.2 “General Advice”

**Go To**

Go to “One Dimension: Mutual-capacitance Sensors” on page xi

## One Dimension: Self-capacitance Sensors

**Size of Slider/Wheel**

What size slider or wheel and how many channels available (3 or more than 3?)

**Small slider (21 – 26 mm long) with 3 channels**

Use a spatially interpolated small slider or wheel
Read Section 5.3.2 “Small Slider Or Wheel”

**Small wheel (12 – 20 mm diameter) with 3 channels**

Use a spatially interpolated small slider or wheel
Read Section 5.3.2 “Small Slider Or Wheel”

**Medium/large slider (20 – 60 mm long) with 3 channels**

Use a spatially interpolated medium/large slider or wheel
Read Section 5.3.3 “Medium/Large Slider Or Wheel”

**Note:** If the slider is at the upper end of the scale, consider using more channels with a resistively interpolated slider, as this may be easier to construct
Read Section 5.4.2 “Medium/Large Slider Or Wheel”

**Medium/large wheel (20 – 60 mm diameter) with 3 channels**

Use a spatially interpolated medium/large slider or wheel
Read Section 5.3.3 “Medium/Large Slider Or Wheel”

**Note:** If the wheel is at the upper end of the scale, consider using more channels with a resistively interpolated wheel, as this may be easier to construct
Read Section 5.4.2 “Medium/Large Slider Or Wheel”

**Large slider or more then 3 channels**

Use a resistively interpolated medium/large slider or wheel
Read Section 5.4.2 “Medium/Large Slider Or Wheel”

**Large wheel or more then 3 channels**

Use a resistively interpolated medium/large slider or wheel
Read Section 5.4.2 “Medium/Large Slider Or Wheel”

## One Dimension: Mutual-capacitance Sensors

**Size of Slider/Wheel**

? What size slider or wheel?

**Small slider (n x 6 mm – n x 8 mm long, 5 – 50 mm high)**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Small Slider or Wheel" on page xii

**Small wheel (15 – 21 mm circumference)**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Small Slider or Wheel" on page xii

**Medium/large slider (n x 6 mm – n x 8 mm long, more than 50 mm high)**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Medium/Large Slider or Wheel" on page xiii

**Medium/large wheel (more than 21 mm circumference)**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Medium/Large Slider or Wheel" on page xiii

**Large slider**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Large Slider or Wheel" on page xiv

**Large wheel**

▶ Go to "One Dimension: Mutual-capacitance Sensors – Large Slider or Wheel" on page xiv

## One Dimension: Mutual-capacitance Sensors – Small Slider or Wheel

**Small Slider or Wheel**

▶ Use a spatially interpolated small slider or wheel (see Section 6.3)

**Number of Layers**

? How many layers (one or two)?

**One layer**

▶ Read Section 6.3.2 “One-Layer Small Slider Or Wheel”

**Two layers**

▶ Read Section 6.3.4 “Two-Layer Small Slider Or Wheel”

## One Dimension: Mutual-capacitance Sensors – Medium/Large Slider or Wheel

**Medium/Large slider or Wheel**

▶ Use a spatially interpolated medium/large slider or wheel (see Section 6.3)

**Number of Layers**

? How many layers (one or two)?

**One layer**

▶ Read Section 6.3.3 “One-Layer Medium/Large Slider Or Wheel”

**Two layers**

▶ Add extra channels and use a resistively interpolated design
Read Section 6.4.3 “Two-Layer Medium/Large Slider Or Wheel” (see also Section 6.4.1)

## One Dimension: Mutual-capacitance Sensors – Large Slider or Wheel

**Large Slider or Wheel**

▶ Add extra channels and use a resistively interpolated design (see Section 6.4 )

**Number of Layers**

? How many layers (one or two)?

- **One layer**

  ▶ Read Section 6.4.2 “One-Layer Medium/Large Slider Or Wheel” (see also Section 6.4.1)

- **Two layers**

  ▶ Read Section 6.4.3 “Two-Layer Medium/Large Slider Or Wheel” (see also Section 6.4.1)

# Section 1

# Introduction To Sensor Design

## 1.1 Introduction

The process for designing products that use touch controls is a complex process with many decisions to be made, such as what materials will be used in their construction and how the mechanical and electrical requirements will be met. Key to this process is the design of the actual sensors (specifically keys, sliders, wheels and touchscreens) that form the interface with the user.

Sensor design is often considered a “black art”; the distributed nature of the electric fields between the sensor and its electrical environment can make simple “lumped element” approximations of sensor behavior misleading at best. Nevertheless, by following a few essential rules, it is possible to produce a resilient design that ensures that the sensors will operate in a reliable and consistent manner.

This design guide describes the rules that can be used to create sensor patterns on PCBs or other conductive material, such as Indium Tin Oxide (ITO). There are, of course, many possible configurations for such sensors, and this guide cannot be exhaustive; however, it will aid in the initial selection and construction of sensors for touch-enabled products, and should provide an excellent starting point.

You should also refer to QTAN0032, *Designing Products with Atmel Capacitive Touchscreen ICs* for an overview on designing capacitive touchscreens.

## 1.2 Self-capacitance and Mutual-capacitance Type Sensors

Atmel® touch controllers allow for two families of sensors, each using one of two charge-transfer capacitive measurement styles:

- **Self-capacitance type sensors**
  A self-capacitance type sensor has only one direct connection to the sensor controller. These sensors tend to emit electric fields in all directions, and as such are quite non-directional. They can work with and without an overlying panel, although a panel is always recommended for electrostatic discharge (ESD) reasons (1). This type of sensor is suitable for implementating sensors for use with QTouch™ sensor controllers.
- **Mutual-capacitance type sensors**
  A mutual-capacitance type sensor has two connections to two parts of the sensor: an X (transmit) electrode, and a Y (receive) electrode. The mutual capacitance from X to Y is measured by the sensor controller. Because of the close-coupled nature of the fields with this type of sensor, it is only suitable for use when bonded to an overlying panel so that no significant air gaps or bubbles are present; the overlying panel forms an essential conduit for the field from X to Y. This type of sensor is suitable for for implementating sensors for use with QMatrix™ sensor controllers.

Background information on Atmel’s capacitive sensing methods can be found at www.atmel.com.

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1. Direct contact with the sensor carries an elevated risk of ESD damage for the control chip.

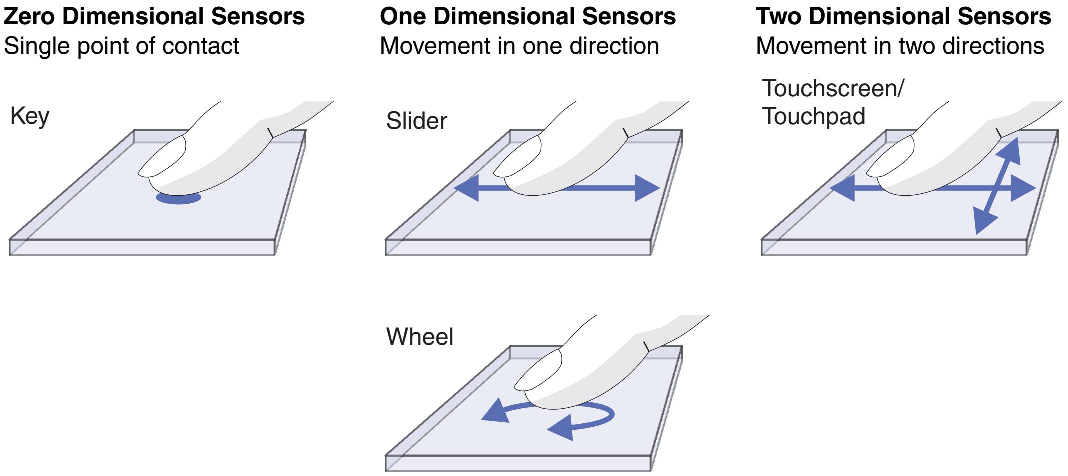
## 1.3 Dimension Groups

In addition to the self- and mutual-capacitance types described in Section 1.2, sensors can also be split into three groups, depending on the number of dimensions they use (see Figure 1-1):

- **Zero-dimensional sensors**
  A zero-dimensional sensor is one that represents a single point of contact. The typical implementation of a zero-dimensional sensor is a key.
- **One-dimensional sensors**
  A one-dimensional sensor is one that detects the linear movement of a finger during touch (that is, along a single axis). Typical implementations of one-dimensional sensors are sliders and wheels.
- **Two-dimensional sensors**
  A two-dimensional sensor is one that detects the movement of a finger during touch along two axes. Typical implementations of two-dimensional sensors are touchscreens and touchpads.

When considering the design of a sensor, you will need to consider both the sensor type and the dimension group, making six possible combinations in total. The combinations for zero-dimensional and one-dimensional sensors are discussed individually in Section 3 to Section 6; two-dimensional sensors are not covered by this guide. For information on designing two-dimensional sensors, please contact Atmel's Touch Technology Division.

***Figure 1-1.*** Sensor Dimensions



## 1.4 Some Important Theory

You will need to be aware of the following terms when reading this document:

- **Cx:** The electrode's natural capacitance, separate from any parasitic capacitance
- **$\varepsilon_r$:** The relative dielectric constant of the overlying panel material (see Figure 1-2 on page 1-3)
- **$\varepsilon_0$:** The capacitance per meter of free space, defined as $8.85 \times 10^{-12}$ F/m
- **T:** The thickness of the overlying panel in meters (see Figure 1-2)
- **A:** The area of the touched region in square meters (see Figure 1-2)
- **Cp:** Any parasitic capacitance added in parallel with Cx
- **SNR:** Signal to noise ratio: a measure of the quality of the capacitive measurement

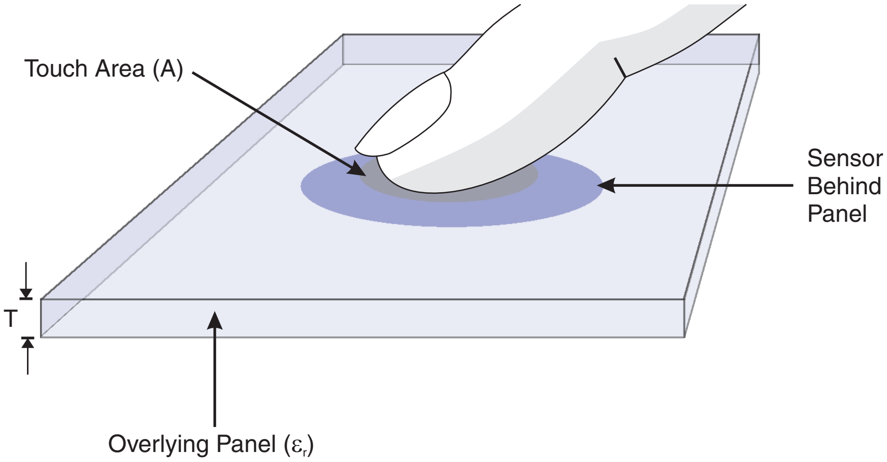
Capacitance (C) is defined in Equation 1-1.

***Equation 1-1.*** Capacitance

$$C = \frac{\varepsilon_0 \times \varepsilon_r \times A}{T}$$

It should therefore be clear that thinner panels and higher dielectric constant materials yield higher capacitance change during touch and hence a higher gain and a better SNR. Section 2.3.3 “Front Panel Materials” on page 2-5 discusses the thickness of the panel and its effect on the SNR.

***Figure 1-2.*** Touchscreen Panel



In the context of capacitive sensors, SNR is defined as in Equation 1-2. (1) See Figure 1-3 for definitions of the touch signal levels.

***Equation 1-2.*** SNR

$$\text{SNR(dB)} = 20\text{Log}(\text{TouchStrength} / \text{NoiseTouched}_{\text{RMS100}})$$

$$\text{TouchStrength} = \text{SignalTouched}_{\text{AVG100}} - \text{SignalUntouched}_{\text{AVG100}}$$

$$\text{NoiseTouched}_{\text{RMS100}} = \sqrt{\frac{\sum_{n=0}^{n=99} (\text{Signal}[n] - \text{SignalTouched}_{\text{AVG100}})^2}{100}}$$

where:

- AVG100 means the simple numeric average of 100 data points, typically taken evenly spaced over a period of 2 seconds.
- RMS100 means the root-mean-square of 100 data points, typically taken evenly spaced over a period of 2 seconds, using the AVG100 figure as a baseline.

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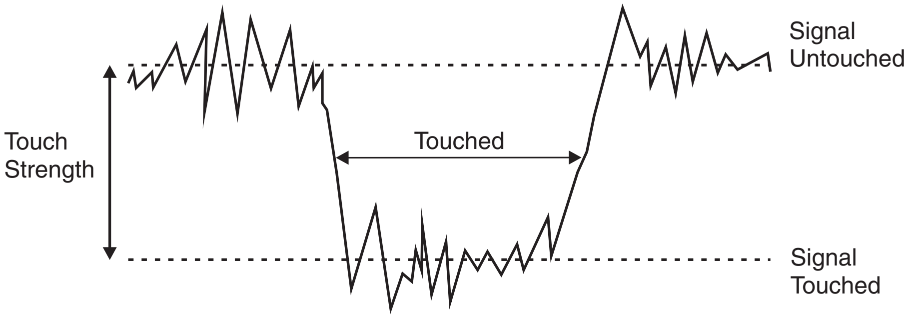
1. Note that this definition uses the RMS noise present during touch, as this is the worst case.

***Figure 1-3.*** Touch Signal Levels



# Section 2

# General Advice

## 2.1 Charge Transfer

Atmel's capacitive sensors work on a principle called charge transfer. This uses a switched capacitor technique to assess relative changes in a sensor's capacitance as it is touched.

Charge transfer works by applying a voltage pulse to series connection of the unknown capacitance Cx and a charge integrator capacitor Cs. By repeating the pulse multiple times, a high resolution measurement system is realized that can detect changes in capacitance of just a few femtofarads (1).

In order to obtain stable and repeatable results, it is important that the voltage pulse is allowed to settle properly and hence transfer all the charge into Cx and Cs (see Figure 2-2 on page 2-2).

Because Cx and Cs are normally connected with some amount of series resistance, the RC time constants so formed will tend to slow down this settling process.

It is therefore important that when designing a capacitive touch system that the amount of series resistance is kept in mind in combination with the size of Cx (the sensor's capacitance).

Series resistance is normally deliberately introduced to improve electromagnetic interference (EMI) and ESD behavior (see the device datasheets for recommended series resistors). For some designs, significant extra resistance can be introduced because of the resistivity of the tracks connecting the sensor, or the resitivity of the electrode material itself. This is normally only true for designs using material like Indium Tin Oxide (ITO), Orgacon™ (2) or Carbon with high Ω/sq values. However, there are situations where adding deliberate extra series resistance can be beneficial, most notably in designs with difficult ESD conditions or where emissions must be controlled to very low levels. A 10 kΩ series resistor can be a good choice. In either case, RC time constants can degrade the charge-transfer process so some precautions must be taken.

For all designs, it is good practice to measure the settling time of the charge-transfer pulses to make sure they are fast enough to work reliably. This can be done by observing the pulses using an oscilloscope and coupling the scope probe to the sensor electrode capacitively (3) using a small coin on top of the overlying panel, or using a small piece of copper tape instead (see Figure 2-1 on page 2-2). The charge pulses should have substantially flat tops, that is the voltage has settled before the pulse ends (see Figure 2-2 on page 2-2).

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1. One femtofarad is 1/1000 of a picofarad.
2. Orgacon™ is a trademark of Agfa-Gevaert Group. Orgacon is a printable conductive ink using a PEDOT polymer base. Care should be taken when assessing this material's suitability for sensor construction due to the high starting resistivity and the fact that this resistivity is known to increase over life depending on its exposure to UV, heat and moisture (and any other oxidising substance). Consult Agfa before making any design decisions.
3. Probing the sensor directly will add the capacitance of the probe and so give an unrealistic wave shape.

***Figure 2-1.*** Measuring the Charge-transfer Pulses

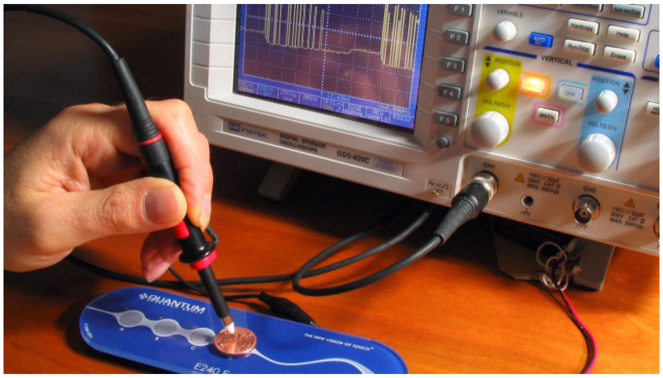
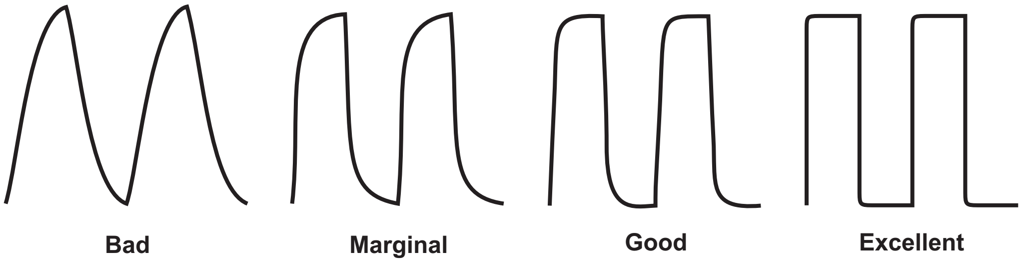


***Figure 2-2.*** Good and Bad Charge Pulses



As a rule, the overall RC time constant of each sensor should be reduced as far as possible, while trying to preserve at least a 1 kΩ series resistor close to the sensor chip. A good rule-of-thumb is given in Equation 2-3.

***Equation 2-3.*** Rule Of Thumb for RC Time Constant

$$\text{Rseries\_total} * (\text{Cx} + \text{Cp}) <= \text{Tcharge} / 5$$ [1]

Where:

- Rseries_total is the total series connection from the sensor chip's pin to the farthest point on the sensor.
- Cx + Cp represents the total capacitance that the sensor chip detects for the sensor (that is, the sensor itself plus any parasitic capacitance). Measuring this can be done for a first order approximation using a commercial capacitance bridge. A more practical approach is to measure the pulse shapes as described above.
- Tcharge varies somewhat from sensor chip to sensor chip, but a good estimate is 1 µs for zero- and one-dimensional sensors, and 2 µs for two-dimensional sensors.

The "Marginal" example in Figure 2-2 represents about 3 time constants; the "Good" example represents about 5 time constants.

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1. The factor of 5 ensures that each charge-transfer pulse settles to better than 99 percent, leaving just 1 percent of charge subject to second order effects, such as the Rseries value, chip output drive strength, and so on..

## 2.2 Components

### 2.2.1 Cs Capacitor

Charge transfer uses an integration capacitor (Cs) to measure changes in Cx. The Cs capacitor accumulates charge over a number of charge transfer pulses. Ultimately, the voltage on Cs is used as the basis of the measurement. Clearly then, the stability of Cs is important to obtain a consistent and repeatable measurement. In general, you can easily achieve this by making sure that Cs is an X7R or X5R type of capacitor. If possible, use a COG type, as these have the highest stability. In practice, though, this limits Cs to around 1 nF, and often Cs needs to be higher – sometimes as much as 100 nF. In this case, use an X7R or X5R type capacitor.

All Atmel capacitive sense chips use drift compensation methods to correct for slow-rate thermal changes in Cs. Faster rate changes are not possible to compensate for in this way, and for this reason you should never try to use Y5R type capacitors; they are simply too unstable.

A short-term change in Cs that can sometimes be observed on sensors using elevated gain is an effect known as dielectric absorption. This is a complex physical mechanism whereby charge becomes "trapped" in discontinuities in the dielectric lattice of the capacitor. This manifests itself as changes in the value of Cs that are a function of the previous voltage history on the capacitor. Dielectric absorption is rarely observed in practice, but every now and then it can disrupt a project, causing shifts in the background reading as the senor chip exits from sleep mode (1). Note that this effect can appear only in sleep modes; it is never seen in a continuous run mode. If this kind of effect is suspected, try changing to another brand of capacitor for Cs. Some modern Hi-K ultra-small X5R capacitors (for example, 0201 size) have been shown to demonstrate such behavior. However, it has not been seen by Atmel as a significant effect for 0402, 0603, 0805 sized components.

### 2.2.2 Series Resistors

The series resistors are non critical and have no special characteristics. 10 percent, or better, tolerance is fine, and generally 200 ppm/°C is more than stable enough.

### 2.2.3 Voltage Regulator

Use a good quality linear regulated supply for Vdd to the sensor chip. Remember that long term shifts in Vdd are compensated for by the internal drift algorithms, but short-term shifts or spikes on Vdd can be problematic. Refer to the sensor chip's datasheet for advice on regulator types.

### 2.2.4 Component Placement

All passive components associated with the capacitive sensor (such as the Cs reference capacitors and associated resistors) should be placed as close to the control chip as is physically possible to assist with EMC compliance. Avoid compromises in layout in this regard; placing such components closer to the chip is always better.

If these parts are placed far from the chip, serious noise problems and instabilities can arise. A common mistake is to place the series resistors at the actual key locations instead of at the chip. The trace length from the chip to the passive components is just as important as the distance from the chip to the actual key.

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1. That is, some period of no charge-discharge activity on Cs, which causes it to change value slightly.

Placing the passive components close to the chip, whilst having a long set of tracks to the chip from the key, negates the desired result, as long tracks act as RF antennas. The series resistor acts to reduce RF coupling both in and out of the sensor circuit. However, the circuit cannot perform this function on RF signals coupled into the chip on a long trace between the chip and the resistor.

## 2.3 Materials

### 2.3.1 Substrates

The substrate is the base material carrying the electrodes.

Almost any insulating material can be used as a substrate, but low-loss substrates are generally preferable, such as PCB materials (FR4, CEM-1, Polyamide and Kapton to name a few), acrylics like Polyethylene Terephthalate (PET) or Polycarbonate. Glass is also an excellent material.

Generally, if the substrate under consideration is commonly used for electronic assemblies, then it will also work well for capacitive sensing. Just be careful to avoid materials that are strongly hydroscopic, such as those that are paper based, as this can cause $\varepsilon_r$ to change substantially with environmental conditions.

When considering the stack of materials that make up the front panel and the sensor substrate, you are always advised to glue the substrate to the front panel using pressure-sensitive or optically clear adhesive, or another suitable bonding agent. Small (less than 1 mm diameter) or infrequent air bubbles in the adhesive are generally acceptable, but large (greater than 2 mm diameter) or frequent bubbles can cause drops in sensitivity and unit-to-unit variances that are not desirable for mass production.

It is never recommended to simply push the substrate up against the front panel, as it is hard to achieve consistent sensor performance from unit to unit. Furthermore, moisture can become trapped between the two layers causing shifts in sensitivity, and optically it is very easy to end up with unsightly Newton rings (1).

It is possible to construct sensors that do not rely on a substrate. These are described in this document under separate sections.

### 2.3.2 Electrode and Interconnection Materials

Common electrode materials include copper, carbon, silver ink, Orgacon™ and ITO.

The lower the Ω/sq resistivity of the material the better. Less than 1 kΩ/sq is preferred (2) as it makes control of any RC time constants much easier.

Interconnections are usually formed from low Ω/sq material because they tend to be long and thin in nature. Remember that a printed silver track at 1 kΩ/sq that is 100 mm long and 0.5 mm wide will have a resistance of 200 kΩ.

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1. The colorful diffraction effect that spreads out around the center of a spec of moisture, oil or other contaminant trapped as a thin film between the layers.
2. As should be obvious, the Ω/sq rating choice is intimately coupled with the shape and size of the electrode. Long thin electrodes or traces build up resistance extremely quickly, even for relatively low resistivities.

It is acceptable to use a flex PCB or FFC/FPC (1) to act as an interconnection, but make sure you are certain that it will be mechanically stable for the intended uses of the product. The traces running in the flex will be part of the touch sensor; so if the flex shifts even a fraction of a millimeter, the capacitance to its surroundings will definitely change and might be significant, causing false touches or drops in sensitivity. Running the flex in close proximity to a metal chassis or other signals, or over the top of noisy circuitry, can cause problems too.

### 2.3.3 Front Panel Materials

Common front panel materials include glass, plexiglas, polycarbonate and PMMA. Remember that glass front panels may require an anti-shatter layer to pass drop and safety tests; this is often an extra PET film bonded to the glass. In general, the same rules apply to front panels as apply to substrates but, of course, a common requirement is to also offer excellent transparency and cosmetic quality.

The panel thickness and its dielectric constant ($\varepsilon_r$) play a large part in determining the strength of electric field at the surface of the control panel. If the metal electrodes are on the inside surface of the substrate, then the thickness and $\varepsilon_r$ of the substrate are also factors.

Glass has a higher $\varepsilon_r$ than most plastics (see Table 2-1). Higher numbers mean that the fields will propagate through more effectively. Thus a 5 mm panel with an $\varepsilon_r$ of 8 will perform similarly in sensitivity to a 2.5 mm panel with an epsilon of 4, all other factors being equal.

A plastic panel up to 10 mm thick is quite usable, depending on key 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 2-1.*** Relative Dielectric Constants for Materials

| **Material** | **Dielectric Constant ($\varepsilon_r$)** |
|---|---|
| Vacuum | 1 (by definition) |
| Air | 1.00059 |
| Glass | 3.7 to 10 |
| Sapphire Glass | 9 to 11 |
| Mica | 4 to 8 |
| Nylon | 3 |
| Silicon | 11 to 12 |
| Silicone Rubber | 3.2 to 9.8 |
| Silicone Moulding Compound | 3.7 |
| Paper | 2 |
| Plexiglas | 3.4 |
| Polycarbonate | 2.9 to 3.0 |
| Polyethylene | 2.2 to 2.4 |
| Polystyrene | 2.56 |
| PET (Polyethylene Terephthalate) | 3 |

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1. FFC = Flat Flexible Conductor, FPC = Flexible Printed Circuit

***Table 2-1.*** Relative Dielectric Constants for Materials (Continued)

| **Material** | **Dielectric Constant ($\varepsilon_r$)** |
|---|---|
| Pyrex Glass | 4.3 to 5.0 |
| Quartz | 4.2 to 4.4 |
| Rubber | 3 |
| FR4 (Glass Fiber + Epoxy) | 4.2 |
| PMMA (Polymethyl Methacrylate) | 2.6 to 4 |
| Typical PSA (Pressure Sensitive Adhesive) | 2.5 to 2.7 |

A useful metric when dealing with panels of different thicknesses and materials is the sensitivity factor (S), given by Equation 2-4.

***Equation 2-4.*** Sensitivity Factor (S)

$$S = \varepsilon_r / t$$

where:

- $t$ is the thickness of the layer in question
- $\varepsilon_r$ is the dielectric constant of the layer in question

In the case of a stack of materials, the combined $\varepsilon_r$ for the whole stack is given in Equation 2-5.

***Equation 2-5.*** Dielectric Constant ($\varepsilon_r$) for a Stack of Materials

$$1/S_{STACK} = \mathrm{Sum}(1/S_{LAYER}[n])$$

where:

- n is the number of layers
- Sum is the sum of all terms

As can be seen, very thick panels will greatly reduce the sensitivity factor. If you need to use materials that are thicker than what is considered normal practice (for example, if you need to sense through a 20 mm glass panel or a 10 mm acrylic panel), then be very careful about anything that increases parasitic loading to the rear of the sensor. More on this in later sections.

When designing a decorated front panel, be aware that some paints and finishes can be substantially conductive (refer to QTAN0021, *Materials and Coatings Selection for Atmel Capacitive-touch Panels*, for more information).

### 2.3.4 PCB to Panel Bonding

Good contact between the substrate and the panel is essential for reliable performance. An unreliable interface which can change by even 100 microns after being touched by a finger can cause unacceptable signal fluctuations. Adhesives or compression mechanisms can be used to reliably overcome these problems. Non-adhesive solutions can for example involve the use of co-convex surfaces that are placed under preloaded pressure when clamped together, to ensure complete surface mating.

Various methods have been used to mechanically clamp electrode substrates to panels, including heat staking plastic posts, screws, ultrasonic welding, spring clips, non-conductive foam rubber pressing from behind, etc.

The most common form of electrode is a filled circle or rectangle of copper on a PCB, corresponding loosely in shape to the key graphic. The PCB is then usually glued with an industrial adhesive such as a two-sided acrylic sheet to the inside of the operator panel. (1)

## 2.4 Nearby LEDs

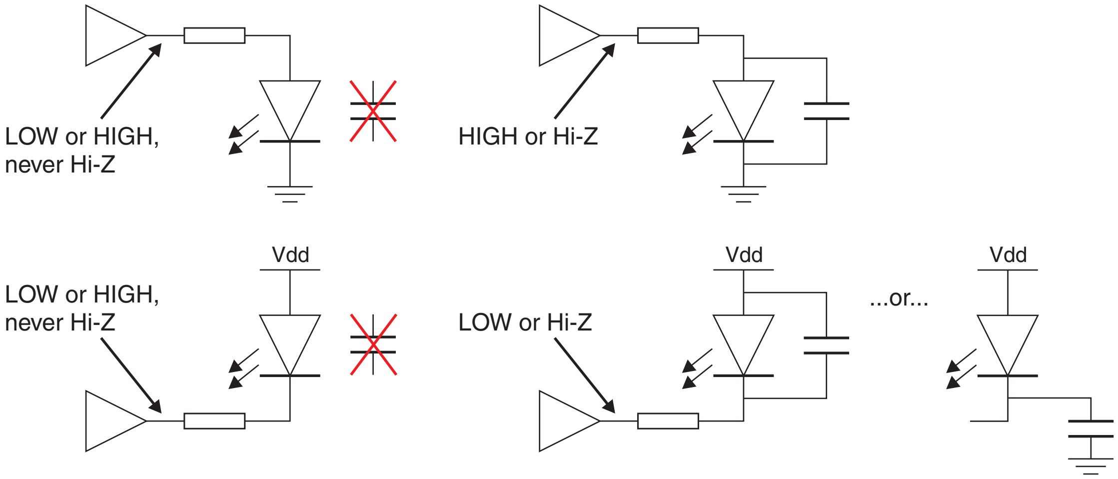
If LEDs are close (that is, less than 4 mm away) to capacitive sensors, you must give some consideration to their change in capacitance between on and off states (and the possible change of the LED driver's output impedance too). It is also necessary to consider the changes in the nature of their drive circuitry.

If changes in capacitance of the LED and associated drive circuit couple to a touch sensor electrode, it is possible to cause detection instability or touch keys that stick either on or off when the LED changes state.

As a general rule, LEDs that are judged as close must be bypassed with a capacitor that has a typical value of 1 nF (2) if either end of the LED changes to a non-low impedance state at any point. This is particularly important for LEDs that are pulled down or up to switch on, but are allowed to float when off.

Note that the bypass capacitor does not need to be physically close to the LED itself. Even if the capacitor is several centimeters away from the LED, it will still serve its purpose. This may aid layouts that are tight for space around the sensors.

***Figure 2-3.*** LED Circuits



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1. One example of acrylic bonding sheet includes 3M type 467MP, although there are other suppliers and types which may prove more suitable.
2. Non critical value. The idea is to simply provide a constant low impedance path as seen by the sensor, on both ends of the LED. Low means less than 1 kΩ at 100 kHz