AN2966
Application note

Capacitor selection guide for STM8T141 and touch sensing library-based capacitive sensors

Introduction

Capacitors feature some non-ideal characteristics that unfortunately limit their use in certain applications. The objective of this application note is to help designers in selecting the right sampling capacitor (C_S) for their applications by investigating the most important undesirable characteristics. For STM8T141 devices, the specific power mode selected and the proximity sensitivity will also directly influence this decision.

1 Charge transfer acquisition principle overview

The STM8T and touch sensing library-based capacitive sensors use the charge transfer acquisition principle to sense changes in capacitance. The electrode capacitance (C_X) is charged to a stable reference voltage (V_{REG} for STM8T141 devices and V_{DD} for general purpose STM8/STM32 devices). The charge is then transferred to a known capacitor referred to as the sampling capacitor (C_S). This sequence is repeated until the voltage on the C_S capacitor reaches an internal reference voltage (V_{TRIP} for STM8T141 devices and V_{IH} for general purpose STM8/STM32 devices). The number of transfers required to reach the threshold depends on the size of the electrode capacitance and represents its value.

To ensure stable operation of the solution, the number of transfers needed to reach the threshold is adjusted by an infinite impulse response (IIR) filter which compensates for environmental changes such as temperature, power supply, moisture, and surrounding conductive objects.

Since the C_S capacitor is an integral part of the design, it is important to consider the non-ideal effects of capacitors.

2 Capacitor characteristics

The most common short comings of capacitors are the following:

- Series resistance
- Series inductance
- Parallel resistance (leakage current)
- Non-zero temperature coefficient
- Dielectric absorption (DA) or soakage
- Dissipation Factor

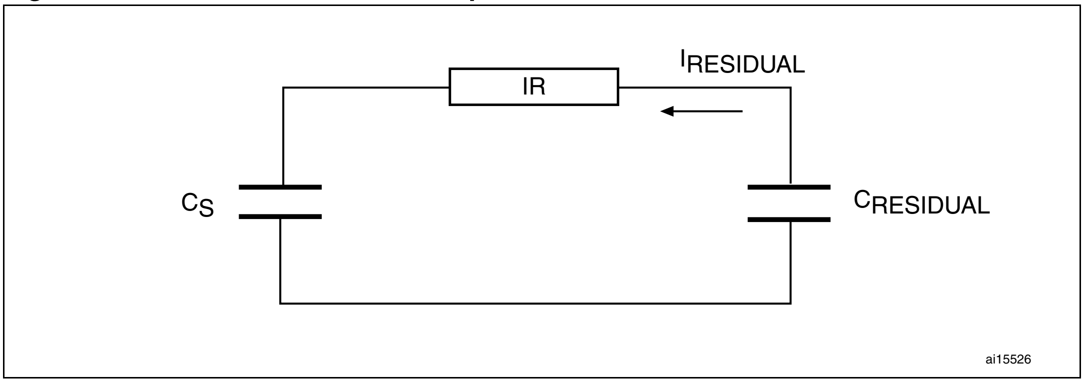
The three most important characteristics that need to be examined are non-zero temperature coefficient, dissipation factor and dielectric absorption (DA). The effect of these non-ideal characteristics on the operation of the system will be briefly examined in the following sections.

2.1 Dielectric absorption or soakage

Dielectric absorption (DA) or soakage can be detrimental to the operation and accuracy of capacitive sensors that rely on a stable reference capacitor.

DA is caused by the charge that is soaked-up in the dielectric and remains there during the discharge period. The charge then trickles back out of the dielectric during the relaxation period and cause a voltage to appear on the C_S capacitor. This phenomenon effectively creates a memory effect in the capacitor. The size of the offset voltage is dependant on the relaxation time between transfers and the discharge time of the C_S capacitor. This phenomenon is illustrated in *Figure 1*. The residual charge bleeds back ($I_{RESIDUAL}$) through the insulation resistor (IR) to cause a voltage offset on the C_S capacitor.

Figure 1. Model of dielectric absorption



This offset voltage influences the sensitivity of the system by reducing the number of transfers needed to reach the internal reference voltage threshold and may cause false proximity detections to occur.

By choosing a capacitor with a low dielectric absorption factor, a higher sensitivity level can be selected, ensuring a more stable and reliable design with improved proximity detections. Refer to *Table 1* for a comparison of dielectric absorption factors for the different types of capacitor dielectrics.

2.2 Non-zero temperature coefficient

To ensure trouble free operation over the final application operating temperature range, it is important to select a capacitor featuring a stable temperature coefficient.

Dielectrics like PET, PEN, PPS and NPO usually have higher temperature characteristics than normal ceramic capacitors and are thus recommended.

2.3 Dissipation factor

The dissipation factor is an indication of the energy loss, usually in the form of heat. Capacitors with a high dissipation factor generally cause self-heating which affects the capacitance. This change in capacitance in turn affects the number of charge transfers needed to reach the internal reference voltage threshold.

This also emphasizes the need to choose a dielectric with a stable temperature coefficient. Please refer to *Table 1* for a comparison of the dissipation factors for the various dielectrics.

3 Capacitor comparison

Table 1 compares the most important characteristics that need to be reviewed when selecting a C_S capacitor.

Table 1. Characteristics of film SMD capacitors

		PET	PEN	PPS	NPO	X7R	Tantalum
Operating temperature (°C)		-55 to 125	-55 to 125	-55 to 140	-55 to 125	-55 to 125	-55 to 125
ΔC/C with temperature (°C)		±5	±5	±1.5	±1	±1	±10
Dissipation factor (%)	1 kHz	0.8	0.8	0.2	0.1	2.5	8
Dissipation factor (%)	10 kHz	1.5	1.5	0.25	0.1		
Dissipation factor (%)	100 kHz	3.0	3.0	0.5	0.1		
Dielectric absorption (%)		0.5	1	0.05	0.6	2.5	n.a.
ESR		Low	Low	Very low	Low	Moderate to high	high
Reliability		High	High	High	High	Moderate	Low

The PPS (polyphenylene sulfide) dielectric and the NPO ceramic capacitors performs excellently in all categories. The PET (metallized polyester) and the PEN (metallized polyphenylene naphthalate) capacitors also perform quite well and can be used in all touch sensing applications.

Tantalum capacitors should be avoided as they have a very high dissipation factor and a high effective series resistance (ESR). X7R ceramic capacitors can be used in certain applications when a less sensitive proximity level is required.

STM8T141 capacitive sensor have selectable low power modes with zoom in which the performance of the X7R dielectric is not acceptable due to its high dissipation factor and capacitance change over temperature. DA has also a considerable influence on application operation in low power modes with zoom, due to the fact that the time between charge transfers varies.

4 Conclusion

As explained, the sampling capacitor characteristics play an important role in the correct and stable operation of a capacitive sensing application. Consequently, it is necessary to select it carefully.

Recommendations for the STM8T141 capacitive sensor are summarized below:

- When the STM8T141 low power modes with zoom are used, PET, PEN, PPS or NPO capacitor types must be used.
- If the STM8T141 is used for proximity detection, PET, PEN, PPS or NPO capacitor types should be used.
- If the STM8T141 is used for touch detection, all capacitor types except tantalum can be used.

Recommendations for touch sensing library based capacitive sensors are summarized below:

- If the solution uses an MCU low power mode to reduce overall power consumption, PET, PEN, PPS or NPO capacitor types should be used.
- If the solution uses linear or rotary touch sensors, PET, PEN, PPS or NPO capacitor types should be used.
- If the solution uses only touchkey sensors, all capacitor types except tantalum can be used.

5 Revision history

Table 2. Document revision history

Date	Revision	Changes
04-May-2009	1	Initial release.
14-Nov-2011	2	Document updated to include only STM8T141 and touch sensing library-based capacitive sensors. Other changes include: *Section 1: Charge transfer acquisition principle overview*: renamed and content rewritten. *Section 2: Capacitor characteristics*: renamed. *Section 2.1: Dielectric absorption or soakage*: replaced 'V_{TRIP}' by 'internal reference voltage threshold'. *Section 2.2: Non-zero temperature coefficient*: last sentence updated. *Section 2.3: Dissipation factor*: added 'charge' to 'charge transfers'; replaced 'V_{TRIP}' by 'internal reference voltage threshold'. *Section 3: Capacitor comparison*: layout and small text changes. *Section 4: Conclusion*: added.