Sampling capacitor selection guide for touch sensing applications on MCUs

Introduction

Capacitors feature some non-ideal characteristics that unfortunately limit their use in some applications. The objective of this document is to help designers in selecting the right sampling capacitor (C_S) for their touch sensing applications by investigating the most important undesirable characteristics.

STMicroelectronics is providing free STMTouch touch sensing firmware libraries, directly integrated into the corresponding STM32Cube package (such as STM32CubeL4).

Table 1. Applicable products

Type	Product series
Microcontrollers	STM32F0 series, STM32F3 series, STM32L0 series, STM32L1 series, STM32L4 series, STM32L4+ series, STM32L5 series, STM32U5 series, STM32WB series, STM32WBA series.

1 Charge transfer acquisition principle overview

An MCU-based touch sensing applications may use the charge transfer acquisition principle, supported by STMTouch touch sensing libraries, to sense changes in capacitance. The electrode capacitance (C_X) is charged to a stable reference voltage (V_{DD} for general purpose Arm®-based STM32 microcontrollers). 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 C_S reaches the internal reference voltage V_{IH}. 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 that compensates for environmental changes such as temperature, power supply, moisture, and surrounding conductive objects.

Since C_S is an integral part of the design, the non-ideal effects of capacitors must be considered.

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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

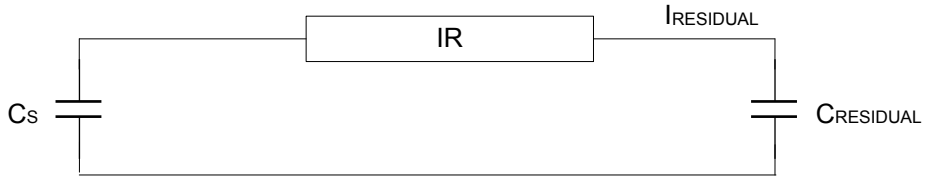
The three most important characteristics that need to be examined are non-zero temperature coefficient, dissipation factor and dielectric absorption (DA). The effect of these non-ideal characteristics on the operation of the system is briefly examined in the following sections.

2.1 Dielectric absorption or soakage

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 dependent on the relaxation time between transfers and the discharge time of the C_S capacitor. This phenomenon is illustrated in the figure below.

Figure 1. Model of dielectric absorption



The residual charge bleeds back ($I_{RESIDUAL}$) through the insulation resistor (IR) to cause a voltage offset on the C_S capacitor. 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 2 for a comparison of dielectric absorption factors for the different types of capacitor dielectrics.

2.2 Nonzero temperature coefficient

To ensure trouble free operation over the final application operating temperature range, the selected capacitor must feature 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 cause self-heating that lay affect 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. Refer to Table 2 for a comparison of the dissipation factors for the various dielectrics.

3 Capacitor comparison

The table below compares the most important characteristics that need to be reviewed when selecting a C_S capacitor.

Table 2. Characteristics of film SMD capacitors

Characteristic		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
	10 kHz	1.5	1.5	0.25	0.1	-	-
	100 kHz	3.0	3.0	0.5	0.1	-	-
Dielectric absorption (%)		0.5	1	0.05	0.6	2.5	-
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 (metalized polyester) and the PEN (metalized polyphenylene naphthalate) capacitors also perform quite well and can be used in all touch sensing applications.

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

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.

The recommendations for STMTouch touch sensing library-based applications are summarized below:

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

Revision history

Table 3. **Document revision history**

Date	Version	Changes
15-Jul-2013	1	Initial release.
11-Jun-2014	2	Added support for STM32L0 Series and STM8AL Series.
20-Oct-2015	3	Updated Table 1. Added support for STM32L4 Series.
23-Jan-2019	4	Updated: • Title of the document • Table 1. Applicable products
23-Aug-2021	5	Updated: • the Introduction section. • the Applicable products table. • the Charge transfer acquisition principle overview section.
10-Jan-2023	6	Updated Section Introduction in the Table 1. Applicable products to incorporate the STM32WBA series. Updated the whole document with minor changes.

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