AN2970
Application note

STM8T14x ProxSense™ charge transfer capacitive sensing technology

Introduction

This application note describes the ProxSense™[a] charge transfer capacitive sensing technology used in STMicroelectronics STM8T14x capacitive sensors.

STM8T14x devices offer a state of the art capacitive sensing engine supporting both touch and proximity sensing. They are designed to easily replace conventional electromechanical switches in cost-sensitive applications.

Table 1. Applicable products

Type	Applicable products
Microcontrollers	STM8T141, STM8T142 and STM8T143

a. ProxSense is a trademark from Azoteq.

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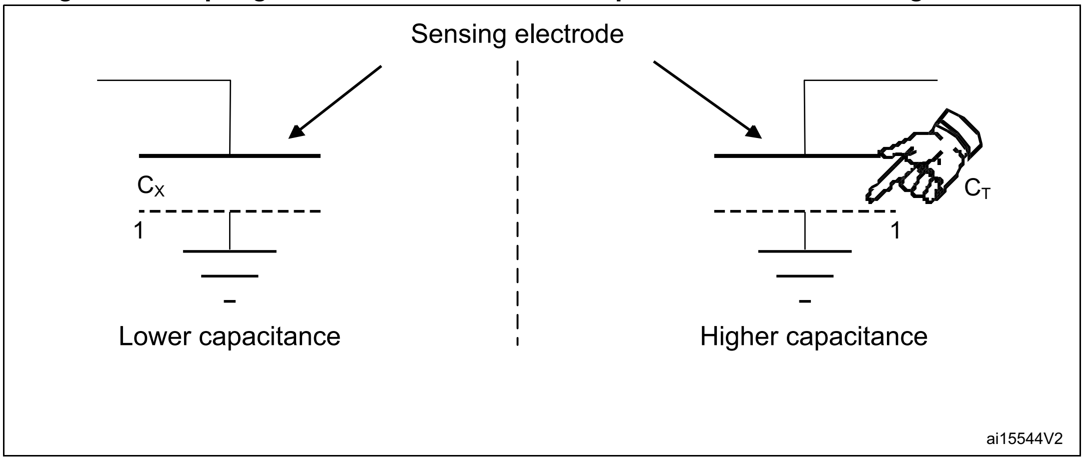
1 Capacitive sensing overview

1.1 Sensing electrode capacitance

A capacitance exists between any reference point relative to ground as long as they are electrically isolated. If this reference point is a sensing electrode, it helps to think of it as a capacitor. The positive electrode of the capacitor is the sensing electrode, and the negative elerode is formed by the surrounding area (virtual ground reference, labeled 1 in *Figure 1*).

Figure 1. Coupling with hand increases the capacitance of the sensing electrode



When a conductive object is brought into proximity of the sensing electrode, the coupling between the object and the electrode increases, together with the capacitance of the sensing electrode relative to ground. For example, a human hand will increase the sensing electrode capacitance as it approaches it. Touching the dielectric panel that protects the electrode increases its capacitance significantly.

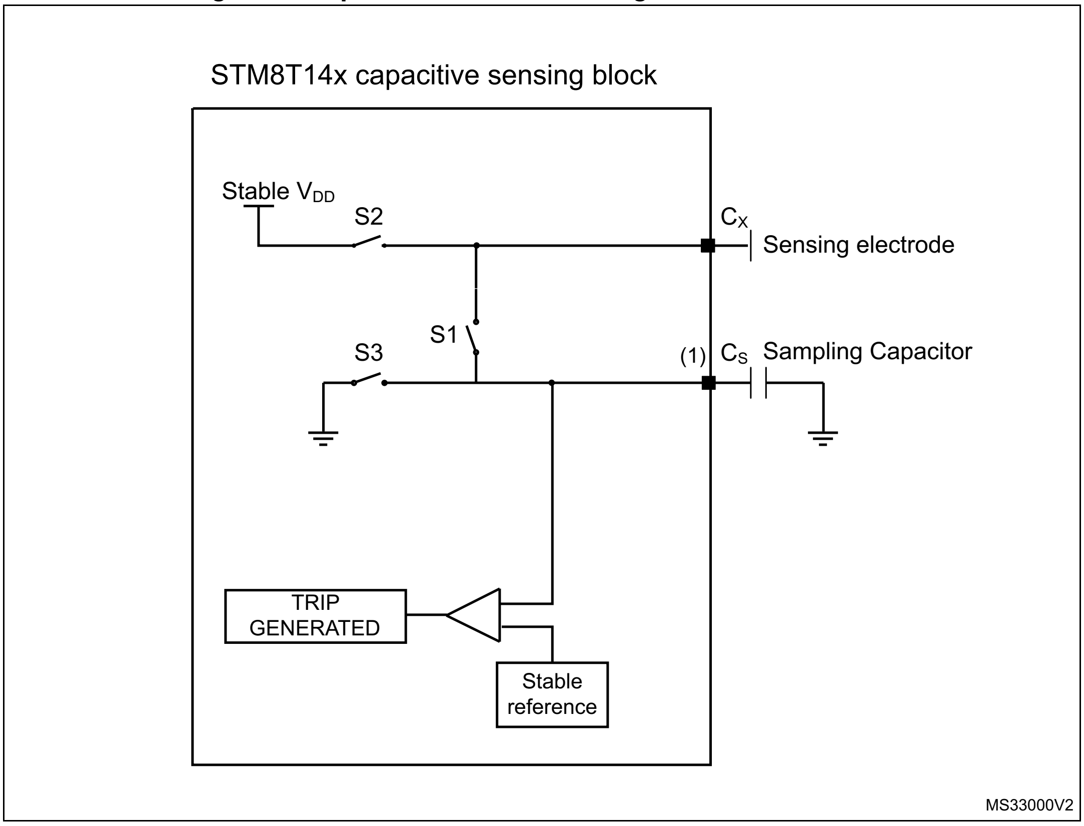
The sensing electrode can be made of any electrically conductive material, such as copper on PCBs, or transparent conductive material like Indium Tin Oxide (ITO) deposited on glass or Plexiglas.

1.2 Principles of charge transfer

The sensing electrode is connected to the C_X pin of the STM8T14x device. The equivalent capacitance of the sensing electrode is referred to as C_X.

C_X is fully charged with a stable reference voltage V_{DD}. The charge on C_X is then transferred to a sampling capacitor (C_S). C_S capacitance is typically from 1000 to 100,000 times bigger than C_X. The process is repeated until the voltage on C_S reaches a threshold. This threshold is referred to as V_{TRIP}. The number of transfer cycles required to reach the threshold represents the size of C_X. Refer to *Figure 4* and *Table 2* for a representation of the charge-transfer equivalent hardware and charge-transfer sequence for a given channel.

Figure 2. Depiction of channel charge-transfer hardware



1. This pin is only available on the STM8T141. On STM8T142 and STM8T143 devices, the sampling capacitor is integrated within the product.

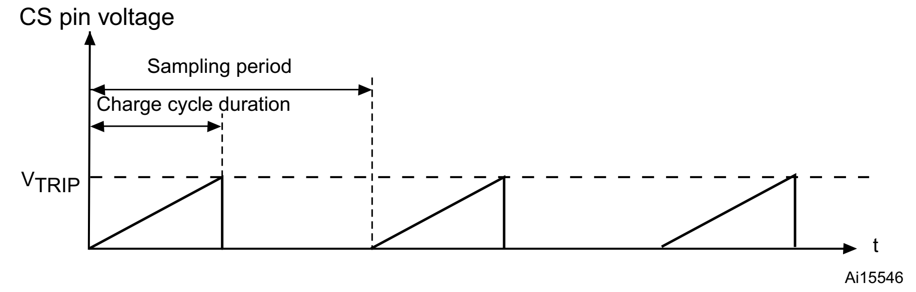
Table 2. Charge transfer sequence (1)

Step	Switch S3	Switch S2	Switch S1	Description
1	1	0	1	C_S discharge
2	0	0	0	Deadtime
3	0	1	0	Charge cycle (C_X charge)
4	0	0	0	Deadtime
5	0	0	1	Transfer cycle (charge transferred to C_S)
6	0	0	0	Deadtime
7	1	0	1	C_X discharge

1. Step 2 to 7 are repeated until the voltage across C_S reaches V_{TRIP} threshold.

The **transfer cycle** refers to the charging of C_X and the transfer of the charge to the C_S capacitor. The **charge cycle** refers to process of charging C_S to V_{TRIP} using a sequence of transfer cycles. The charge cycle duration refers to the time needed to complete one C_S charge cycle when no proximity or touch (thus the longest duration of a charge cycle with the current system parameters). It is graphically illustrated in *Figure 3*.

Figure 3. Charge cycle



The charge cycles can be probed from the C_S pin (STM8T141 only) or from the C_X pin. *Figure 4* and *Figure 5* show the evolution of the C_X voltage during the charge and transfer cycles.

Figure 4. Voltage across C_X over a charge cycle

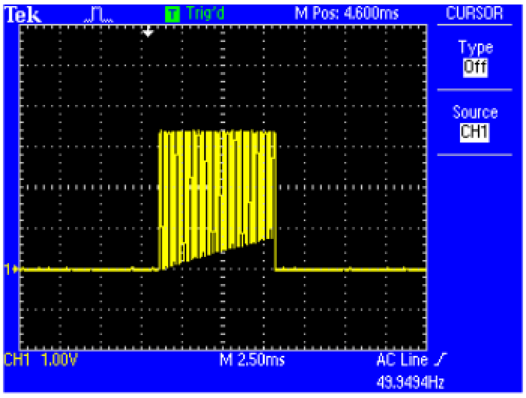
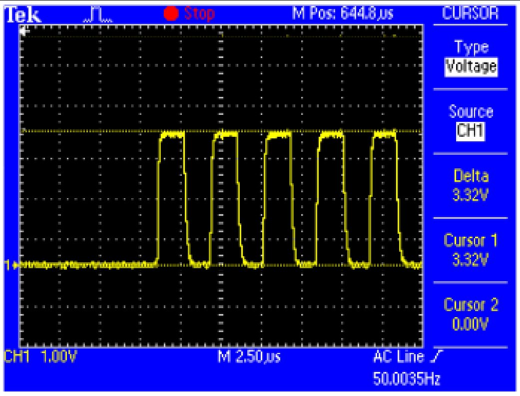


Figure 5. Ideal transfer cycles



In addition, the devices can compensate to environmental changes by tracking the average capacitance of the sensing electrode. This average value is compared to the latest charge cycle to determine whether a proximity or touch occurred.

1.3 Transfer rate

The transfer cycles can be performed at a default rate depending on the internal oscillator frequency. According to the device, this frequency can be modified either through OTP option bytes.

The oscillator is used to determine the rate at which the charge transfers is performed. A maximum efficiency is achieved when enough time is allowed to fully charge C_X to V_{DD} and completely transfer this charge to the C_S capacitor.

A transfer rate between 100 kHz and 250 kHz is a good choice in normal operating conditions. The default transfer rate is in this range.

A serial resistor R_X connected to the C_X pin negatively influences the transfer cycle. This resistor improves the conductive object electrical isolation from the sensing electrode and provides additional ESD protection for the device. Typical R_X value ranges from 1 to 2kΩ.

Figure 5 and *Figure 6* show ideal charge cycles probed from the C_X pin. In *Figure 5*, it can be noted that the sensing electrode charges up to V_{DD}. In *Figure 6*, the charge cycle halts when V_{TRIP} is reached.

Figure 6. Ideal charge cycles

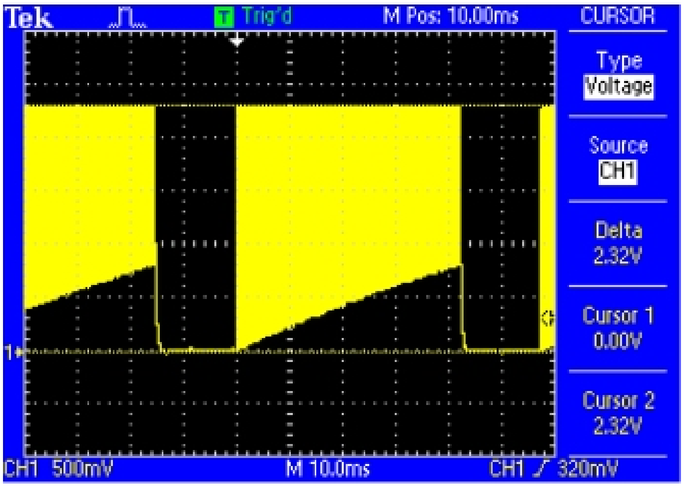


Figure 7 and *Figure 8* shows non-ideal charge transfers and the resulting charge cycle.

It can be noted that the sensing electrode is charged up to 2.12 V instead of V_{DD}. By comparing *Figure 8* to *Figure 6*, it can be noted that the offset is due to the fact that a fraction of the sensing electrode charge is not transferred to the C_S capacitor. This can be corrected by decreasing either the transfer rate or R_X.

Figure 7. Non-ideal transfer cycles

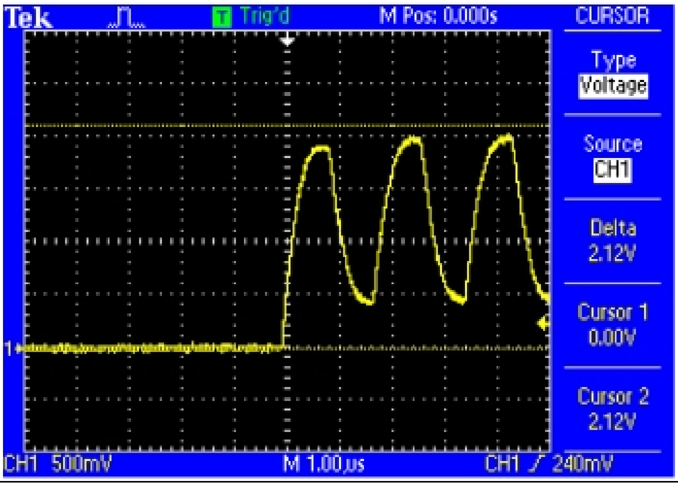
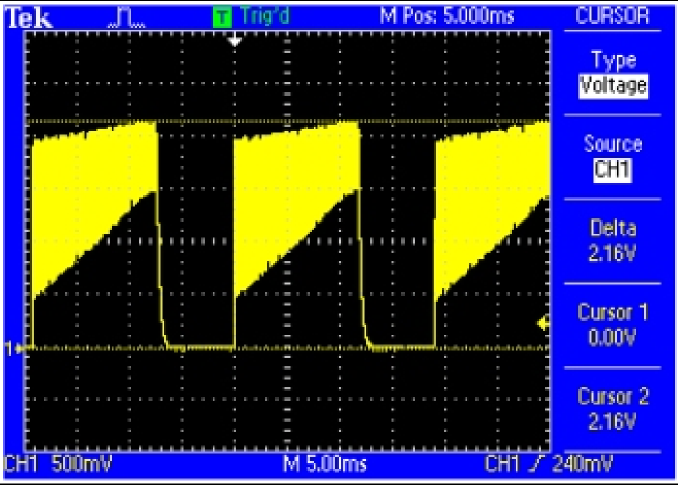


Figure 8. Charge cycle resulting from non-ideal transfer cycles



Note: Attaching a probe to the sensing electrode increases the sensing electrode capacitance by a few picoFarads, depending on the probe. This has an instant negative influence on the sensitivity of the system. After a short period of time, the system automatically adjusts to compensate this change.

2 Revision history

Table 3. Document revision history

Date	Revision	Changes
04-May-2009	1	Initial release.
12-Sep-2013	2	Replaced “STM8T and STM8TS” with “STM8T14x”. Updated *Introduction*. Updated *Figure 2: Depiction of channel charge-transfer hardware*. Added Table Of Content (TOC), List Of Tables (LOT), List Of Figures (LOF). Added *Table 1: Applicable products*. Updated titles: *Figure 1: Coupling with hand increases the capacitance of the sensing electrode*. *Figure 7: Non-ideal transfer cycles*. *Figure 8: Charge cycle resulting from non-ideal transfer cycles*. Transfer rate updated as 250 kHz in *Section 1.3: Transfer rate*.