AN2970
Application note

Principles of capacitive touch and proximity sensing technology

The objective of this document is to present the principles of capacitive sensing and charge transfer used in STMicroelectronics STM8T and STM8TS capacitive sensors. All devices can be configured in touch or proximity sensing.

1 Capacitive sensing overview

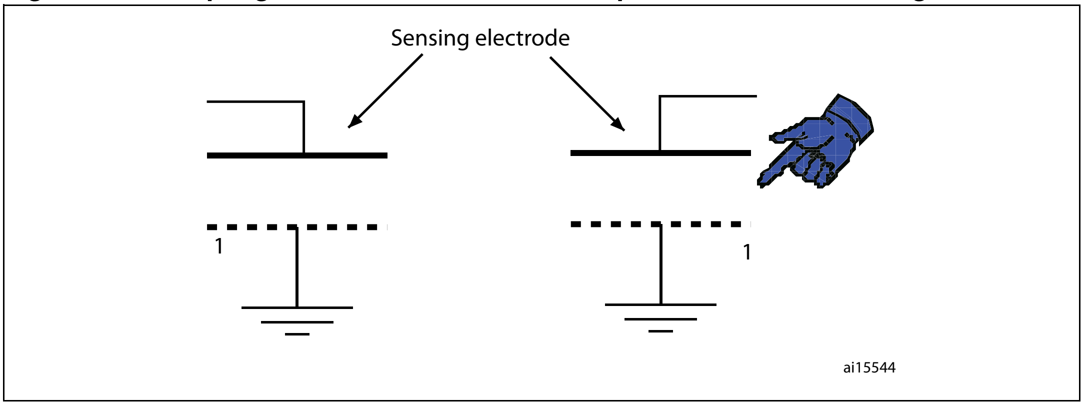
1.1 Sensing electrode capacitance

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 electrode is formed by the surrounding area (virtual ground reference, labelled 1 in *Figure 1*).

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.

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



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1.2 Principles of charge transfer

The sensing electrode is connected to the CX pin of the STM8T or STM8TS 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 transferred to a reference 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 (approximately 20% of V_{DD}). 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 3* and *Table 1* 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

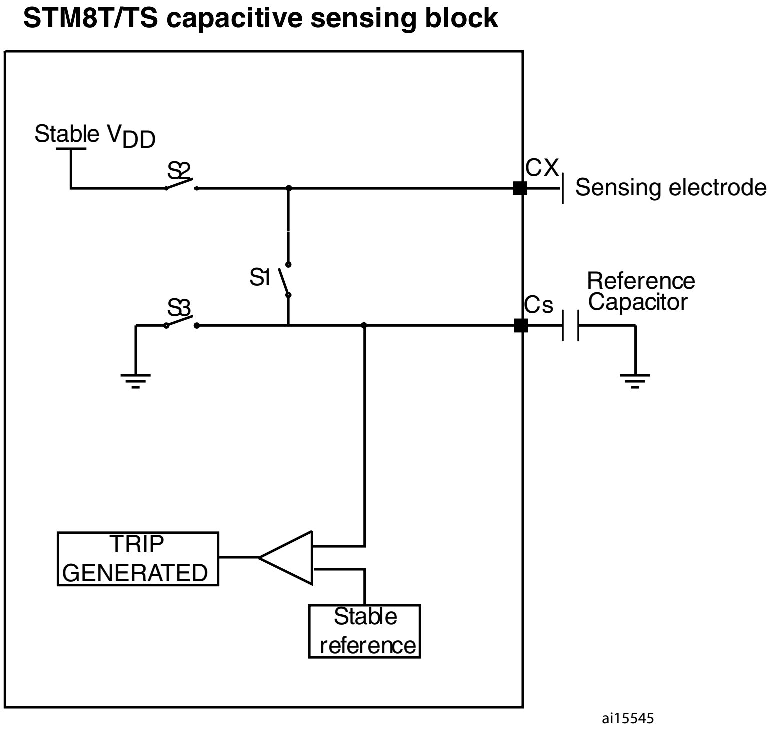


Table 1. Charge transfer sequence (1)

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.

Figure 3 and *Figure 4* show the evolution of the C_X voltage during one and five charge transfer sequences, respectively. 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). The charge cycles can be probed from the CS pin. It is graphically illustrated in *Figure 5*. Refer to *Section 1.4: C_S capacitor* for details on how to select C_S capacitors.

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.

Figure 3. Voltage across C_X over a full charge transfer sequence

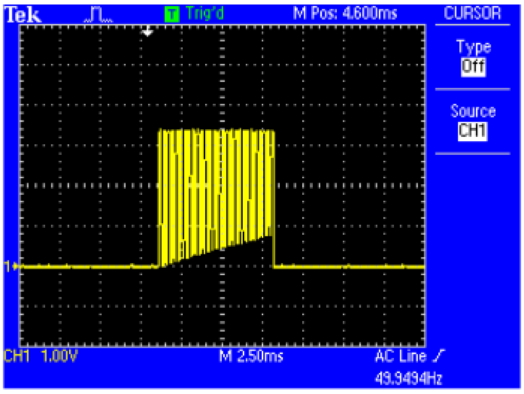


Figure 4. Voltage across C_X over the first 5 charge transfers

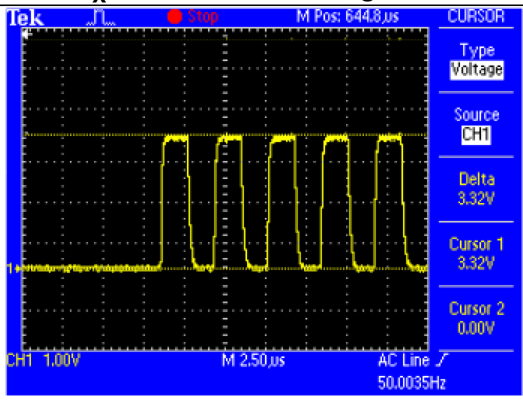
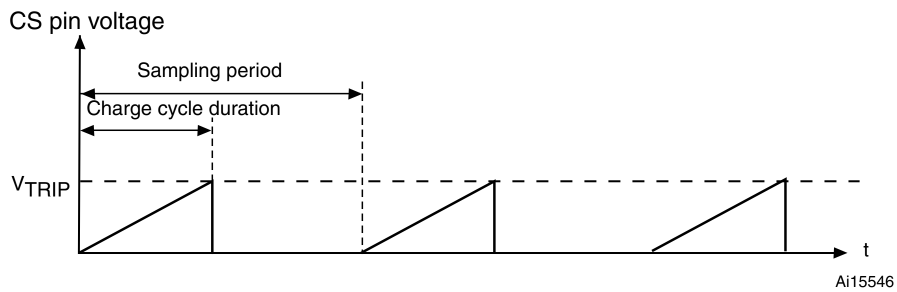


Figure 5. Charge cycle



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 or by the application software. It is recommended to modify the oscillator frequency for advanced designs only.

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 150 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 CX 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 4 and *Figure 6* show ideal charge cycles probed from the CX pin. In *Figure 4*, it can be noted that the sensing electrode charges up to V_{DD}, and that the charge cycle halts when V_{TRIP} is reached.

Figure 6. Ideal charge transfers

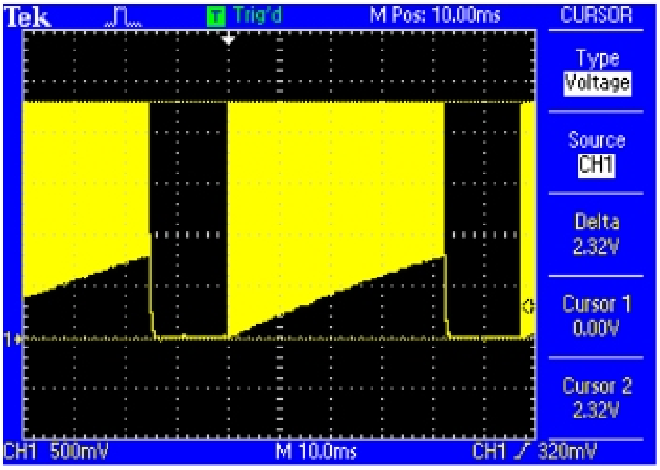


Figure 7 and *Figure 8* shows non-ideal charge transfers and the resulting charge cycle.

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 (oscillator frequency) or R_X.

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.*

Figure 7. Non-ideal charge transfers

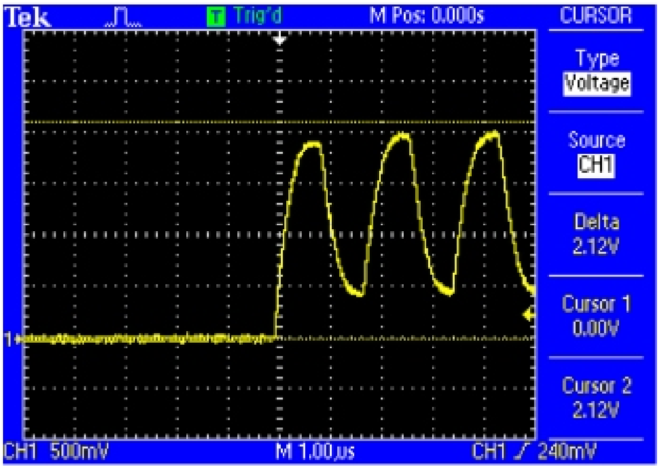
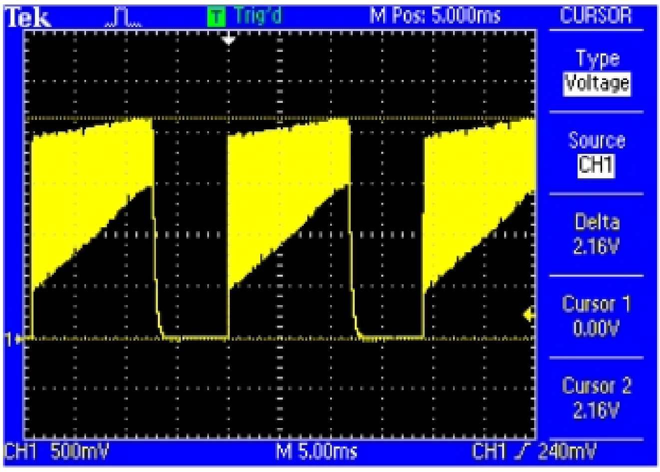


Figure 8. Charge cycle resulting from non-ideal charge transfers



1.4 C_S capacitor

The function of the C_S capacitor is to collect the charge from the sensing electrode. It also influences the sensitivity of the system. A bigger C_S capacitor will ensure that the C_X capacitance is computed with a higher resolution. This will increase the sensitivity of the device.

When the STM8T and STM8TS device is powered from an AC supply voltage, the charge cycle is always synchronized with the positive zero crossings (ZC) of the AC voltage. The charge cycle starts after the zero crossing when the device is ready. The ZC feature is not available on all devices.

When the device is powered from a DC supply voltage, most devices generate an internal 50 Hz sampling frequency ($f_{SAMPLING}$) and synchronize the charge cycles with this frequency (see *Section 1.3: Transfer rate*).

The minimum and maximum charge cycle duration ($t_{SAMPLING}$) is determined by the following:

- Minimum charge cycle duration: every charge cycle must consist of at least 32 charge transfers.
- Maximum charge cycle duration: no more than 214 charge transfers are allowed in a charge cycle.

A larger sensing electrode surface will require a larger C_S capacitor and vice versa. Since the C_X capacitance is normally unknown, it is easier to design the C_S capacitor using a trial-and-error method. The C_S capacitor typically ranges from 10 nF to 1 µF.

It can be noted that the bigger the sensing electrode, the more likely it is for noise to couple into the system. This could influence the sensitivity setting chosen for the device.

2 Revision history

Table 2. Document revision history

Date	Revision	Changes
04-May-2009	1	Initial release.