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STM8T141

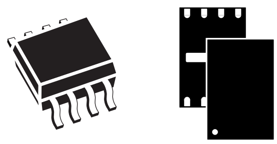
Single-channel capacitive sensor for touch or proximity detection with shielded sensing electrode

Features

- Touch or proximity detection (a few centimeters)
- Built-in driven shield function:
  - Enhance proximity detection
  - Protect sensing electrode from noise interference
- Ultra-low power modes suitable for battery applications (11 µA in extreme low power mode)
- On-chip integrated voltage regulator
- Environment compensation filter
- User programmable options include:
  - Four detection thresholds
  - Four output modes
  - Four low power modes
  - Reference freeze timeout
- Minimal external components

Applications

- Consumer electronics
- Power-critical and battery applications
  - Wake-up on proximity
- Home and office appliances
  - Find-in-the-dark (FITD) applications using proximity detection
  - Sanitary ware and white goods
- Flameproof human interface devices for use in hazardous environments



SO8 (narrow)

UFDFPN8 (2 x 3 mm)

Table 1. Device summary

Feature	STM8T141
Operating supply voltage	2.0 V to 5.5 V
Supported interface	Single key state output
Operating temperature	–40° to +85 °C
Packages	8-pin SO 8-pin UFDFPN

Contents

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1 Description

The STM8T141 is a ProxSense™ single-channel, fully integrated, charge-transfer, capacitive sensor that is designed to replace conventional electromechanical switches in cost-sensitive applications.

The STM8T141 is offered in 8-pin packages and is ideally suited for 1-button applications. It can be configured either in touch or proximity sensing mode for wake-up or backlighting on actuation.

The extremely low current consumption makes it an ideal solution for battery-powered applications.

The device features an internal voltage regulator to enhance detection sensitivity and stability.

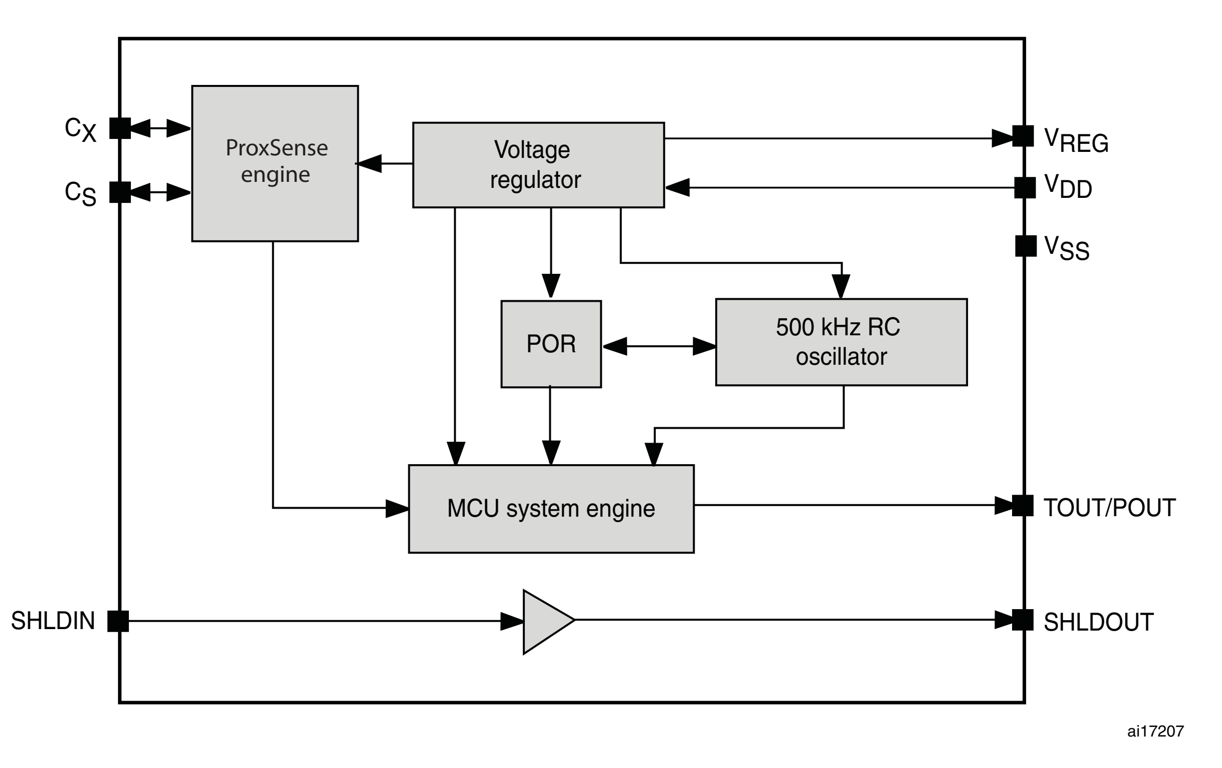
The STM8T141 touchpad can sense through almost any dielectric and can thereby contain the electronics in a sealed environment.

The STM8T141 also incorporates the advantages of using a driven shielding capability. This makes it possible to separate the sealed electronics from the sensing electrode. The shield feature enables the designer to protect part of the sensing element from unwanted environmental interference and enhances proximity detection when used with battery (DC) applications.

Note: ProxSense™ is a trademark of Azoteq.

2 Block diagram

Figure 1. STM8T141 block diagram



RC oscillator

The 500-kHz RC oscillator is an internal fixed frequency oscillator used to supply the clock to the MCU system engine.

Power-On-Reset (POR)

The POR generates a reset signal depending on the power supply level and the clock pulses received from the RC oscillator.

Voltage regulator

The voltage regulator has an internal comparison and feedback circuit that ensures the V_{REG} voltage is kept stable and constant. The regulator requires an external smoothing capacitor.

MCU system engine

The MCU system engine controls the capacitive sensing engine and processes touch and proximity detection signals.

ProxSense engine

The ProxSense engine circuitry employs a charge-transfer method to detect changes in capacitance.

3 Pin descriptions

Figure 2. S08 pinout

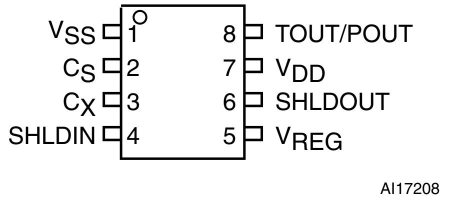


Figure 3. UFDFPN8 pinout

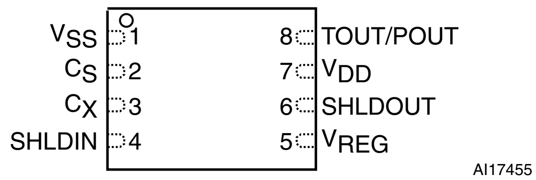


Table 2. STM8T141 pin descriptions

Pin no. (SO8 / UFDFPN8)	PIn type[1]	Pin name	Pin function
1	S	V_{SS}	Ground
2	SNS	C_S	Capacitive sensing channel pin to C_S[2]
3	SNS	C_X	Capacitive sensing channel pin to R_X
4	I	SHLDIN[3]	Shield input
5	S	V_{REG}	Internal voltage regulator output [4]
6	OD	SHLDOUT	Shield output
7	S	V_{DD}	Supply voltage
8	PP	TOUT/POUT	Touch/proximity[5] output (active high)

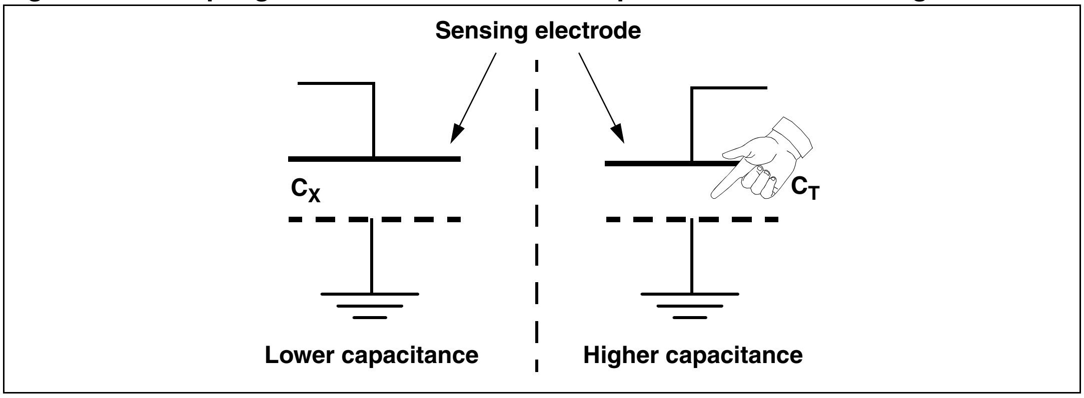
1. I: input pin, OD: open drain, PP: output push-pull pin, S: supply pin and SNS: capacitive sensing pin.
2. Use COG or NPO capacitor type.
3. If the active shield is unused, please connect this pin to V_{SS}.
4. Requires a low ESR, 1µF capacitor to ground. This output must not be used to power other devices.
5. Depending on the value of bits [1:0] of OPT0.

4 STM8T ProxSense technology

4.1 Capacitive sensing overview

A capacitance exists between any reference point and ground as long as they are electrically isolated. If this reference point is a sensing electrode, it can help 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 in *Figure 4*).

Figure 4. Coupling with hand increases the capacitance of the sensing electrode



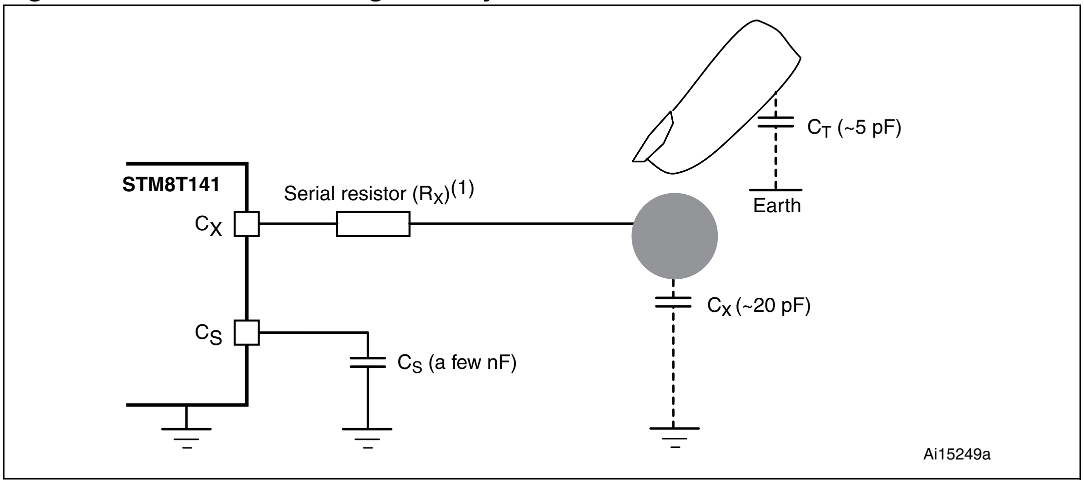
When a conductive object is brought into proximity of the sensing electrode, coupling appears between them, and the capacitance of the sensing electrode relative to ground increases. For example, a human hand raises the capacitance of the sensing electrode as it approaches it. Touching the dielectric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

4.2 Charge transfer acquisition principle

To measure changes in the electrode capacitance, STM8T devices employ bursts of charge-transfer cycles.

The measuring circuitry is connected to the C_X pin. It is composed of a serial resistor R_X plus the sensing electrode itself of equivalent capacitance C_X (see *Figure 5*). 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. The dielectric panel usually provides a high degree of isolation to prevent ESD discharge from reaching the STM8T touch sensing controller. Connecting the serial resistor (R_X) to the C_X pin improves ESD immunity even more.

Figure 5. STM8T measuring circuitry



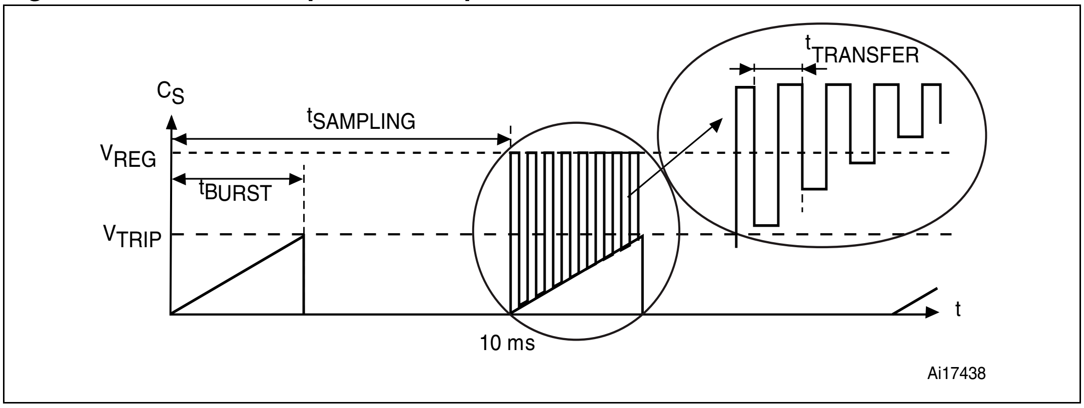
1. R_X must be placed as close as possible to the STM8T device.

The principle of charge transfer is to charge the electrode capacitance (C_X) using a stable power supply. When C_X is fully charged, part of the accumulated charge is transferred from C_X to an external sampling capacitance, referred to as C_S. The transfer cycle is repeated until the voltage across the sampling capacitor C_S reaches the end of acquisition reference voltage (V_{TRIP}). The change in the electrode capacitance is detected by measuring the number of transfer cycles composing a burst (see *Figure 6*).

Throughout this document the following naming conventions apply:

- The charge transfer period ($t_{TRANSFER}$) refers to the charging of C_X and the subsequent transfer of the charge to C_S.
- The burst cycle duration (t_{BURST}) is the time required to charge C_S to V_{TRIP}.
- The sampling period ($t_{SAMPLING}$) is the acquisition rate.

Figure 6. Conversion period examples



5 STM8T processing

The STM8T141 device is designed to ensure reliable operation whatever the environment and operating conditions. To achieve this high level of robustness, dedicated processing have been implemented:

- Signal and reference calculation
- Determining touch/proximity
- Self-calibration
- Environmental compensation filter
- Debounce filter

5.1 Signal and reference calculation

Capacitive touch or proximity sensing is a technique based on detecting the electrode capacitance change when someone is in proximity of the sensing electrode. The capacitance change, induced by the presence of a finger or a hand in the device detection area, is sensed by the variation in the number of charge transfer pulses composing the burst. The charge transfer pulse number, also called “signal” is compared to a reference to decide if there is a touch/proximity detection or not.

At power-up, a calibration sequence is performed to compute one reference value per capacitive sensing channel. The reference is extracted from 32 burst measurements. Then, the ECF takes care of its slow evolution over time.

To speed up the calibration process, the device is kept in normal mode whatever the low power mode selected. The device operates in the selected low power mode when the calibration process is completed.

5.2 Determining touch/proximity

The minimum difference between the reference and the signal necessary to report a touch/proximity is the detection threshold (D_{Th}). A time filtering, similar to the debouncing of the mechanical switches, is applied to avoid noise induced detections.

Four different detection threshold settings are available and selectable by option byte. The touch and sensitive touch levels are relative, which means the actual sensing distance is not influenced by the Cs capacitor. The two thresholds should be able to adapt to various surroundings and panel material or thickness. The proximity sensitivity thresholds are absolute. This implies that the detection distance increases with the Cs capacitor. It provides an easy way to tune the proximity sensing distance according to the application needs.

5.3 Environment compensation filter (ECF)

5.3.1 ECF principle

The capacitive sensing channel reference value increases or decreases according to environmental conditions such as temperature, power supply, moisture, and surrounding conductive objects. The STM8T141 includes a built-in digital infinite impulse response (IIR) filter capable of tracking slow changes in the environment called the Environment Compensation Filter (ECF). This is a first order digital low pass filter with a gain of one. The filter makes the reference follow slow changes of the signal while fast changes are recognized as a touch or proximity.

When a touch or proximity condition is detected, the corresponding capacitive sensing channel reference is frozen.

Figure 7. Environmental compensation filter (ECF) example 1

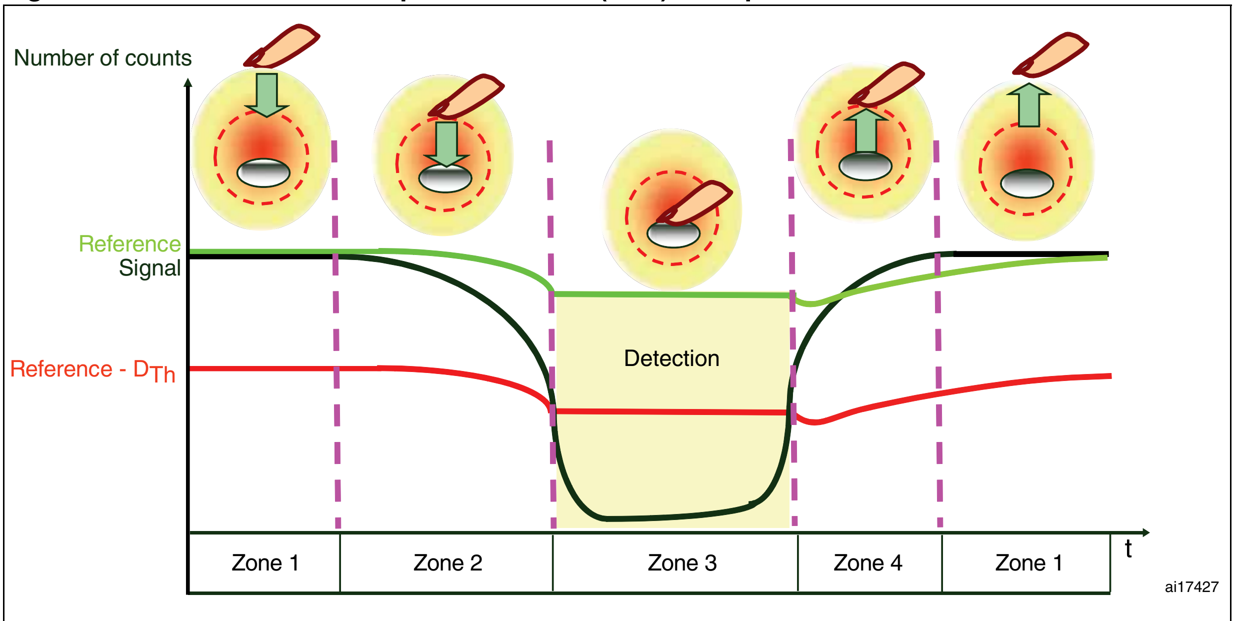


Table 3. Explanation of ECF example 1

	Zone 1	Zone 2	Zone 3	Zone 4
Event description	The object (finger) is outside the electrode field range. Electrode environment is stable	The object, is inside the electrode field range. It induces a signal change but, not large enough to cross the detection threshold (Dth). The reference adapts slowly to the object proximity.	The object comes inside the detection range before the reference compensates for its presence. A touch or proximity event is triggered because the signal level falls below the reference - D_{Th}.	The object exits from the electrode's detection range.
Detection state	No detection		Detection	No detection
ECF operation	Active		Halt	Active
Reference	Adapting		Frozen	Adapting

Figure 8. Environmental compensation filter (ECF) example 2

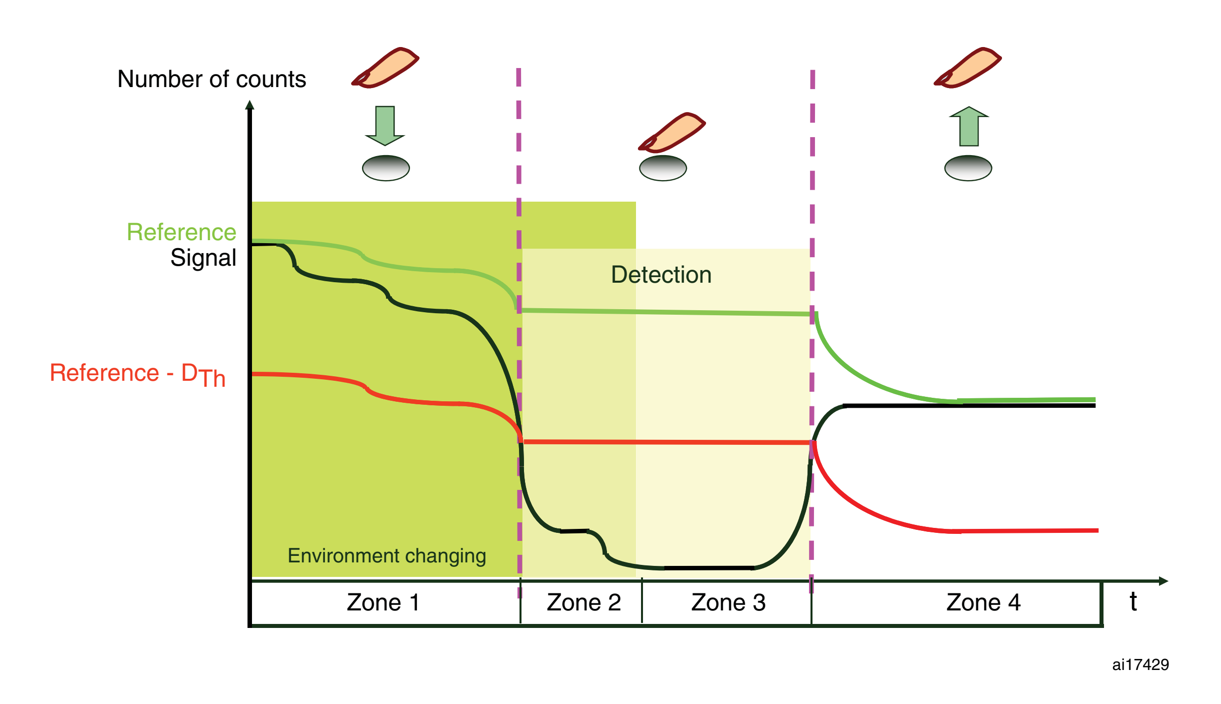


Table 4. Explanation of ECF example 2

	Zone 1	Zone 2	Zone 3	Zone 4
Event description	The system environment changes and the device adapts its reference according to this environment change.	An object (finger) is detected. The environment continues to change.	The object is still under detection but, the environment is not changing anymore.	The object exits from detection.
Detection operation	No detection	Detection		No detection
ECF state	Active	Halt		Active
Reference	Adapting	Frozen		Adapting
Surrounding environment	Changing		Stable	

5.3.2 Reference freeze timeout

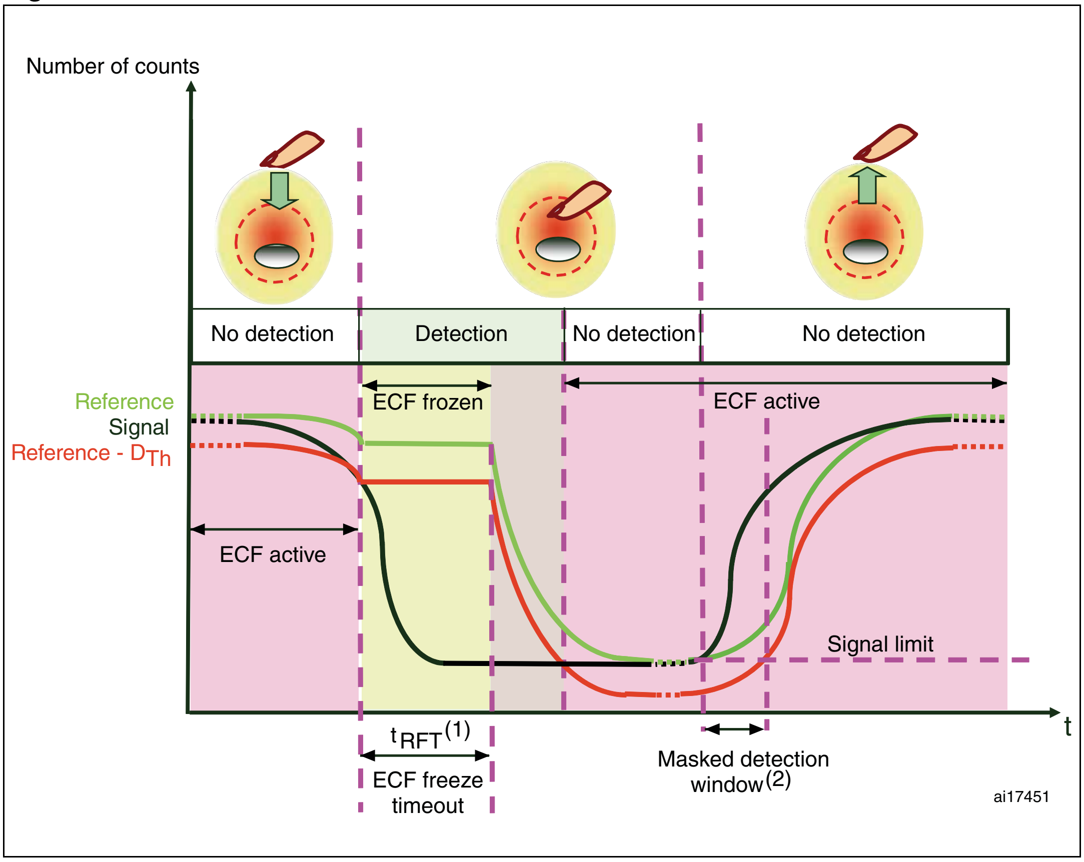
To prevent an object under detection from influencing the reference value, the ECF is halted as soon as a detection happens. Consequently, the reference is frozen.

In order to be able to recover from a sudden environment change, the reference freeze ends after a maximum programmable delay called the “reference freeze timeout” (t_{RFT}).

When a detection lasts longer than the t_{RFT}, the ECF is enabled again and the reference moves toward the detection signal. After a short period of time, the difference between the signal and the reference become smaller than the detection threshold and the device reports no detection.

Note: Reference freeze timeout was incorrectly called “recalibration timeout” in previous versions of this document.

Figure 9. Reference freeze timeout



1. See max values of t_{RFT} in *Table 16: General capacitive sensing characteristics*.
2. Between the moment when the finger is removed from the sensor and the instant the reference - D_{Th} curve crosses the signal limit, the device is unable to detect a new touch. This delay is called “masked detection window”. It depends on the environmental change or object signal variation speed inside the electrode’s field. The detection threshold also impacts the masked detection window.

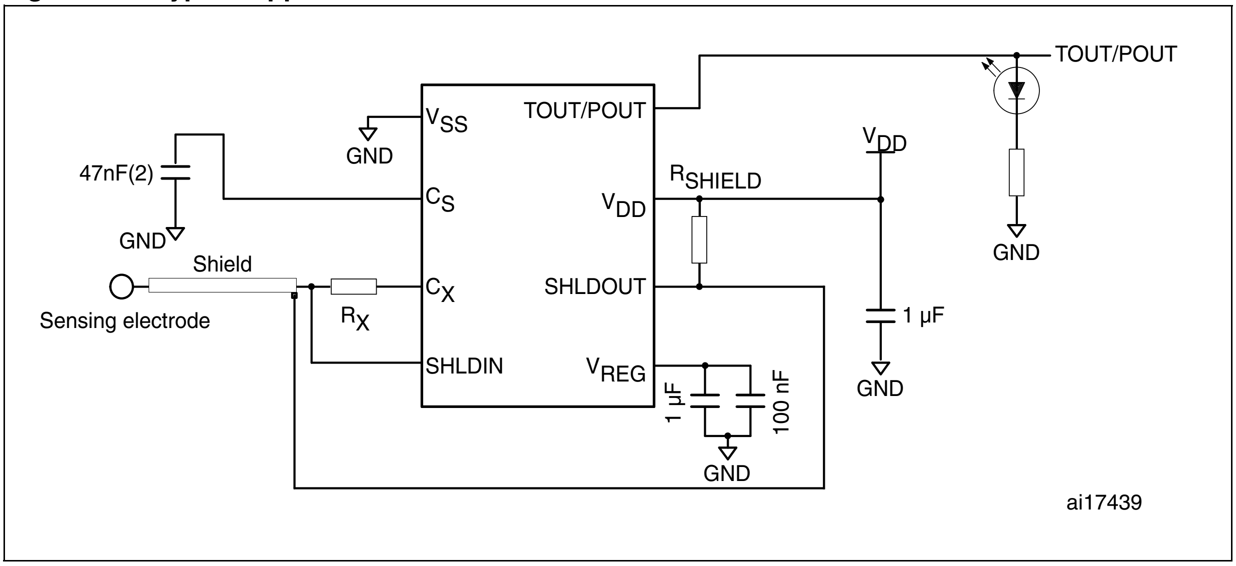
5.3.3 Debounce filter

The debounce filter mechanism works together with the ECF to dramatically reduce the effects of noise on the touch and proximity detection. Debouncing is applied to acquisition samples to filter undesired abrupt changes.

The number of consecutive detection debounce count (DDC) and end of detection debounce count (EDDC) needed to identify a proximity/touch detection are defined in *Section 9.5: Capacitive sensing characteristics on page 33*.

6 Typical application diagram

Figure 10. Typical application shematic

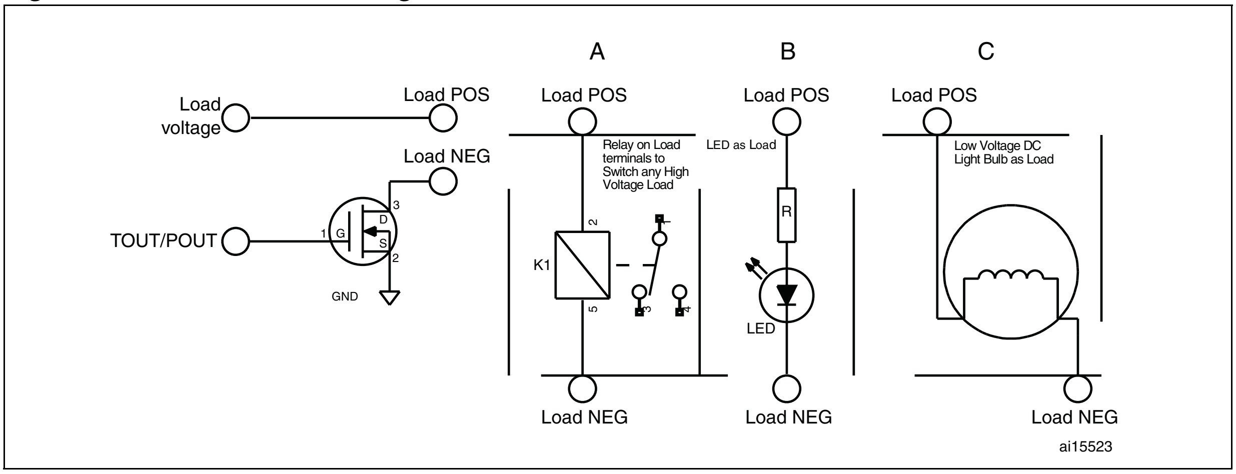


1. If the active shield is not used, The SHLDIN pin must be grounded, SHLDOUT should be left unconnected, and R_{SHIELD} can be removed.
2. Use COG or NPO or higher grade capacitor.

The smaller the value of the R_{SHIELD} resistor, the better its effect but, the greater the device consumption.

Pin TOUT/POUT can directly drive a HV FET (as shown in *Figure 11*) that, in turn, can drive any load.

Figure 11. Possible load configurations



A touch or proximity detection is defined as an actuation (high = logical '1' and low = logical '0').

7 Device operation

The STM8T141 can be configured through a set of selectable one-time programmable (OTP) option bytes. These options can be used in their default (unconfigured) state or set for specific applications. For large orders, preconfigured devices are available (please refer to *Section 11: Ordering information*).

The STM8T141 can be configured to act as a touch or proximity detection device. A number of other options are also user programmable, including:

- Four output modes
  - Active mode
  - Toggle mode
  - 3-second Latch mode
  - 30-second Latch mode
- TOUT/POUT output mode selection
- Four detection thresholds
  - Two for touch detection
  - Two for proximity detection
- Four power modes
  - Normal power mode
  - Three low power modes
- Reference freeze timeout

7.1 Option byte description

A set of tools is supplied by STMicroelectronics to program the user OTP options for prototyping purposes. Please refer to *Section 12: STM8T141 development tools* for more details.

Note: Devices that are not yet programmed ("blank" devices) are delivered cleared (at value '0') for all bits.

Table 5. Option bytes

<table>
<tr><th rowspan="2">Option byte no.</th><th colspan="8">Option bits</th><th rowspan="2">Factory default setting</th></tr>
<tr><th>Bit 7</th><th>Bit 6</th><th>Bit 5</th><th>Bit 4</th><th>Bit 3</th><th>Bit 2</th><th>Bit 1</th><th>Bit 0</th></tr>
<tr><td>OPT1</td><td colspan="5">Reserved</td><td>Sampling period</td><td>Charge transfer frequency</td><td>Reserved</td><td>0xX0</td></tr>
<tr><td>OPT0</td><td colspan="2">Power mode</td><td colspan="2">Detection threshold</td><td colspan="2">Reference freeze timeout</td><td colspan="2">TOUT/POUT output mode</td><td>0x00</td></tr>
</table>

The user options allow the STM8T141 to be customized for each specific application. Default values for the oscillator, conversion rate ($t_{SAMPLING}$), filter freeze and device reset settings should be used initially for first designs.

Table 6. **Option byte description**

Option byte no.	Description
OPT1	**Bits [7:3]**: *Reserved*
	Bit 2: *Sampling period* ($t_{SAMPLING}$)(*Section 7.6: Sampling period*) 0: Conversion period is 20 ms 1: Conversion period is 10 ms
	Bit 1: *Charge transfer frequency* ($f_{TRANSFER}$)(*Section 7.5: Charge transfer frequency*) 0: 125 kHz 1: 250 kHz
	Bit 0: *Reserved*
OPT0	**Bits [7:6]**: *Power mode* (*Section 7.4: Power modes*) 00: Low Power mode with Zoom 01: Normal Power mode 10: Extreme Low Power mode with Zoom 11: Extreme Low Power mode
	Bits [5:4]: *Detection threshold* (*Section 7.3: Detection threshold*) 00: Standard proximity 01: Standard touch 10: Sensitive proximity 11: Sensitive touch
	Bits [3:2]: *Reference freeze timeout* (*Section 5.3.2: Reference freeze timeout*) 00: 15-second reference freeze timeout 01: 45-second reference freeze timeout 10: Reserved 11: Infinite reference freeze
	Bits [1:0]: *TOUT/POUT output mode* (*Section 7.2: TOUT/POUT output mode*) 00: Active mode 01: Toggle mode 10: 3-second Latch mode 11: 30-second Latch mode

7.2 TOUT/POUT output mode

Four output modes are available on the STM8T141:

- Active mode
- Toggle mode
- 3-second Latch mode
- 30-second Latch mode

For each output operation described, touch or proximity detection can be used. Upon the detection of either of these actions, the TOUT/POUT pin will latch high, otherwise the TOUT/POUT pin stays low. The detailed working of each user interface is described below.

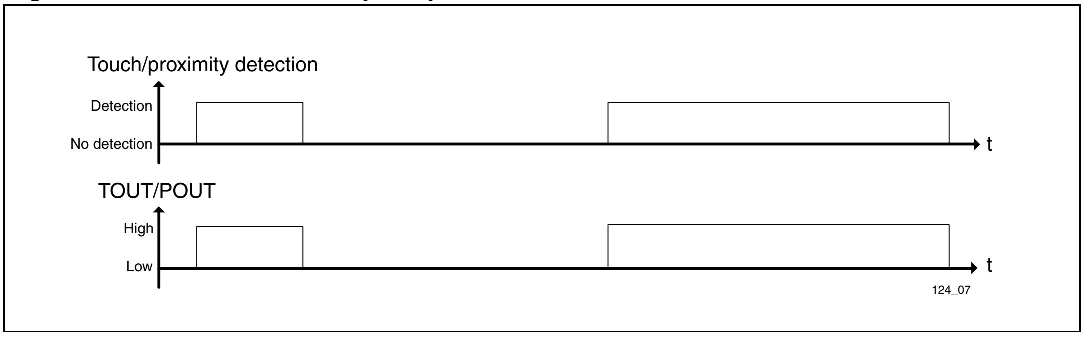
The TOUT/POUT pin is active high, and can source enough current to directly drive a LED. The pin is sourced from V_{DD} when active. The TOUT/POUT pin always goes high for a minimum time of t_{HIGH}. For more information, please refer to *Section 9: Electrical characteristics*.

Bits [1:0] of option byte OPT0 are used to select the correct output mode.

7.2.1 Active

Upon the detection of an actuation, the condition of the TOUT/POUT pin will change to high and stay high for as long as the touch or proximity detection condition occurs. *Figure 12* illustrates this output operation.

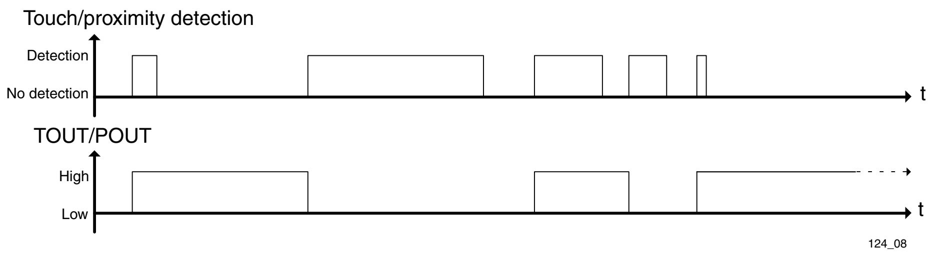
Figure 12. Active mode output operation



7.2.2 Toggle

Upon the detection of an actuation, the TOUT/POUT pin will toggle between high and low. Thus if TOUT/POUT is low, an actuation will change it to high, and also if TOUT/POUT is high, an actuation will change it to low. *Figure 13* illustrates this output operation.

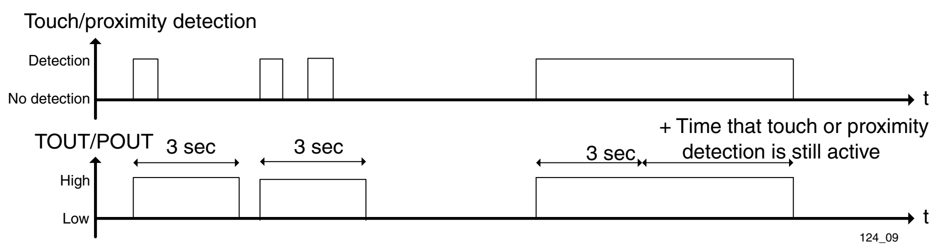
Figure 13. Toggle mode output operation



7.2.3 3-second latch

Upon the detection of an actuation the TOUT/POUT pin will latch high for 3 seconds minimum. If the actuation occurs for longer than 3 seconds, the TOUT/POUT pin will stay high and will only go low when the actuation stops.

Figure 14. 3-second latch mode output operation

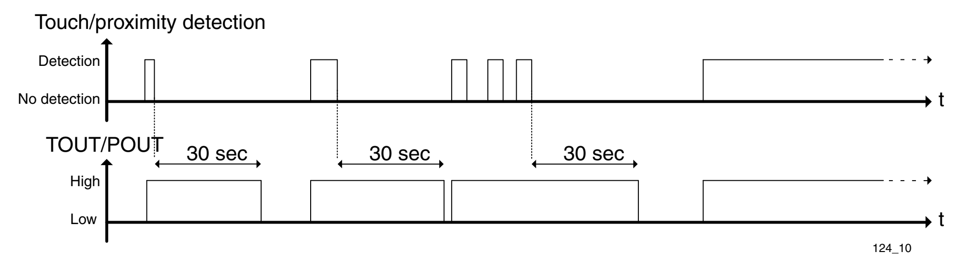


7.2.4 30-second latch

Upon the detection of an actuation, the TOUT/POUT pin will latch high. After 30 seconds from when the actuation stops, the TOUT/POUT pin will go low.

If the TOUT/POUT pin is high and another actuation occur before the 30 seconds has expired, the counter will reset and only 30 seconds after the new actuation has stopped, will the TOUT/POUT pin go low. *Figure 15* illustrates this output operation.

Figure 15. 30-second latch mode output operation



7.3 Detection threshold

The user has a choice between four detection threshold levels (D_{Th}) at which the touch or proximity detection condition is triggered. This depends on which threshold configuration is selected. See *Table 7* for more details regarding the detection threshold selections.

Bits [5:4] of option byte OPT0 are used to select the correct detection threshold levels.

Table 7. Detection thresholds

Sensitivity	D_{Th} setting	Description
Most sensitive	Sensitive proximity threshold	Proximity for battery-powered applications.
↑	Standard proximity threshold	Proximity with good ground. Contact through 3 mm acrylic glass and no ground.
	Sensitive touch threshold	Contact through thin acrylic glass with battery application.
Least sensitive	Standard touch threshold	Contact through thin dielectric with good ground.

7.4 Power modes

The STM8T141 device offers four power modes. The low power modes are specifically designed for battery applications:

- Normal Power mode
- Low Power mode with Zoom
- Extreme Low Power mode with Zoom
- Extreme Low Power mode

Burst cycles can occur either every 10 ms or 20 ms according to the selected sampling period ($t_{SAMPLING}$). By selecting low power modes, extra delays are interlaced between bursts. This improves the device current consumption at the expense of the response time.

Bits [7:6] of option byte OPT0 are used to select the correct power mode.

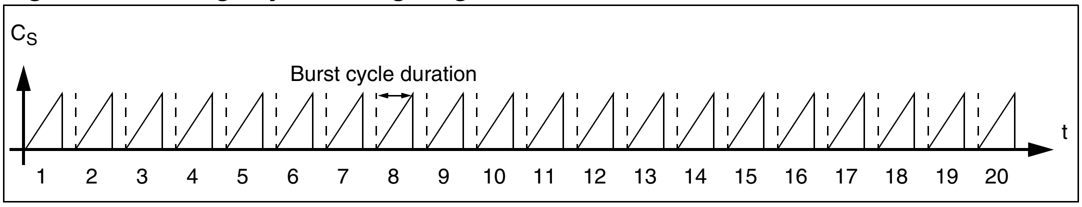
Table 8. Low power period according to selected power mode

Power mode	Condition	t_{LP} value
Normal Power mode		0
Low Power mode with Zoom	Touch or proximity detection	0
	Untouched	4 x $t_{SAMPLING}$
Extreme Low Power mode with Zoom	Touch or proximity detection	0
	Untouched	16 x $t_{SAMPLING}$
Extreme Low Power mode		16 x $t_{SAMPLING}$

7.4.1 Normal Power mode

When in Normal Power mode, burst cycles occur at the rate of $t_{SAMPLING}$. No extra delays are added between burst cycles (*Figure 16*).

Figure 16. Charge cycle timing diagram in Normal Power mode

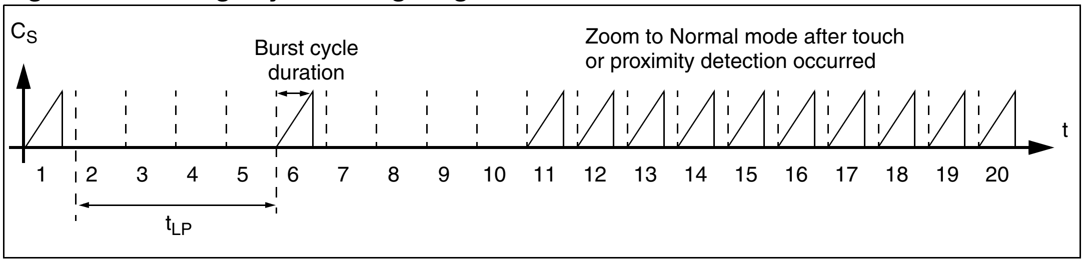


7.4.2 Low Power mode with Zoom

With the STM8T141 in Low Power mode with Zoom, burst cycles occur every 5th $t_{SAMPLING}$ period (or 20% of the Normal Power mode).

Once activity is detected, the STM8T141 device wakes up from Low Power mode with Zoom to Normal Power mode with charge cycles occurring every $t_{SAMPLING}$ period. The device will return to Low Power mode after an end of low power period (t_{ELP}) when no touch or proximity detection conditions are detected. This enables the device to reduce power consumption when not in use, and still have a sufficient response time when needed (*Figure 17*).

Figure 17. Charge cycle timing diagram in Low Power mode with Zoom

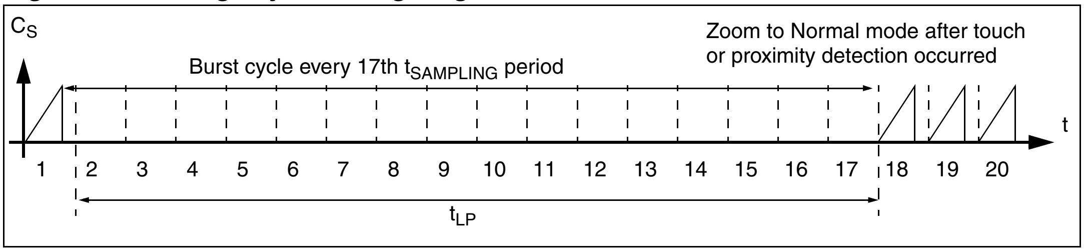


7.4.3 Extreme Low Power mode with Zoom

With the STM8T141 in Extreme Low Power Mode with Zoom, burst cycles only occur every 17th $t_{SAMPLING}$ period (or 5.88% of the Normal Power mode).

Once activity is detected, the STM8T141 device wakes up from Extreme Low Power mode and Zoom to Normal Power mode with charge cycles occurring every $t_{SAMPLING}$. The device will return to Low Power mode after an end of low power period (t_{ELP}) when no touch or proximity detection conditions are detected. This enables the device to reduce power consumption when not in use and still have a sufficient response time when needed (*Figure 18*).

Figure 18. Charge cycle timing diagram in Extreme Low Power mode with Zoom

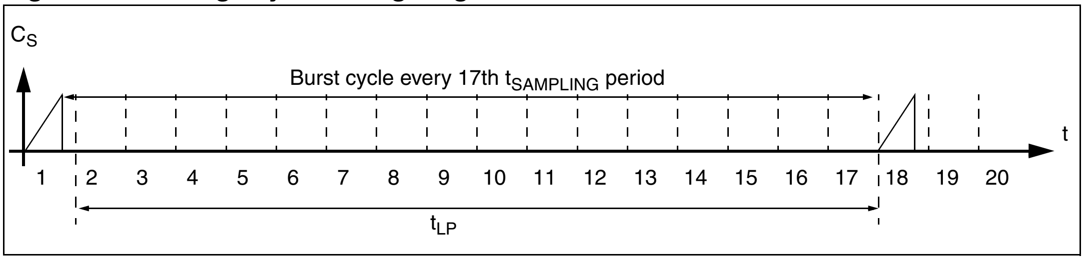


7.4.4 Extreme Low Power mode

With the STM8T141 in Extreme Low Power mode, burst cycles only occur every 17th $t_{SAMPLING}$ period (or 5.88% of the Normal Power mode), thus adding 16 extra delays of $t_{SAMPLING}$ between charge cycles to conserve power.

This reduces the amount of burst cycles in Extreme Low Power mode even more than Low Power mode which in turn saves even more power but comes at the expense of a higher system response time (*Figure 19*).

Figure 19. Charge cycle timing diagram in Extreme Low Power mode



7.5 Charge transfer frequency

The STM8T141 offers two charge transfer frequencies. The charge transfer frequency must be adjusted depending on the C_S capacitor. The charge transfer frequency may need to be raised to 250 kHz in order to reduce t_{BURST} when the C_S capacitance is large.

- 125 kHz
- 250 kHz

Bit 1 of option byte OPT1 is used to select the correct charge transfer frequency.

7.6 Sampling period

The default sampling period ($t_{SAMPLING}$) is configurable in order to allow different compromises between power consumption and conversion rates:

- 20-ms sampling rate to reduce average power consumption
- 10-ms sampling rate to increase detection response time

When using a faster sampling rate ($t_{SAMPLING}$ = 10 ms), all the timing values of the Power modes will occur at twice the speed.

BIt 2 of option byte OPT1 is used to select the correct conversion period.