Overview of Capacitive Touch and Proximity Sensing Technology

1. Sense Plate Capacitance

![Diagram](https://via.placeholder.com/150)

Figure 1: Coupling with the human hand will increase the capacitance of the sense plate.

There exists a capacitance between any reference point relative to ground, as long as electrical isolation exists between them. If this reference point is a sensing plate, it helps to think of it as a capacitor. The positive plate of the capacitor is the sensing plate, and the negative plate is formed by the surrounding area (virtual ground reference, labelled 1 in Figure 1).

When an object is brought into proximity of the sensing plate, there will be increased coupling between the two and the capacitance of the sense plate, relative to ground, will increase. For example, a human hand will increase the sense plate capacitance as it approaches the sense plate. Touching the plate will increase the capacitance significantly.

The sense plate can be any electrically conductive object. This includes glass or perspex plates with a conductive surface, or the base of a metal desk lamp. The sense plate is connected to the CX Pin of all modules. The capacitance of the CX plate is referred to as $C_X$.

2. The Charge Transfer and Charge Cycle principles

To measure a change in $C_X$, the IQS Family employs the charge transfer method of capacitive sensing. Charge is continuously transferred from the $C_X$ capacitor into a charge collection reference capacitor, referred to as $C_S$, until the voltage on $C_S$ reaches $V_{TRIP}$.

Throughout this document the following applies when the capacitive sensing is mentioned: the transfer cycle refers to the charging of $C_X$ and transferring the charge to the $C_S$ capacitor. The Charge Cycle refers to process of charging $C_S$ to $V_{TRIP}$ using charge transfers.

A charge cycle is used to take a measurement of the capacitance of a sense antenna relative to earth at a specific time. This measurement is referred to as a current sample (CS) measurement.

The Charge Cycles can be probed from the CS pin on most IQS IC’s and is graphically illustrated in Figure 2.

![Figure 2 Charge Cycle](https://via.placeholder.com/150)

3. Long Term Average (LTA)

All ProxSense™ ICs have a built-in long term averaging filter for each sensing channel, which is capable of intelligently tracking very slow changes in the environment. This is the dynamic reference value of a channel, and is referred to as the LTA.

The filter calculates the average value of the current samples (CS) measurements. When the difference between CS and LTA exceeds $C_A$, an activity is recorded, and a response is generated (this response can be a pin changing polarity / data outputted to another device via a communication protocol). The LTA filter halts for $T_{HALT}$.

How the filter works: With the detection of a user proximity, the LTA filter will freeze (reference value is kept) for $T_{HALT}$. If a activity (proximity/touch) is maintained for $1C_A$ determined by IC threshold setting
longer than \( T_{\text{HALT}} \), the system will time-out. After this time-out the LTA filter (reference value) will start to recalibrate the system to this condition, causing the response that the IC had to the activity to reset. Sensitivity will be restored after the activity is ended and the system is allowed to calibrate to the undisturbed sensing environment.

\( T_{\text{HALT}} \) is user configurable in different manners for different ProxSense™ ICs.

4. \( C_S \) Capacitors

External \( C_S \) capacitors are only available on the IQS123, IQS124, IQS125, IQS126, IQS240, IQS221, IQS222 and IQS410 ICs. On all other ICs, please refer to Section 7. ICl.

The function of the reference \( C_S \) capacitor is to collect the charge from the sensing plate. It also influences the sensitivity of the system.

The charge cycle duration refers to the time needed to complete one \( C_S \) charge cycle, when no activity (proximity or touch) occurs (thus the longest duration of a charge cycle with the current system parameters). See Figure 1 for graphical clarification.

A bigger \( C_S \) capacitor will ensure that the \( C_X \) capacitance is computed with more resolution. This will increase the sensitivity of the device, but also the susceptibility to noise.

The minimum and maximum charge cycle duration is determined by the following.

1. Minimum – every charge cycle must consist of at least 32 charge transfers.
2. Maximum – no more than \( 2^{14} \) charge transfers are allowed in a charge cycle.

A larger sense plate surface will require a larger \( C_S \) capacitor and vice versa. Since the \( C_X \) capacitance is normally unknown, it is easiest to design the \( C_S \) capacitor using a trial-and-error method. The \( C_S \) capacitor will typically be ranged between 10nF to 1\( \mu \)F. It must be noted that the bigger the sense plate, the more likely it is for noise to couple into the system. This could influence the sensitivity setting chosen for the applicable device.

5. Sample Rate of Charge Cycles

The Sample Rate (also known as conversion rate\( (T_{\text{CONV}}) \)) can be set on most ProxSense™ ICs.

IQS123, IQS124, IQS125, IQS126, IQS240, IQS221:

\( T_{\text{CONV}} \) options include 10ms and 20ms. \( T_{\text{CONV}} \) gives an indication of the regularity of the \( C_S \) measurements taken.

Using \( T_{\text{CONV}} = 10\text{ms} \) increases the \( C_S \) measurements taken and has an increased response time of the system. See Figure 3 for a graphical illustration. Low Power modes will have an a longer sampling time, and decreased response time of the system.

![Figure 3: Conversion Rate (\( T_{\text{CONV}} \))](image)

If an AC supply is used, the charge cycle is always synchronized to the positive zero crossings (ZC) of the AC line voltage. (ZC only on IQS117, IQS120, IQS125 and IQS221) The charge cycle will start \( T_{\text{CHARGE}} \) after a zero crossing when the device is ready.

In DC mode, the IQS Family (except IQS125) generates an internal 50Hz reference \( (T_{\text{CONV}}) \) and synchronises the charge cycles to this reference.

6. ATI

6.1 Introduction

The latest range of ProxSense™ capacitive sensing IC’s (IQS127, IQS420, IQS440) features market leading technology incorporated to ensure the ultimate proximity detection distance and ease of implementation into new designs.
The Antenna Tuning Implementation (ATI) feature uses advance signal processing algorithms to optimise the hardware sensing circuits.

This section will provide application information on the topic of ATI and highlight the advantages gained by using this feature on ProxSense™ devices.

6.2 Background Information
Parasitic capacitance is the capacitance that exists between electronic components or conducting objects because of their proximity to each other. This capacitance is undesired for any proximity sensor using the surface capacitance method of sensing. This parasitic capacitance ($C_{\text{PARASITIC}}$) gets added to the capacitance of the sense plate ($C_{\text{SENSE_PLATE}}$), increasing the total capacitance of the sense plate environment ($C_{\text{ENVIRONMENT}}$) as depicted in Figure 4.

![Figure 4: Illustration of environmental capacitance](image)

The capacitance to an approaching hand ($C_{\text{HAND}}$) increases as the hand comes closer to the sense plate. $C_{\text{HAND}}$ gets compared to $C_{\text{ENVIRONMENT}}$ to determine if a proximity or touch condition exists. A smaller $C_{\text{ENVIRONMENT}}$ will yield a more sensitive sensor. The ATI algorithm controls $C_{\text{ENVIRONMENT}}$ and the proximity sensing distance can be increased considerably as depicted in Figure 6.

6.3 ATI Overview
As mentioned above, ground planes, PCB traces or large metal objects such as device enclosures increases the parasitic capacitance which in turn considerably decreases the device sensitivity. The ATI feature counters this undesirable effect, ensuring optimum proximity detecting distance under all circumstances as illustrated by Figure 5 and Figure 6 respectively.

Present capacitive sensing solutions in the market require the designer to change the size of the external sampling capacitor. This has limited benefit and may increase the noise susceptibility. With the ATI feature, this need no longer exists.

6.4 Summary
The advantages of ATI can be summarised as follows:

- Increased sensitivity
- Automatic sensitivity adjustment for various sense pads
- Easier to integrate into new designs
- Excellent proximity detection
- No external components or programming to adjust sensitivity

No ‘tuning’ of components, settings or layouts to achieve optimum sensitivity.
7. ICI

ICI is implemented into the new generation ProxSense™ devices, including the IQS127, IQS420, IQS440.

The Internal Capacitor Implementation (ICI) feature eliminates the need for any external sampling (Cs) capacitors. The Cs capacitor has now been integrated on-chip. This translates to a significant reduction in system cost, especially for the multi-channel devices where multiple Cs capacitors were required in the past.

For the single channel devices (IQS127), it is possible to realise a sensor with only the IC, provided you have a regulated supply. In mobile applications where size is of paramount importance, this is an extremely valuable feature.

Combined with the Antenna tuning Implementation (ATI), the designer does not need to change any external components to adjust the device sensitivity. The device senses the antenna environment and then automatically adjust the sensitivity for optimal results in most applications.

The ICI combined with the ATI offers designers using the ProxSense™ range of devices the following features:

- Reduced system cost
- Space saving
- No external sensitivity adjustment
- Lower component count
- More pin functions in a smaller package
- Higher immunity to external interference (RF, temperature)
- Automatic sensitivity adjustment

No problems associated with component ageing and drift.

8. Advanced Options

8.1 Reset Function

The Reset function is available on the IQS123, IQS124, IQS125 and IQS126 IC.

Setting this option will enable the IC to reset itself if activity persists for more than 60 seconds on the OUT pin. (POUT pin for IQS126.)
8.2 Oscillator (Transfer Rate)

The oscillator frequency can be set by resistors in the IQS117 and IQS120 IC’s (see datasheet) and chosen with fuse options in the IQS123, IQS124, IQS125, IQS126, IQS240 and IQS221 IC’s. (This is only used for advanced designs, otherwise left default.)

The oscillator is used to determine the rate at which the charge transfers occur. Maximum efficiency is achieved when enough time is allowed to fully charge \( C_X \) to \( V_{DD} \) and then completely transfer this charge to the \( C_S \) capacitor.

A transfer rate between 100 kHz and 250 kHz is a good choice under normal circumstances. (The default transfer rates are also in between these values.)

The series resistor \( R_X \) in the \( C_X \) charge path influences the transfer cycle negatively. This resistor helps with electrical isolation for the user from the sense plate and also provides extra ESD protection for the IC. Typically \( R_X \) is ranged between 1kΩ and 2kΩ.

Figure 7 and Figure 8 shows how the ideal sense plate voltage of a charge transfer and charge cycle should look. Notice that in Figure 7, the sense plate charges up to \( V_{DD} \). Also notice that the Charge Cycle halts when reaching \( V_{TRIP} \).

Figure 9 and Figure 10 show the sense plate voltage of non-ideal charge transfers and the resulting charge cycle. Notice in Figure 9 that the sense plate does not charge up to \( V_{DD} \), but to 2.12V instead. Comparing Figure 10 to Figure 8, the offset is due to the fraction of the sense plate charge not being transferred to the \( C_S \) capacitor. These problems can be corrected by either decreasing the transfer rate (oscillator frequency), or decreasing \( R_X \).

NOTE: Attaching a probe to the CX pin will increase the sense plate capacitance by a few Pico-farads, depending on the probe used. This will have an instant negative influence on the sensitivity of the system when it is attached. After a short while the system will adjust to accommodate this change.

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