ProxSense® IQS213 Datasheet

Multiple Swipe Function Capacitive Sensor IC with Variable User Interface and Advanced Auto-Off Features

Overview

Unparalleled Features

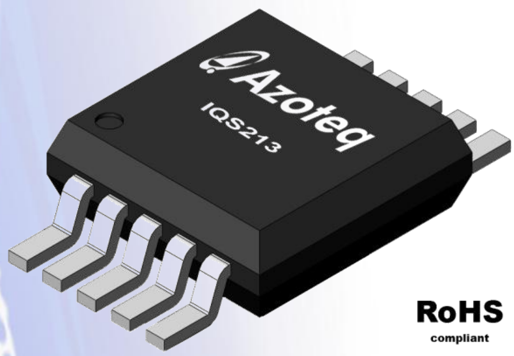
- Sub 4µA* current consumption (“Zero-Power” electronic switch)
- **I**nternal **C**apacitor **I**mplementation (ICI) – Reference capacitor on-chip
- **A**utomatic **T**uning **I**mplementation (**ATI**) - Automatic tuning for optimal operation in various environments & compensation against sensitivity reducing objects

The **IQS213** ProxSense® IC is a fully integrated two or three channel capacitive swipe function sensor with market leading sensitivity and automatic tuning of the sense electrodes. The **IQS213** provides a minimalist implementation requiring few external components, with programming options and an I^{2}C compatible interface that allow configuration for specialised applications.

Main Features

- 2 or 3 Channel (Mutual or Self Capacitance) Input device
- Swipe Function or Differentiated Touch and Distributed Proximity Electrode Implementation
- Variable User Interface with Adjustable Swipe Function Configuration
- Auto-Off and Advanced Auto-Off Warning Function
- Supply voltage: 1.8V to 3.6V
- Internal voltage regulator and reference capacitor
- Advanced on-chip digital signal processing
- OTP (One Time Programmable) options available
- I^{2}C compatible interface
- Low Power Modes (sub 4µA*)
- Variable Proximity & Touch Thresholds
- Small outline MSOP-10 package

MSOP-10



RoHS compliant

Applications

- Sanitary ware, toys, office equipment
- Flashlights, headlamps, keychain lights
- Splash- / waterproof devices
- Swipe-to-Unlock / Wake from Standby applications
- Replacement for electro-mechanical switches

Advantages

- Prevents accidental activation of conventional touch sensors
- Improved digital filtering to reduce external noise
- High immunity against aqueous substances
- Highly adjustable device with continuous data or event driven I^{2}C communication

Available options

T_A	MSOP10
-40°C to 85°C	IQS213

*Current consumption dependant on selected Low Power settings.

Contents

1 Functional Overview

The **IQS213** is a two or three channel capacitive proximity and touch sensor with variable swipe function configurations. Additional features include internal voltage regulation and reference capacitor (C_S), which enables cost efficient and minimal component designs. The device offers flexible design approaches by allowing the connection of two or three sense antennas in either surface or projected capacitance configurations.

For swipe function applications the device has a single logic output to indicate swipe actions and one complementary output for consecutive swipe/touch activities. The device can also be configured to operate with individual touch outputs, with an additional proximity output when implementing surface capacitance sense electrodes.

Full control by a master device is achieved by configuring the logic outputs in a serial data (I^2C) communication option on TO0 (SCL), TO1 (SDA) and TO2 (RDY).

The device automatically tracks slow varying environmental changes via various filters, detects noise and has an Automatic Tuning Implementation (**ATI**) to tune the device for optimal sensitivity.

1.1 Applicability

All specifications, except where specifically mentioned otherwise, provided by this datasheet are applicable to the following ranges:

- Temperature: -40°C to +85°C
- Supply voltage (V_{DDHI}): 1.8V to 3.6V

2 Analogue Functionality

For self-capacitance configured sense electrodes the analogue circuitry measures the capacitance of the sense antennas attached to the C_X pins through a charge transfer process that is periodically initiated by the digital circuitry. For mutual-capacitance configurations the capacitance is measured between the transmit (TX) and receive (CRX) pins. The measuring process is referred to as a conversion and consists of the discharging of C_S and C_X, the charging of C_X and then a series of charge transfers from C_X to C_S until a trip voltage is reached. The number of charge transfers required to reach the trip voltage is referred to as the Count (CS) Value.

The capacitance measurement circuitry makes use of an internal C_S and voltage reference (V_{REG}).

The analogue circuitry further provides functionality for:

- Power on reset (POR) detection.
- Brown out detection (BOD).

3 Digital Functionality

The digital processing functionality is responsible for:

- Device setup from OTP settings after POR.
- Management of BOD and WDT events.
- Initiation of conversions at the selected rate.
- Processing of CS and execution of algorithms.
- Monitoring and automatic execution of the ATI algorithm.
- Signal processing and digital filtering.
- Detection of PROX and TOUCH events.
- Managing outputs of the device.
- Managing serial communications.
- Manage programming of OTP options.

4 Hardware Configuration

4.1 IQS213 - MSOP10 Pin-Out

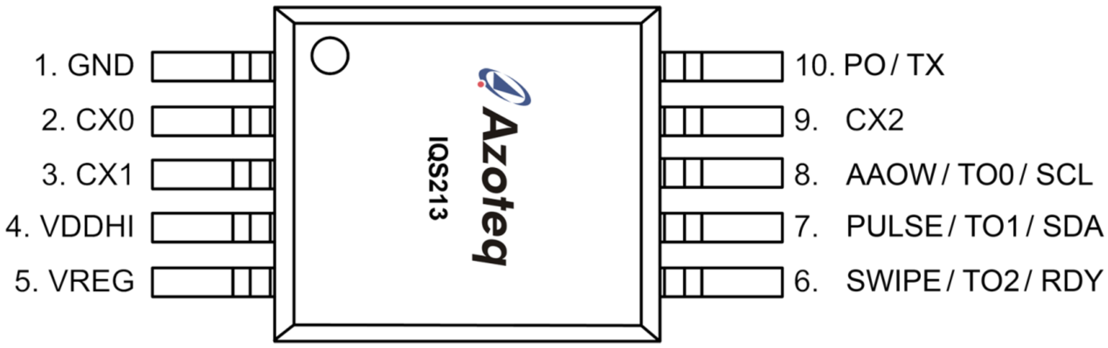


Figure 4.1 : Pin-out of IQS213 Surface package

Table 4.1 : IQS213 Pin-out

IQS213 Pin-out			
Pin	Name	Type	Function
1	GND	Supply Input	Ground Reference
2	CX0 (CRX0)	Analogue	Sense Electrode 0
3	CX1 (CRX1)	Analogue	Sense Electrode 1
4	VDDHI	Supply Input	Supply Voltage Input
5	VREG	Analogue Output	Internal Regulator Pin (Connect 1µF bypass capacitor)
6	SWIPE/TO2/RDY	Digital Output	Swipe Output/Touch Output/I²C: RDY Output
7	PULSE/T01/SDA	Digital Output	Pulse Output/Touch Output/I²C: SDA Output
8	AAOW/TO0/SCL	Digital I/O	Auto-Off Warning/Touch Output/I²C: SCL Input
9	CX2 (CRX2)	Analogue	Sense Electrode 2
10	PO/TX	Digital Output / Transmitter	Proximity Output/ Mutual Sense Electrode

4.2 Reference Design

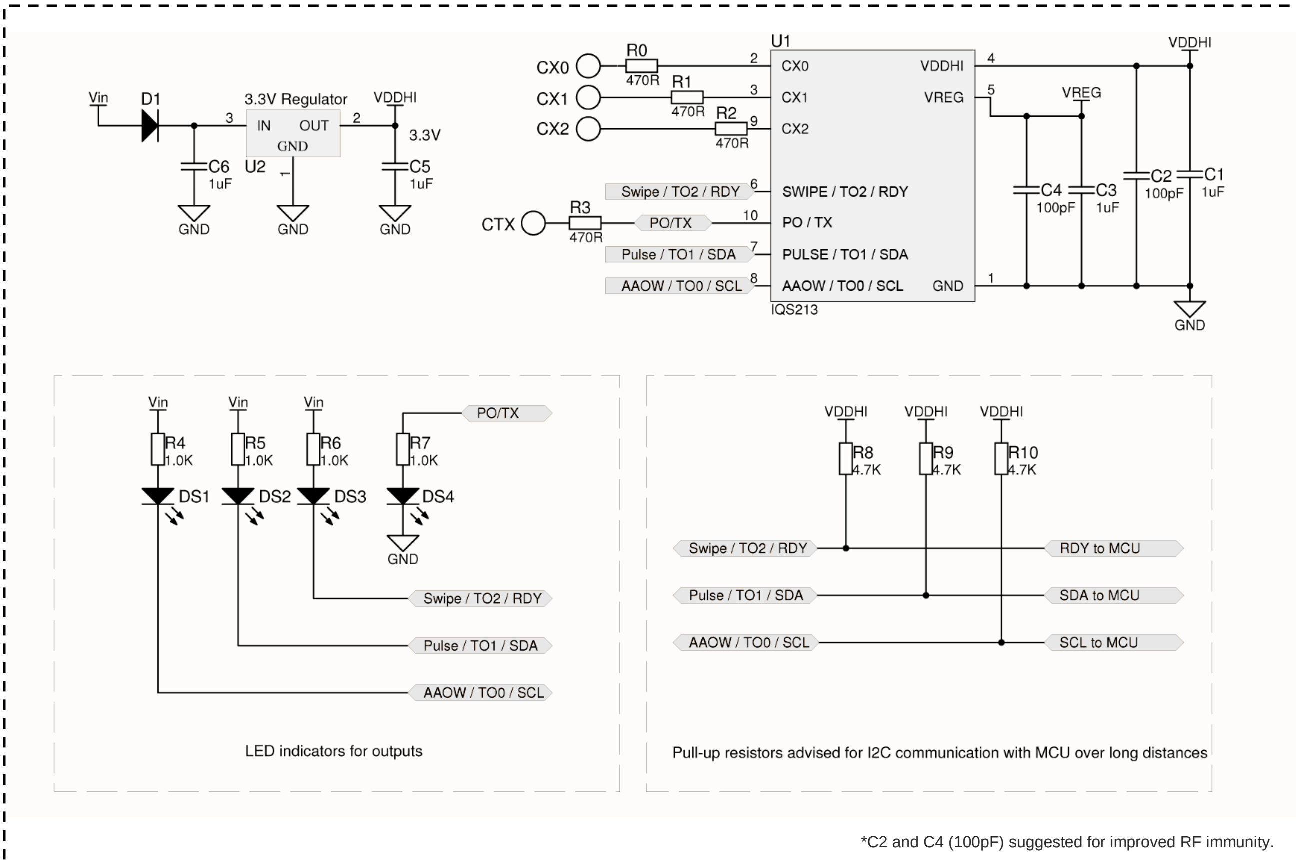


Figure 4.2 : IQS213 Reference Design

4.2.2 Power Supply and PCB Layout

Azoteq IC's provide a high level of on-chip hardware and software noise filtering and ESD protection (refer to application note "***AZD013 – ESD Overview***"). Designing PCB's with better noise immunity against EMI, FTB and ESD in mind, it is always advisable to keep the critical noise suppression components like the de-coupling capacitors and series resistors in **Figure 4.2** as close as possible to the IC. Always maintain a good ground connection and ground pour underneath the IC. For more guidelines please refer to the relevant application notes as mentioned in **Section 4.2.3**.

4.2.3 Design Rules for Harsh EMC Environments

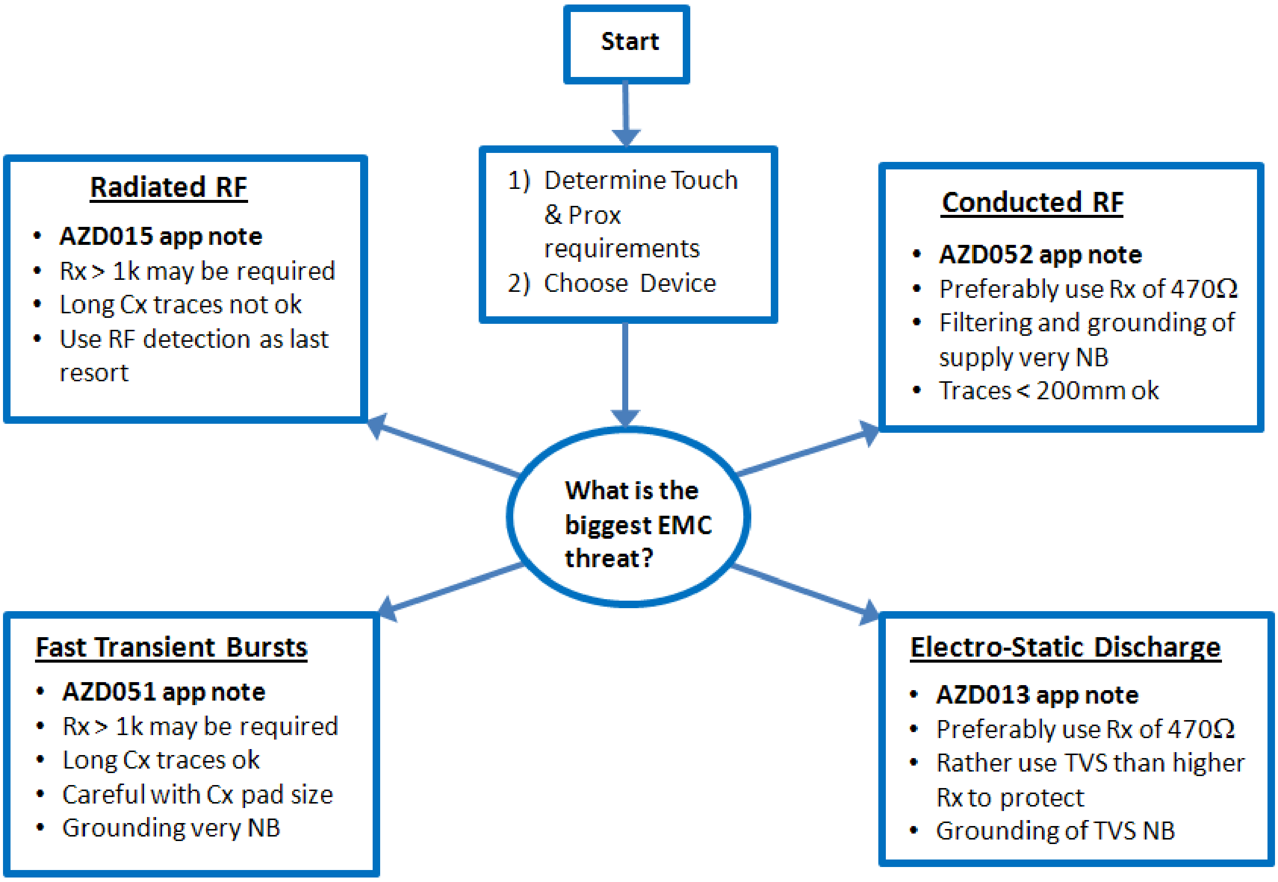


Figure 4.3 : EMC Design Rules

- ***Applicable application notes: AZD013, AZD015, AZD051, AZD052.***

4.2.4 High Sensitivity

Through patented design and advanced signal processing, the device is able to provide extremely high sensitivity to detect proximity. This enables designs to detect proximity at distances that cannot be equaled by most other products. When the device is used in environments where high levels of noise exist, a reduced proximity threshold is proposed to ensure reliable functioning of the sensor.

When the capacitance between the sense antenna and ground becomes too large the sensitivity of the device may be influenced. For more guidelines on layout, please refer to application note ***AZD008***, available on the Azoteq web page: www.azoteq.com.

5 User Configurable Options

The **IQS213** provides **O**ne **T**ime **P**rogrammable (OTP) user options (each option can be modified only once). However, the **IQS213** can enter streaming mode in a start-up state (*Test Mode*) where the OTP options can be configured and evaluated, before programming. The device is fully functional in the default (un-configured) state. OTP options are intended for specific applications.

The configuration of the device can be done on packaged devices or in-circuit. In-circuit configuration may be limited by values of external components chosen.

5.1 Configuring of Devices

Azoteq offers a Configuration Tool (CT210 or later) and associated software (USBProg.exe) that can be used to program the OTP user options for prototyping purposes. More details regarding the configuration of the device with the USBProg program can be found in *"**AZD007 - USBProg Overview**"* available on the Azoteq website.

Alternate programming solutions of the **IQS213** also exist. For further enquiries regarding this subject, please contact your local distributor or submit enquiries to Azoteq at: ProxSenseSupport@azoteq.com

5.2 User Selectable Configuration Options

Table 5.1 : User Selectable Configuration Options : Bank 0

bit7	Bank 0						bit0
THALT1	THALT0	LOGIC	FLOAT RX	MUTUAL	IC TYPE2	IC TYPE1	IC TYPE0

Bank0: bit7:6	**THALT1:THALT0: LTA Halt Time**	**Section 6.5**
	00 = 2.5s 01 = 20s 10 = 60s 11 = Never	
Bank0: bit5	**LOGIC: Output Logic**	**Section 6.4**
	0 = Active Low[1] 1 = Active High	
Bank0: bit4	**FLOAT RX: Float Sense Electrodes**	**Section 6.8**
	0 = No 1 = Yes	
Bank0: bit3	**MUTUAL: Capacitive Technology**	**Section 6.2**
	0 = Self Capacitance 1 = Mutual Capacitance	
Bank0: bit2:0	**IC TYPE: Select IC type**	**Section 6.1**
	000 = 1zz 12z z2z - 2CH SWIPE 001 = 1zz x2x zz3 - 3CH SWIPE (Thresholds * 2) 010 = 1zz z2z zz3 - 3CH SWIPE 011 = 1zz 12z z2z z23 zz3 - 3CH SWIPE 100 = 2CH Normal - 2 Channel Touch Sensor 101 = 3CH Normal - 3 Channel Touch Sensor 110 = 1zz 1xz x2x zx3 zz3 - 3CH SWIPE 111 = 1zz, x2x, zz3 - 3CH SWIPE	

[1] Active Low configurations are software open-drain (**SW OD**).

Note: The proximity output on the PO/TX-pin (pin 10) is multiplexed with the transmit signal (TX) for mutual capacitance electrodes, and is Active High ONLY for such configurations.

Table 5.2 : User Selectable Configuration Options : Bank 1

bit7	Bank 1						bit0
CH2 TTH1	CH2 TTH0	CH1, CH3 TTH1	CH1, CH3 TTH0	TTH ALT	PTH DIV	LP1	LP0

Bank1: bit7:6	**CH2 TTH1:CH2 TTH0: Channel 2 Touch Threshold**	**Section 6.8**
	TTH ALT = 0 00 = 4 01 = 8 10 = 12 11 = 16	***TTH ALT = 1*** 00 = 22 01 = 28 10 = 36 11 = 48
Bank1: bit5:bit4	**CH1, CH3 TTH: Ch 1 & Ch 3 Touch Threshold**	**Section 6.8**
	TTH ALT = 0 00 = 4 01 = 8 10 = 12 11 = 16	***TTH ALT = 1*** 00 = 22 01 = 28 10 = 36 11 = 48
Bank1: bit3	**TTH ALT: Alternative Touch Thresholds**	**Section 6.8**
	0 = No 1 = Yes	
Bank1: bit2	**PTH DIV: Proximity Threshold Divider Selection**	**Section 6.7**
	0 = 2 *(Prox threshold = CH1 TTH / 2)* 1 = 4 *(Prox threshold = CH1 TTH / 4)*	
Bank1: bit1:0	**LP1:LP0: Low Power Selection**	**Section 6.6**
	00 = NP - Normal Power 01 = 128ms - Low Power Mode 1 10 = 256ms - Low Power Mode 2 11 = 512ms - Low Power Mode 3	

Table 5.3 : User Selectable Configuration Options : Bank 2

bit7	Bank 2: SWIPE IC						bit0
ACF	Pin7_OUT	CHG_FRQ	Min_State	Zero_End	Zero_State	SWIPE UI1	SWIPE UI0

Bank2: bit7	**ACF: AC Filter Selection**	**Section 6.14**
	0 = Disabled 1 = Enabled	
Bank2: bit6	**Pin7_OUT: SWIPE IC Pin 7 Output Selection**	**Section 6.13**
	0 = Touch 1 = Pulse	
Bank2: bit5	**CHG_FRQ: Charge Transfer Frequency**	**Section 8.3**
	0 = 0.5MHz / 1.0MHz (Self - / Mutual Capacitance) 1 = 1.0MHz / 2.0 MHz (Self - / Mutual Capacitance)	
Bank2: bit4	**Min_State: Minimum State Time**	**Section 6.12**
	0 = 1 Sample 1 = 2 Samples	
Bank2: bit3	**Zero_End: End Swipe on Zero State (zzz)**	**Section 6.11**
	0 = Disabled 1 = Enabled	
Bank2: bit 2	**Zero_State: Allow Zero States In Swipe Sequence**	**Section 6.10**
	0 = Disabled 1 = Enabled	
Bank2: bit 1:bit0	**SWIPE UI1: SWIPE UI0: Swipe UI Selection**	**Section 6.9**
	00 = Single Direction 01 = Bi-Directional 10 = Directional 11 = Dual Swipe	

Table 5.4 : User Selectable Configuration Options : Bank 2

bit7	Bank 2: Normal Touch IC						bit0
ACF		CHG_FRQ			Toggle CH3	Toggle CH2	Toggle CH1

Bank2: bit7	**ACF: AC Filter Selection** **Section 6.14**
	0 = Disabled 1 = Enabled
Bank2: bit6	
Bank2: bit5	**CHG_FRQ: Charge Transfer Frequency** **Section 8.3**
	0 = 0.5MHz / 1.0MHz (Self - / Mutual Capacitance) 1 = 1.0MHz / 2.0 MHz (Self - / Mutual Capacitance)
Bank2: bit4	
Bank2: bit3	
Bank2: bit 2	**Toggle CH3: Channel 3 Touch Output = Toggle**
	0 = Disabled 1 = Enabled
Bank2: bit 1	**Toggle CH2: Channel 2 Touch Output = Toggle**
	0 = Disabled 1 = Enabled
Bank2: bit 0	**Toggle CH1: Channel 1 Touch Output = Toggle**
	0 = Disabled 1 = Enabled

Table 5.5 : User Selectable Configuration Options : Bank 3

bit7	Bank 3						bit0
				AAO_CLR	AAO	ATI_Target	ATI_Base

Bank3: bit7	**System Use**
Bank3: bit6	**System Use**
Bank3: bit5	**System Use**
Bank3: bit4	**System Use**
Bank3: bit3	**AAO_CLR: Clear Auto-Off Timer On Event** **Section 6.18**
	0 = Touch Event 1 = Proximity Event
Bank3: bit 2	**AAO: Advanced Auto-Off Function Selection** **Section 6.18**
	0 = Enabled 1 = Disabled
Bank3: bit 1	**ATI_Target: ATI Target Value** **Section 6.17**
	Proximity ***Touch*** 0 = 320 160 1 = 640 320
Bank3: bit 0	**ATI_Base: ATI Base Value (All Channels)** **Section 6.16**
	0 = 50 1 = 100

Table 5.6 : User Selectable Configuration Options : Bank 4

bit7	Bank 4						bit0
				I^2C Debug			

Bank4: bit7	**System Use**
Bank4: bit6	**System Use**
Bank4: bit5	**System Use**
Bank4: bit4	**System Use**
Bank4: bit3	**I^2C Debug: I^2C Interface (Default = Event-Mode) Section 6.19**
	0 = Disabled 1 = Enabled
Bank4: bit 2	**System Use**
Bank4: bit 1	**System Use**
Bank4: bit 0	**System Use**

6 Description of User Selectable Options

This section briefly describes the individual user programmable options of the **IQS213**, with additional information and detailed descriptions being provided in **Section 8**.

Thresholds and other settings can also be evaluated in Test Mode streaming without programming the OTP options. For the appropriate software, please visit: www.azoteq.com

6.1 IQS213 IC Type

The **IQS213** has 6 selectable Swipe Switch setup configurations, allowing the user maximum freedom in the design of the intended application. The device type configuration specifies the required user input, which is identified by a sequence of a combination of input states, where a *[number]* (e.g. 1, 2 or 3) indicates a touch condition/state on that specific channel, a *[z-character]* indicates a zero condition/state and a *[x-character]* indicates a "don't care" condition/state (i.e. a number or zero condition is acceptable). The input states related to sequences accepting x-character conditions are also referred to as relaxed states.

- **2CH SWIPE - 1zz 12z z2z :** 2-Channel swipe switch operation.
- **3CH SWIPE – 1zz x2x zz3 (TH*2) :** 3-Channel swipe switch operation.
- **3CH SWIPE - 1zz z2z zz3 :** 3-Channel swipe switch operation.
- **3CH SWIPE - 1zz 12z z2z z23 zz3 :** 3-Channel swipe switch operation.
- **3CH SWIPE - 1zz 1xz x2x zx3 zz3 :** 3-Channel swipe with relaxed states.
- **3CH SWIPE - 1zz x2x zz3 :** 3-Channel swipe with relaxed states.

The **IQS213** also has 2 selectable normal setup configurations, which allows the user to implement standard touch and proximity sensing features.

- **2CH Normal Mode :** 2-Channel Normal Touch operation.
- **3CH Normal Mode :** 3-Channel Normal Touch operation.

With the device setup in either 2-channel or 3-channel Normal Mode, touch events corresponding to the different sense electrodes will be output on TO0 (pin 8), TO1 (pin 7) and TO2 (pin 6), with a proximity output available on PO (pin 10).

During Normal Mode operation, setting the different "Toggle_CH*x*" bits in Bank 2, will enable the touch output signals to toggle.

6.2 Self- / Mutual Capacitance

Enabling the mutual capacitance option, will cause the measurement of the sense electrode capacitance between the transmit (TX) and receive (CRX) pins.

The proximity output on the PO/TX-pin (pin 10) is multiplexed with the transmit signal (TX) for mutual capacitance electrodes, and is Active High ONLY for such configurations.

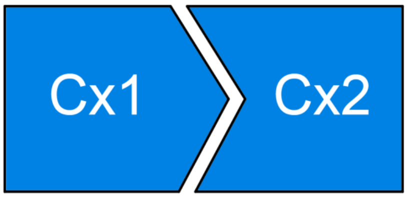
The implementation of a mutual capacitance sense electrode will result in a higher charge frequency (i.e. f_{Cm} = 1MHz) compared to that of a self capacitance configuration (i.e. f_{Cs}= 500kHz). Setting bit5 in Bank2 will double the charge frequency for both mutual- and self capacitance configurations (i.e. f_{Cm} / f_{Cs}= 2MHz / 1MHz).

A higher charge frequency selection is preferred for increased immunity against aqueous substances when used in most mutual capacitance configurations.

6.2.1 Capacitive Sense Electrode Design Samples

6.2.1.1 Self Capacitance Electrodes

2-Channel Self Capacitance Electrode

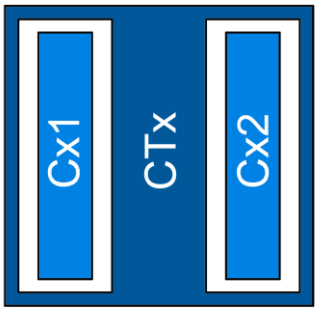


3-Channel Self Capacitance Electrode

Figure 6.1 : Self Capacitance Swipe Switch Sample Electrodes.

6.2.1.2 Mutual Capacitance Electrodes

2-Channel Mutual Capacitance Electrode



3-Channel Mutual Capacitance Electrode

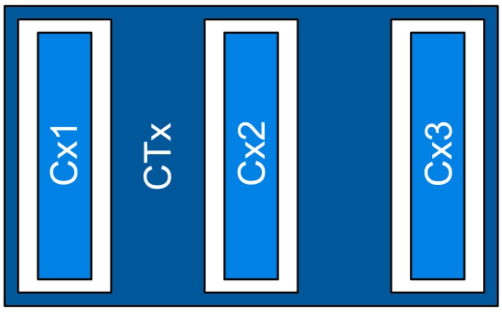


Figure 6.2 : Mutual Capacitance Swipe Switch Sample Electrodes.

6.3 Float Rx

During the charge transfer process (see **Figure 8.1**) the channels that are not being processed during the current cycle, is effectively grounded to decrease the effects of noise-coupling between the sense electrodes. Selecting the "Float RX" option (Bank0 bit4), will thus result in the non-current channels to float (i.e. not grounded) during the charge cycle of the current channel.

6.4 Output Logic Select

The **IQS213** can be set to sink or source current in stand-alone mode (I^2C Debug = Disabled), by setting the logic output Active High (Push-Pull) or Active Low (SW OD).

For Active Low operation, the device output pins are set in a software open-drain (SW OD) configuration, which requires the use of external pull-up resistors on the output pins.

The proximity output on the PO/TX-pin (pin 10) is multiplexed with the transmit signal (TX) for mutual capacitance electrodes, and is Active High ONLY for these configurations. Thus for self capacitance configurations, the proximity output on PO (pin10) depends on the selected output logic (Bank0 bit5).

6.5 Halt Time

The Halt Timer is started when a proximity or touch event occurs and is restarted when that event is removed or reoccurs. When a proximity condition occurs on any of the channels, the LTA (**L**ong-**T**erm **A**verage) value for that channel will be "halted", thus its value will be kept fixed, until the proximity event is cleared, or the halt timer reaches the halt time. The halt timer will count to the selected halt time (t_{HALT}), which can be configured in the user selectable options (i.e. Bank0 bit7:6), and if the timer expires, all outputs will be cleared.

It is possible that the CS (Count) value could be outside the ATI band (ATI Target +- 12.5%) when the timer expires, which will cause the device to perform a re-ATI event.

The designer needs to select a halt timer value (t_{HALT}) to best accommodate the required application:

- **2.5 seconds** : Halt LTA for 2.5 seconds after the last proximity or touch event.
- **20 seconds** : Halt LTA for 20 seconds after the last proximity or touch event.
- **60 seconds** : Halt LTA for 60 seconds after the last proximity or touch event.
- **Never** : Never halt LTA

∗ *With the 'Never' option, the detection of a proximity or touch event will not halt the LTA and the LTA will adjust towards the CS value until the CS value is reached. The touch and proximity output of a channel will thus be cleared automatically when the difference between the LTA and CS is less than the specified threshold value.*

6.6 Low Power Modes

The **IQS213** IC has three low power modes specifically designed to reduce current consumption for battery applications.

The power modes are implemented around the occurrence of a charge cycle every t_{SAMPLE} seconds (refer to **Table 6.1**). Lower sampling frequencies typically yield significant lower power consumption (but also decreases the response time).

During normal operation charge cycles are initiated approximately every 2.6ms in the stand-alone setup and 3.9ms in the I^2C debug setup. This is referred to as Normal Power Mode (NP). The **IQS213** by default charges in Normal Power Mode.

While in any low power mode, only Channel 0 is active and the device will zoom to NP whenever the CS value indicates a possible proximity or touch event on CH0 (refer to **Figure 6.3**). This improves the response time. The device will remain in NP for t_{ZOOM} seconds and then return to the selected low power mode. The Zoom function allows reliable detection of events with the current samples being produced at the NP rate. (Please see **Section 8.4**)

Table 6.1 : Low Power Mode Timing (t_{LP})

Power Mode	t_{SAMPLE}
NP (Default)	2.6 ms
LP1	128 ms
LP2	256 ms
LP3	512 ms

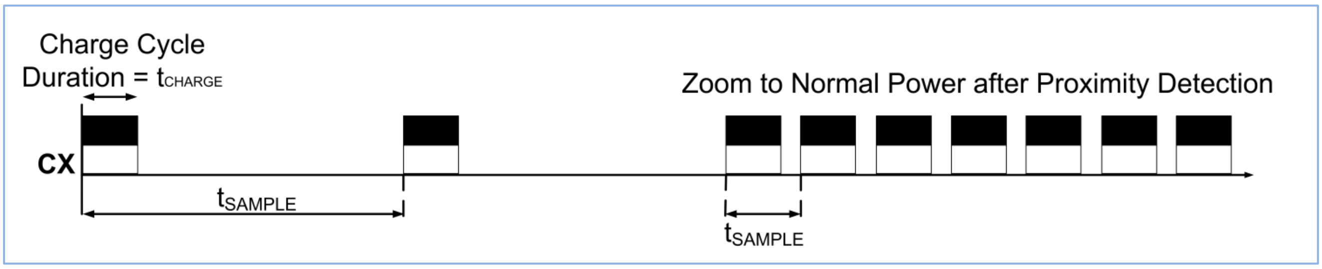


Figure 6.3 : LP Modes – Charge Cycles

6.7 Proximity Threshold

The **IQS213** has 8 proximity threshold (P_{TH}) settings. The proximity threshold is selected by the designer to obtain the desired sensitivity and noise immunity. The proximity event is triggered based on the selected proximity threshold, which is calculated by dividing the selected touch threshold value of channel 1 ($CH1_{TTH}$) with the value corresponding to the $PROX_{DIV}$ bit (i.e. 2 or 4). The proximity threshold is expressed in terms of counts, the same as the CS value.

For proximity events, the difference between the LTA and CS (in counts) of the proximity channel should be greater than P_{TH} for at least 4 consecutive samples. (See **Section 8.7**)

6.8 Touch Thresholds

The **IQS213** has 8 touch threshold settings. The touch threshold is selected by the designer to obtain the desired touch sensitivity.

The touch event is triggered based on the selected touch threshold, which is expressed as a fraction of the LTA, given by:

$T_{TH} = x/255 \times LTA$. (See **Section 8.8**)

For a touch event, the difference between LTA and CS (counts) of the touch channel should be greater than the selected touch threshold for at least 2 consecutive samples.

On the **IQS213** device, the touch threshold settings are grouped for channels 1 and 3 (CH1,3 T_{TH}) and is separate for channel 2 (CH2 T_{TH}).

The **IQS213** device is by default setup without the alternative threshold settings. The alternative threshold values can be selected by setting the TTH_ALT bit (i.e. bit3 in Bank1).

If for specific applications the designer requires larger touch threshold values than the available selections, they may select the "3CH SWIPE – 1zz x2x zz3 (TH*2)" IC TYPE in Bank0 of the user configurable options.

This selection is for a three channel sense electrode configuration only and will automatically multiply the threshold selections by two.

6.9 IQS213 SWIPE UI

The **IQS213** has 4 selectable swipe switch user interface (UI) configurations. The swipe UI specifies the required event(s) to activate the outputs of the device:

- **Single Direction:**

  The device only acknowledges swipe events in the direction of **CH1 ▸ CH2** for a 2-channel and **CH1 ▸ CH2 ▸ CH3** for a 3-channel device setup.

- **Bi-Directional:**

  The device acknowledges swipe events in both the forward (**CH1 ▸ CH2 ▸ ...**) and reverse (**... ▸ CH2 ▸ CH1**) directions.

- **Directional:**

  A swipe event in the forward (**CH1 ▸ CH2 ▸ ...**) direction will enable the swipe output (ON) and a swipe in the reverse (**... ▸ CH2 ▸ CH1**) direction will disable the output (OFF).

- **Dual Swipe:**

  This UI requires a swipe event in one direction, followed by a swipe event in the opposite direction within 1 second, to enable the swipe output (ON). Thereafter, a single swipe in any direction will subsequently disable the swipe output again (OFF).

6.10 Zero States Allowed

Setting the **Zero_State** bit in Bank2, will allow the occurrence of zero or "no touch" conditions between the different state combinations in each sequence of the selected IC type (refer to **Section 6.1** for IC types).

This grants the designer a certain degree of freedom in the selected device sensitivity and implemented sense electrode.

If for example the IC type is selected to be "**3CH SWIPE - 1zz z2z zz3**", then the sequence '**1zz** zzz **z2z** zzz **zz3**' of state combinations will also be acknowledged as a valid swipe event.

6.11 End on Zero State

Setting the **Zero_End** bit in Bank2, will append an additional zero or "no touch" state to the required sequence of state combinations.

If for example the IC type is selected to be "**3CH SWIPE - 1zz z2z zz3**", then the sequence '**1zz z2z zz3** **zzz'** of state combinations will be acknowledged as a valid swipe event ONLY.

6.12 State Times

The minimum, maximum and overall swipe state times controls the effective period during which a successful swipe event can be recognized. The state times are defined in swipe state samples, where each sample period t_{STATE} is equal to 4 charge transfer periods. For stand-alone device operation this results in a state sample time of approximately t_{STATE} = 10.4ms.

The state time values can also be set up or changed in I²C debug mode.

6.12.1 Minimum State Time

The minimum state time (t_{MIN}) defines the minimum period (in multiples of t_{STATE}) for which each combination of states (e.g. 1zz) must be present during processing of the current sequence of the state combination. Selecting shorter minimum state times will effectively allow faster swipe events.

6.12.2 Maximum State Time

The maximum state time defines the maximum period for which each combination of states (e.g. 1zz) may be present during processing of the current sequence of the state combination.

This value is fixed at $t_{MAX} = 45*t_{STATE}$ by default, but is accessible in I²C debug mode. Selecting longer maximum state times will effectively allow slower swipe events.

6.12.3 Overall State Time

The overall state time is the total allowable time for performing a swipe event and is by default set to 1 second. This value can also be changed in I²C debug mode in steps of 250ms.

6.13 Touch/Swipe (Pin7) Output

The **IQS213** has one complementary output on pin 7 of the IC. This pin can be configured to output either touch events or pulses upon swipe events, after the swipe output (pin 6) has been enabled.

By default the **IQS213** will output a logic signal for touch events on any of the three sense electrodes. If the **Pin7_Out** bit in Bank2 is set, the device will output a short pulse for every consecutive swipe event within 2 seconds after the first swipe event.

The generated pulses have different pulse widths (t_{PULSE}), depending on the direction of the swipe event:

- **Long Pulse:** A long pulse ($t_{PULSE} \approx$ 9ms) will be output for swipes in the forward (**CH1 ▸ CH2...**) direction.
- **Short Pulse:** A short pulse ($t_{PULSE} \approx$ 3ms) will be output for swipes in the reverse **(... ▸ CH2 ▸ CH1**) direction.

6.14 AC Filter

The AC filter can be implemented to provide better stability of the proximity channel's count (CS) measurements in electrically noisy environments by setting the **ACF** bit in Bank2.

The AC filter also enforces a longer minimum sample time for detecting proximity events, which may result in a slower response rate when the device enters low power modes.

6.15 ATI Method

In the stand-alone configuration the **IQS213** is automatically set up in Full ATI to set up the device for optimal sensitivity.

In the I²C debug configuration, the **IQS213** can be set up to start in two ways, Full ATI and Partial ATI. In Full ATI mode, the device automatically selects the multipliers through the ATI algorithm to setup the **IQS213** as close as possible to its default sensitivity for the environment where it was placed. The designer can, however, select Partial ATI, and set the multipliers to a pre configured value. This will cause the **IQS213** to only calculate the compensation (not the compensation and multipliers as in Full ATI), which allows the freedom to make the **IQS213** more or less sensitive for its intended environment of use. (Please refer to **Section 8.9.**)

6.16 Base Value

The **IQS213** has the option to change the base value of all channels during the ATI algorithm. Depending on the application, this provides the user with another option to select the sensitivity of the **IQS213** without changes in the hardware (CX sizes and routing, etc). By setting the **ATI_Base** bit in Bank3, the base value can be set to be 50 or 100. A lower base value will typically result in a higher sensitivity of the device. (Refer to **Section 8.9**)

6.17 ATI Target Value

The default target counts of the **IQS213** are 320 for the proximity channel, and 160 for the touch channels.

However, for some applications, a more sensitive device and higher target is required. Therefore, the **ATI_Target** bit in Bank3 can be set, changing the targets to 640 for the proximity channel, and 320 for the touch channels. (See **Section 8.9**)

6.18 Auto-Off / Advanced Auto-Off Warning

To prevent battery drainage in the unlikely event of a false activation of the output load, the **IQS213** is equipped with an Auto-Off functionality. The Auto-Off (AAO) feature can be disabled by setting the **AAO** bit in Bank3.

6.18.1 Advanced Auto-Off Warning (AAOW)

In stand-alone operation the Advanced Auto-Off Warning (AAOW) timer is set for 10 minutes. After the first warning, a second warning will be given after 30s. Another 30s after the second warning, the device will switch off automatically (i.e. disable all outputs).

In I²C operation the Auto-Off (AAO) and Advanced Auto-Off Warning (AAOW) timers can be set to any value in multiples of 30s.

6.18.2 AAOW Clear / Reset

The AAO timer is by default cleared (reset) on a touch event on any channel. Setting the **AAO_CLR** bit in Bank3, the AAO timer will be reset upon a proximity event.

6.19 I²C Debug

A streaming option is available that allows for serial data communication on the **IQS213**. Data streaming is done via an I²C compatible 3-wire interface, which consist of a data (**SDA**), clock (**SCL**) and ready (**RDY**) line (for **IQS213** pin-out refer to **Figure 4.1**).

The **IQS213** can only function as a slave device on the bus, and will only acknowledge on address **0x44H**.

The RDY line is to be used by the host controller as an indication of when to start communication to the device. The RDY line will be active low when it is ready for communication, and it will go high when it is doing conversions. The **IQS213** will not acknowledge (ACK) on its address while the RDY line is high (i.e. while the **IQS213** is doing conversions).

7 Additional Features

7.1 Noise Detection

The **IQS213** has advanced integrated immunity to RF noise sources such as GSM cellular telephones, DECT, Bluetooth and WIFI devices. Design guidelines should however be followed to ensure the best noise immunity. (Please see **Section 8.10**)

7.1.1 Notes for layout:

- A ground plane should be placed under the IC, except under the CX lines.
- Place the sensor IC as close as possible to the sense electrodes.
- All the tracks on the PCB must be kept as short as possible.
- The capacitor between VDDHI and GND as well as between VREG and GND must be placed as close as possible to the IC.
- A 100 pF capacitor can be placed in parallel with the 1uF capacitor between VDDHI and GND. Another 100 pF capacitor can be placed in parallel with the 1uF capacitor between VREG and GND.
- When the device is too sensitive for a specific application a parasitic capacitor (max 5pF) can be added between the CX line and ground.
- Proper sense antenna and button design principles must be followed.
- Unintentional coupling of sense antenna to ground and other circuitry must be limited by increasing the distance to these sources.
- In some instances a ground plane some distance from the device and sense antenna may provide significant shielding from undesirable interference.
  - ∗ However, if after proper layout, interference from an RF noise source persists, see application note ***AZD015***.

8 ProxSense® Module

The **IQS213** contains a ProxSense® module that uses patented technology to provide detection of PROX/TOUCH on numerous sensing lines.

The ProxSense® module is a combination of hardware and software, based on the principles of charge transfer measurements.

For I^{2}C communication related data registers, please refer to the **IQS213** Memory Map in **Section 10**.

8.1 Charge Transfer Concepts

Capacitance measurements are taken with a charge transfer process that is periodically initiated.

Self capacitance sensing measures the capacitance between the sense electrode (Cx) relative to ground.

Mutual capacitance sensing measures the capacitance between 2 electrodes referred to as the transmitter (CTX) and receiver (CRX).

The measuring process is referred to as a charge transfer cycle and consists of the following:

- Discharging of an internal sampling capacitor (Cs) and the antenna capacitors (self: Cx or mutual: CTX & CRx) on a channel.
- charging of Cx's / CTX's connected to the channel
- and then a series of charge transfers from the Cx's / CRX's to the internal sampling capacitors (Cs), until the trip voltage is reached.

The number of charge transfers required to reach the trip voltage on a channel is referred to as the Count or CS value.

The device continuously repeats charge transfers on the sense electrodes connected to the Cx pin. For each channel a Long Term Average (**LTA**) is calculated (12 bit unsigned integer values). The CS values (12 bit unsigned integer values) are processed and compared to the LTA to detect Touch and Proximity events.

For more information regarding capacitive sensing, refer to the application note: "***AZD004 – Azoteq Capacitive Sensing***".

Please note: Attaching scope probes to the Cx/CTX/CRX pins will influence the capacitance of the sense electrodes and therefore the related CS values of those channels. This will have an instant effect on the CS measurements.

8.2 ProxSense® Module Setup

The **IQS213** samples its channels in 4 time slots, with one internal Cs capacitor. The charge sequence is illustrated in **Fig. 8.1**.

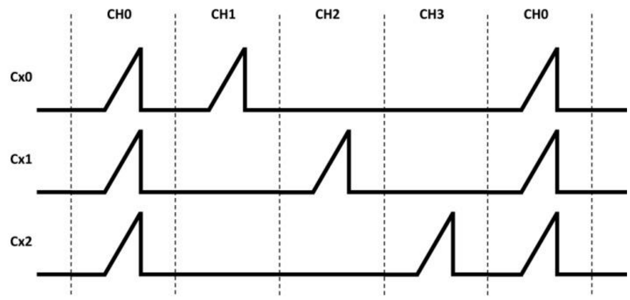


Figure 8.1 IQS213 Charge Transfers

The **IQS213** charges its four channels, **CH0** (Distributed Proximity Channel) and three Touch Channels (**CH1, CH2 and CH3**) independently during the four time slots. During these time slots, the non-current channels can either be grounded or set to float.

8.3 Self- or Mutual Capacitance

The I**QS213** IC can be used in either self- or mutual capacitance configurations. The IC is default in a 2-channel self capacitance setup. This can be changed to a mutual capacitance configuration in the user selectable options

(Bank0 bit3). The technology enabled on the IC will be reported in the SYSFLAGS register.

The **IQS213** has two selectable charge transfer frequencies. For mutual capacitance sense electrodes the charge frequency is by default set at f_{Cm} = 1MHz, and for self capacitance configurations f_{Cs}= 500kHz. Setting the **CHG_FRQ** bit in Bank2 will double the charge frequency for both mutual- and self capacitance configurations (i.e. f_{Cm} / f_{Cs}= 2MHz / 1MHz).

A higher charge frequency selection is preferred for increased immunity against aqueous substances when used in most mutual capacitance electrode configurations.

8.4 Rate of Charge Cycles

8.4.1 Normal Power rate

With the **IQS213** in Normal Power (NP) mode, the sense channels are charged at a fixed sampling frequency (f_{SAMPLE}) per channel. This is done to ensure regular samples for processing of results. It is calculated as each sample having a time (t_{SAMPLE} = charge period (t_{CHARGE}) + computation time)) of approximately 2.6ms, thus the time between consecutive samples on a channel ($t_{CHANNEL}$) will optimally be $t_{SAMPLE} = 4 * t_{SAMPLE} \approx 10.4$ms (or 96Hz). The charge sequence and timings are illustrated in **Figure 8.2**.

If a channel is thus disabled, the sampling rate on the remaining channels will reduce with approximately 2.6ms.

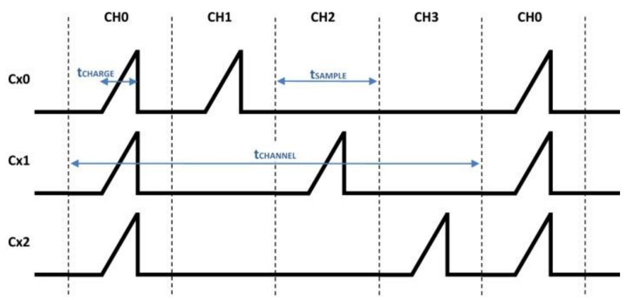


Figure 8.2 Signals on CX's / CRX's during Normal Power Mode.

8.4.2 Low Power rates

Low current consumption charging modes are available. In any Low Power (LP) mode, there will be an applicable low power time (t_{LP}). This is determined by the LP_PERIOD register. The value written into this register multiplied by 16ms will yield the LP time (t_{LP}).

Please note that this time is only applicable from value 03h and higher loaded into the LP_PERIOD register. The values 01h and 02h will have a different time. See **Table 6.1** for all timings.

With the detection of an undebounced proximity event the IC will zoom to NP mode, allowing a very fast reaction time for further possible touch / proximity events. All active channels will be consecutively charged every T_{LP}.

If a LP rate is selected through register LP_Period and charging is not in the zoomed in state (NP mode), the LP_Active bit (SYSFLAGS register) will be set.

8.5 Touch Report Rate

During Normal Mode operation, the touch report rate of the **IQS213** device depends on the charge transfer frequency, the number of channels enabled and the length of communications performed by the master device.

8.6 Active channels

The user has the option to enable the third channel (CH3) during I²C operation. This can be done in the SWIPE_SETTINGS register (SET_3CH bit). Only two channels (CH1 and CH2) are default enabled.

Note: During Low Power (LP) modes only CH0 is active.

8.7 Long Term Average (LTA)

The LTA filter can be seen as the baseline or reference value. The LTA is calculated to continuously adapt to any environmental drift. The LTA filter is calculated from the CS value for each channel. The LTA filter allows the device to adapt to environmental (slow moving) changes/drift. Actuation (Touch or Prox) decisions are made by comparing the CS value with the LTA reference value.

The 12bit LTA value is contained in the LTA_H and LTA_L registers.

Please refer to Section 6.5 for LTA Halt Times.

8.8 Determine Touch or Prox

An event is determined by comparing the CS with the LTA. Since the CS reacts differently when comparing the self- with the mutual capacitance technology, the user should consider only the conditions for the technology used.

An event is recorded if:

- Self: CS < LTA – **Threshold**
- Mutual: CS > LTA + **Threshold**

Threshold can be either a Proximity or Touch threshold, depending on the current channel being processed.

Please refer to **Section 6.7** and **6.8** for proximity and touch threshold selections.

8.9 ATI

The **A**utomatic **T**uning **I**mplementation (**ATI**) is a sophisticated technology implemented on the new ProxSense® series devices. It allows for optimal performance of the devices for a wide range of sense electrode capacitances, without modification or addition of external components.

The ATI allows the tuning of two parameters, an ATI Multiplier and an ATI Compensation, to adjust the sample value for an attached sensing antenna.

ATI allows the designer to optimize a specific design by adjusting the sensitivity and stability of each channel through the adjustment of the ATI parameters.

The **IQS213** has an automated ATI function. The auto-ATI function is default enabled, but can be disabled by setting the ATI_OFF and ATI_Partial bits in the PROX_SETTINGS registers.

The ATI_Busy bit in the SYSFLAGS register will be set while an ATI event is busy.

8.9.1 ATI Sensitivity

In I^{2}C mode, the designer can specify the global BASE value for all channels and the TARGET values for the proximity (CH0) and touch (CH1,CH2,CH3) channels. A rough estimation of sensitivity can be calculated as:

$$Sensitivity = \frac{TARGET}{BASE}$$

As can be seen from this equation, the sensitivity can be increased by either increasing the Target value or decreasing the Base value. It should, however, be noted that a higher sensitivity will yield a higher noise susceptibility.

8.9.2 ATI Target

The target is reached by adjusting the COMPENSATION bits for each channel.

The target value is written into the respective channel's TARGET registers. The value written into these registers multiplied by 8 will yield the new target value.

8.9.3 ATI Base (MULTIPLIER)

The following parameters will influence the base value:

- CS_SIZE[i]: Size of sampling capacitor.
- PROJ_BIAS bits: Adjusts the biasing of some analogue parameters in the mutual

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[i] Changing CS_SIZE if ATI_OFF = 0 will change CS

capacitive operated IC. (Only applicable in mutual capacitance mode.)

- MULTIPLIER bits.

The base value used for the ATI function can be implemented in 2 ways:

1. ATI_PARTIAL = 0. ATI automatically adjusts MULTIPLIER bits to reach a selected base value[ii]. Base values are available in the BASE_VALUE register.
2. ATI_PARTIAL = 1. The designer can specify the multiplier settings. These settings will give a custom base value from where the compensation bits will be automatically implemented to reach the required target value.

8.9.4 Re-ATI

An automatic re-ATI event will occur if the CS is outside its re-ATI limits. The re-ATI limit is calculated as the target value divided by 8. For example:

Target = 320

Re-ATI will occur if CS is outside 320±40.

During I^2C operation, a re-ATI event can also be issued by the master by setting the REDO_ATI bit. It will clear automatically after the ATI event was started.

8.10 RF Detection

In cases of extreme RF interference, the on-chip RF detection is suggested. This detector can be enabled by setting the Noise_Detect bit in the PROX_SETTINGS1 register. By connecting a suitable antenna to the RF pin, it allows the device to detect RF noise and notify the master of possible corrupt data.

Noise affected samples are not allowed to influence the LTA filter, and also do not contribute to proximity or touch detection. With the detection of noise, the NOISE_FOUND bit in SYSFLAGS will be set.

8.10.1 RF detector sensitivity

The sensitivity of the RF detector can be selected by setting an appropriate RF detection voltage through the RF_TRIM bits. Please see application note **AZD015** for further details regarding this option.

[ii] ATI function will use user selected CS_SIZE and PROJ_BIAS (if applicable) and will only adjust the MULTIPLIER bits to reach the base values.

9 Communication

The **IQS213** can communicate on the I²C compatible bus structure. It uses a 3-wire serial interface bus which is I²C compatible and comprise of a data (**SDA**), clock (**SCL**) and optional ready (**RDY**) line (for **IQS213** pin-out refer to **Figure 4.1**).

The **IQS213** has one available I²C address, **I²C address = 0x44H**.

The maximum I²C compatible communication speed for the **IQS213** is 400kbit/s.

9.1 Event Mode

The **IQS213** will by default be configured to only communicate with the master if a change in an event occurs. For this reason, it would be highly recommended to use the RDY line when communicating with the **IQS213**, especially in Low Power (LP) modes. These communication requests are referred to as Event Mode triggering (only changes in events are reported).

Event mode can be disabled by setting the EVENT_MODE_OFF bit.

The events responsible for resuming communication can be chosen through the EVENT_MASK register. By default all events are enabled.

The device can also communicate on polling basis, using only the SDA and SCL lines.

9.2 I²C Specific commands

9.2.1 IC Reset indication

SHOW_RESET can be read to determine whether a reset occurred on the device. This bit will be a '1' after a reset. The value of SHOW_RESET can be cleared to '0' by writing a '1' in the ACK_RESET bit.

9.2.2 WDT

The WDT is used to reset the IC if a problem (for example a voltage spike) occurs during communication. The WDT will time-out after t_{WDT}, if no valid communication occurs for this time.

9.3 I²C Read and Write specifics

For more details, please refer to the **IQS213** Memory Map (**Section 10**) for device memory register descriptions and application note: "***AZD066: IQS213 Communication Interface Guideline***" document available at: www.azoteq.com.

10 IQS213 Memory Map

10.1 Memory Registers

Table 10.1 : IQS213 Memory Registers

Register Address	Register Name	Description	
00H	Product Number	'D43' / '2BH'	Device Information
01H	Version Number	'01'	
10H	Sys_flags0	System Flags - **See Table 10.2**	Device Specific Data
11H	Swipe Flags	Swipe Switch Flags - **See Table 10.2**	
35H	Touch CHs	Channels Touched - **See Table 10.2**	Count Data
3DH	Chan_num	Number of Currently Processed Channel	
42H	CS High	Count (CS) value [high byte]	
43H	CS Low	Count (CS) value [low byte]	
83H	LTA High	Long Term Average [high byte]	
84H	LTA Low	Long Term Average [low byte]	
C4H	Current Sate	Swipe Engine Current State	
C5H	Measured State	Current Measured State (Acc. to Touches)	
C6H	Next State	Swipe Engine Next Expected State	
C7H	Swipe States	Combination of States Required for Swipe	
C8H	Swipe Min Timer	Minimum timer counts – swipe periods	
C9H	Swipe Max Timer	Maximum Overall timer – 250ms periods	
CAH	Swipe Max State Timer	Maximum Per State timer – swipe periods	
CBH	Swipe Settings	**IQS213 Set Up - See Table 10.2**	Device Settings
CCH	Prox Settings 0	**IQS213 Set Up - See Table 10.2**	
CDH	Prox Settings 1	**IQS213 Set Up - See Table 10.2**	
CEH	Prox Settings 2	**IQS213 Set Up - See Table 10.2**	
CFH	Target CH0	(Target CH0) *8 = Channel 0 Target Value	
D0H	Target CH1-CH3	(Target CH1-CH3) *8 = Channel 1-3 Target Value	
D1H	Prox Threshold	Proximity Threshold Value	
D2H	Touch Threshold 1	Channel 1 Touch Threshold [CS value]	

Register Address	Register Name	Description	
D3H	Touch Threshold 2	Channel 2 Touch Threshold [CS value]	Device Settings
D4H	Touch Threshold 3	Channel 3 Touch Threshold [CS value]	
D5H	Base Value	ATI Base Value [0-256]	
D6H	Event Mask	Events Allowed - **See Table 10.2**	
D7H	Mirror_CH0	Mirror – lower 6 bits – NN PPP	
D8H	Mirror_CH1	Mirror – lower 6 bits – NN PPP	
D9H	Mirror_CH2	Mirror – lower 6 bits – NN PPP	
DAH	Mirror_CH3	Mirror – lower 6 bits – NN PPP	
DBH	PCC0	CH0 Compensation	
DCH	PCC1	CH1 Compensation	
DDH	PCC2	CH2 Compensation	
DEH	PCC3	CH3 Compensation	
DFH	AAOW Timer	(AAOW Timer)*30s = Auto-Off Warning time	Device Settings
E0H	AO Timer	(AO Timer)*30s = Auto-Off time	
E1H	Swipe Min Samples	Set minimum samples per state [x+1]	
E2H	Swipe Max Samples	Set maximum samples per state [x+1]	
E3H	Swipe Overall Limit	Set Overall Swipe Length Limit [*250ms]	
E4H	LP Period	(LP Period)*16ms = Low Power Charge Timing (t_{LP})	
E5H	Touch States 0	Swipe Engine Configuration	
E6H	Touch States 1	Swipe Engine Configuration	
E7H	Touch States 2	Swipe Engine Configuration	
E8H	Touch States 3	Swipe Engine Configuration	
E9H	Touch States 4	Swipe Engine Configuration	
EAH	Touch States 5	Swipe Engine Configuration	
EBH	Touch States6	Swipe Engine Configuration	
ECH	Touch States 7	Swipe Engine Configuration	
EDH	Default Comms	Default Comms pointer	

Table 10.2 : IQS213 Memory Register bits

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Prox Settings 0	Show Reset	ACK Reset	Reseed	Redo ATI	ATI Partial	Float CX	THALT1	THALT0
Prox Settings 1	Comms WDT OFF	Event Mode OFF	Debug I2C	AO Clear Prox	AO OFF	ACF OFF	ATI OFF	Noise Detect OFF
Prox Settings 2					IO_OUT	CS_Cap	Proj_B1	Proj_B0
Swipe Settings	Set_3CH	Touches/Pulses	Swipe UI	Swipe UI	End_Zero	Zero_State	States Relaxed	Swipe Active
Swipe Flags	Swipe Pulse Flag	Time Out Flag	Slide Occurred	DualSwipe Active	Swipe Direction	AO Triggered	Final State	Start State
Event Mask				Noise Event	ATI Event	Swipe Event	Touch Event	Prox Event
Sys_flags0	System Use	LP Active	Active High	Mutual CapSense	Filter Halt	ATI Busy	Noise Found	Zoom
Touch CHs	Swipe Output				CH3	CH2	CH1	CH0/Prox

10.2 Memory Registers Description

10.2.1 Device Information

00H

Access		Bit	7	6	5	4	3	2	1	0
			Product Number (Prod_NR)							
R		Value	43 (Decimal)							

01H

Access		Bit	7	6	5	4	3	2	1	0
			Software Number (SW_NR)							
R		Value	SW_NR							

- **[00H] PROD_NR** : The product number for the IQS213 is 43 (decimal).
- **[01H] SW_NR** : Device ROM software version number can be read in this byte.

10.2.2 Device Specific Data

10H			System Flags (Sys_flags0)							
Access		Bit	7	6	5	4	3	2	1	0
R		Name	System Use	LP Active	Active High	Mutual CapSense	Filter Halt	ATI Busy	Noise Found	Zoom

- **[10H] Sys_flags0**: bit7: System Use
  bit6: LP Active – Indicates if device is in a Low Power Mode.
  bit5: Active High – Bit is set if Output Logic is Active High.
  bit4: Mutual CapSense – Bit is set if Mutual Capacitance technology is used.
  bit3: Filter Halt – Indicates if LTA filters are halted.
  bit2: ATI Busy – Indicates if ATI algorithm is being performed.
  bit1: Noise Found – Bit is set if RF noise is detected. (RF Detection must be enabled)
  bit0: Zoom – Indicates if device is zoomed to Normal Power.

11H			Swipe Switch Flags (Swipe Flags)							
Access		Bit	7	6	5	4	3	2	1	0
R/W		Name	Swipe Pulse Flag	Time Out Flag	Slide Occurred	DualSwipe Active	Swipe Direction	AO Triggered	Final State	Start State

- **[11H] Swipe Flags**: bit7: Swipe Pulse Flag – Bit is set if Pin7 Output = Pulses
  bit6: Time Out Flag – Bit is set if Max State Timer is exceeded.
  bit5: Slide Occurred – Bit is set if Swipe event has occured. (**Note: Bit must be cleared manually**)
  bit4: DualSwipe Active – Bit is set if Swipe UI = Dual Swipe.
  bit3: Swipe Direction – 0 = Forward direction, 1 = Reverse direction.
  bit2: AO Triggered – Bit is set if Auto-Off Warning has been set.
  bit1: Final State – Bit is set if Swipe Engine is in Final State.
  bit0: Start State – Bit is set if Swipe Engine is in Start State.

10.2.3 Current Sample (CS) or Count Data

35H		Touch/Output Data (Touch CHs)							
Access	**Bit**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
R	**Name**	Swipe Output				CH3	CH2	CH1	CH0/Prox

- **[35H] Touch CHs**:
  bit7: Swipe Output – Bit is toggled on Swipe Events. (**Note:** This bit corresponds to the IC swipe output (Pin6) and is UI dependent.)
  bit6: Not used.
  bit5: Not used.
  bit4: Not used.
  bit3: CH3 – Bit is set if a Touch is present on this channel.
  bit2: CH2 – Bit is set if a Touch is present on this channel.
  bit1: CH1 – Bit is set if a Touch is present on this channel.
  bit0: CH0/Prox – Bit is set if a Proximity Event is present.

3DH		Channel Number (Chan_num)							
Access	**Bit**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
R	**Name**					CH3	CH2	CH1	CH0/Prox

- **[3DH] Chan_num**:
  bit7: Not used.
  bit6: Not used.
  bit5: Not used.
  bit4: Not used.
  bit3: CH3 – Bit is set if CH3 data is currently processed.
  bit2: CH2 – Bit is set if CH2 data is currently processed.
  bit1: CH1 – Bit is set if CH1 data is currently processed.
  bit0: CH0/Prox – Bit is set if CH0 data is currently processed.

Note: These bits indicate which channel's data is currently available in the CS and LTA bytes.

42H		Count (CS) Value High byte (CS High)							
Access	**Bit**	7	6	5	4	3	2	1	0
R	**Value**	Variable (High byte)							

- **[42H] CS High**: bit7:0: Count (CS) Value High Byte of currently processed channel. (See Channel Number.)

43H		Count (CS) Value Low byte (CS Low)							
Access	**Bit**	7	6	5	4	3	2	1	0
R	**Value**	Variable (Low byte)							

- **[43H] CS Low**: bit7:0: Count (CS) Value Low Byte of currently processed channel. (See Channel Number.)

83H		Long Term Average High byte (LTA High)							
Access	**Bit**	7	6	5	4	3	2	1	0
R	**Value**	Variable (High byte)							

- **[83H] LTA High**: bit7:0: Long Term Average (LTA) value High Byte of currently processed channel. (See Channel Number.)

84H		Long Term Average Low byte (LTA Low)							
Access	**Bit**	7	6	5	4	3	2	1	0
R	**Value**	Variable (Low byte)							

- **[84H] LTA Low**: bit7:0: Long Term Average (LTA) value Low Byte of currently processed channel. (See Channel Number.)

10.2.4 Device Settings

CBH		Swipe Switch Settings (Swipe Settings)							
Access	Bit	7	6	5	4	3	2	1	0
R/W	Name	Set_3CH	Touches/Pulses	Swipe UI1	Swipe UI0	End_Zero	Zero_State	States Relaxed	Swipe Active

- **[CBH] Swipe Settings**:

bit7: Set_3CH – Bit is set if 3 channels are active.

bit6: Touches/Pulses – Bit indicates/set output on IC pin 7.

bit5:4: Swipe UI1:Swipe UI0 – Bits indicate/set selected swipe user interface (UI).

bit3: End_Zero – R/W bit. (See **Section 6.11**)

bit2: Zero_State – R/W bit. (See **Section 6.10**)

bit1: States Relaxed – R/W bit. (See **Section 6.1**)

bit0: Swipe Active – Bit indicates/set selection of Swipe/Normal Mode IC TYPE. (See **Section 6.1**)

CCH		ProxSense® Module Settings 0 (Prox Settings 0)							
Access	Bit	7	6	5	4	3	2	1	0
R/W	Name	Show Reset	ACK Reset	Reseed	Redo ATI	ATI Partial	Float CX	THALT1	THALT0

- **[CCH] Prox Settings 0**:

bit7: Show Reset – Bit is set if device was reset.

bit6: ACK Reset – Set bit to acknowledge device reset (i.e Clear Show Reset bit).

bit5: Reseed – Set bit to reseed LTA filter values.

bit4: Redo ATI – Set bit to perform ATI algorithm.

bit3: ATI Partial – R/W bit. (See **Section 8.9**)

bit2: Float CX – R/W bit. (See **Section 6.3**)

bit1:0: THALT1:THALT0 – Bits indicate/set LTA halt period. (See **Section 6.5**)

CDH		ProxSense® Module Settings 1 (Prox Settings 1)							
Access	Bit	7	6	5	4	3	2	1	0
R/W	Name	Comms WDT OFF	Event Mode OFF	Debug I2C	AO Clear Prox	AO OFF	ACF OFF	ATI OFF	Noise Detect OFF

- **[CDH] Prox Settings 1**:

  bit7: Comms WDT OFF – R/W bit. (See **Section 9.2**)

  bit6: Event Mode OFF – Set bit to disable Event Mode I^2C.

  bit5: Debug I^2C – Bit is set during I^2C operation. (Read only)

  bit4: AO Clear Prox – Set bit to clear Auto-OFF timer on Prox.

  bit3: AO OFF – Set bit to disable Auto-OFF function.

  bit2: ACF OFF – Bit is set if AC Filter is Disabled. (R/W)

  bit1: ATI OFF – Set bit to disable Auto-ATI functionality. (See **Section 8.9**)

  bit0: Noise Detect OFF – Set bit to disable RF detection.

CEH		ProxSense® Module Settings 2 (Prox Settings 2)							
Access	Bit	7	6	5	4	3	2	1	0
R/W	Name					IO_OUT	CS_Cap	Proj_B1	Proj_B0

- **[CEH] Prox Settings 2**:

  bit7: Not used.

  bit6: Not used.

  bit5: Not used.

  bit4: Not used.

  bit3: IO_OUT – Set bit to enable/disable additional output on PO/TX pin (IC pin 10) during I^2C operation.

  bit2: *CS_Cap – R/W bit for selection of Internal Reference Capacitor size. (0 =29.9pF; 1= 59.8pF)

  bit1:0 *Proj_B1:Proj_B0 – R/W bits for selection of internal bias current for mutual capacitance configurations.

***Please Note:** It is **not recommended** to adjust the settings of the internal reference capacitor (Cs) and bias current (i.e. bit2:0) of the *ProxSense® Module Settings 2* register.

D6H		I²C Debug – Event Mode Event Mask (Event Mask)							
Access	**Bit**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
R/W	**Name**				Noise Event	ATI Event	Swipe Event	Touch Event	Prox Event

- **[D6H] Event Mask**:
  - bit7: Not used.
  - bit6: Not used.
  - bit5: Not used.
  - bit4: Noise Event – Set bit to mask RF Noise events during Event Mode I²C comms. (Requires RF-detection = Enabled.)
  - bit3: ATI Event – Set bit to mask ATI events during Event Mode I²C comms.
  - bit2: Swipe Event – Set bit to mask Swipe events during Event Mode I²C comms.
  - bit1: Touch Event – Set bit to mask Touch events during Event Mode I²C comms.
  - bit0: Prox Event – Set bit to mask Proximity events during Event Mode I²C comms.

11 Electrical Specifications – All Preliminary

11.1 Absolute Maximum Specifications

Note: *Exceeding these maximum specifications may cause damage to the device.*

Operating temperature	-40°C to 85°C
Supply Voltage (V_{DDHI} – V_{SS})	3.6V
Maximum pin voltage	V_{DDHI} + 0.5V
Maximum continuous current (specific pins)	2mA
Pin voltage (Cx)	V_{REG}
Minimum pin voltage	V_{SS} - 0.5V
Minimum power-on slope	100V/s
ESD protection (Human Body Model)	±4kV
Maximum pin temperature during soldering	350°C (5 seconds)

11.2 General Characteristics (Measured at 25°C)

Table 11.1 IQS213 General Operating Conditions

DESCRIPTION	Conditions	PARAMETER	MIN	TYP	MAX	UNIT
Supply voltage		V_{DDHI}	1.80	3.30	3.60	V
Internal regulator output	1.80 ≤ V_{DDHI} ≤ 3.60	V_{REG}	1.63	1.70	1.77	V
Normal Power operating current [1]	1.80 ≤ V_{DDHI} ≤ 3.60 t_{LP} = N/A	I_{IQS213_NP}		217		μA
Low power 1 operating current[1]	1.80 ≤ V_{DDHI} ≤ 3.60 t_{LP} = 128ms	I_{IQS213_LP1}		3.6		μA
Low power 2 operating current[1]	1.80 ≤ V_{DDHI} ≤ 3.60 t_{LP} = 256ms	I_{IQS213_LP2}		2.3		μA
Low power 3 operating current[1]	1.80 ≤ V_{DDHI} ≤ 3.60 t_{LP} = 512ms	I_{IQS213_LP3}		1.7		μA

1. Typical values measured for a stand-alone 3-channel, mutual capacitance device configuration, with CHG FRQ = 1MHz, ATI Target = 320/160, no external pull-up resistors connected. Altering the projected current bias settings, reference capacitor (CS) size, number of active channels and ATI Target values will affect the measured current.

Table 11.2 Start-up and shut-down slope Characteristics

DESCRIPTION	Conditions	PARAMETER	MIN	MAX	UNIT
POR	V_{DDHI} Slope ≥ 100V/s	POR	1	1.55	V
BOD		BOD	1	1.5	V

Table 11.3 Debounce employed on IQS213

DESCRIPTION	Conditions	Debounce Value
Proximity debounce value	Proximity event	4 (Up and Down)
Touch debounce value	Touch event	2 (Up and Down)

11.3 Timing Characteristics

Table 11.4 Main Oscillator[3]

SYMBOL	DESCRIPTION	Conditions	MIN	TYP	MAX	UNIT
F_{OSC}	IQS213 Main oscillator	$1.80 \le V_{DDHI} \le 3.60$		4		MHz

Table 11.5 General Timing Characteristics for $1.80V \le V_{DDHI} \le 3.60V$

SYMBOL	DESCRIPTION	Conditions	MIN	TYP	MAX	UNIT
$t_{START-UP}$	Start-up time before the first communication is initiated by the IQS213			15		ms
f_{CX}	IC transfer frequency			See CHG_FRQ in **Section 8.3**		MHz
t_{CHARGE}	Charge time of channel			CS * (1/f_{CX})		ms
$t_{CHANNEL}$	Stand-alone / I^2C Mode			2.6 / 3.9		ms
t_{SAMPLE}				Active channels * $t_{CHANNEL}$		ms
t_{BP}	Channel sampling period in BP and DYCAL_TURBO = OFF			t_{SAMPLE}		ms
t_{BP_TURBO}	Channel sampling period in BP and DYCAL_TURBO = OFF			Active channels * t_{CHARGE}		ms
t_{LP}	Low Power Charging time			CS*(1/F_{CX})+t_{CHARGE}		
t_{WDT}	WDT time-out while communicating			160		ms

[3] All timings are derived from the main oscillator.

Table 11.6 IQS213 Charging Times

POWER MODE	TYPICAL (ms)
Normal Power Mode	2.6
Low Power Mode 1	128
Low Power Mode 2	256
Low Power Mode 3	512

**NOTE: with ACF = ON, detection and release times will dramatically increase due to the CS having to go through a filtering process adding a delay.

LP Response time Example:

LOW_POWER = 08h (8D) » t_{LP} = 16ms x 8 = 128ms

Channels active = 3 » t_{SAMPLE} = 4 x 2.6ms = 10.4ms

ACF = OFF » Fast respose on CS

Large CS change » Touch debounce = 2

$DetectionTime_{LP128}$ = 10.4ms + 128ms + (2)*10.4ms = 159.2 ms (max.)

12 Packaging Information

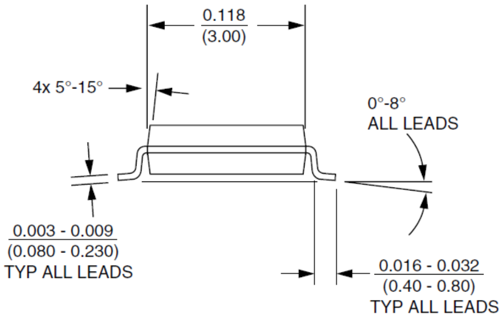


Figure 12.1 MSOP-10 Back view.

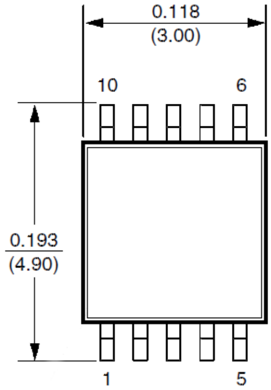


Figure 12.3 MSOP-10 Top view.

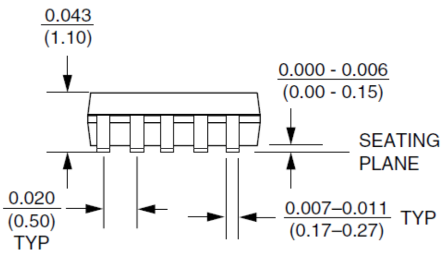


Figure 12.2 MSOP-10 Side view.

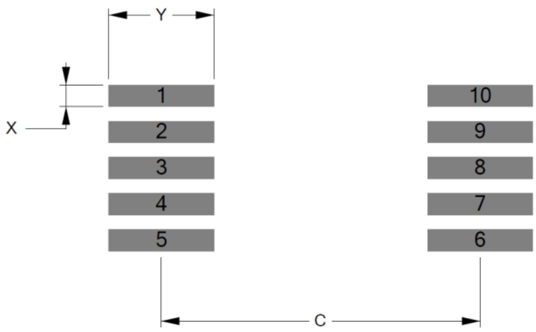


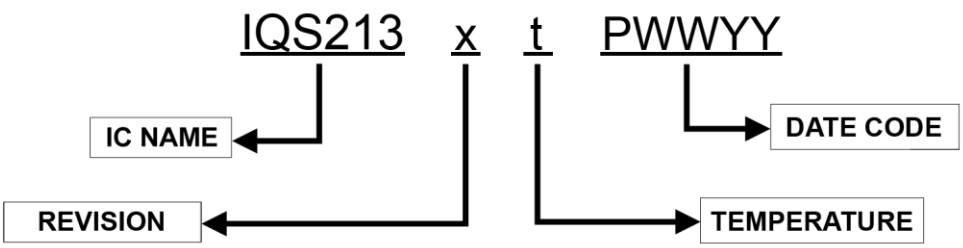
Figure 12.4 MSOP-10 Footprint.

Table 12.1 MSOP-10 Footprint Dimensions from Figure 12.4.

Dimension	[mm]
Pitch	0.50
C	4.40
Y	1.45
X	0.30

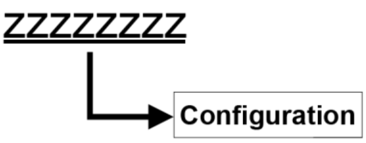
13 Device Marking

13.1 Top marking



IC NAME	**IQS213**	**=**	IQS213	
REVISION	**x**	=	IC Revision Number	
TEMPERATURE RANGE	**t**	=	i	-40°C to 85°C (Industrial)
		=	c	0°C to 70°C (Commercial)
DATE CODE	**P**	=	Package House	
	WW	=	Week	
	YY	=	Year	

13.2 Bottom Marking



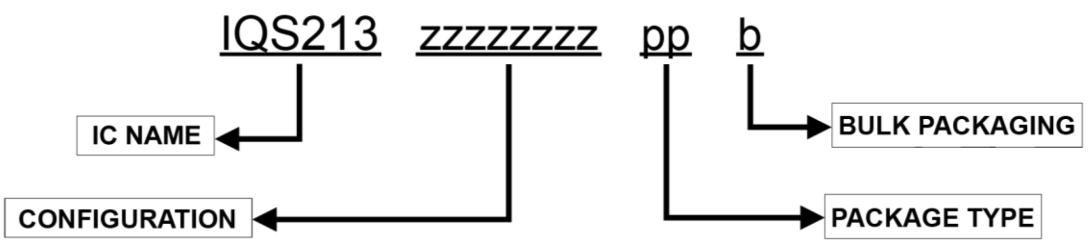
Configuration	**zzzzzzzz**	=	Device Configuration / User Programmable Options [Default = 00000000]

14 Ordering Information

Orders will be subject to a MOQ (Minimum Order Quantity) of a full reel. Contact the official distributor for sample quantities. A list of the distributors can be found under the "Distributors" section of www.azoteq.com.

The Part-number can be generated by using USBProg.exe or the Interactive Part Number generator on the website.

14.1 General Part Order Number



CONFIGURATION	zzzzzzzz	=	User Programmable Option Selection
PACKAGE TYPE	MS	=	MSOP10
BULK PACKAGING	R	=	Reel (4000pcs/reel)

15 Contact Information

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