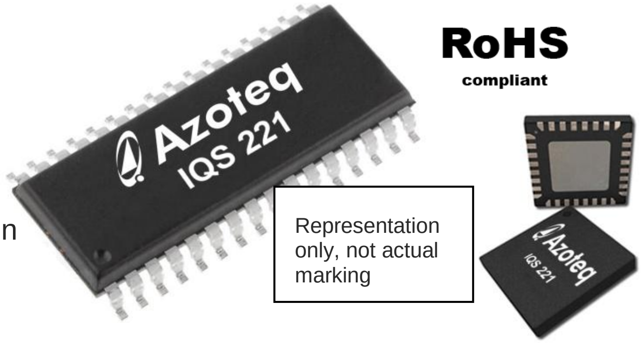
IQS221 Datasheet

IQ Switch® - ProxSense® Series

9-Channel Capacitive Touch Sensor with Proximity Detection

The IQS221 ProxSense® IC is a fully integrated multi-channel capacitive sensor. The IC can be operated as a stand-alone device or interfaced with a microprocessor. Additionally it features an internal system regulator, ensuring class leading proximity sensitivity, stability and unparalleled cost.

Through unique patented technology a solution is offered to replace conventional electromechanical switches in a cost effective manner. ProxSense® is capable of detecting a differentiated physical contact (Touch) or Proximity condition through almost any dielectric, allowing the designer to project touch pads or sliders through a variety of materials.



RoHS compliant

Main Features

- Multiple channel touch sensor
- Direct or Coded or serial data output
- Used in Slide switches and Keypads
- Automatic Environment Compensation
- On-Chip Integrated Series regulator
- On-Chip Digital Signal Processing
- Synchronises to AC supply voltage (or external synchronisation source)
- User selectable Proximity and Physical Contact(Touch) sensitivity settings
- Low Power Mode suitable for battery applications (27uA)
- Suitable for various dielectrics overlays
- Detect Touch through up to 7mm overlay
- Active driven shield pin
- OTP options
- Development and Programming tools available (VisualProxSense and USBPRog)
- QFN5x5-32 / SO-32 packages offered

Applications

- Consumer electronics
- GSM cellular telephones / PDA’s
- White goods and appliances
- Keypads / any electromechanical switches
- POS terminals
- Flame proof, hazardous environment

Human Interface Devices

- Wake-up from standby applications
- GUI trigger on proximity detection (Azoteq Patent)

Available options

T_A	SO-32 & QFN5x5-32
0°C to 70°C	IQS221

Contents

1 Overview

Actuation with built-in intelligence is now possible through touch or mere proximity to a sense pad. The IQS221 enables easy integration of a multiple channel proximity sensor.

The IQS221 can be operated in standalone applications in the Direct and Coded Modes. The IQS221 also offers 2 Serial Modes in which the IQS221 can communicate with a Master Module. The device uses the industry standard SPI Protocol when used in the Serial output mode.

The IQS221 is designed to operate from a DC supply voltage, but can be synchronised to an AC supply voltage, enabling improved proximity sensitivity. An integrated series regulator eliminates the need for expensive external regulators. Current consumption is low enough for battery powered devices. (27uA in LP4)

Value is added through a variety of sensitivity settings, automatic or fixed low power operation, user selectable sensitivity settings and control over the environmental compensation.

1.1 Applicability

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

- Temperature 0C to +70C
- Supply voltage (V_{DDHI}) 3.0V to 5.0V

2 Analogue Functionality

The analogue circuitry measures the capacitance of a sense electrode attached to the Cx pin through a charge transfer process that is periodically initiated by the digital circuitry. The measuring process is referred to as a conversion and consists of the discharging of Cs and Cx, the charging of Cx and then a series of charge transfers from Cx to Cs until a trip voltage is reached. The number of charge transfers required to reach the trip voltage is referred to as the count (CS).

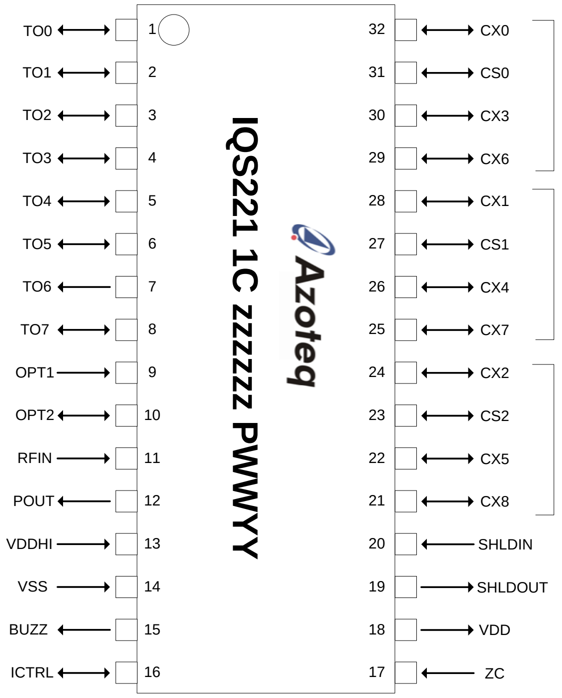
The capacitance measurement circuitry makes use of the external Cs capacitor and should be chosen for every specific application (recommended sizes given in datasheet).

The IQS221 deploys circuitry to drive a shield that will follow the voltage sensed on Cx (dependent onto which Cx SHLDIN is connected).

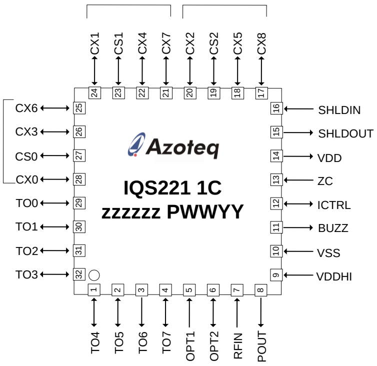
The IQS221 further also deploys advanced RF immunity and a RF detection circuit capable of detecting the presence of RF signals that may influence CS. The circuitry notifies the digital circuitry when RF has been detected.

3 Device Details

3.1 SO-32 & QFN32-5x5 Packages



SO-32 Package



QFN5x5-32 Package

3.2 Pin-out SO-32

Pin	Name	Function	I/O	POR[1] Option	Description
1	TO0	TO0	Bi-directional	CX[0:7] Touch0	Physical contact Output 0
2	TO1 / MOSI	TO1	Output	CX[0:7] Touch1	Physical contact Output 1
		MOSI	Input		Data output from master
3	TO2 / SOMI	TO2	Output	CX8 Touch0	Physical contact Output 2
		SOMI	Output		Data output from slave
4	TO3 / RDY	TO3	Bi-directional		Physical contact Output 3
		RDY	Output		Data available indication from slave
5	TO4 / SCK	TO4	Bi-directional	CX8 Touch1	Physical contact Output 4
		SCK	Input		Clock from Master
6	TO5 / /SS	TO5	Bi-directional	CX[0:7] Prox	Physical contact Output 5
		/SS	Input		Not Slave select, active low
7	TO6	TO6	Output	CX8 Prox0	Physical contact Output 6
8	TO7	TO7	Bi-directional	CX8 Prox1	Physical contact Output 7
9	OPT1	OPT1	Input	-	Dynamic LP / NP Dynamic Switching
10	OPT2	OPT2	Bi-directional	-	Dynamic Halt Charge, Ready
11	RFIN	RF Input	Input	-	RF antenna input for RF detection
12	POUT	POUT	Output	-	Proximity Output
13	VDDHI	VDDHI	Supply Input	-	Supply Voltage Input
14	VSS	VSS	Ground Input	-	GND Reference
15	Buzz	BUZZ	Output	-	Buzzer Output
16	ICTRL	ICTRL	Custom	-	Current Reference
17	ZC	ZC	Analogue Input	-	Zero Cross AC input
18	VDD	VDD	Analogue Output	-	Internal Regulator Pin (Connect 1uF Capacitor to VSS)
19	SHLDOUT	SHLDOUT	Output	-	Shield Output
20	SHLDIN	SHLDIN	Bi-directional	-	Shield Input
21	CX8	CX8	Bi-directional	-	Sense Electrode 8
22	CX5	CX5	Bi-directional	-	Sense Electrode 5
23	CS2	CS2	Bi-directional	-	Reference Capacitor 2
24	CX2	CX2	Bi-directional	-	Sense Electrode 2
25	CX7	CX7	Bi-directional	-	Sense Electrode 7
26	CX4	CX4	Bi-directional	-	Sense Electrode 4
27	CS1	CS1	Bi-directional	-	Reference Capacitor 1
28	CX1	CX1	Bi-directional	-	Sense Electrode 1
29	CX6	CX6	Bi-directional	-	Sense Electrode 6
30	CX3	CX3	Bi-directional	-	Sense Electrode 3
31	CS0	CS0	Bi-directional	-	Reference Capacitor 0
32	CX0	CX0	Bi-directional	-	Sense Electrode 0

[1] POR = Power On Reset. POR options are used to determine Prox/Touch sensitivity with start-up

3.3 Pin-out QFN32-5x5

Pin	Name	Function	I/O	POR[2] Option	Description
1	TO4 / SCK	TO4	Bi-directional	CX8 Touch1	Physical contact Output 4
		SCK	Input		Clock from Master
2	TO5 / /SS	TO5	Bi-directional	CX[0:7] Prox	Physical contact Output 5
		/SS	Input		Not Slave select, active low
3	TO6	TO6	Output	CX8 Prox0	Physical contact Output 6
4	TO7	TO7	Bi-directional	CX8 Prox1	Physical contact Output 7
5	OPT1	OPT1	Input	-	Dynamic LP / NP Dynamic Switching
6	OPT2	OPT2	Bi-directional	-	Dynamic Halt Charge, Ready
7	RFIN	RF Input	Input	-	RF antenna input for RF detection
8	POUT	POUT	Output	-	Proximity Output
9	VDDHI	VDDHI	Supply Input	-	Supply Voltage Input
10	VSS	VSS	Ground Input	-	GND Reference
11	Buzz	BUZZ	Output	-	Buzzer Output
12	ICTRL	ICTRL	Custom	-	Current Reference
13	ZC	ZC	Analogue Input	-	Zero Cross AC input
14	VDD	VDD	Analogue Output	-	Internal Regulator Pin (Connect 1uF Capacitor to VSS)
15	SHLDOUT	SHLDOUT	Output	-	Shield Output
16	SHLDIN	SHLDIN	Bi-directional	-	Shield Input
17	CX8	CX8	Bi-directional	-	Sense Electrode 8
18	CX5	CX5	Bi-directional	-	Sense Electrode 5
19	CS2	CS2	Bi-directional	-	Reference Capacitor 2
20	CX2	CX2	Bi-directional	-	Sense Electrode 2
21	CX7	CX7	Bi-directional	-	Sense Electrode 7
22	CX4	CX4	Bi-directional	-	Sense Electrode 4
23	CS1	CS1	Bi-directional	-	Reference Capacitor 1
24	CX1	CX1	Bi-directional	-	Sense Electrode 1
25	CX6	CX6	Bi-directional	-	Sense Electrode 6
26	CX3	CX3	Bi-directional	-	Sense Electrode 3
27	CS0	CS0	Bi-directional	-	Reference Capacitor 0
28	CX0	CX0	Bi-directional	-	Sense Electrode 0
29	TO0	TO0	Bi-directional	CX[0:7] Touch0	Physical contact Output 0
30	TO1 / MOSI	TO1	Output	CX[0:7] Touch1	Physical contact Output 1
		MOSI	Input	-	Data output from master
31	TO2 / SOMI	TO2	Output	CX8 Touch0	Physical contact Output 2
		SOMI	Output	-	Data output from slave
32	TO3 / RDY	TO3	Bi-directional	-	Physical contact Output 3
		RDY	Output	-	Data available indication from slave

[2] POR = Power On Reset. POR options are used to determine Prox/Touch sensitivity with start-up

3.4 Schematic

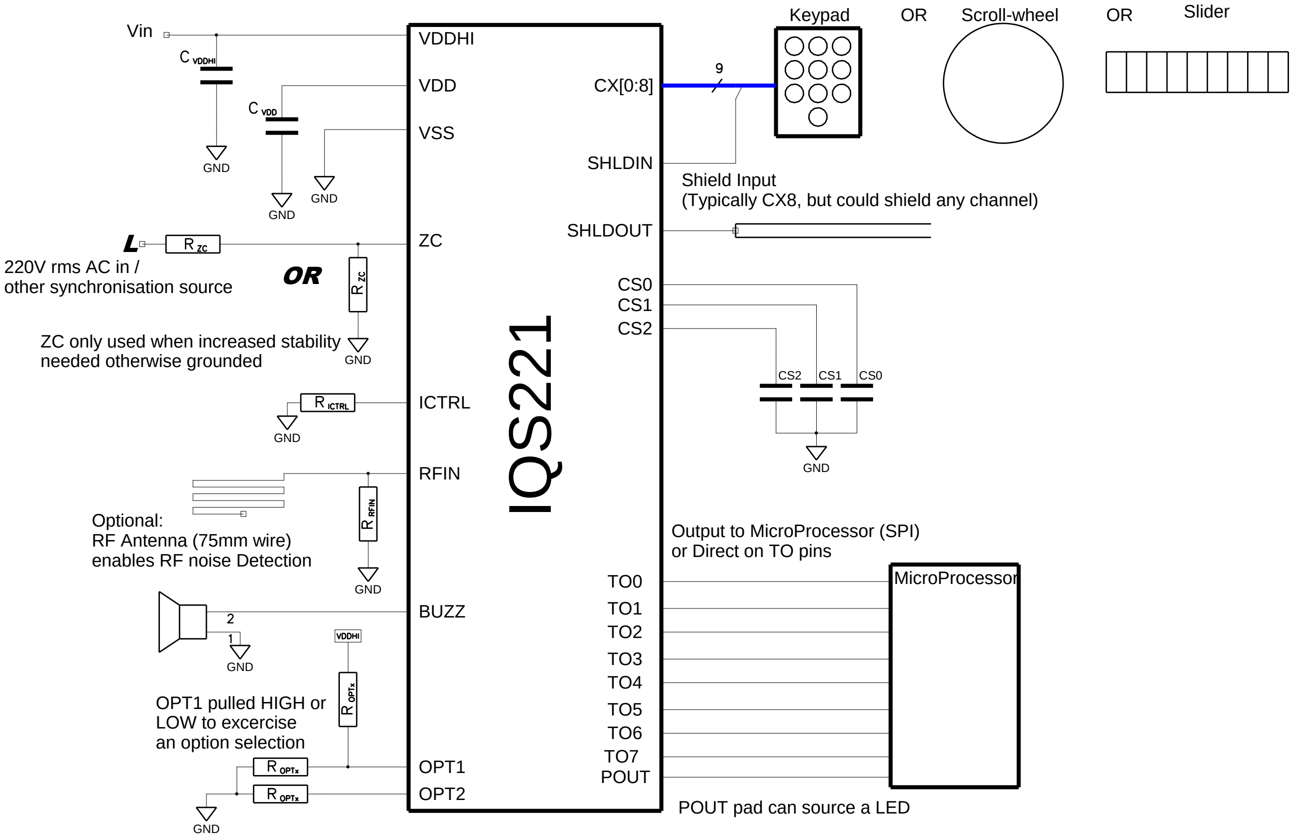


Figure 3-1: Typical Connection Diagram for IQS221

3.4.1 Typical Values

<table>
<tr><th>Component</th><th>Value</th><th>Comment</th></tr>
<tr><td>Cs[2:0]</td><td>33nF</td><td>Range: 10nF – 100nF. Higher value will have increased sensitivity but decreased response time.</td></tr>
<tr><td>R_{ICTRL}</td><td>43kΩ</td><td>IC current reference</td></tr>
<tr><td>R_{CX}</td><td>2kΩ</td><td>Resistor between CX pad and touch pad. Resistor increases ESD immunity</td></tr>
<tr><td>V_{DD}</td><td>1uF</td><td>Adding a 100pF capacitor in parallel will increase EMC (RF) immunity</td></tr>
<tr><td>V_{DDHI}</td><td>1uF</td><td>Adding a 100pF capacitor in parallel will increase EMC (RF) immunity</td></tr>
<tr><td>R_{OPTx}</td><td>100kΩ</td><td>R_{OPTx} used as static selection or dynamically:<table><tr><th></th><th>HIGH</th><th>LOW</th></tr><tr><td>OPT1</td><td>NP</td><td>LP</td></tr><tr><td>OPT2</td><td>Halt Charge Transfers</td><td>Normal Operation</td></tr></table></td></tr>
<tr><td>R_{TOx}</td><td>100kΩ</td><td>Used for sensitivity selection on TO pins (alternatively the FG can be set / value written in through SPI)</td></tr>
<tr><td>R_{RFIN}</td><td>50Ω</td><td>RF matching impedance</td></tr>
<tr><td rowspan="2">R_{ZC}</td><td>100kΩ to GND</td><td>IC not synchronised to external source OR</td></tr>
<tr><td>R_{ZC} to synch. source</td><td>Synchronised to external source with maximum amplitude V_{ZC}
(i.e. if synchronized to 230V AC, 3 x 20kΩ (125mW) resistors)</td></tr>
<tr><td>R_{SHLD}</td><td>100kΩ</td><td>RSHLD (SHLDOUT to VDDHI) increases shielding, only required if shield is used. Smaller resistor will give better shielding but increased current consumption</td></tr>
</table>

Detailed Description

4 Configuration Options

The IQS221 provides One Time Programmable (OTP) user options (each option can be modified only once). The device is fully functional in the default (unconfigured) 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.

Azoteq can supply pre-configured devices for large quantities.

4.1 Device Configuration

Azoteq offers a Configuration Tool (CTxxx) and accompanying 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 is explained by application note: *"AZD007 – USBProg Overview"* which can be found on the Azoteq website.

Alternate programming solutions of the IQS221 also exist. For further enquiries regarding this matter please contact Azoteq at ProxSenseSupport@azoteq.com or the local distributor

Table 4-1: User Selectable Configuration Options: Bank 0

TO5	TO2	TO1	TO0	OUTPUT3	OUTPUT2	OUTPUT1	OUTPUT0

bit 7 bit 0

bit 0-3	**OUTPUT3:OUTPUT0:** Output function 0000 = DIR-A: Direct Mode 0001 = DIR-B: Direct Mode (all channels) 0010 = DIR-F: Toggle Mode 0011 = DIR-C: Minimum Mode (Cx8 independent) 0100 = DIR-E: Minimum Mode (Toggle) 0101 = DIR-G: Current Mode 0110 = CODED-J: Current Mode 0111 = DIR-D: Minimum Mode (all channels) 1000 = CODED-I: Minimum Mode (all channels) 1001 = CODED-H: Minimum Mode (Cx8 independent) 1010 = NOT USED 1011 = SPI-L: Normalized values on SPI 1100 = SPI-M: Raw values on SPI 1101 = NOT USED 1110 = NOT USED 1111 = NOT USED	-Section 6.1
bit 4-5	**TO1:TO0:** TO pins' state control Channel 0:7 Touch sensitivity selection	-Section 6.3
bit 6	**TO2:** TO pin state control Channel 8 Touch sensitivity selection (with external TO4)	-Section 6.3
bit 7	**TO5:** TO pin state control Channel 7 Proximity sensitivity selection	-Section 6.3

Table 4-2: User Selectable Configuration Options: Bank 1

FASTCHARGE	LP1	LP0	XLP	EXT/INT_SEN	PROXLVLSEL	TO7	TO6
bit 15							bit 8

bit 8-9	**TO7:TO6:** TO pins' state control See Table 4-1	-Section 6.3
bit 10	**PROXLVLSEL:** Proximity Level selection 0 = Default 1 = Alternative	-Section 6.3
bit 11	**EXT/INT_SEN:** Input sensitivity through External / Internal selections 0 = External 1 = Internal	-Section 6.3
bit 12	**XLP:** Additional Low power Mode enable/disable control bit 0 = enable XLP 1 = disable XLP	-Section 6.4
bit 13-14	**LP1:LP0:** Low power mode select (only used if OPT1 = LOW) 00 = LP1 01 = LP2 10 = LP3 11 = LP4	-Section 6.5
bit 15	**FASTCHARGE:** Fast charge enable/disable control bit 0 = disable Fast charge (TSAMPLE = ±20ms) 1 = enable Fast charge (TSAMPLE = ±15ms)	-Section 6.6

Table 4-3: User Selectable Configuration Options: Bank 2

-	ND	-	CONVDIV	SHIELD	ZOOM	HALT1	HALT0
bit 23							bit 16

bit 16-17	**HALT1:HALT0:** Halt filter time-out (T_{HALT}) control bits 00 = 20 seconds 01 = 40 seconds 10 = Never halt 11 = Always halt	-Section 6.7
bit 18	**ZOOM:** Zoom enable/disable control bit 0 = Disable Zoom 1 = Enable Zoom	-Section 6.8
bit 19	**SHIELD:** Shield enable/disable control bit 0 = Enable Shield 1 = Disable Shield	-Section 8
bit 20	**CONVDIV:** Set the conversion frequency 0 = 250kHz (nominal) 1 = 125kHz (nominal)	-Section 6.9
bit 21	**-:** Not used	
bit 22	**ND:** Noise detect enable/disable control bit 0 = Enable ND 1 = Disable ND	-Section 9.2
bit 21	**-:** Not used	

5 Measuring capacitance using the 'Charge Transfer' method

The charge transfer method of capacitive sensing is employed on the IQS221. (The Charge Cycle principle is thoroughly described in APP NOTE "AZD0004: Azoteq Capacitive Sensing".)

A charge cycle is used to take a measurement of the capacitance of a sense electrode (connected to CXx) relative to ground. It consists of a series of pulses charging Cx and discharging Cx to the reference capacitor, at the charge transfer frequency (F_{CX} - refer to Section 6.9). The count of the pulses required to reach a trip voltage on the reference capacitor is referred to as a **count** (CS) which is the instantaneous capacitive measurement. The CS is used to determine if either a physical contact or proximity event occurred (see Section 6.7 for more details on how a proximity and physical contact events are determined and differentiated between).

Three CX channels are multiplexed into one CS reference capacitor as indicated in Table 5-1 and **Figure 5-1**. The Charge Cycles of the IQS221 can be measured on the CS Pins.

From Table 5-1, the designer should determine which CS capacitors to place, depending on the number of CX channels employed.

Typical size of CS capacitor is 33nF, but it can range from 10nF (less sensitive) to 100nF (very sensitive / almost unstable), depending on the layout. If more ground planes or foreign traces exist close to the CX lines, it is advisable to have a bigger CS capacitor.

Example: A 5 channel application will utilise CX[0, 1, 3, 4, 6] for the Touch pads and CS0 and CS1. Unused CX channels are grounded.

For applications requiring Proximity sensing, it is proposed to utilise CX8 and CS2, as CX8 has an individual threshold setting for improved Proximity sensitivity. A large copper pour will serve as a good Proximity electrode.

Table 5-1- Multiplexed charging scheme

CX			CS
Group A	**Group B**	**Group C**	
CX0	CX3	CX6	CS0
CX1	CX4	CX7	CS1
CX2	CX5	CX8	CS2

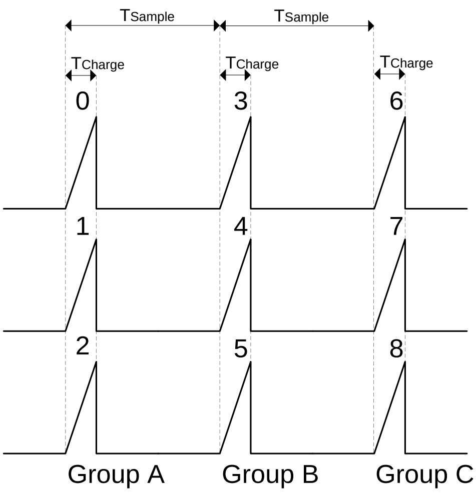


Figure 5-1- Multiplexed charging scheme

Please Note: If using the IQS221 capacitive sensor in an application which may have a wide operating temperature (∆ ≥ 30°C) it is recommended to use COG capacitors to maintain the same sensitivity throughout.

6 Descriptions of User Functions

The IQS221 IC can be configured to act as a multi-channel physical contact (/touch) sensor, while all the channels can sense proximity. The IC can be fully customised for almost any design by using a combination of internal programmable functions and external chosen options through resistors. The User Options include.

- A variety Output Functions
- Different Power modes
- Fast Charge Selector
- Control over the IIR Adaptation
- Zoom Option
- Dynamic LP / NP switching
- Dynamic Charge halting
- Sensitivity settings

6.1 Output Function

The output mode is programmed by setting the required configuration bits. A number of output configurations are available on the IQS221. The possible output configurations of the IQS221 fall in three categories, which include Direct, Binary Coded or interfaced with a microprocessor (SPI).

For all Direct and Binary Coded User Interfaces (UI's): Upon the detection of a proximity on any of the pins, the POUT pin will go HIGH for as long as the proximity condition occurs.

The POUT pin is active high, and can source I_{POUT}, enough to drive a LED.

All output pins are sourced from VDDHI when active. The Buzzer is enabled except if stated otherwise.

Table 6-1- User selectable Output modes

UI #	Output pin Function
Direct Mode	
DIR-A	Direct Mode
DIR-B	Direct Mode (all channels)
DIR-C	Minimum Mode (CX8 independent)
DIR-D	Minimum Mode (all channels)
DIR-E	Minimum Mode (Toggle)
DIR-F	Toggle Mode
DIR-G	Current Mode
Binary Coded Mode	
Coded - H	Minimum Mode (CX8 independent)
Coded - H	Minimum Mode (all channels)
Coded - H	Current Mode
Serial Peripheral Interface (SPI) Mode	
SPI-L	Normalized values
SPI-M	Counts (raw)

Direct Modes

6.1.1 DIR-A Direct Mode

DIR-A gives an Active HIGH output on pins TO[0,1,2,3,4,5,6,7] if a touch is detected on the corresponding sensing pins CX[0,1,2,3,4,5,6,8].

(Note: CX7 is not used in this configuration)

Table 6-2- DIR-A

Pin State	Input Pins	Output Pins
Active HIGH	CX[0,1,2,3, 4,5,6,8]	TO[0,1,2,3, 4,5,6,7]

6.1.2 DIR-B Direct Mode (all channels)

DIR-B gives an Active HIGH output on pins TO[0,1,2,3,4,5,6,7], BUZZ if a touch is detected on the corresponding sensing pins CX[0,1,2,3,4,5,6,7,8].

Table 6-3- DIR-B

Pin State	Input Pins	Output Pins
Active HIGH	CX[0,1,2,3, 4,5,6,7,8]	TO[0,1,2,3, 4,5,6,7], BUZZ

*No buzzer functionality, only logical output

6.1.3 DIR-C Minimum Mode (Cx8 independent)

The touch creating the biggest change in capacitance, or in other words pressed with the largest part of the finger will register as the current touch. Only one touch at a time registered, except for CX8 which works independent.

Example: Upon the detection of a touch on one of the CX pins, the corresponding TO pin will latch HIGH for the duration of the touch. If a second touch is detected and the change in capacitance created by this touch is bigger than the first touch, it will register as the new touch.

Table 6-4- DIR-C

Pin State	Input Pins	Output Pins
Button with largest capacitive change is Active High	CX[0,1,2,3, 4,5,6]	TO[0,1,2,3, 4,5,6]
Active High	CX8	TO7

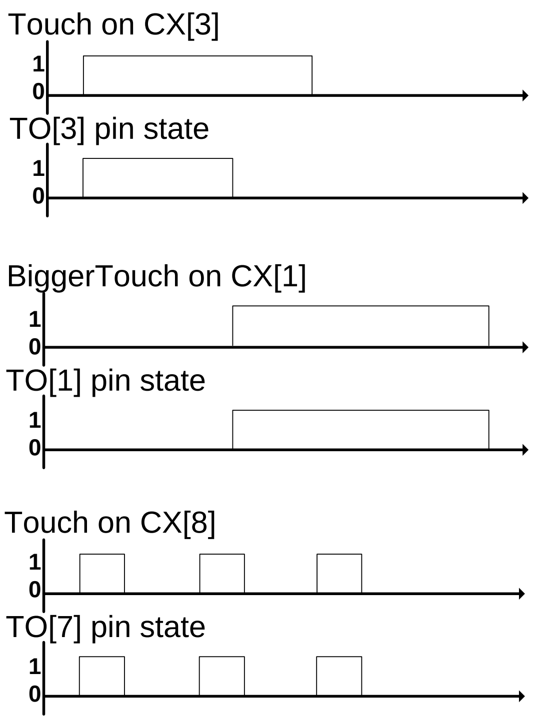


Figure 6-1: DIR-C

6.1.4 DIR-D Minimum Mode (all channels)

Table 6-5- DIR-D

Pin State	Input Pins	Output Pins
Button with largest capacitive change is Active High	CX[0,1,2,3, 4,5,6,7,8]	TO[0,1,2,3, 4,5,6,7], BUZZ

*No buzzer functionality, only logical output

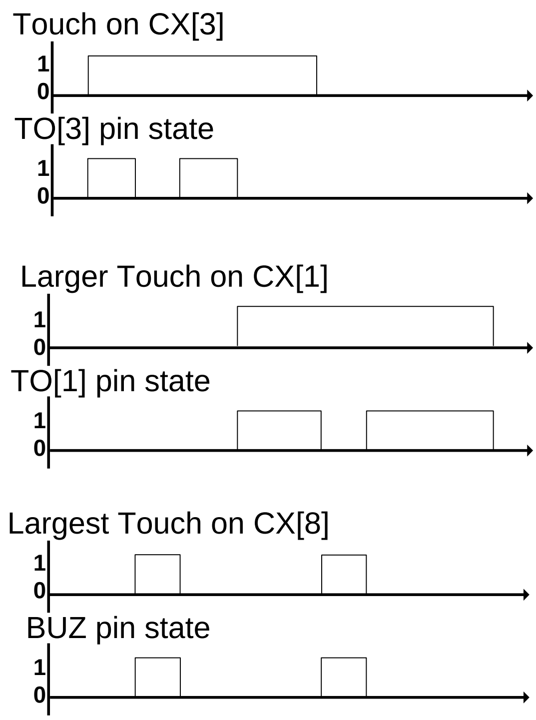


Figure 6-2: DIR-D

6.1.5 DIR-E Minimum Mode (Toggle)

Upon the detection of a touch on one of the CX pins, the corresponding TO pin will toggle HIGH. If a second touch is detected (which creates a larger change in capacitance) on another pin, this pins' corresponding TO pin will toggle HIGH. The pins' state will stay the same, until toggled again.

Only the touch creating the largest change in capacitance to occur is recorded and the corresponding TO pin will toggle HIGH.

Only one touch at a time registered, except for CX8 which works independent.

Table 6-6- DIR-E

Pin State	Input Pins	Output Pins
Button with largest capacitive change is Toggled High	CX[0,1,2,3, 4,5,6]	TO[0,1,2,3, 4,5,6]
Active High	CX8	TO7

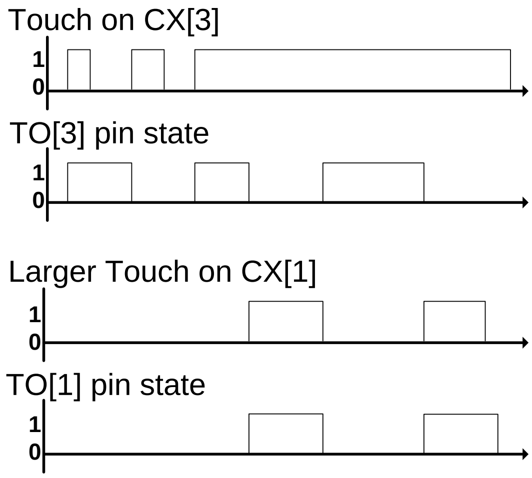


Figure 6-3: DIR-E

6.1.6 DIR-F Toggle Mode

Upon the detection of a touch on pins CX[0,1,2,3,4,5,6,8], the corresponding TO pin will toggle between HIGH and LOW. The pin will stay in that state until toggled again.

Example: If the TO[1] pin is LOW, a touch will change it to HIGH, and also if TO[1] is HIGH, a touch will change it to LOW.

Table 6-7- DIR-F

Pin State	Input Pins	Output Pins
Toggle	CX[0,1,2,3, 4,5,6,8]	TO[0,1,2,3, 4,5,6,7]

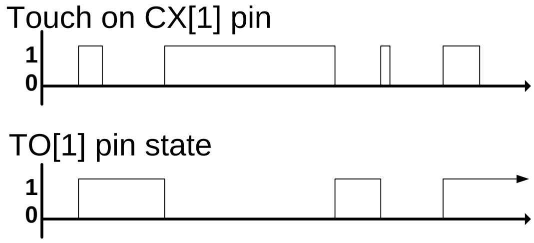


Figure 6-4: DIR-F

6.1.7 DIR-G Current Mode

Upon the detection of a touch on one of the CX pins, the corresponding TO pin will latch HIGH for the duration of the touch. If a second touch is detected on another pin, this pins' corresponding TO pin will latch HIGH and cause the first pins' TO pin to latch LOW. Thus only the latest touch that occurred is recorded. A touch on CX8 will be outputted to the Buzz pin.

Table 6-8- DIR-G

Pin State	Input Pins	Output Pins
Last button touched is Active High	CX[0,1,2,3, 4,5,6,7,8]	TO[0,1,2,3, 4,5,6,7], BUZZ

*No buzzer functionality, only logical output

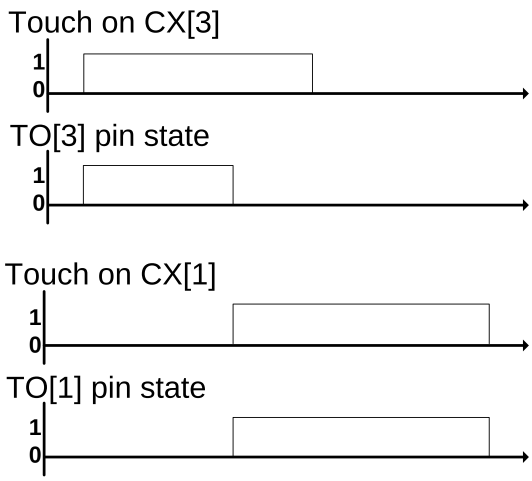


Figure 6-5: DIR-G

Binary Coded Mode

The outputs of these modes are coded in binary to pins TO[3:0]. The '1's and '0's denote logical HIGH and logical LOW irrespectively. See Table 6-9 for the Binary Coded Outputs.

Table 6-9- Binary Coded values

	TO3	TO2	TO1	TO0	Decimal
CX0	0	0	0	1	1
CX1	0	0	1	0	2
CX2	0	0	1	1	3
CX3	0	1	0	0	4
CX4	0	1	0	1	5
CX5	0	1	1	0	6
CX6	0	1	1	1	7
CX7	1	0	0	0	8
CX8	1	0	0	1	9

6.1.8 CODED-H Minimum Mode (CX8 independent)

The touch creating the biggest change in capacitance, or in other words pressed with the largest part of the finger will register as the current touch. The channel that registers the largest touch will be outputted to TO[3:0] in binary.

Only one touch at a time registered, except for CX8 which works independent. CX8 is outputted to TO4, and not as displayed in Table 6-9.

Example: Upon the detection of a touch on CX4, the binary coded value '0101'b will be outputted onto TO[3:0]. This value will latch HIGH for the duration of the touch. If a second touch is detected and the change in capacitance created by this touch is bigger than the first touch, it will register as the new touch.

Table 6-10- CODED-H

Pin State	Input Pins	Output Pins
Button with largest capacitive change is Active High	CX[0,1,2,3, 4,5,6,7]	Binary Coded on TO[0,1,2,3]
Active High	CX8	TO4

6.1.9 CODED-I Minimum Mode

The touch creating the biggest change in capacitance, or in other words pressed with the largest part of the finger will register as the new touch. The channel that registers the largest touch will be outputted to TO[3:0] in binary.

Only one touch at a time registered. See Table 6-9 for coded values.

Example: Upon the detection of a touch on CX2, the binary coded value '0011'b will be outputted onto TO[3:0]. This value will latch HIGH for the duration of the touch. If a second touch is detected and the change in capacitance created by this touch is bigger than the first touch, it will register as the new touch.

Table 6-11- CODED-I

Pin State	Input Pins	Output Pins
Button with largest capacitive change is Active High	CX[0,1,2,3, 4,5,6,7,8]	Binary Coded on TO[0,1,2,3]

6.1.10 CODED-J Current Mode

Upon the detection of a touch on one of the CX pins, the corresponding binary value will be outputted to the TO[3:0] pins. The pins will latch HIGH for the duration of the touch. If a second touch is detected on another pin, this pins' corresponding binary value will be outputted to pins TO[3:0], overwriting the first touch's value.

Only the latest touch that occurred is recorded. CX8 operates independently and is outputted to TO4.

Table 6-12- CODED-J

Pin State	Input Pins	Output Pins
Last button touched is Active High	CX[0,1,2,3, 4,5,6,7]	Binary Coded on TO[0,1,2,3]
Active High	CX8	TO4

SPI

The SLAVE SPI protocol is used for serial communication with a MCU. The SPI protocol for the IQS221 has the 4 typical pins used in SLAVE SPI communication:

- Master out slave in (MOSI) – TO1
- Slave out master in (SOMI) – TO2
- Serial clock (SCK) – TO4
- Slave Select (/SS) – TO5

Additionally a 5th pin is used namely:

- Ready (RDY) – TO3

The IQS221 should be configured in one of the SPI modes, before SPI communication can commence between the IQS221 and a MCU.

The /SS on the IQS221 must be LOW for it to respond to the MCU (MASTER). This allows the MCU to share the same SPI lines with numerous SLAVES.

The RDY pin is used to alert the MCU that the IQS221 has data available. Only when the MCU sees this, can it clock out a byte from the IQS221. The RDY pin will go low for every byte of data it has available.

The RDY line is driven LOW by the IQS221 after the first rising edge of the SCK from the MCU, and will only go HIGH again when the next data byte is available.

The MCU SPI should be set up so that:

- The MCU is MASTER
- The MCU waits for RDY to be HIGH before initiating the data transfer
- Input data (SOMI) is sampled at end of data output time
- Data transmission occurs on the rising edge of the clock (SCK)
- Idle state for clock is a HIGH

The SPI timing is illustrated in Figure 6-7. The data for groups A, B and C are sent after the conversions for the relevant group are complete.

Example: The data for CX0, CX1 and CX2 are sent together, and in the next cycle the data for CX3, CX4 and CX5 are sent together. Refer to Figure 6-6.

The following functions differ when the IC operates in a SPI mode:

- OPT2 – This pin can be used to wake up the IQS221 / continue data transfer with the IQS221, after a SLEEP / STOP_TRANSMIT command. A falling edge will wake the IQS221
- Sensitivity selections are internal and set through SPI commands.
- TO4 – This selection should be sent via a SPI command.

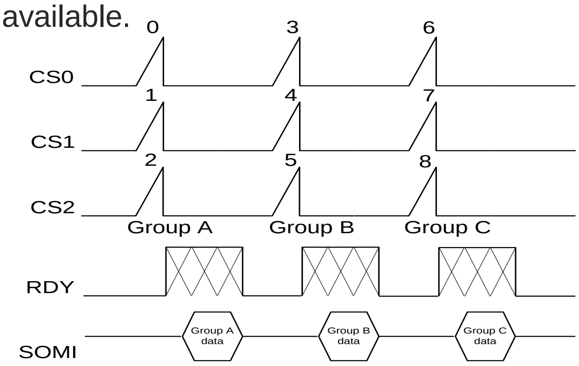


Figure 6-6: SPI Data Transfer after Conversion

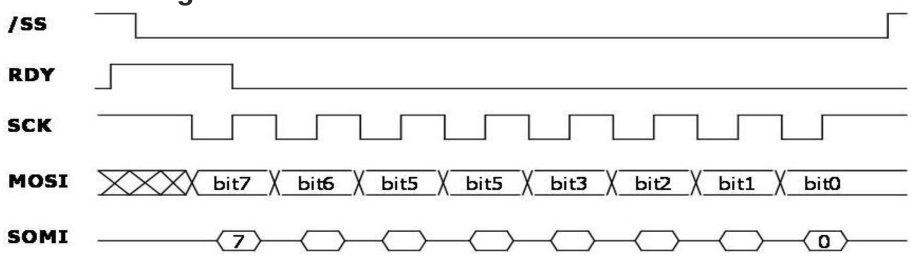


Figure 6-7: SPI Timing

6.1.11 SPI-L Relative Values

Relative values of each channel are sent via SPI. The relative values are derived from the raw data of each channel normalised with the filter value of the same channel. This relative value gives the designer the ability to see which channel gives the largest change with a user touch.

If the Count is exactly the same as the filter value, then the value sent would be 256. The bigger the touch/proximity, the smaller this value would become. In this mode a SPI string of 12 bytes is sent out in a cycle. The 12 bytes are indicated in Table 6-13.

Table 6-13- SPI-L – Description of Bytes sent

		Bytes Sent by IQS221		Bytes Received by IQS221	
Byte #	Bit #	Value	Function	Value	Function
1	7:0	0xFF	Header1	Command Header	Note[5]
2	15:8	<ND CBA><cba><d>	Header2[1]	Command Data	Note[5]
3	23:16	CH[7:0] [2]	Active channels	Length	Note[6]
4	31:24	Relative I	MSB	D/C	Don't care
5	39:32	Relative I	LSB	D/C	Don't care
6	47:40	Relative II	MSB	D/C	Don't care
7	55:48	Relative II	LSB	D/C	Don't care
8	63:56	Relative III	MSB	D/C	Don't care
9	71:64	Relative III	LSB	Length	Note[6]
10	79:72	ThresholdX	Note[3]	D/C	Don't care
11	87:80	ThresholdY	Note[3]	D/C	Don't care
12	95:88	CRC	Note[4]	D/C	Don't care

6.1.12 SPI-M Raw Data Out

Count and filter values of each channel is sent as Raw data via SPI. The designer has the freedom to implement a custom User Interface using a MCU. The data is sent according to Table 6-14.

The SPI functionality is identical to that described above in Section 6.1.11, with the addition of a LENGTH byte = 0x04 sent to stop the SPI after byte 15.

For both SPI modes, if a proximity is detected on any of the channels, POUT will latch HIGH for the duration of the proximity event, the Buzz also functions on a TOUCH.

Table 6-14- SPI-M – Description of Bytes sent

		Bytes Sent by IQS221		Bytes Received by IQS221	
Byte #	Bit #	Value	Function	Value	Function
1	7:0	0xFF	Header1	Command Header	Note[5]
2	15:8	<ND CBA><cba><d>	Header2[1]	Command Data	Note[5]
3	23:16	CH[7:0]	Active channels	Length	Note[6]
4	31:24	CS I	MSB	D/C	Don't care
5	39:32	CS I	LSB	D/C	Don't care
6	47:40	CS II	MSB	D/C	Don't care
7	55:48	CS II	LSB	D/C	Don't care
8	63:56	CS III	MSB	D/C	Don't care
9	71:64	CS III	LSB	Length	Note[6]
10	79:72	LT I	MSB	D/C	Don't care
11	87:80	LT I	LSB	D/C	Don't care
12	95:88	LT II	MSB	D/C	Don't care
13	103:96	LT II	LSB	D/C	Don't care
14	111:104	LT III	MSB	D/C	Don't care
15	119:112	LT III	LSB	Length	Note[6]
16	127:120	ThresholdX	Note	D/C	Don't care
17	135:128	ThresholdY	Note	D/C	Don't care
18	143:136	CRC	Note	D/C	Don't care

Note1: <ND> = Set when Noise Detected (Noise Detection scheme must be enabled in configuration bits – default enabled)
<CBA>= Touch(III);Touch(II);Touch(I)
<cba> = Prox(III); Prox(II); Prox(I)
<d> = Channel 8 active
Example: If Group A data is being sent (CX0, CX1 and CX2), and a touch is detected on CX1 and CX2; then <CBA> = 110.

Note2: Along with bit 'd' sent in Byte #2, these 9 bits indicate which 3 channels' data is sent in Byte #4 - #9. If one of the channels in this group is disabled, the bit would be = 0.

Example if Group A data is being sent (CX0, CX1 and CX2); then d=0 and Byte #3 = 00000111.

Table 6-15: Note3:

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
ThresholdX	PROXL VLSEL	TO7	TO6	TO5	TO4	TO2	TO1	TO0
ThresholdY	x	x	x	x	x	halt C	halt B	halt A

ThresholdX: The current sensitivity settings as decoded in Table 6-21 to Table 6-24 are shown. PROXLVLSEL - This overwrites the status of Alternative PROX level selection OTP bit.

ThresholdY: Indicates the state of the respective filter, whether it is being halted from the IQS221

Note4: The CRC byte is a simple XOR of all the bytes sent, this can be used together with the header for synchronising, as well as confirmation that all data was transmitted correctly.

Note5: Data can be sent to the IQS221 to adjust a variety of settings. These commands can be decoded as:

Table 6-16: SPI Commands

SPI Command	Function
0xE1	Prox/Touch settings
0xB4	Configuration settings
0xD2	Command settings

Example: Overwriting the sensitivity settings can be achieved by sending a command header = E1, and then data in the same formatting as ThresholdX. See Table 6-18 below.

Note6: The length packet determines the number of bytes sent out in the SPI cycle. Once the length byte is received, the IQS221 will adjust the number of bytes it sends out immediately, followed by the CRC byte.

Table 6-17: Length Packet

Length byte	Interrupt at:
0x00	No interrupt
0x01	Interrupt after Byte3
0x02	Interrupt after Byte9
0x04	Interrupt after Byte15

Table 6-18: ThresholdX data

Command	0xE1							
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Data	PROXLVLSEL	TO7	TO6	TO5	TO4	TO2	TO1	TO0

bit7 **PROXLVLSEL**: PROX Level select control bit (See Section 6.3)
1 = enable alternative Proximity level selection
0 = default

bit6:0 **TO7:TO0**: TO pins' state control bits (See Section 6.3)

Table 6-19: Configuration Settings

Command	0xB4							
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Data	SHIELD	ZOOM	HALT1	HALT0	FASTCHARGE	LP1	LP0	XLP

bit7 **SHIELD**: Shield enable/disable control bit (See Section 8)
1 = enable Shield
0 = disable shield

bit6 **ZOOM**: Zoom enable/disable control bit (See Section 6.8)
1 = disable Zoom
0 = enable Zoom

bit5:4 **HALT1/HALT0**: Halt filter time-out (T_{HALT}) select (See Section 6.7)
11 = Always halt
10 = Never halt

01 = 40s
00 = 20s

bit3 **FASTCHARGE**: Fast charge enable/disable control bit (See Section 6.6)
1 = enable Fast charge (T_{SAMPLE} = ±15ms)
0 = disable Fast charge (T_{SAMPLE} = ±20ms)

bit2:1 **LP1/LP0**: Low power mode select (only used if OPT1 = LOW or set with Command 0xD2) (See Section 6.5)
11 = 440ms
10 = 330ms
01 = 220ms
00 = 110ms

bit0 **XLP** = Additional Low power Mode enable/disable control bit
1 = enable XLP
0 = disable XLP

Table 6-20: Command settings

Command	0xD2							
Data	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	RESEED	-	-	NP/LP	SLEEP	STOPSPI	ND	CONVDIV

bit7 **RESEED**: Force a filter reseed to 8 counts below count
1 = force RESEED on filter
0 = filter unaffected

bit6 Unused

bit5 Unused

bit4 **NP/LP**: Normal power / Low power mode select
1 = Low power mode
0 = Normal power mode

bit3 **SLEEP**: Sleep enable/disable control bit[7]
1 = enable Sleep
0 = IQS221 unaffected

bit2 **STOPSPI**: Stop SPI communication enable/disable control bit[8]
1 = enable STOPSPI
0 = IQS221 unaffected

bit1 **ND** = Noise Detect enable/disable control bit
1 = disable ND
0 = enable ND

Bit0 **CONVDIV** = Set the conversion frequency (See Section 6.9)
1 = 125kHz (nominal)
0 = 250kHz (nominal)

Writing of values is optional. If no valid command header is received, the values are ignored.

Note7: If IQS221 receives a SLEEP instruction from the master, the conversions will stop once the current group of conversions is finished and the serial communications halted.

The device can only be woken by a falling edge on OPT2 from the master. Once the IQS221 wakes up, the charge conversions and serial communication can continue. The master must sample the RDY line which will indicate when the slave is ready to transmit data again.

Note8: Once the IQS221 receives a STOPSPI instruction from the master the current cycle of serial communication will complete, then all communication will stop.

Please note that an external pull-down will be required, to keep the OPT2 line in a defined state during this time. The serial communication can then resume on one of the following two ways:

a.) If a proximity is detected by the IQS221, the RDY line will go HIGH to indicate to the master that serial communication can resume.

b.) The master must indicate to the slave that it's ready to resume serial communications by pulling /SS LOW (as is normal for selecting a device). Then it must wait for the RDY as usual to know when data is available.

To allow the SLEEP & STOPSPI to be controlled by the master the /SS & OPT2 can be connected together externally, giving the master the ability to wake the IC from sleep and resume communications without the need for an extra I/O.

6.2 Disabling Channels

Disabling a channel is done with a PULL-Down resistor on the CX pin that should be disabled to GND. Typical values used for PULL-Down resistors are 10kΩ.

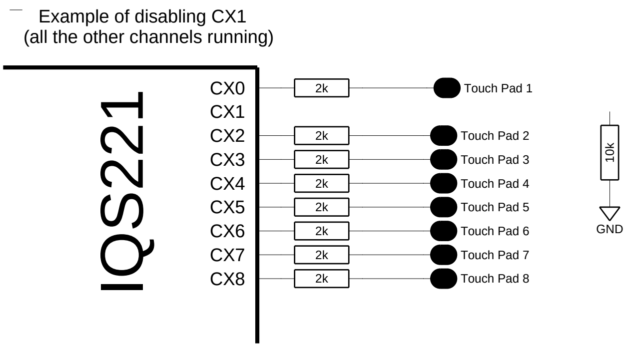


Figure 6-8: Disable CX1

6.3 Sensitivity Settings

3 methods to adjust the sensitivity of a device exist:

- Resistors on the pins TO0, TO1, TO2, TO4, TO5, TO6 and TO7
- Internally on OTP bits (except TO4) – discarding the need for resistors
- All settings can also be set through SPI commands

An option exist (configurable with the OTP Configuration Bits) to choose between using the external (default) or internal sensitivity options. The selection values are determined at POR and used for as long as power is supplied to the IQS221. See section 6.1.11 for SPI output mode sensitivity selections (internal selection is default in SPI).

Proximity / Touch Detection: The measured values are compared with the LTA values for each channel. A Proximity or Touch condition will register if the difference between the measured value and LTA Average value are equal to or bigger than the sensitivity level selected.

The proximity sensitivity level is determined by a change of a fixed amount of capacitance whilst a Touch is registered if the measured value changes by a specified fraction of the Average Filter Value.

Touch Sensitivity (external): The Touch threshold values are specified in Table 6-21 & Table 6-22. The touch threshold values for CX[7:0] are the same while CX[8] can be adjusted independently. All selections are performed on the TO pins when not in SPI mode. The designer has a choice between four touch sensitivity levels for CX[8:0]. CX8 has an independent touch sensitivity setting.

Proximity Sensitivity (external): The Proximity threshold values are specified in Table 6-23 & Table 6-24. The proximity threshold values for CX[7:0] are determined by a combination of the states of the TO3 and TO5 pins, while the threshold values for CX[8] are determined by the states of TO6 and TO7.

The proximity threshold values for CX[7:0] are the same while CX[8] can be adjusted independently. All selections are performed on the TO pins when not in SPI mode.

The designer has a choice between five proximity sensitivity levels for both CX[7:0] and CX[8].

Green Font selections are User Selectable with OTP bits and can be directly related to the USBProg.exe program.

Table 6-21: CX[7:0] Touch Sensitivity

TO1	TO0	Sensitivity Level (C_Δ)
LOW	LOW	A (1/32)
LOW	HIGH	C (2/16)
HIGH	LOW	B (1/16)
HIGH	HIGH	D (3/16)

Table 6-22: CX8 Touch Sensitivity

TO4	TO2	Sensitivity Level (C_Δ)
LOW	LOW	A (1/32)
LOW	HIGH	C (2/16)
HIGH	LOW	B (1/16)
HIGH	HIGH	D (3/16)

Table 6-23: Channel [7:0] - Proximity Sensitivity level		TO5	
		Low	High
PROX Level Selection	Default	H (6)	F (2)
	Alternative	I (12)	L (disable)

Table 6-24: Channel 8 - Proximity Sensitivity level		TO7 / TO6	TO7 / TO6	TO7 / TO6	TO7 / TO6
		LOW / LOW	LOW / HIGH	HIGH / LOW	HIGH / HIGH
PROX Level Selection	Default	H (6)	I (12)	G (4)	F (2)
	Alternative	J (16)	E (1)	K (32)	L (disable)

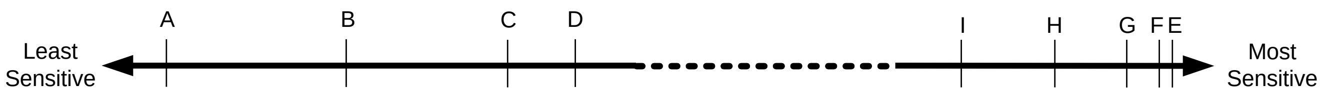


Figure 6-9: Touch Sensitivity Scale

Figure 6-10: Proximity Sensitivity Scale

Internal Selections: These options are only used if the EXT/INT Sensitivity Selection bit is configured to **Internal** with the OTP Configuration Bits. The selections are as shown in Table 6-25 to Table 6-28.

Green Font selections are OTP bits and can be directly related to the USBProg.exe program.

Table 6-25: Channel [7:0] - Internal Touch Sensitivity

CH[7:0] - Internal TOUCH Sensitivity Level (C_{Δ})	Sensitivity Level*
Level 1 (Most Sensitive) {default}	**A (1/32)**
Level 2	**B (1/16)**
Level 3	**C (2/16)**
Level 4 (Least Sensitive)	**D (3/16)**

Table 6-26: Channel 8 - Internal Touch Sensitivity level (C_{Δ})	TO4	
	LOW	HIGH
CH8 – Internal TOUCH Sensitivity: {default}	**A (1/32)**	**B (1/16)**
CH8 – Internal TOUCH Sensitivity:	**C (2/16)**	**D (3/16)**

Table 6-27: Channel [7:0] - Proximity Sensitivity Level (C_{Δ})	PROX Level Selection	
	Default	Alternative
Prox[7:0]: {default}	**H (6)****	**I (12)**
Prox[7:0]:	**F (2)**	**L (Disable)**

Table 6-28: Channel 8 - Proximity Sensitivity Level (C_{Δ})	PROX Level Selection	
	Default	Alternative
Prox[8]: Level 1 (Most Sensitive)	**F (2)**	**L (Disable)**
Prox[8]: Level 2 {default}	**H (6)**	**J (16)**
Prox[8]: Level 3	**G (4)**	**K (32)**
Prox[8]: Level 4 (Least Sensitive)	**I (12)**	**E (1)**

*Refer to Figure 6-10 and Figure 6-9
**Please refer to APP Note: *"AZD006 – VisualProxSense Overview"* for details regarding sensitivity and levels

6.4 Additional Low Power Mode

This option is user configurable with the OTP Configuration Bits. See Section 4 for more details regarding the programming of the OTP bits.

Using this feature enables the designer to implement a semi-sleep mode in the IQS221.

This feature entails that if no proximity has been detected for 50s or more, all channels except CX8 will seize charging. CX8 will continue to charge according to the original chosen time basis.

The other channels will now only be charged every 3s to keep the relevant filters updated. With the detection of a proximity condition on CX8, the conversions of the other channels will resume at the normal conversion rate.

This mode can be used in conjunction with the LP Modes or stand-alone.

6.5 Charge Period in Low Power (LP) Mode

Choosing a Power Mode

The IQS221 IC has four power modes. The low power modes are specifically designed for battery applications and applications not requiring immediate responses.

The Low Power Modes are selected dynamically by polling the OPT1 Pin LOW. See section 6.10.1 for more details.

The different Power Modes are user configurable with the OTP Configuration Bits. Please see Section 4 for more details regarding the programming of the OTP bits.

The different power modes control the duty cycle between charge transfers (TLP). Refer to Section 5 for more details on the charge transfers. The timings (TLP) given in Table 6-30 are measured from the end of the first conversion to the start of the following conversion. See Figure 6-11.

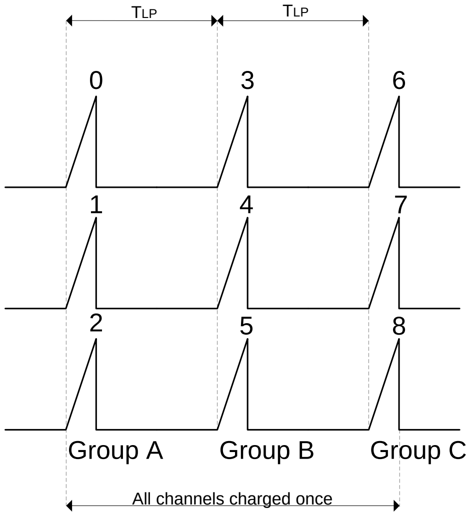


Figure 6-11: Measurement of T_{LP}

Table 6-29: LP Timings

Power Mode	Timing* (T_{LP})
LP1	110ms
LP2	220ms
LP3	330ms
LP4	440ms

*Timings are approximate

6.6 Fast Charge Selection

Conversions are done at a default rate (T_{SAMPLE} – See section 5) in NP Mode. Enabling the Fast Charge Selection enables the CS conversions to occur at a faster rate.

Choosing the Fast Charge selector, improves response time, but could result in slightly higher power consumption.

This option is user configurable with the OTP Configuration Bits. Please see Section 4 for more details regarding the programming of the OTP bits.

6.7 Long Term Average (LTA) Filter & using T_{HALT}

The IQS221 has a built-in IIR filter that is capable of intelligently tracking changes in the environment. The filter is implemented on each channel independently.

The filter calculates the average value (Long Term Average (LTA)) of the measurements. The LTA values are compared to the Measured values (Count (CS)) to determine if a proximity or physical contact activity has occurred. If a difference of C_Δ[3] is found between the LTA and CS value a proximity or physical contact activity is recorded. The applicable channel responds to this detected activity and the IIR Adaptation Filter freezes to keep the LTA value as reference.

Halting the filter: T_{HALT} is user configurable with the OTP Configuration Bits. Please see Section 4 for more details regarding the programming of the OTP bits.

Table 6-30: Filter Adaptation Conditions

T_{HALT}	Filter
20s (default)	Filter halts for 20s, and then recalibrate
40s	Filter halts for 40s, and then recalibrate
Never	Filter Adaptation NEVER halts
Always	Always halt filter

*Timings are approximate

How the filter works: With the detection of a proximity the LTA filter freezes for T_{HALT}, as indicated in Table 6-30. If this proximity condition is maintained for longer than T_{HALT}, the relevant channel will be recalibrated and its outputs reset. This is implemented to adapt to a rapid change in the environment and prevent a permanent stuck condition.

With the detection of a touch condition, the T_{HALT} counters will reset, and re-start the halting of the channels' filters (the system will thus not loose sensitivity while operated by a user).

6.8 Zoom Option

The Zoom mode is default enabled but the Zoom mode is only available if the Low Power (LP) Mode is selected (dependent on OPT1, See Section 6.10.1). In the LP mode, conversions are done according to T_{LP} in Table 6-29.

With the detection of a proximity, the conversion rate zooms in to the NP Mode (TSAMPLE). Operation then occurs in the zoomed in state for TZOOM after the last proximity has been detected. When TZOOM is timed out, the conversions are done according to the LP timing selections once again.

The different Zoom Modes are user configurable with the OTP Configuration Bits. See Section 4 for more details regarding the programming of the OTP bits.

6.9 Conversion Divider

The frequency of the charge transfers occur nominally at 250kHz. Enabling the conversion divider with an OTP bit (or through a serial command) will divide the frequency of charge transfers by 2 (changing it to 125kHz), effectively doubling the conversion rate.

This will result in a slower response time, and more current consumption, but is advantageous when an extremely large sense electrode is used, and the charge transfers can not be completed with the normal transfer rate. See the application note: "AZD004 - Azoteq Capacitive Sensing" for a complete description of the advantage of this feature.

6.10 Dynamic User Options

Table 6-31: Dynamic options

	HIGH	LOW
OPT1 LP / NP	NP	LP
OPT2 HC / RDY	Halt Charge Transfers	Normal Operation

6.10.1 OPT1 – LP/NP Mode Operation

The OPT1 Pin is used to dynamically toggle (with MCU), or fix (with resistor) between Normal Power and Low Power Mode. If OPT1 is LOW, the conversions

[3] C_Δ = Change in Capacitance: Determined by sensitivity settings

are determined by the LP mode and thus the selections made in Table 6-29. If OPT1 is HIGH, the conversion rate is T_{SAMPLE} (dependent on selection made in section 6.6).

6.10.2 OPT2 – HC / RDY Operation

The IQS221 issues a RDY signal after all the channels have completed a charge transfer, thus after every Group C conversion in section 6.5.

The charge transfers on the IQS221 IC can be dynamically halted (Halt Charge (HC)) by polling the OPT2 Pin HIGH with a MCU. If this signal occurs during a group of conversions, the group will finish its conversions and the following conversions on the IQS221 will be halted until the OPT2 Pin is Polled LOW again.

7 Zero Cross Function

The ZC Pin is used by the IQS221 to synchronise with AC. This enables the IC to do charge transfers synchronised to AC, which entails the charge transfers occurring at 20ms intervals (nominally). Otherwise the IQS221 will run at its internal clock frequency. If ZC function is not used, the ZC pin should be tied to ground through a 100kΩ resistor.

Using this function greatly enhances stability of the system, which in turn improves the proximity detection distance.

Typical values for current protection resistors when synchronising to $220V_{AC}$ is 2 x 510kΩ. When synchronising to any other device and the synchronization pulses exceed VDDHI, current protection resistors should be used.

8 Shield Function

The IQS221 has a shielding function built-in. Advantages of the shield:

- The shield enables the user to separate the Sensing Electrode from the sealed electronics
- The shield enables the designer to shield the sensing wire from unwanted environmental interference like water passing in a water pipe or people passing over the sense wire.
- The shield enhances proximity detection when used with battery (DC) applications.

Connecting the Shield

Ideally, a Coaxial cable is used for the shield. A Rx (nominally 2kΩ) resistor should be connected to the Cx pin, and the other side of the Rx resistor is connected to the Centre Core. This node is also connected to the SHLDIN pin. The SHLDOUT pin should be connected to the Metallic Shield part of the Coaxial cable. A pull-up resistor (R) should be added between SHLDOUT and VDDHI (100kΩ ≤ R ≤ 1MΩ). NOTE: Smaller R ensures better shielding but increases current usage.

The typical Cx channel used to shield is Cx8, as it is able to operate independently (Cx8 has an independent sensitivity setting). See Figure 8-1 for a more detailed explanation.

$VDDHI_{(MIN)}$ = 4.7V when using the Shield function.

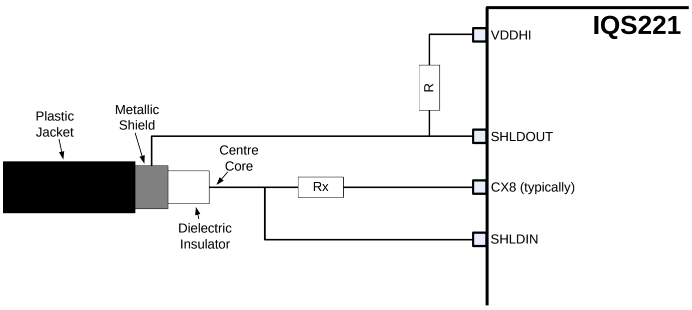


Figure 8-1: Connecting the Coaxial Cable

9 Additional Features

9.1 Buzzer

The IQS221 gives the designer the ability to employ a Buzzer by outputting an applicable signal onto the Buzz pin. This signal will not be outputted to some of the Output Modes. (See Section 6.1 for more details).

The Buzzer will function as follows: Upon the detection of a touch the Buzzer will click once, and if the touch persists, the Buzzer will have a small delay where after it will have a repetitive click. (Toggle Output Mode will only click when an Output Pin changes state).

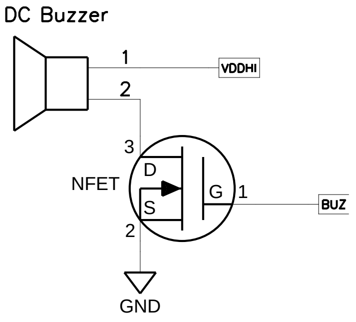


Figure 9-1: Typical DC Buzzer Connection

9.2 RF Noise Immunity and Detection

The IQS221 has advanced immunity to high power RF noise, typically transmitted by GSM cellular telephones, DECT, Bluetooth and WIFI devices. Design guidelines can be followed to help with the noise immunity:

- A ground plane should be placed under the IC, except under the CX lines.
- All the tracks on the PCB must be kept as short as possible.
- The capacitor between VDDHI and VSS as well as between VREF and VSS, 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 VSS. Another 100 pF capacitor can be placed in parallel with the 1uF capacitor between VREF and VSS.

It is still possible for a condition to exist with the transmitter placed in extreme close proximity to the IC that the IC might react to this transmitted power. The Noise Detection feature should be used for these applications (It is default enabled, but can be disabled with an OTP Configuration Bit).

For this exception, the IQS221 has a built-in Noise Detection scheme. The IQS221 is thus able to detect Cellular telephone noise or any other high power transmitted noise on the RFIN pin.

For this function the RFIN pin would require an external antenna mounted, to increase efficiency of noise detection. The details of the aforementioned antenna can be seen in Application Note: “AZD015 – RF Immunity and detection in ProxSense devices”.

With the detection of noise, the IQS221 will halt, keeping all outputs in the same state as they were before noise was detected. The Noise Detection scheme can be disabled if needed with an OTP Configuration Bit.

10 Reference Designs

10.1 SPI Design Example

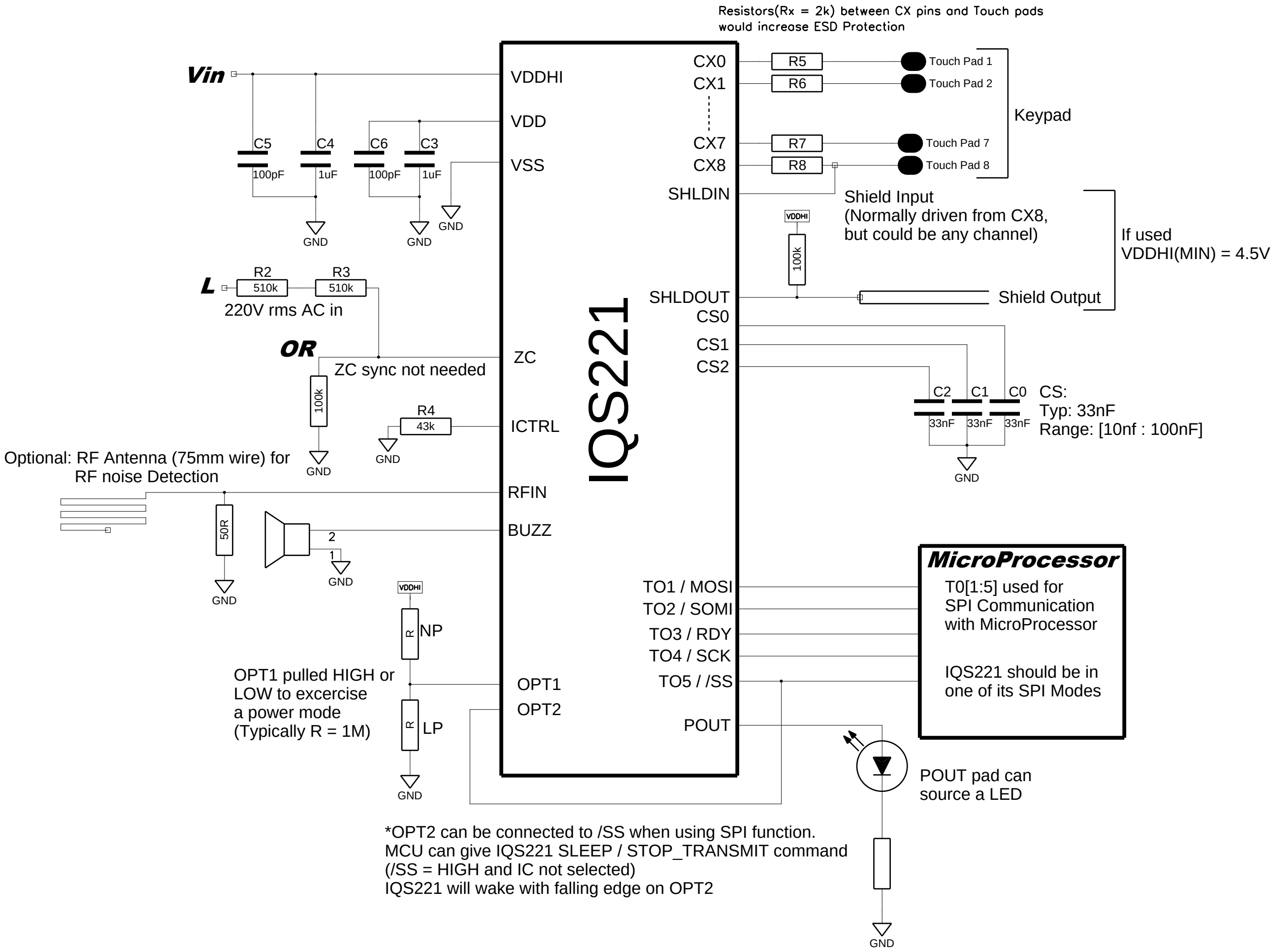


Figure 10-1: SPI Design

10.2 Direct Design Example

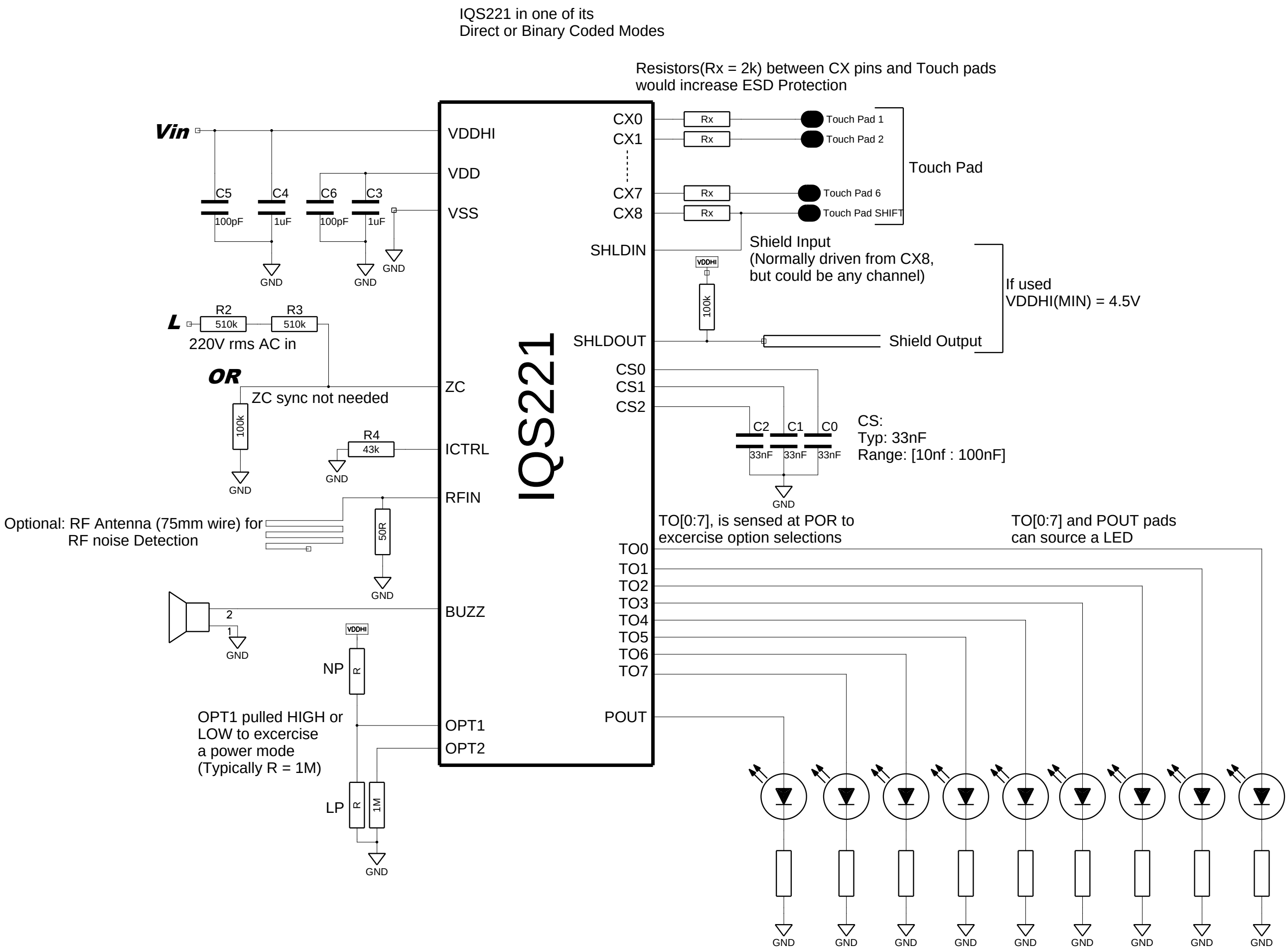


Figure 10-2: Direct Design

11 Specifications

11.1 Absolute Maximum Specifications

Exceeding these maximum specifications may cause damage to the device.

Operating Temperature	0°C to 70°C
Supply Voltage (V_{DDHI}, - V_{SS})	5.5V
Maximum Pin Voltage (V_{DD}, POUT, TOx, OPT2)	V_{DDHI} + 0.5V
Pin Voltage (CS, CX)	2.5V
Minimum Pin Voltage (V_{DDHI}, V_{DD}, POUT, CS, CX)	V_{DDHI} - 0.5V
Minimum Turn On Slope	10V/s
ESD Protection (All Pads)	2kV

11.2 Operating Conditions (Measured at 25°C)

Table 11-1: Operating conditions

DESCRIPTION	PARAMETER	MIN	TYP	MAX	UNIT
Internal Regulator Output[4]	V_{DD}	2.2	2.5	2.8	V
Supply Voltage Input (No Shield Implemented)	V_{DDHI}	3	5	5.5	V
Supply Voltage Input (Shield implemented)	V_{DDHI}	4.7	5	5.5	V
Normal Operating current[5]	$I_{IQS221\ NORMAL}$		195		μA
Low Power Operating current[6]	$I_{IQS221\ LOWPOWER}$		27		μA
CS trip voltage	V_{TRIP}	600	730	785	mV
Zero cross input voltage	V_{ZC}	0.9*V_{DDHI}	V_{DDHI}	V_{DDHI} + 0.5V	V
POUT High Voltage	V_{POUT_HIGH}		V_{DDHI}		V
Input Low Voltage on pins TO[0:4], TO2	V_{IL}		0.1*V_{DDHI}		V
Input High Voltage on pins TO[0:4], TO2	V_{IH}		0.9*V_{DDHI}		V

11.3 Output Characteristics

Table 11-2: Output Pins (POUT, TO[7:0], Buzz) Characteristics

Symbol	Description	Parameter	Conditions	IQS221			UNIT
				MIN	TYP	MAX	
V_{OH}	Output High Voltage	I_{SOURCE} = 6mA	V_{DDHI} = 5V		4		V
		I_{SOURCE} = 4mA	V_{DDHI} = 3.3V		2.3		
V_{OL}	Output Low Voltage	I_{SINK} = 9mA	V_{DDHI} = 5V		1.25		
		I_{SINK} = 5mA	V_{DDHI} = 3.3V		0.9		

Note 4: V_{DDHI} = 5V
Note 5: V_{DDHI} = 5V, Charge Cycle Duration < 10ms in Normal Power Mode
Note 6: V_{DDHI} = 3V, Charge Cycle Duration < 10ms in LP4

11.4 Timing Characteristics

Table 11-3: Timing Characteristics

DESCRIPTION	SYMBOL	IQS221			UNIT
		MIN	TYP	MAX	
Output Minimum High Time on TO pins	T_{HIGH}		60		ms
Output pins' latching time	T_{LATCH}		3		s
Time before switching back to LP Mode	T_{ZOOM}		3.3		s
CX charging Oscillator[7]	F_{CX}	213	250	287	kHz
Filter Freeze Condition	T_{HALT}		Refer to Table 6-30		s
Charge Cycle Delay Time[8]	T_{SAMPLE}	15[9]	20	22	ms
Low Power Delay Time	T_{LP}		Refer to Table 6-29		ms
Touch Response Time	$T_{DEBOUNCE.Touch}$	30[10]	120[11]		ms
Proximity Response Time	$T_{DEBOUNCE.Prox}$	60[10]	240[11]		ms
Charge Times	T_{CHARGE}		Determined by C_S Capacitor		ms

11.5 Moisture Sensitivity Level

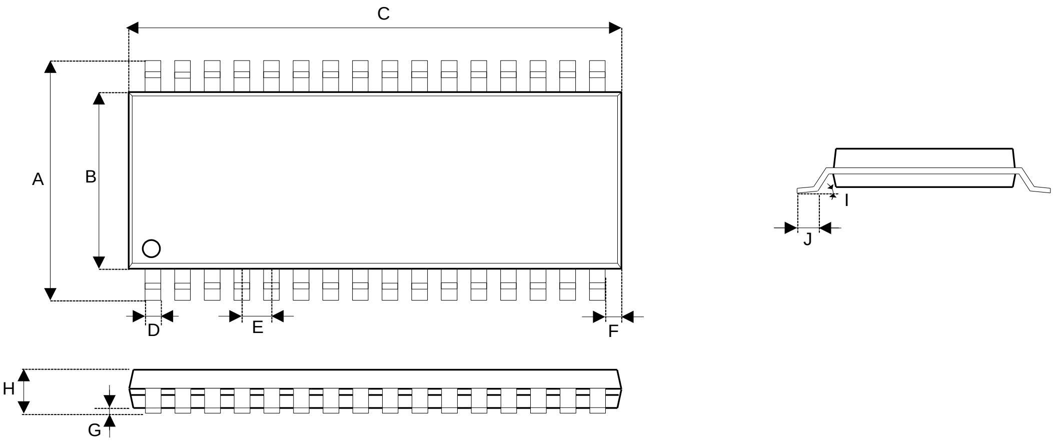
Moisture Sensitivity Level (MSL) relates to the packaging and handling precautions for some semiconductors. The MSL is an electronic standard for the time period in which a moisture sensitive device can be exposed to ambient room conditions (approximately 30°C/60%RH) before reflow occur.

Table 11-4: MSL

Package	Level (duration
SO-32	MSL 3 (168 hours)
QFN5x5-32	MSL 3 (168 hours)

Note 7: Enabling Conversion Divider (with OTP bit 20) will divide F_{CX} by 2
Note 8: Time for One Charge Cycle if $T_{CHARGE} < 20$ms
Note 9: Fast Charge Selection Enabled (See Section 6.6)
Note 10: CS < 10ms and only 1 Group active – 3 channels (See **Figure 5-1**)
Note 11: CS < 10ms and all Channels active

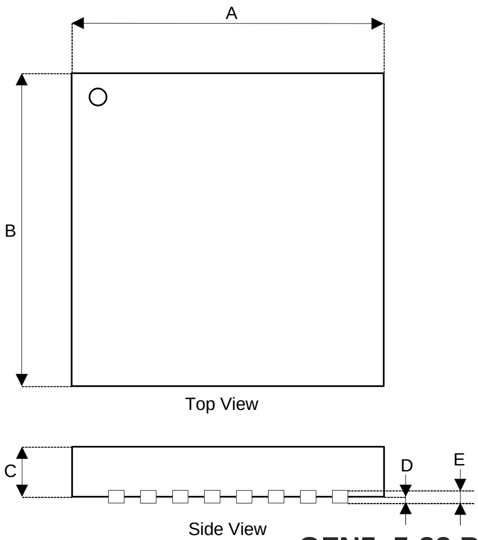
12 Packaging Information

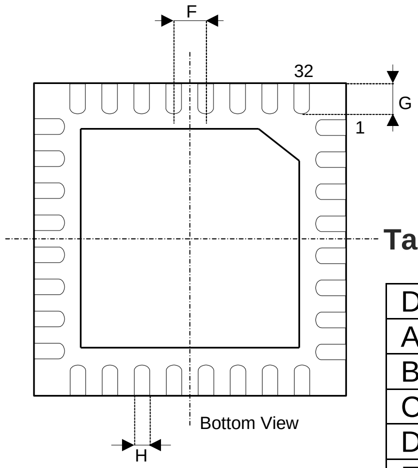


SO-32 Packaging[12]

Table 12-1: SO-32 Dimensions

Dimension	Min	Max
A	10.2 mm	10.6 mm
B	7.42 mm	7.62 mm
C	20.88 mm	21.08 mm
D	0.3 mm	0.5 mm
E	1.27 mm typ	
F	0.77 mm typ	
G	0.1 mm	0.25 mm
H	2.14 mm	2.34 mm
I	4° typ	
J	0.55 mm	0.95 mm





QFN5x5-32 Packaging[11]

Table 12-2: QFN5X5-32 Dimensions

Dimension	Min	Max
A	4.900 mm	5.100 mm
B	4.900 mm	5.100 mm
C	0.700 mm	1.000 mm
D	0.000 mm	0.050 mm
E	0.178 mm	0.228 mm
F	0.450 mm	0.550 mm
G	0.300 mm	0.500 mm
H	0.180 mm	0.300 mm

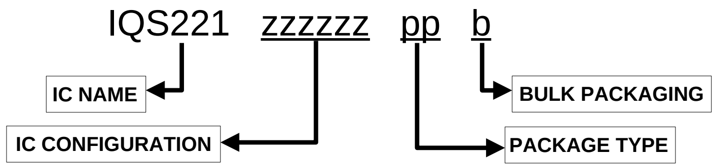
[12] Drawing not on Scale

13 Datasheet and Part-number Information

13.1 Ordering Information

For large orders, Azoteq can provide pre-configured devices.

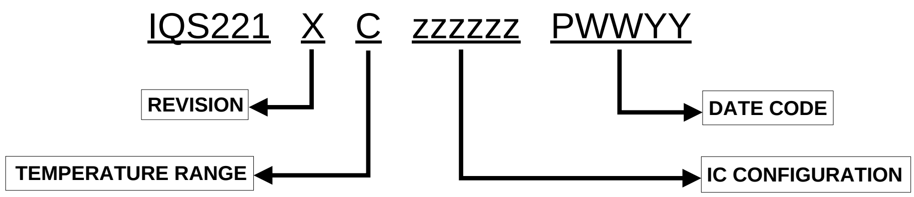
The Part-number can be generated by using USBProg.exe or the Interactive Part Number generator in the ProxSense -> Multiple Channel section of www.azoteq.com. Contact distributor for smaller quantities.



IC CONFIGURATION		zzzzzz	=	IC Configuration (hexadecimal)
PACKAGE TYPE		QN	=	QFN5x5-32 (Quad Flat Package No Leads)
		SO	=	SO-32/SOIC 32 Pin (Small Outline Package)
BULK PACKAGING	QFN5x5-32:	R	=	Reel (3000pcs/reel)
	SO-32:	T	=	Tube (20pcs/ tube) – MOQ = 1200pcs

Example: IQS221 008B28 QN R = IQS221 IC in configuration 008B28, packaged in QFN5x5-32 package and shipped in a Reel

13.2 Device Packaging Convention



REVISION	X	=	IC Revision Number
TEMPERATURE RANGE	C	=	0°C to 70°C (Commercial)
	I	=	-40°C to 85°C (Industrial)
IC CONFIGURATION	zzzzzz	=	IC Configuration (hexadecimal)
DATE CODE	P	=	Package House
	WW	=	Week
	YY	=	Year

Example: IQS221 2C 008B28 12308 = Revision 2; Commercial Temperature Range; Output Configuration 008B28; Packaged at House 1 the 23RD week of 2008

13.2.1 Batch Numbering for Pre-Production Samples

Batch Number	Description
IQS221ENG E5 / D5 / D6	Engineering run #1
IQS221PPS E7	Pre-Production Sample #0 (SO-32 and QFN5x5-32)
IQS221PPS E11 (or Date Code: x2009)	Pre-Production Sample #1 (SO-32 and QFN5x5-32)
IQS221 1C zzzzzz PWWYY	First Production version

13.3 Datasheet Revision History

Version 4.00

- First production version datasheet

Version 4.01

- Inserted Section 11.5

Version 4.02

- Updated MOQ for QFN5x5-32 Reel quantity to 3000pcs/reel

Version 4.03

- Corrected MSL data

Version 4.04

- Corrected package marking orientation on figures

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The following patents relate to the device or usage of the device: US 6,249,089 B1, US 6,621,225 B2, US 6,650,066 B2, US 6,952,084 B2, US 6,984,900 B1, US 7,084,526 B2, US 7,084,531 B2, US 7,265,494 B2, US 7,291,940 B2, US 7,329,970 B2, US 7,336,037 B2, US 7,443,101 B2, US 7,466,040 B2, US 7,498,749 B2, US 7,528,508 B2, US 7,119,459 B2, EP 1 120 018 B1, EP 1 206 168 B1, EP 1 308 913 B1, EP 1 530 178 B1, ZL 99 8 14357.X, AUS 761094

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