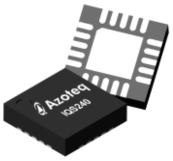
IQS240

IQ Switch® - ProxSense™ Series

4-Channel Capacitive Touch Sensor with Proximity Detection

Features



- Class leading proximity sensitivity
- Direct, Coded and Serial Operation
- Automatic Environment Compensation
- On-Chip Integrated Series regulator
- On-Chip Digital Signal Processing
- Synchronises to AC supply voltage (external synchronisation source)
- Suitable for various dielectrics
- User selectable **Proximity** and **Touch** sensitivity settings
- Low Power Mode suitable for battery applications (27uA)
- Detect Touch through an overlay of 7mm or more
- Available in SO-20 and QFN4x4-20 packages
- Class leading noise immunity

Applications

- Consumer Electronics
- White goods and appliances
- POS Terminals
- Smart Phones
- PDA's
- Flame Proof, Hazardous environment Human Interface Devices
- Proximity Detection
- Replacement for electromechanical switches
- Find-In-The-Dark (FITD) applications

Description

The ProxSense™ IQS240 is a fully integrated four-channel capacitive sensor Integrated Circuit (IC). The IQS240 can be operated as a stand-alone device or interfaced with a controller unit. The device also features an internal system regulator, ensuring class leading proximity sensitivity and stability at an unparalleled cost.

Through unique patented technology a cost effective solution is offered to replace conventional electromechanical switches. ProxSense™ is capable of detecting a differentiated touch or proximity condition through almost any dielectric, allowing designers to project touch pads or sliders through a variety of materials. A further benefit is the reduced cost associated with mechanical deterioration over time or from working in harsh environments.

Datasheet for date code: x2009* or later

*Date code on package of IQS240 (see description of date code in Section 11.2)

Available options

T_A	SO-20 & QFN4x4-20
-40°C to 85°C	IQS240

Contents

1 Overview

This document contains device specific information for the IQS240. The IQS240 is a four channel touch and proximity sensor. The device can operate in standalone applications in direct and coded modes, and in 2 Serial Modes using a 5 wire SPI protocol.

The device is designed to operate from a DC supply voltage, but can be synchronised to an AC supply, which increases proximity sensitivity. An integrated series regulator eliminates the need for an external regulator.

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 -40C to +85C
- Supply voltage (V_{DDHI}) 3.0V to 5.0V

2 Analogue Functionality

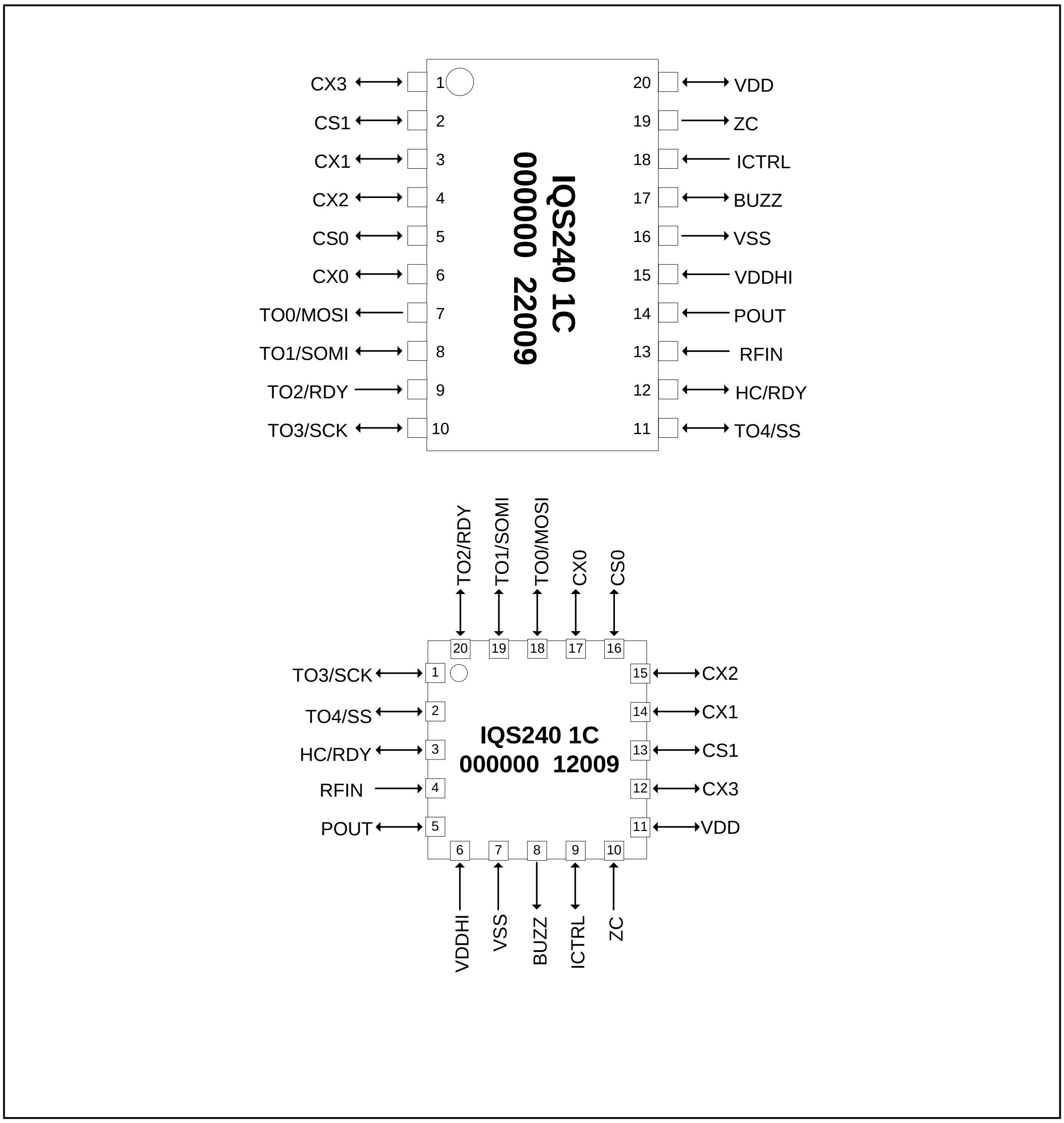
The analogue circuitry measures the capacitance of a sense electrode attached to the Cx pin through a charge transfer process that is periodically initiated by the digital circuitry. The measuring process is referred to as a conversion and consists of the discharging of Cs and Cx, the charging of Cx 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.

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 an advanced RF immunity and a RF detection circuit capable of detecting the presence of RF signals that may influence the count value. The circuitry notifies the digital circuitry when RF has been detected.

3 Device Details

3.1 SO-20 and QFN4x4-20 Packages



3.2 IQS240 Pin-out

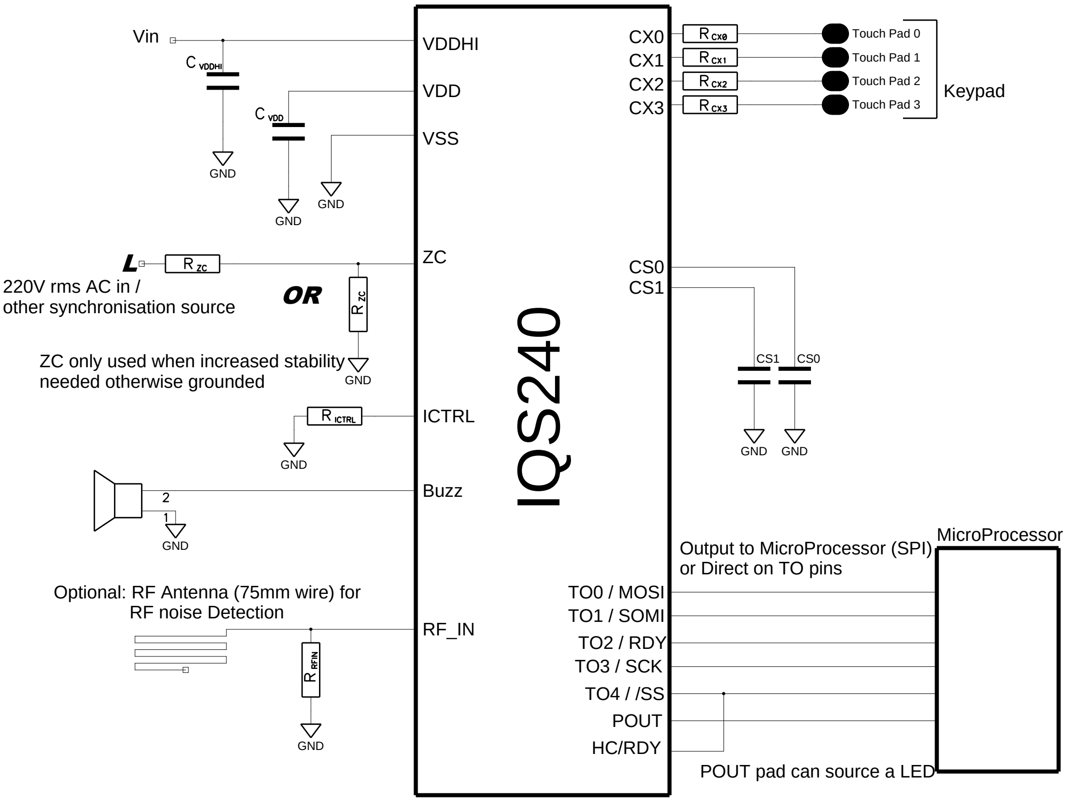
Table 3-1 Pin-out Description for IQS240

Pin		Name	I/O	POR[1] Option	Description
SO-20	QFN4x4-20				
1	12	Cx3	Bi-directional	-	Sense Electrode 3
2	13	Cs1	Bi-directional		Reference capacitor 1
3	14	Cx1	Bi-directional	-	Sense Electrode 1
4	15	Cx2	Bi-directional	-	Sense Electrode 2
5	16	Cs0	Bi-directional	-	Reference capacitor 0
6	17	Cx0	Bi-directional	-	Sense Electrode 0
7	18	TO0 /MOSI	Output	CX[0:3] Touch Sensitivity_0	Touch Output 0
			Input		Data output from master
8	19	T01 /SOMI	Output	CX[0:3] Touch Sensitivity_1	Touch Output 1
			Output		Data output from slave
9	20	TO2 /RDY	Bi-directional	-	Touch Output 2
			Output		Data available indication from slave
10	1	TO3 /SCK	Bi-directional	CX[0:3] Prox Sensitivity_0	Touch Output 3
			Input		Clock from Master
11	2	TO4 / $\overline{SS}$	Bi-directional	CX[0:3] Prox Sensitivity_1	Resistor Selection
			Input		Slave select, active low
12	3	HC /RDY	Bi-directional	-	Dynamic Halt Charge
					Ready
13	4	RFIN	Input	-	RF antenna input for RF detection
14	5	POUT	Output	-	Proximity Output
15	6	VDDHI	Supply Input	-	Supply Voltage Input
16	7	VSS	Ground Input	-	GND Reference
17	8	BUZZ	Output	-	Buzzer Output
18	9	ICTRL	Custom	-	Current Reference
19	10	ZC	Analogue Input	-	Zero Cross High Voltage AC input
20	11	VDD	Analogue Output	-	DC regulator output

---

[1] Power On Reset

4 Circuit Overview



*HC/RDY can be connected to /SS when using SPI function.
MCU can give IQS240 SLEEP / STOP_TRANSMIT command
(/SS = HIGH and IC not selected)
IQS240 will wake with falling edge on HC/RDY

Figure 4-1: Typical Connection Diagram for IQS240

<table>
<tr><th>Component</th><th>Value</th><th>Comment</th></tr>
<tr><td>Cs[1:0]</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>$R_{HC/RDY}$</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>
</table>

5 User Selectable Options

The IQS240 has a number of selectable OTP (One Time Programmable) user options. These OTP options can be used in the default (unconfigured) state or certain OTP options can be set for specific applications. Configuring the device can be done on the packaged device or in-circuit. For large orders, Azoteq (PTY) LTD can supply pre-configured devices.

Configuring the device:

Azoteq (PTY) LTD offers a Configuration Tool (CTxxx) and accompanying software (USBProg.exe) that can be used to program these OTP user options for prototyping purposes. More details regarding the configuration of the device with the USBProg program is explained in the application note: *"AZD007 – USBProg Overview".*

Alternative programming options of the IQS240 exist, for further enquiries regarding this matter please contact Azoteq at ProxSenseSupport@azoteq.com.

Figure 5-1 shows the User Configurable Bits for the IQS240.

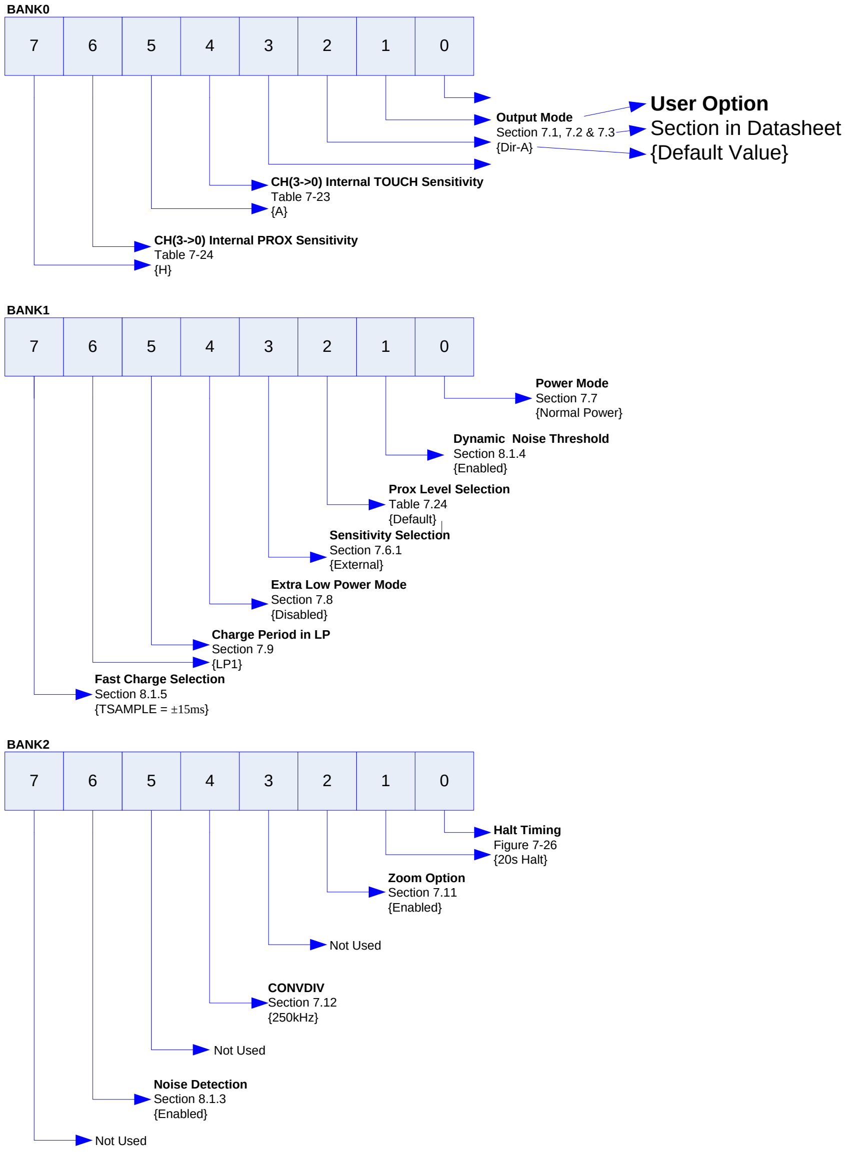


Figure 5-1 Configuration bits for the IQS240

6 Charge Transfer

The charge transfer method of capacitive sensing is employed on the IQS240. Refer to the application note "AZD0004: Azoteq Capacitive Sensing", which thoroughly describes the charge cycle principle. A Charge Cycle is used to detect either a physical contact or proximity event, depending on the application.

For the IQS240, two Cx channels are multiplexed into one Cs capacitor as indicated in Table 6-1. The Charge Cycles of the IQS240 can be measured on the Cs Pins.

For applications requiring proximity Cx3 is recommended as the proximity sensing channel, since the Dynamic Noise Threshold is implemented on this channel (refer to Section 5) as well as the AC filter (refer to Section 8.1.5). Refer to application note: "AZD008 – Design Guidelines for Touch Pads" for information of designing optimal sense pads.

Figure 6-1 shows the charging scheme with the 'Fast Charge' enabled (AC filter switched on) and

Figure 6-2 shows the charging scheme with the 'Fast Charge' disabled (AC filter switched off).

Table 6-1 Multiplexed charging scheme

CS		
Group A	Group B	
Cx0	Cx2	Cs0
Cx1	Cx3	Cs1

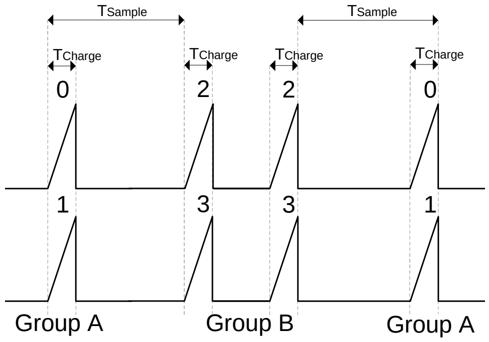


Figure 6-1- Multiplexed charging scheme with 'Fast Charge' enabled (AC Filter on)

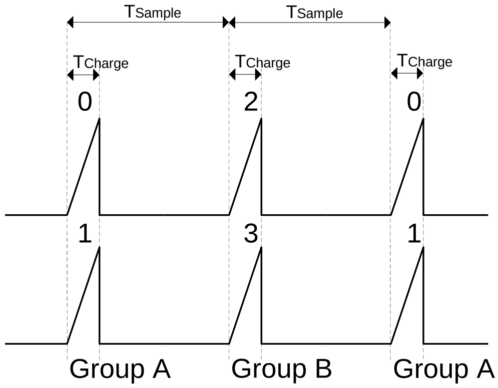


Figure 6-2 Multiplexed Charging Scheme with 'Fast Charge' disabled (AC Filter off)

7 Descriptions of User Options

The IQS240 can be customised for almost any design by using a combination of OTP functions and externally selected options through resistors. The user options include:

- A variety of Output Modes
- Different Power modes
- Fast Charge Selector
- Control over the IIR Adaptation
- Zoom Option
- Dynamic Charge halting
- Dynamic Filter halting
- Different Sensitivity settings

7.1 *Output Mode*

The Output Mode is programmed by setting the required OTP configuration bits. A number of output configurations are available on the IQS240. The possible output configurations of the IQS240 fall in three categories, which include Direct, Binary Coded or interfaced with a microprocessor.

A "Virtual Demo" explaining the different UI outputs is available on the Azoteq website (www.azoteq.com).

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[1] for as long as the proximity condition occurs. The POUT pin is active high, and can source enough current to drive a LED. The pin is sourced from VDDHI when active. The Buzzer is enabled except if explicitly stated otherwise.

Table 7-1: User Selectable Output Modes

UI #	Output pin Function
Direct Mode	
DIR-A	Direct Mode
DIR-B	Toggle Mode
DIR-C	Current Mode
DIR-D	Minimum Mode
DIR-E	Minimum Mode (Toggle)

Minimum modes are well suited to PCB layouts where sense pads are close to each other or where tracks are close to sense pads and false detections need to be avoided.

Table 7-2 Binary Coded Modes

Binary Coded Mode	
CODED-F	Current Mode (CX3 independent)
CODED-G	Minimum Mode (CX3 independent)
CODED-H	Minimum Mode (all channels)
Serial Peripheral Interface (SPI) Mode	
SPI-I	Normalized values
SPI-J	Count (raw)

7.2 *Direct Modes*

7.2.1 *DIR-A Direct Mode*

The Direct Mode Output gives an Active HIGH output on pins TO[0,1,2,3] if a touch is detected on the corresponding sensing pins CX[0,1,2,3].

Table 7-3 DIR-A Direct Mode

Pin State	Input Pins	Output Pins
Active HIGH	CX[0,1,2,3]	TO[0,1,2,3], Buzz, Pout

7.2.2 *DIR-B Toggle Mode*

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

Table 7-4: DIR-B Toggle Mode

Pin State	Input Pins	Output Pins
Toggle	CX[0,1,2,3]	TO[0,1,2,3], Buzz, Pout

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

---

[1] High = Logical '1' = V_{DDHI} (V),

LOW = Logical '0' = 0 (V)

7.2.3 DIR-C Current Mode

On a touch detection the corresponding TO pin will latch HIGH for the duration of the touch. If a second touch is detected on a different pin, this pin’s TO will latch HIGH and cause the first pin’s TO to latch LOW. Therefore only the latest touch is outputted.

Table 7-5: DIR-C Current Mode

Pin State	Input Pins	Output Pins
Last button touched is Active HIGH	CX[0,1,2,3]	TO[0,1,2,3], Buzz, Pout

7.2.4 DIR-D Minimum Mode (All Channels)

The touch channel which registers the biggest change in capacitance (pressed with the largest part of the finger) will register as the current touch on the corresponding TO pin. Only one touch is detected at a time.

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.

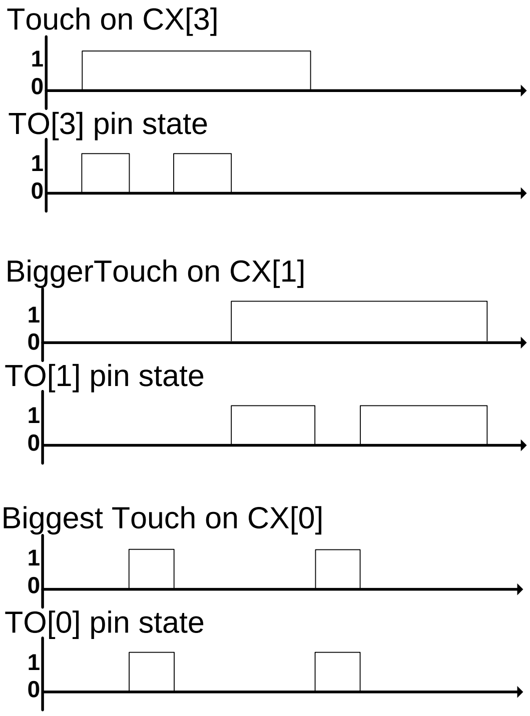


Figure 7-1 DIR-D Minimum Mode

7.2.5 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 pin’s corresponding TO pin will toggle HIGH. The pin’s state will stay the same, until toggled again.

Only the touch with the largest change in capacitance that occurred is recorded and the corresponding TO pin will toggle HIGH.

Table 7-6: DIR-E Minimum Mode (Toggle)

Pin State	Input Pins	Output Pins
Largest button touched is Toggled HIGH	CX[0,1,2,3]	TO[0,1,2,3]

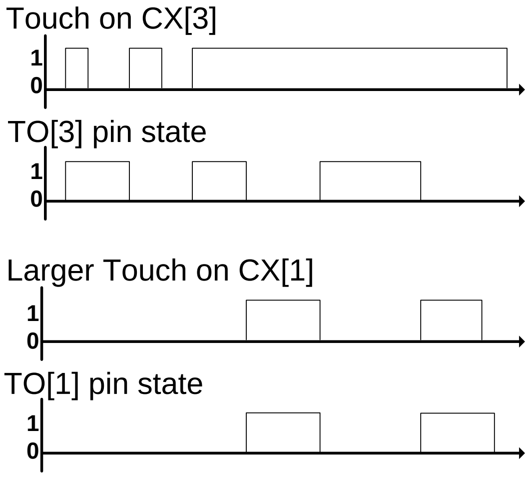


Figure 7-2: DIR-E Minimum Mode (Toggle)

7.3 Binary Coded Modes

The outputs of these modes are coded in binary to pins TO[2:0]. The ‘1’s and ‘0’s denote logical HIGH and logical LOW respectively. See Table 7-7 for the Binary Coded Outputs.

Table 7-7: Binary Coded values

	TO2	TO1	TO0	Decimal
CX0	0	0	1	1
CX1	0	1	0	2
CX2	0	1	1	3
CX3	1	0	0	4

7.3.1 Coded-F Current Mode

If a touch is detected on one of the CX pins, the corresponding binary value will be outputted to TO[2:0]. The pins will latch HIGH for the duration of the touch. If a second touch is detected on another pin, this pin's corresponding binary value will be outputted to TO[2:0], overwriting the first touch's value.

Only the latest touch that occurred is recorded. CX3 operates independently and is outputted to TO3 and the corresponding binary value is outputted to TO[2:0].

Table 7-8: Coded-F Current Mode

Pin State	Input Pins	Output Pins
Last button touched is Active HIGH	CX[0,1,2,3]	Binary Coded on TO[0,1,2]
Active HIGH	CX[3]	TO[3]

7.3.2 CODED-G Minimum Mode (CX3 independent)

The touch channel which creates the biggest change in capacitance (pressed with the largest part of the finger) will register as the current touch. The channel value will be outputted in binary format to TO[0:2].

Only one touch at a time is registered, except for CX3 which works independently. CX3 is outputted to TO3, and not as displayed in Table 7-7.

Example: If a touch is detected on CX1, the binary coded value '010'b will be outputted onto TO[0:2]. 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 7-9: Coded-G Minimum Mode (CX3 independent)

Pin State	Input Pins	Output Pins
Largest button touched is Active HIGH	CX[0,1,2]	Binary Coded on TO[0,1,2]
Active HIGH	CX[3]	TO[3]

7.3.3 CODED-H Minimum Mode (All Channels)

The touch channel which creates the biggest change in capacitance (pressed with the largest part of the finger) will register as the current touch. The channel value will be outputted in binary format to TO[0:2]. Only one touch at a time is registered.

Table 7-10: Coded-H Minimum Mode

Pin State	Input Pins	Output Pins
Largest button touched is Active HIGH	CX[0,1,2,3]	Binary Coded on TO[0,1,2,3]

7.4 SPI Modes[1]

The SLAVE SPI protocol is used for serial communication with a controller. The SPI protocol for the IQS240 has the 4 typical pins used in SLAVE SPI communication:

- Master out slave in (MOSI) – TO0
- Slave out master in (SOMI) – TO1
- Serial clock (SCK) – TO3
- Slave Select (/SS) – TO4

Additionally a 5th pin is used namely:

- Ready (RDY) – TO2

The IQS240 should be configured in one of the SPI modes, before SPI communication can commence between the IQS240 and a master module.

The $\overline{SS}$ on the IQS240 must be LOW for it to respond to a master module. This enables the IQS240 to be incorporated into a SPI daisy chain configuration. The RDY however is not affected by the $\overline{SS}$.

The RDY pin is used to alert the master module that data is available from the IQS240. Once the master module receives a RDY signal, it can clock out a byte from the device. The RDY line is driven LOW by the IQS240 after the first rising edge of the SCK from the controller, and will only go HIGH again when the next data byte is available.

---

[1] A Chinese version of this section as an application note (AZD016) on www.azoteq.com

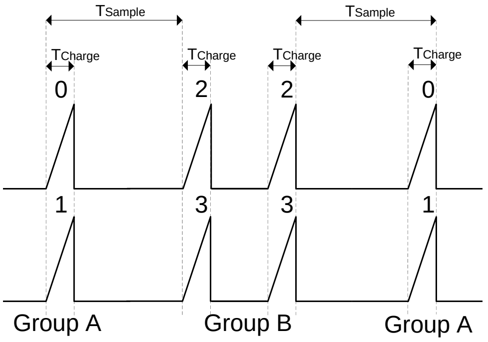
The master module SPI should be set up so that:

- It is set up as MASTER.
- The master module waits for RDY to be HIGH before initiating the data transfer
- Input data (SOMI) is sampled at the 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 7-4. The data for groups A and B (refer to Figure **6-1**) are sent after the conversions for the relevant group are complete. E.g. the data for CX0 and CX1 are sent together, and in the next cycle the data for CX2 and CX3 are sent together (refer to Figure 7-3).

The following functions differ when the device is operating in a SPI mode:

- HC/RDY – This pin can be used to wake up the device / continue data transfer after a SLEEP / STOPSPI command. A falling edge will wake the IQS240
- Sensitivity selections are internal and set through SPI commands.



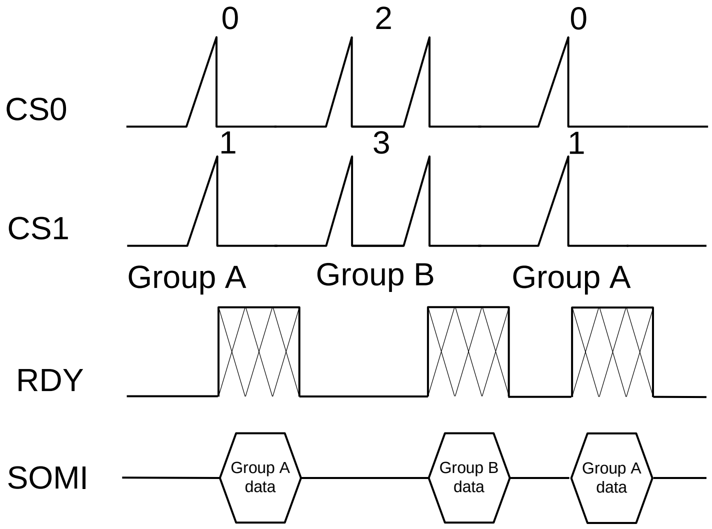


Figure 7-3 SPI Data Transfer after Conversions (Shown with AC Filter on)

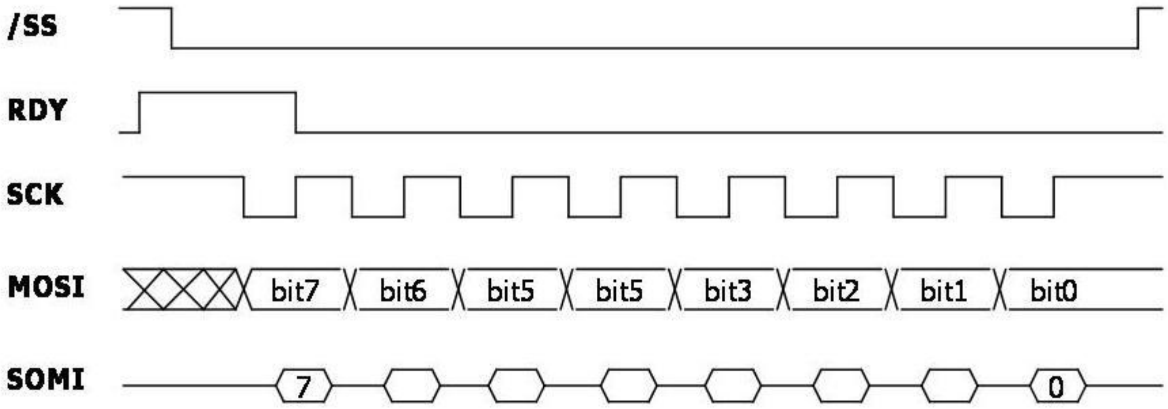


Figure 7-4 SPI Data Transfer Timing Diagram

7.4.1 SPI-I Raw Data Out

Count values of each channel are sent as raw data via SPI. This data can then be used to implement a customised user interface on a master module. The raw format is shown in Table 7-11. If a proximity condition is triggered, POUT will latch HIGH for the duration of the proximity event.

The SPI communication protocol's length can be varied by sending appropriate length bytes during the transmission cycle (refer to Section 7.4.3). In addition various commands can be sent during the transmission cycle (refer to Section 7.4.4), each command has a unique identifier and data value.

7.4.2 SPI-J Relative Values

Relative values of each channel are sent via SPI. The Relative values are derived from the raw data of each channel normalized with the filter value of the same channel. This relative value indicates which channel experiences the largest change with a user touch. The format for the relative mode is shown in Table 7-12. If a proximity condition is triggered, POUT will latch HIGH for the duration of the proximity event.

The relative mode also supports variable length transmission cycles and the various SPI commands (refer Sections 7.4.3 and 7.4.4).

Table 7-11 Raw SPI Protocol

		Bytes Sent By IQS240		Bytes Received By IQS240	
Byte #	**Bit #**	**Value**	**Function**	**Value**	**Function**
1	0:7	0xFF	Header 1	Command	Footnote[1]
2	8:15	<ND><BA><ba><xxx>	Header 2[2]	Command Data	Footnote[1]
3	16:23	<xxxx><CH[3:0]>	Active channels[3]	Length	Footnote[4]
4	24:31	Cs A	MSB	D/C	Don’t care
5	32:39	Cs A	LSB	D/C	Don’t care
6	40:47	Cs B	MSB	D/C	Don’t care
7	48:55	Cs B	LSB	Length	Footnote[4]
8	56:63	LT A	MSB	D/C	Don’t care
9	64:71	LT A	LSB	D/C	Don’t care
10	72:79	LT B	MSB	D/C	Don’t care
11	80:87	LT B	LSB	Length	Footnote[4]
12	88:95	Threshold X	Footnote[5]	D/C	Don’t care
13	96:103	CRC	Footnote[6]	D/C	Don’t care

Table 7-12 Relative SPI protocol

		Bytes Sent By IQS240		Bytes Received By IQS240	
Byte #	**Bit #**	**Value**	**Function**	**Value**	**Function**
1	0:7	0xFF	Header 1	Command	Footnote[1]
2	8:15	<ND><BA><ba><xxx>	Header 2[2]	Command Data	Footnote[1]
3	16:23	<xxxx><CH[3:0]>	Active channels[3]	Length	Footnote[4]
4	24:31	Relative A	MSB	D/C	Don’t care
5	32:39	Relative A	LSB	D/C	Don’t care
6	40:47	Relative B	MSB	D/C	Don’t care
7	48:55	Relative B	LSB	Length	Footnote[4]
8	56:63	Threshold X	Footnote[5]	D/C	Don’t care
9	64:71	CRC	Footnote[6]	D/C	Don’t care

---

[1] Refer to Section 7.4.4

[2]

	bit7	bit6	Bit5	bit4	bit3	bit2	bit1	bit0
Header 2	ND	B	A	b	a	x	x	X

<ND> = Set when Noise Detected (Noise Detection scheme must be enabled in configuration bits – default enabled)
<BA> = Touch B; Touch A;
<ba> = Prox B; Prox A
<xxx> = Unused

[3] <CH[3:0]> = Positional indication of the active channels
<xxxx> = Unused

[4] Refer to Section 7.4.3

[5]

	bit7	bit6	Bit5	bit4	bit3	bit2	bit1	bit0
ThresholdX	D/C	PROXLVLSEL	Halt A	Halt B	TO4	TO3	TO1	TO0

<PROXLVLSEL> = The state of the PROXLVLSEL OTP bit. This can be overwritten via SPI commands (refer to Section 0)
<Halt A, Halt B> = The halt state of the filter
<TO[4:0]> = TO bits are decoded to indicate the current sensitivity settings (refer to Section 0)

[6] Simple XOR of the bytes transmitted. This can be used in conjunction with the header for synchronization.

7.4.3 SPI Protocol Length Variability

During transmission bytes can be sent to the IQS240 to change the length of the SPI protocol. These bytes must be sent at the right interval in the transmission cycle (refer to Table 7-11 and Table 7-12). The values of these length bytes are shown in Table 7-13. **Note:** The CRC is always sent at the end of a data packet regardless of the length of the packet.

Table 7-13 SPI Length Bytes

Length Byte	Interrupt at:
0x00	No interrupt
0x01	Interrupt after byte 3
0x02	Interrupt after byte 7
0x04	Interrupt after byte 11

7.4.4 SPI Commands

The SPI commands are sent during the transmission cycle of the first and second byte of SPI communication. The first byte is the command identifier while the second is the command data. If an invalid command is sent it will be ignored. Table 7-14 shows a summary of the available SPI commands.

Table 7-14 SPI Commands

SPI Command	Function
0xE1	Prox/Touch Settings (refer to Table 7-17)
0xB4	Configuration Settings (refer to Table 7-18)
0xD2	Command Settings (refer to Table 7-19)
0x20	Custom Prox Threshold
0x13	Custom Touch Threshold CH3
0x12	Custom Touch Threshold CH2
0x11	Custom Touch Threshold CH1
0x10	Custom Touch Threshold CH0

7.4.4.1 Custom Prox Threshold

The custom prox threshold command is used to change the proximity threshold of all the channels. When used the threshold will be calculated as follows:

$$\boxed{PTH = LTA - CPTH}$$

PTH: Prox Threshold

LTA: Long Term Average

CPTH: Custom Prox Threshold

The format for the custom prox command is shown in Table 7-15. Once the proximity threshold has been changed with the custom prox threshold command, the threshold will be retained until POR, or until replaced using the custom prox threshold command. **Note: This command cannot be used in conjunction with the Dynamic Noise Threshold** (refer to Section 8.1.4).

Table 7-15 Custom Prox Threshold Format

Command	**0x20**
Data	**0 ≤ CPTH ≤ 255**

7.4.4.2 Custom Touch Threshold

The touch thresholds for each individual channel can be set using the custom touch threshold commands (refer to Table 7-14). When used, the threshold will be calculated as follows:

$$\boxed{TTH = CTTH \times \frac{LTA}{64}}$$

TTH: Touch Threshold

CTTH: Custom Touch Threshold

LTA: Long Term Average

The custom touch threshold value **should not exceed 63, and should not be less than 1**. If a CTTH value of 0 is sent it will be replaced by a value of 1. Conversely if the CTTH value exceeds 63 the upper bits will be masked out. The format for the custom touch threshold commands is shown in Table 7-16.

Table 7-16 Custom Touch Threshold Format

Command	**0x13,0x12,0x11,0x10**
Data	**CTTH**
Command	**0xE1**

7.4.4.3 Sleep Command

If IQS240 receives a SLEEP instruction from the master (refer to Table 7-19), the current group of conversions will be completed, serial communications will stop and the device will go into sleep mode.

When the device wakes up, the charge conversions and serial communication will be continued. The master must sample the RDY line which will indicate when the slave is ready to transmit data again.

7.4.4.4 STOPSPI Command

When the device receives a STOPSPI instruction (refer to Table 7-19) the current SPI transmission will be completed after which all communication will stop.

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

a.) If a proximity condition is detected by the device the device will automatically resume communication with the master and the RDY line will go HIGH to indicate that data is available.

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 & HC/RDY can be connected together externally, giving the master the ability to wake the device from sleep and resume communications without the need for an extra I/O.

Table 7-17 Prox/Touch Settings Format

Command	**0xE1**							
Bit #	**bit7**	**bit6**	**bit5**	**bit4**	**bit3**	**bit2**	**bit1**	**bit0**
Data	PROXLVLSEL	DYNNTH	-	TO4	-	TO3	TO1	TO0

bit7 **PROXLVLSEL**: PROX Level select control bit (refer to Section 7.5)

1 = enable alternative Proximity level selection

0 = default

bit6 **DYNNTH**: Dynamic Noise Threshold control bit (refer to Section 8.1.4)

0 = enable Dynamic Noise Threshold

1 = disable Dynamic Noise Threshold

bit5 Unused

bit3 Unused

bit4:0 **TO4, TO3, TO1, TO0**: TO pins’ state control bits (refer to Section 7.5)

Table 7-18 Configuration Settings Format

Command	**0xB4**							
Bit #	**bit7**	**bit6**	**bit5**	**bit4**	**bit3**	**bit2**	**bit1**	**bit0**
Data	-	ZOOM	HALT		FASTCHARGE	LP Timing		XLP

bit7 Unused

bit6 **ZOOM**: Zoom enable/disable control bit (refer to Section 7.11)

0 = enable Zoom

1 = disable Zoom

bit5:4 **HALT**: Halt filter time-out select (refer to Section 7.10)

11 = Always halt

10 = Never halt

01 = 40s

00 = 20s

bit3 **FASTCHARGE**: Fast charge enable/disable control bit (refer to Section 8.1.5)

0 = enable Fast charge (T_{SAMPLE} = ±15ms)

1 = disable Fast charge (T_{SAMPLE} = ±20ms)

bit2:1 **LP1/LP0**: Low power mode select (only used if device is in LP mode, refer to Section 7.7)

11 = 240ms

10 = 190ms

01 = 130ms

00 = 70ms

bit0 **XLP** = Additional Low power Mode enable/disable control bit (refer to Section 7.8)

1 = enable XLP

0 = disable XLP

Table 7-19 Command Settings Format

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

bit7 **RESEED**: Force a filter reseed to 8 counts below the most recent 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 = IQS240 unaffected

bit2 **STOPSPI**: Stop SPI communication enable/disable control bit[8]

1 = enable STOPSPI

0 = IQS240 unaffected

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

1 = disable ND

0 = enable ND

bit0 **CONVDIV** = Set the conversion frequency (refer to Section 7.127.12)

1 = 125kHz (nominal)

0 = 250kHz (nominal)

7.5 Disabling Channels

Disabling a channel is done with a PULL-Down resistor on the CX pin. Typical values used for PULL-Down resistors are 10kΩ.

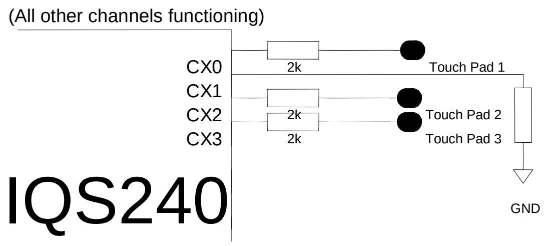


Figure 7-5: Disable CX1

7.6 Sensitivity Settings

All sensitivity options can be set internally or with option resistors on the pins TO0, TO1, TO3 and TO4.

The device can be set to either read the external TO pin values or to use internal values assigned to the TO pins. This option is user configurable with the OTP configuration bits. Please see Section 5 for more details regarding the programming of OTP bits.

The TO values are read at POR and are used for as long as power is applied, or until these values are over-written using the TO settings SPI command (refer to Table 7-17).

7.6.1 Proximity and Touch Detection

To determine proximity and touch conditions on the channels, the capacitance measured on a channel is compared to the average filter value of the channel. A proximity or touch condition occurs if the difference (C_Δ) between the measured value and average value is greater than or equal to the touch or proximity threshold (TTH or PTH).

Table 7-20 Touch and Proximity Conditions

$C_\Delta \leq TTH$	A Touch condition occurred
$C_\Delta \leq PTH$	A Proximity condition occurred

The proximity sensitivity level is determined by a change of a fixed amount of capacitance whilst a touch condition is triggered 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 7-21. The touch threshold is applied to all of the channels (CX[0:3]). All selections are performed on the TO pins when not in SPI mode.

Proximity Sensitivity (external): The proximity threshold values are specified in Table 7-22. The proximity threshold selection is applied to all of the channels (CX[0:3]). All selections are performed on the TO pins when not in SPI mode.

Internal Selections: These options are only used if the EXT/INT Sensitivity Selection option is set as '**Internal**' using *USBProg*. The selections are as shown in Table 7-23 to Table 7-24. **Green Font** selections are User Selectable with *USBProg*.

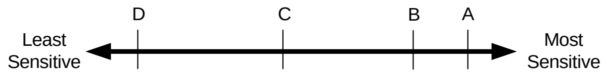


Figure 7-6 Touch Sensitivity Scale

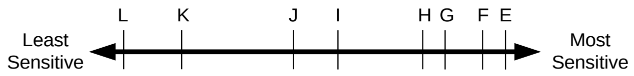


Figure 7-7 Proximity Sensitivity Scale

Table 7-21 Channel [0:3] Touch Sensitivity

TO1	TO0	Sensitivity Level (C_Δ)
0	0	A (1/32)
0	1	C (2/16)
1	0	B (1/16)
1	1	D (3/16)

Table 7-22: Channel [0:3] - Proximity Sensitivity	**TO4 / TO3**	**TO4 / TO3**	**TO4 / TO3**	**TO4 / TO3**
	LOW / LOW	LOW / HIGH	HIGH / LOW	HIGH / HIGH
MORE sensitive (Default)	6(H)	12(I)	4(G)	2(F)
LESS sensitive	16(J)	1(E)	32(K)	Disable(L)

Table 7-23: Channel [0:3] - Internal Touch Sensitivity	**Sensitivity Level (C_Δ)**
Level 1 (Most Sensitive)	A
Level 2	B
Level 3	C
Level 4 (Least Sensitive)	D

Table 7-24: Channel [0:3] – Internal Proximity Sensitivity[1]	**Prox Levels Selection**	
	Default	**Alternative**
Level 1 (Most Sensitive)	2(F)	Disable(L)
Level 2	6(H)	16(J)
Level 3	4(G)	32(K)
Level 4 (Least Sensitive)	12(I)	1(E)

---

[1] Please refer to the application note : *"AZD006 -VisualProxSense Overview"* for details regarding sensitivity levels

7.7 Power Mode

The IQS240 can operate in either a Normal Power mode (NP) or in a Low-Power Mode (LP). The device operates in NP mode by default; however the LP mode can be selected by configuring the appropriate OTP bits (refer to Section 5).

If the device is in LP mode, the conversion rate can be set to one of the selections shown in Table 7-25 by selecting the appropriate OTP bits (refer to Section 5). If the device is operating in NP mode, the conversion rate is T_{Sample} (dependent on selection made in section 8.1.5).

7.8 Extra Low Power Mode

This option is user configurable using *USBProg* and the Azoteq Configuration Tool (CTxxx). (See www.azoteq.com for more details)

This feature enables the designer to implement a semi-sleep mode in the IQS240.

This mode is entered if no touches are detected for 50 seconds or more. **All** channels except Channel 3 will cease charging. Channel 3 will continue to charge normally. The other channels will be recharged every 3 seconds to keep the filters updated. When a touch or proximity is detected the device will leave extra low power mode and return to normal operation.

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

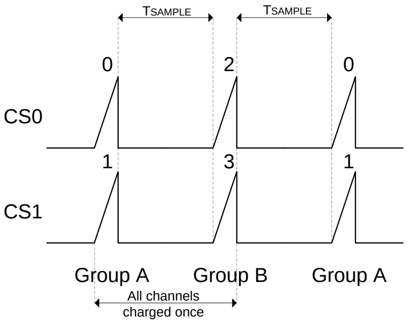
7.9 Charge Period in Low Power (LP) Mode

7.9.1 Choosing a Power Mode

The IQS240 has four power modes. The low power modes are ideal for battery applications.

The low power modes are selected using the *USBProg* program and the Azoteq Configuration Tool (CTxxx). (See www.azoteq.com for more details)

The different power modes control the duty cycle between charge transfers (T_{LP}). Refer to Section 7.7 for more details on the charge transfers. The timings (T_{LP}) given in Table 7-25 are measured from the end of the first conversion to the start of the following conversion. See Figure **7-8**.



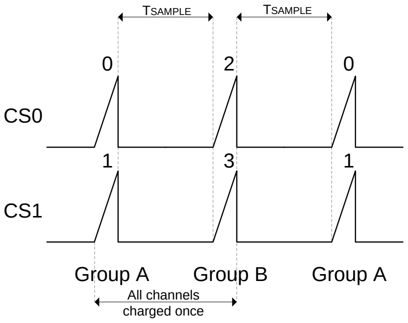


Figure 7-8: Measurement of T_{LP} (shown with AC filter Switched off)

Table 7-25: LP timings

Power Mode	Timing* (T_{SAMPLE})
LP1	70ms
LP2	130ms
LP3	190ms
LP4	240ms

*Timings are approximate

7.10 IIR Filter Selection

The IQS240 intelligently filters the conversions to keep track of environmental changes. The filter averages the conversions for each channel. The average is compared to the measured value to determine if a proximity or touch condition occurred.

If a difference of C_{Δ}[1] is found between the average and measured value, a proximity or touch condition is triggered. The applicable channel responds to this detected activity and the IIR adaptation filter freezes to keep the average value as reference.

T_{HALT} is user configurable with the OTP Configuration Bits. Please see Section 5 for more

---

[1] C_{Δ} = Change in Capacitance

details regarding the programming of the OTP bits.

Table 7-26 Filter Adaptation Conditions

T_{HALT}	**Filter**
20s	Filter halts for 20s, and then recalibrate
40s	Filter halts for 40s, and then recalibrate
Never	Filter Adaptation NEVER halts
Always	Filter Adaptation always halts

Filter Operation: When a proximity condition is detected the filter is halted for T_{HALT} as indicated in Table 7-26. If the proximity condition lasts longer than T_{HALT}, the channel will be recalibrated and the output reset. This is to enable the device to adapt to rapid changes in the environment and prevent a permanent stuck condition.

The detection of a proximity on a channel will cause its IIR filter to freeze as mentioned above, if a touch follows the proximity condition, T_{HALT} will reset.

7.11 Zoom Option

Zoom mode is only available if the Low Power (LP) Mode is selected (See Section 7.7). In the LP mode, conversions are done according to T_{LP} in Table 7-25.

With the detection of a proximity condition, the conversion rate zooms in to the NP (Normal Power) Mode (T_{Sample}). The device then operates in the zoomed in state for 3s after the last proximity has been detected. When 3 seconds elapses, the conversions are done according to the LP timing selections once again.

7.12 Conversion Divider (CONVDIV)

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 cannot be completed with the normal transfer rate. See App Note AZD004 “Azoteq Capacitive Sensing” for a complete description of the advantage of this feature.

7.13 HC / RDY Operation

The IQS240 issues a RDY signal after all the channels have completed a charge transfer, thus after every Group B conversion in Figure 7.8

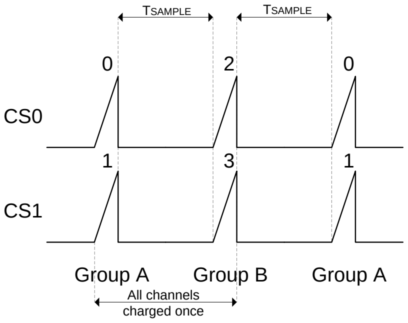


Figure 7-8T_{RDY} = T_{Sample}.

The charge transfers on the IQS240 can be dynamically halted (Halt Charge (HC)) by pulling the HC/RDY pin HIGH **when the device is in a direct mode**. If this signal occurs during a group of conversions, the current group of conversions will be finished after which all conversions will be halted until the HC/RDY Pin is pulled LOW again.

The HC/RDY pin is used to wake up the device from sleep mode after the SLEEP SPI command is sent. HC/RDY should be pulled high for the duration of the device sleeping. The device can be woken by periodically pulling the HC/RDY pin low.

8 Additional Features

8.1.1 Zero Cross Function

The ZC pin is used by the IQS240 to synchronize to AC. This enables the device to do charge transfers synchronized to an AC signal, which entails the charge transfers occurring at 20ms (assuming a 50Hz AC signal) intervals. Otherwise the IQS240 will run at its internal clock frequency. If the ZC function is not used, the ZC pin should be tied to ground through a 100kΩ resistor (refer to Figure 4-1).

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

Typically 2 x 510kΩ resistors are used for current limiting when synchronising to 110VAC or 220VAC. Whenever the ZC pin is used to synchronise to a signal with pulses exceeding VDDHI, current protection resistors should be used.

8.1.2 Buzzer

The IQS240 BUZ pin outputs a buzz signal whenever a touch condition is triggered. When a touch condition occurs the buzzer will click once, and if the touch condition persists, after a small delay the buzzer will continue clicking (toggle output modes will only click when an output pin changes state).

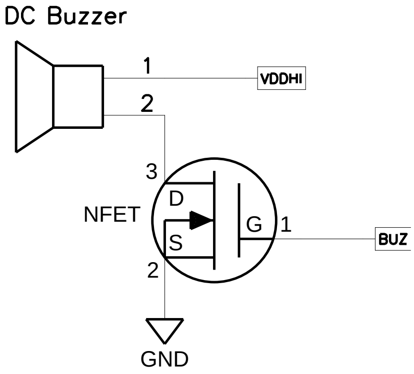


Figure 8-1 Typical DC Buzzer Configuration

8.1.3 RF Noise Immunity and Detection

The IQS240 has advanced immunity to high power RF noise typically transmitted by GSM cellular telephones. There is still a possibility of the device reacting to noise if a cellular phone is placed extremely close to the device.

In addition to the RF immunity the IQS240 has a built-in Noise Detection Scheme. The IQS240 is therefore able to detect cellular noise or any other high power transmitted noise on the RFIN pin.

In some applications the RFIN pin would be required to have an external antenna mounted, to increase efficiency of noise detection. The details of the above mentioned antenna can be seen in the application Note: “AZD015 – RF Detection Antenna.pdf”.

When noise is detected, the IQS240 halts and disables proximity and touch condition outputs. The Noise Detection scheme can be disabled if needed with an OTP Configuration Bit.

8.1.4 Dynamic Noise Threshold

The IQS240 has a Dynamic Noise Threshold setting. When activated the noise threshold monitors the average amount of ambient noise in the operational environment and adjusts the proximity threshold accordingly. If the device is operational in a very noisy environment the proximity sensitivity is adjusted dynamically to desensitize the device. The Dynamic Noise Threshold is default enabled and can be disabled by selection of the appropriate OTP bits (refer to Section 5).

8.1.5 Fast charge (AC Filter)

The AC filter is enabled when enabling ‘Fast Charge’ (default enabled). The Cs will sample at a rate which satisfies the AC filter criteria and filters out the effect of AC noise (50Hz & 60Hz) that may be present in the environment. This greatly increases the stability and sensitivity of the device. In LP modes the AC filter criteria will still apply by double conversions at every LP interval.

The AC filter can be disabled by disabling ‘Fast Charge’ (refer to Section 5). When the AC filter is disabled the Charge selection occurs at approximately half the rate. This in turn decreases response time slightly but also decreases current consumption.

The default sampling rate (T_{SAMPLE}) is ±15ms and has an alternative option of ±20ms.

See Figure 6-1 & Figure 6-2 for T_{SAMPLE}.

9 Reference Designs

SPI Example Design

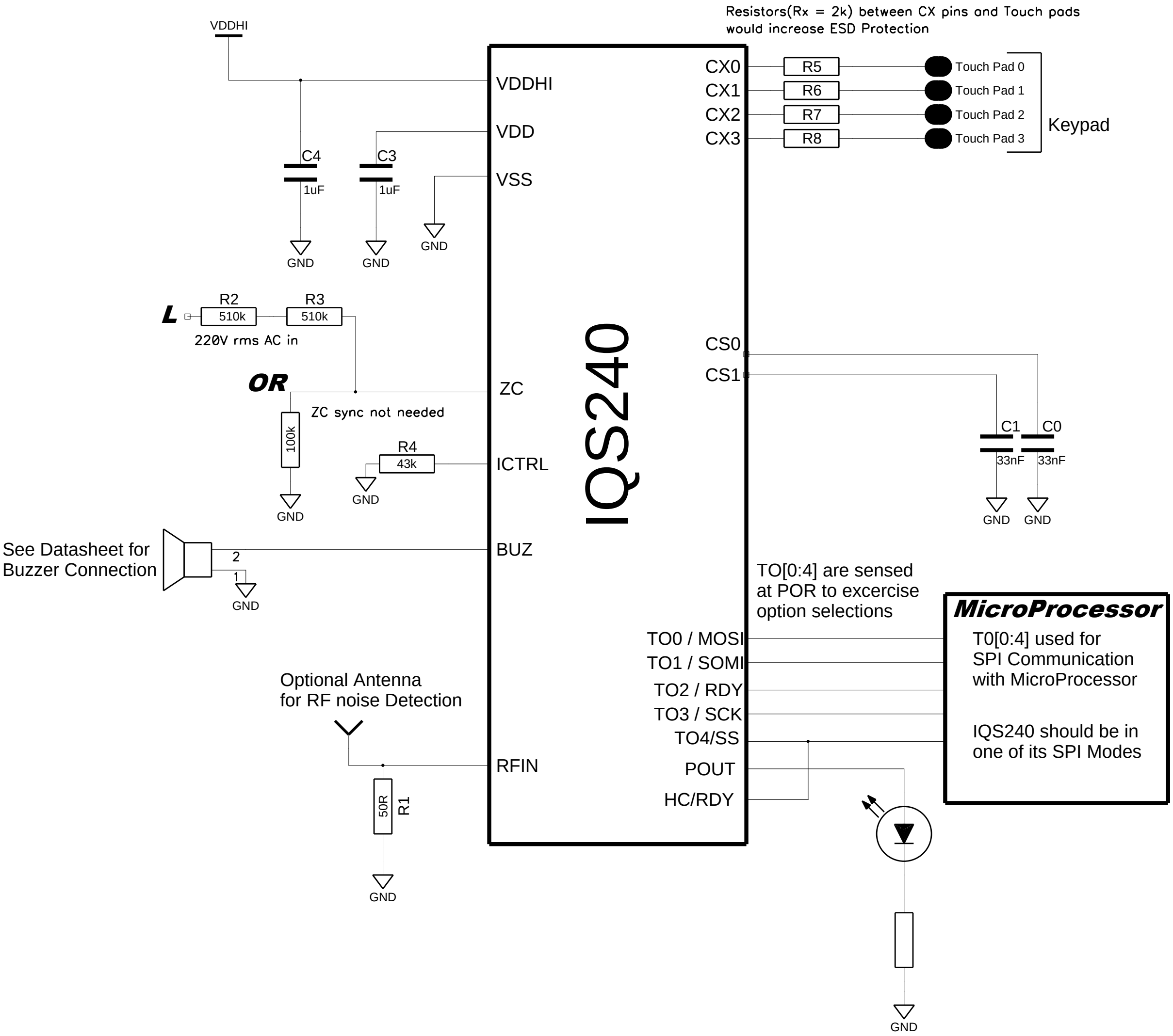


Figure 9-1: SPI Design Example

Direct Example Design

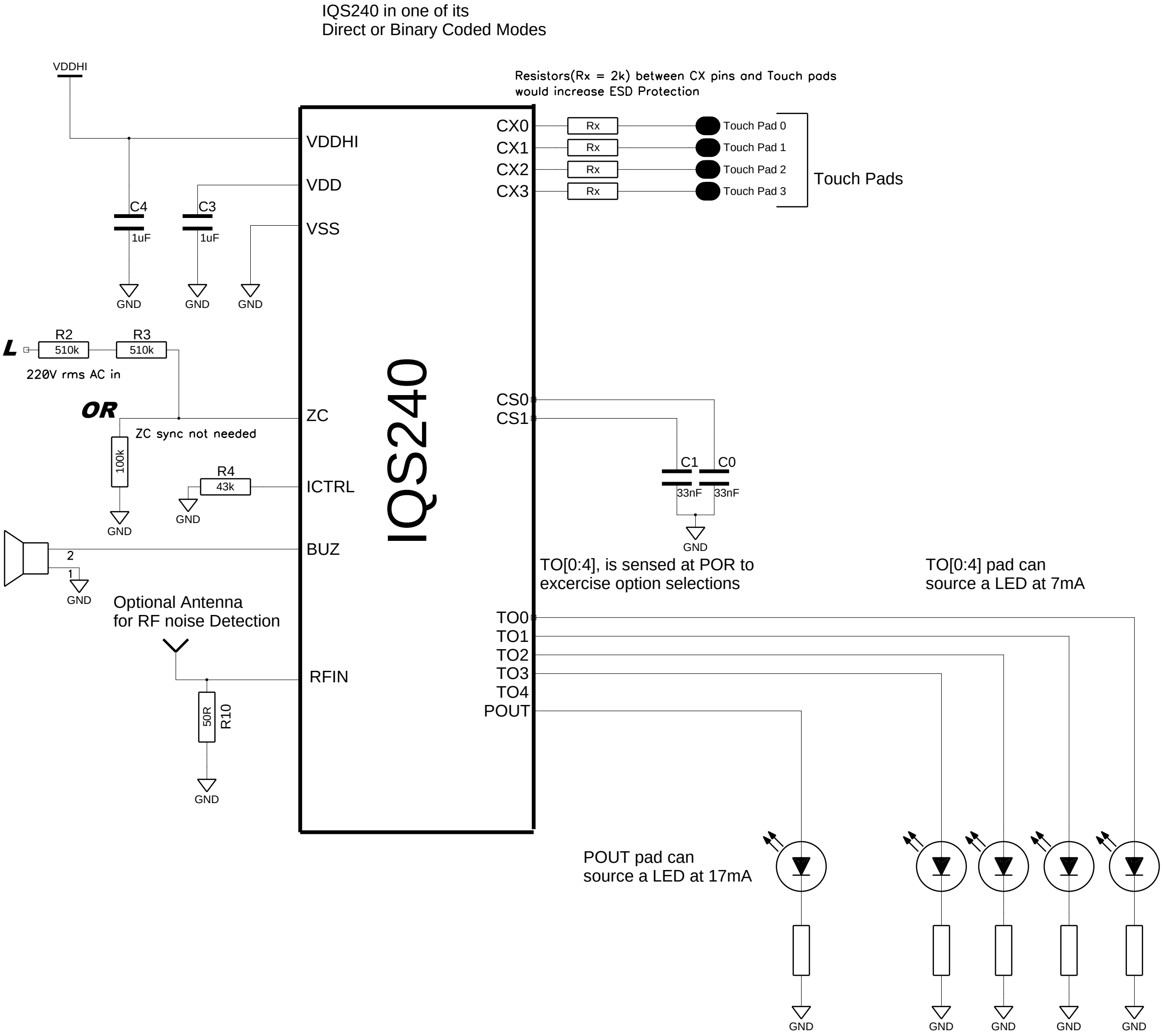


Figure 9-2: Direct Design Example

10 Electrical Specifications

10.1 Absolute Maximum Specifications

Exceeding these maximum specifications may cause damage to the device.

Operating Temperature	-40°C to 85°C
Storage Temperature	-55°C to 125°C
Maximum Pin Voltage (VDDHI, VDD, VSS, POUT, TOx, HC/RDY,FH)	5.5V
Pin Voltage (Cs, Cx)	2.5V
Minimum Pin Voltage (VDDHI, VDD, VSS, POUT, Cs, Cx)	-0.5V
Minimum Turn On Slope	1V/s
ESD Protection (All Pads)	2kV

10.2 Operating Conditions *(Measured at 25°C)*

Table 10-1

DESCRIPTION	PARAMETER	MIN	TYP	MAX	UNIT
Internal Regulator Output[1]	V_{DD}	2.2	2.5	2.8	V
Supply Voltage	V_{DDHI}			5.5	V
Normal Operating current[2]	$I_{IQS240\ NORMAL}$		190		µA
Low Power Operating current[3]	$I_{IQS240\ LOWPOWER}$		27		µA
Power On Reset[4]	POR		1.8		V
Cs trip voltage	V_{TRIP}	560		700	mV
POUT High Voltage	V_{POUT_HIGH}		V_{DDHI}		V
Input Low Voltage on pins TO[0:4]	V_{IL}		$0.1*V_{DDHI}$		V
Input High Voltage on pins TO[0:4]	V_{IH}		$0.9*V_{DDHI}$		V
Input Low Voltage on pins CX[0:3]	V_{IL-CX}		$0.1*V_{DD}$		V
Input High Voltage on pins CX[0:3]	V_{IH-CX}		$0.9*V_{DD}$		V

10.3 Output Characteristics

Table 10-2 Output Pin (TO[5:0], POUT, BUZZ) Characteristics

Symbol	Description	Parameter	Conditions	MIN	TYP	MAX	UNIT
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		

---

[1] V_{DDHI} = 5V

[2] V_{DDHI} = 3V, Charge Cycle Duration < 10ms in Normal Power Mode

[3] V_{DDHI} = 3V, Charge Cycle Duration < 10ms in LP4

[4] POR slope = 100V/s, see Figure 10-1 for recommended timing specifications

10.4 Timing Characteristics

Table 10-3 Timing Characteristics for the IQS240

DESCRIPTION	SYMBOL	MIN	TYP	MAX	UNIT
Output Minimum High Time on TO pins	T_{HIGH}		60		ms
Time before switching back to LP Mode	T_{LOW_POWER}		3.3		s
Cx charging Oscillator[1]	F_{CX}	213	250	287	kHz
Filter Freeze Condition	T_{HALT}		Refer to Table 7-26		s
Charge Cycle Delay Time[2]	T_{Sample}[3]	13	15	17	ms
Charge Cycle Delay Time[2]	T_{Sample}[4]	17	20	23	ms
Low Power Delay Time	T_{LP}		Refer to Table 7-25		ms
Proximity Response Time	$T_{DEBOUNCE.Prox}$		80		ms
Charge Times	T_{CHARGE}		Determined by C_S Capacitor		ms

10.5 Touch Response Times

Table 10-4 Touch Response Times[5] [6]

Operating Mode	50 Hz Mode			100 Hz AC Filter Mode			UNIT
	MIN	TYP	MAX	MIN	TYP	MAX	
NP	45	60	80	35	200	60	ms
LP1	145	210	280	155	230	300	ms
LP2	265	390	520	275	410	540	ms
LP3	385	570	760	395	590	780	ms
LP4	485	730	970	495	740	990	ms

10.6 POR specification

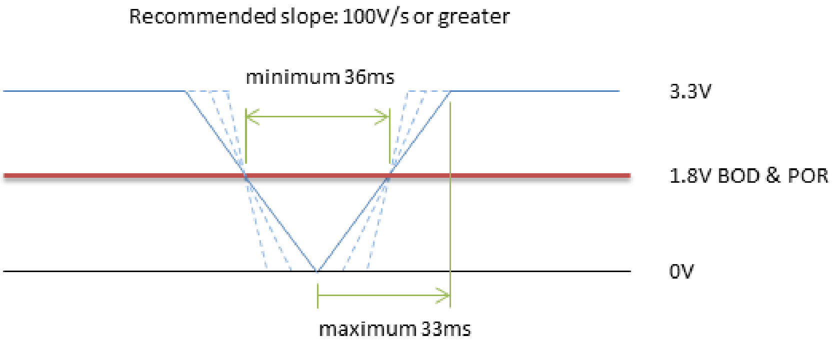


Figure 10-1: POR timing and slope specifications

---

[1] Enabling Conversion Divider (with *USBProg*) will divide F_{CX} by 2

[2] Time for One Charge Cycle if $T_{CHARGE} < 20ms$

[3] Fast Charge Selection: ±15ms (See Section 8.1.5)

[4] Fast Charge Selection: ±20ms (See Section 8.1.5)

[5] Values calculated for direct modes

[6] T_{Charge} = 5ms

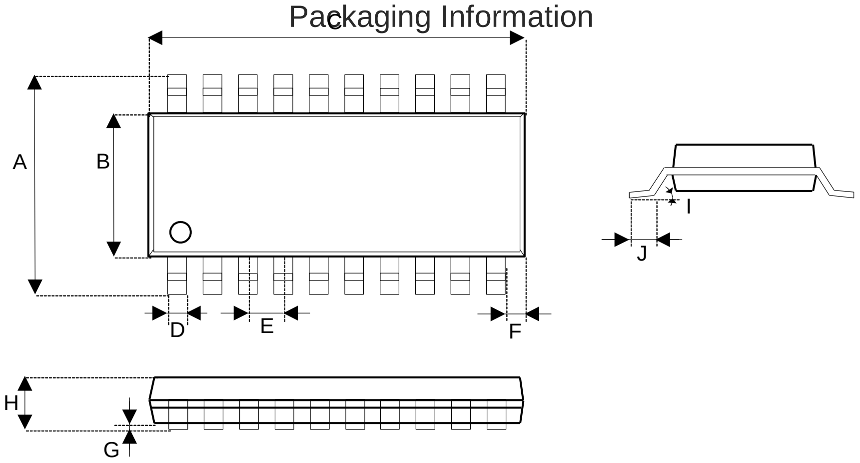


Figure 10-2 SO-20 Package

Table 10-5 SO-20 Dimensions

Dimension	Min	Max
A	7.60 mm	8.20 mm
B	5.20 mm	5.40 mm
C	12.35 mm	12.55 mm
D	0.40 mm	0.48 mm
E	1.27 mm Typ	
F	0.29 mm Typ	
G	0.05 mm	0.20 mm
H	1.85 mm	2.2 mm
I	5° Typ	
J	0.3 mm	0.7 mm

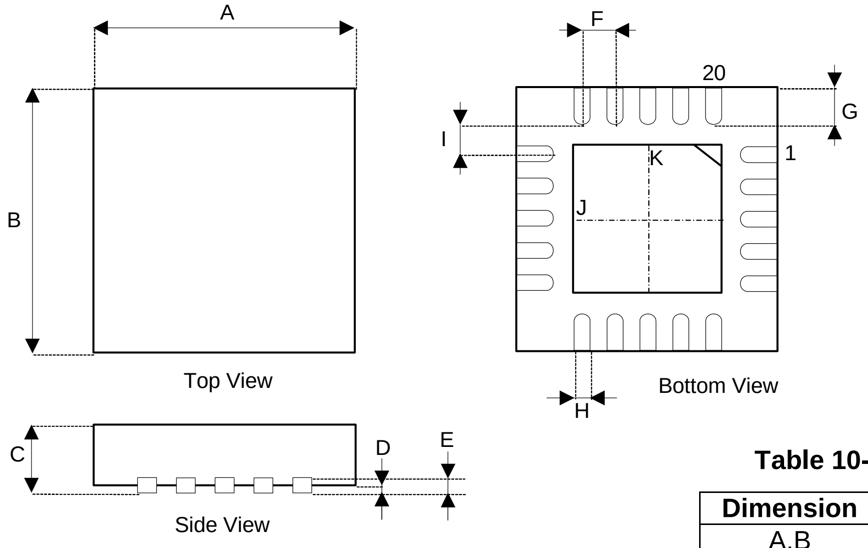


Figure 10-3 QFN4x4-20 Package

Table 10-6 QFN4x4-20 Dimensions

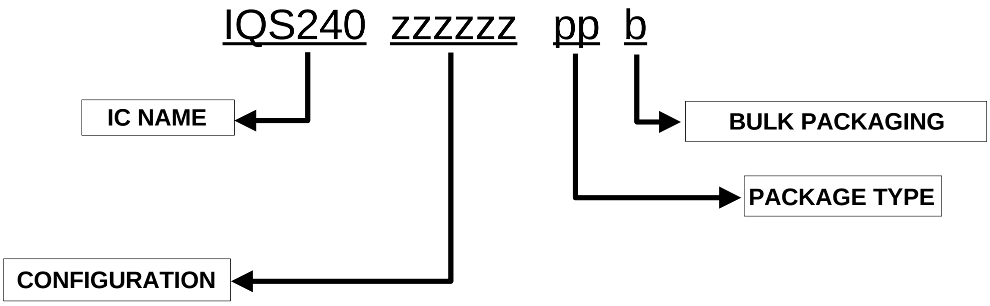
Dimension	Min	Max
A,B	3.90 mm	4.10 mm
C	0.70 mm	0.90 mm
D	0.00 mm	0.05 mm
E	0.203 mm Ref.	
F	0.5 mm Typ	
G	0.30mm	0.50 mm
H	0.18 mm	0.30 mm
I	0.2 mm Min.	
J,K	1.90 mm	2.10 mm

11 Datasheet and Part-number Information

11.1 Ordering Information

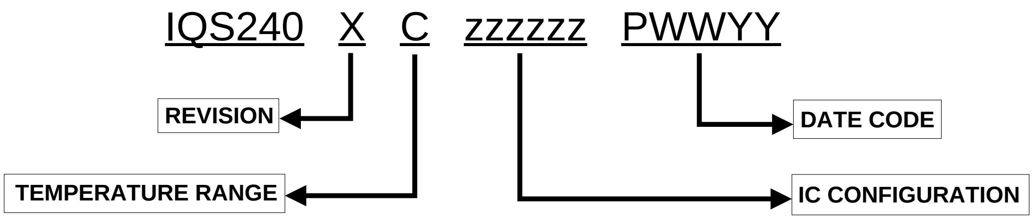
For large orders, Azoteq PTY (LTD) can provide pre-configured devices.

The Part-number can be generated by using USBProg.exe or the Interactive Part Number generator on the "Virtual Demos" section of www.azoteq.com.



CONFIGURATION		zzzzzz	=	IC Configuration (hexadecimal)	
PACKAGE TYPE		QN	=	QFN4x4-20	
		SO	=	SO-20	
BULK PACKAGING	QFN4x4-20	R	=	Reel: 3000pcs/reel	MOQ = 3000 pcs
		T	=	Tube: 120/pcs/tube	MOQ = 1200 pcs
	SO-20	T	=	Tube: 40/pcs/tube	MOQ = 1600 pcs

11.2 Device Numbering 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: IQS240 2C 008B28 12308 = Revision 2; Commercial Temperature Range; Output Configuration 008B28; Packaged at House 1 the 23RD week of 2008

PRETORIA OFFICE

Physical Address
160 Witch Hazel Avenue
Hazel Court 1, 1st Floor
Highveld Techno Park
Centurion, Gauteng
Republic of South Africa

Tel: +27 12 665 2880
Fax: +27 12 665 2883

Postal Address
PO Box 16767
Lyttelton
0140
Republic of South Africa

PAARL OFFICE

Physical Address
109 Main Street
Paarl
7646
Western Cape
Republic of South Africa

Tel: +27 21 863 0033
Fax: +27 21 863 1512

Postal Address
PO Box 3534
Paarl
7620
Republic of South Africa

WWW.AZOTEQ.COM

ProxSenseSupport@azoteq.com

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 7,119,459 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 7,755,219 B2, US7,772,781, US 7,781,980 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

IQ Switch, ProxSense and the IQ logo are trademarks of Azoteq.

The information appearing in this Data Sheet is believed to be accurate at the time of publication. However, Azoteq assumes no responsibility arising from the use of the specifications described. The applications mentioned herein are used solely for the purpose of illustration and Azoteq makes no warranty or representation that such applications will be suitable without further modification, nor recommends the use of its products for application that may present a risk to human life due to malfunction or otherwise. Azoteq products are not authorized for use as critical components in life support devices or systems. No licenses to patents are granted, implicitly or otherwise, under any intellectual property rights. Azoteq reserves the right to alter its products without prior notification. For the most up-to-date information, please contact ProxSenseSupport@azoteq.com or refer to the website.