IQS7210A DATASHEET

Versatile trackpad/touchscreen controller aimed at small and medium sized applications. Capacitive touch, proximity, gesture detection and inductive/capacitive button input.

1   Device Overview

The IQS7210A ProxFusion® IC is aimed at wearables, remote controls, gaming controllers and other small to medium sized applications requiring a trackpad or touchscreen. The controller IC also supports an inductive (waterproof) or capacitive button for wake-up or secondary user interface applications. Class leading power consumption and flexible low power modes can vastly extend battery life.

1.1   Main Features

> Highly flexible ProxFusion® device
> 12(QFN) / 10(WLCSP) external sensor pad connections
> Self/Mutual capacitive sensors configuration for display wake-up
> Inductive or capacitive button configuration
> ULP wake-up on touch
  - Wake-up on screen/trackpad and/or
  - Wake-up on button touch/press
> Sensor flexibility
  - Automatic sensor tuning for optimum sensitivity
  - Internal voltage regulator
  - Reference capacitor
  - On-chip noise filtering
  - Detection debounce and hysteresis
  - Wide range of capacitance detection
> Trackpad/Touchscreen
  - Up to 2 fingers tracking
  - High resolution coordinate outputs
  - Fast response: Coordinate report rate up to 100Hz
  - Individual sensor touch (for up to 25+1 touch key applications)
  - Integrated touch size output (area and strength) for touch integrity
  - Single finger gesture recognition engine
  - Electrode mapping for optimal PCB layout
  - Configurable coordinate resolution and orientation
  - Compatible with wide range of overlay materials and thicknesses
  - Compatible with multiple 1-and 2-layer sensor patterns
  - Adjustable sensing frequency offset for limiting potential display interference
  - No calibration required - systems automatically compensated for mechanical & temperature changes
  - Water immunity features
> Inductive/Capacitive button
  - Inductive (metal detection/force sensing) or
  - Capacitive (mutual- or self-capacitive touch sensing)
> Design and manufacturing support
  - Touch pattern layout drawing
  - Full FPC layout package (example & customized)
  - Test guide for touch pattern
  - RFI immunity design support
> Design simplicity
  - PC Software for debugging and obtaining optimal performance
  - One-time settings programming (during MP) or pre-programmed devices
  - Auto-run from programmed settings for simplified integration

RoHS2
Compliant

WLCSP18 & QFN20
package
Representation only

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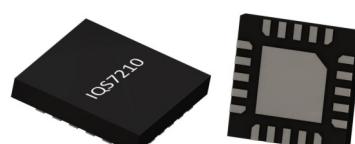
- No production line calibration required
- Display cover lens thickness
  - Minimum thickness: 0.5mm
  - Maximum thickness: 2-4mm depending on design parameters
- Minimize display noise
  - Advanced DSP for touch performance
  - Display and charger interference avoidance
  - Auto adjusting digital filters
- Supports different display touch panel types
  - On-cell
  - Add-on touch panel
- Screen resolution
  - 256 per channel
  - Example: 1792x512 (8x3 channels), 1024x1024 (5x5 channels)
- Automated system power modes for optimal response vs consumption
- I²C communication interface with IRQ/RDY(up to fast plus -1MHz)
- Event and streaming modes
- Customizable user interface due to programmable memory
- Supply voltage
  - 1.8V(-5%) to 3.5V @ 14MHz
  - Minimum 2.2V @ 18MHz
- Small packages
  - WLCSP18 (1.62x 1.62x0.5 mm) - interleaved 0.4mm x 0.6mm ball pitch
  - QFN20 (3 x 3 x 0.5 mm) - 0.4mm pitch

1.2 Applications

- Smart watches
- Fitness bands
- True Wireless Stereo (TWS) earbuds
- Game controller touch pads
- Headphones

1.3 Block Diagram
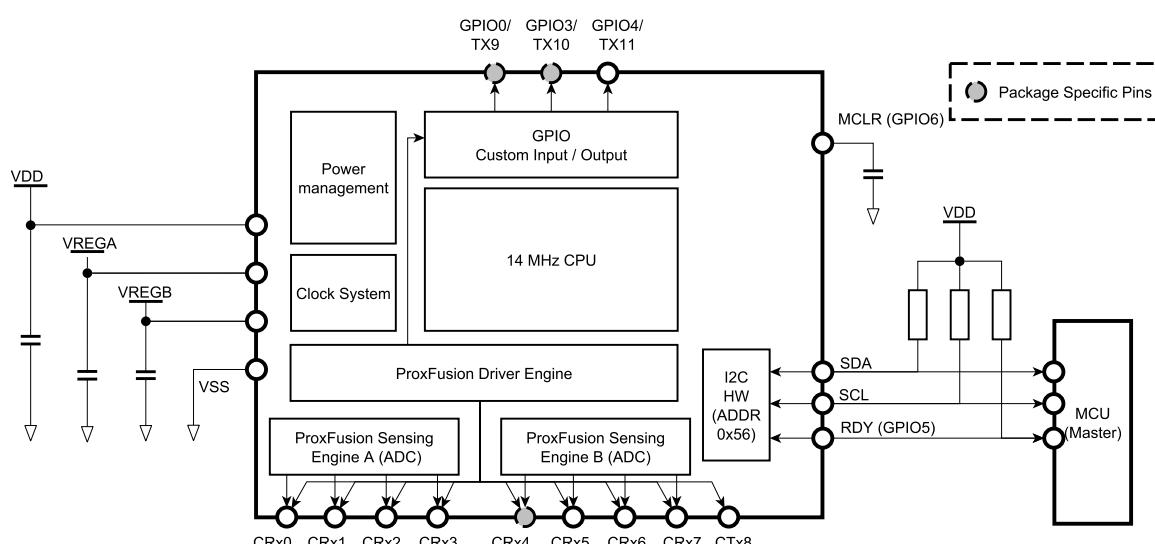
Figure 1.1: Functional Block Diagram[i]

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[i]WLCSP18 packages do not have a CRX4 and combines GPIO0 and GPIO3

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1.4 Option Summary

Table 1.1: Maximum Sensor Configurations - QFN20

	Trackpad square	Trackpad rectangle
Trackpad + inductive button option	5x5	7x3
Trackpad + self-cap touch button option	5x5	8x3

Table 1.2: Maximum Sensor Combinations - WLCSP18

	Trackpad square	Trackpad rectangle
Trackpad + inductive button option	4x4	5x3
Trackpad + self-cap touch button option	5x4	6x3

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Table 1.3: Trackpad Configurations with Different Sensor Combinations[ii]

Total Sensors	Total Rxs	Total Txs	Channels	Timeslots	Possible?
11	1	10	10	10	✓
	2	9	18	9	✓
	3	8	24	16	✓
	4	7	28	14	✗
	5	6	30	18	✗
	6	5	30	15	✗
	7	4	28	16	✗
10	1	9	9	9	✓
	2	8	16	8	✓
	3	7	21	14	✓
	4	6	24	12	✓
	5	5	25	15	✓
	6	4	24	12	✓
	7	3	21	12	✓
9	1	8	8	8	✓
	2	7	14	7	✓
	3	6	18	12	✓
	4	5	20	10	✓
	5	4	20	12	✓
	6	3	18	9	✓
	7	2	14	8	✓
8	1	7	7	7	✓
	2	6	12	6	✓
	3	5	15	10	✓
	4	4	16	8	✓
	5	3	15	9	✓
	6	2	12	6	✓
	7	1	7	4	✓

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> QFN20 package has a maximum of 11 sensors available if a self-capacitive button is implemented.
> OFN20 package has a maximum of 10 sensors available if inductive or mutual capacitive button is implemented .
> WLCSP18 package has a maximum of 9 sensors available if a self-capacitive button is implemented.
> WLCSP18 package has a maximum of 8 sensors available if inductive or mutual capacitive button is implemented.

[ii]Sensor combinations with less sensors than listed below, are possible.

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Contents

2 Hardware Connection

2.1 WLCSP18 Pin Diagrams

Table 2.1: 18-pin WLCSP18 Package

Pin no.	Signal
A1	CTx9/GPIO0CTx10/GPIO3[i]
A3	SCL/GPIO2
A5	MCLR/GPIO6
B2	CTx11/GPIO4
B4	SDA/GPIO1
C1	CTx8
C3	RDY/GPIO5
C5	VDD
D4	VSS
D2	CRx2/CTx2
D4	VSS
E1	CRx6/CTx6
E3	CRx1/CTx1
E5	VREGD
F2	CRx5/CTx5
F4	CRx0/CTx0
G1	CRx7/CTx7
G3	CRx3/CTx3
G5	VREGA

Ball-side View

Top-side View
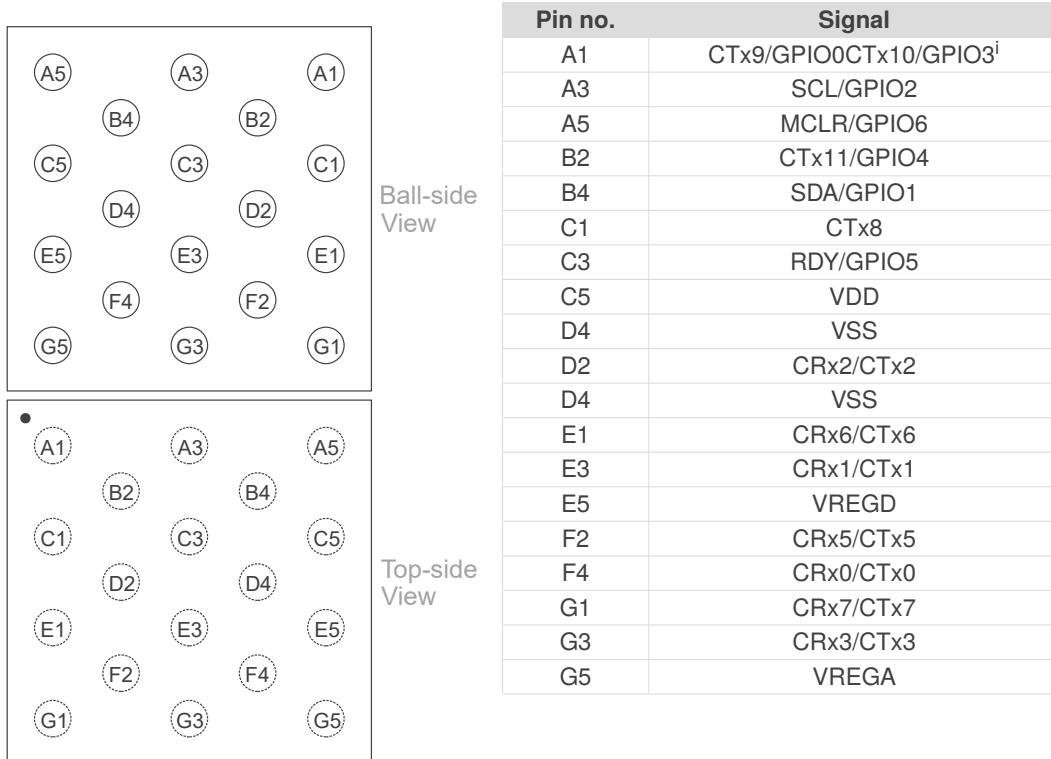
2.2 QFN20 Pin Diagram

Table 2.2: 20-pin QFN Package (Top View)
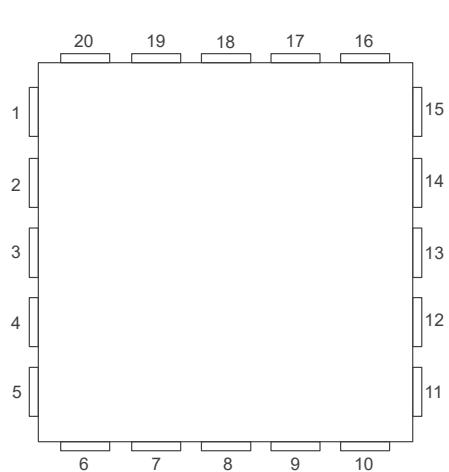
Pin no.	Signal name	Pin no.	Signal name
1	VDD	11	CRx6/CTx6
2	VREGD	12	CRx7/CTx7
3	VSS	13	CTx8
4	VREGA	14	CTx9/GPIO0
5	CRx0/CTx0	15	CTx10/GPIO3
6	CRx1/CTx1	16	CTx11/GPIO4
7	CRx2/CTx2	17	RDY/GPIO5
8	CRx3/CTx3	18	SCL/GPIO2
9	CRx4/CTx4	19	SDA/GPIO1
10	CRx5/CTx5	20	MCLR/GPIO6

Area name	Signal name
Tab	Thermal pad (floating)

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2.3 Pin Attributes

Table 2.3: Pin Attributes

Pin no.		Signal name	Signal type	Buffer type	Power source
WLCSP18	QFN20				
C5	1	VDD	Power	Power	N/A
E5	2	VREGD	Power	Power	N/A
D4	3	VSS	Power	Power	N/A
G5	4	VREGA	Power	Power	N/A
F4	5	CRx0/CTx0	Analog		VREGA
E3	6	CRx1/CTx1	Analog		VREGA
D2	7	CRx2/CTx2	Analog		VREGA
G3	8	CRx3/CTx3	Analog		VREGA
-	9	CRx4/CTx4	Analog		VREGA
F2	10	CRx5/CTx5	Analog		VREGA
E1	11	CRx6/CTx6	Analog		VREGA
G1	12	CRx7/CTx7	Analog		VREGA
C1	13	CTx8	Analog		VREGA
A1	14	CTx9/GPIO0	Prox/Digital		VREGA/VDD
B4	19	SDA/GPIO1	Digital		VDD
A3	18	SCL/GPIO2	Digital		VDD
A1	15	CTx10/GPIO3	Prox/Digital		VREGA/VDD
B2	16	CTx11/GPIO4	Prox/Digital		VREGA/VDD
C3	17	RDY/GPIO5	Digital		VDD
A5	20	MCLR/GPIO6	Digital		VDD

[i]Please note that CTx9 and CTx10 are connected together in the WLCSP18 package

2.4   Signal Descriptions

Table 2.4: Signal Descriptions

Function	Signal name	Pin no.		Pin type[ii]	Description
		WLCSP18	QFN20		
ProxFusion®	CRx0/CTx0	F4	5	IO	ProxFusion® channel
	CRx1/CTx1	E3	6	IO	
	CRx2/CTx2	D2	7	IO	
	CRx3/CTx3	G3	8	IO	
	CRx4/CTx4	-	9	IO	
	CRx5/CTx5	F2	10	IO	
	CRx6/CTx6	E1	11	IO	
	CRx7/CTx7	G1	12	IO	
	CTx8	C1	13	IO	CTx8 pad
	CTx9/GPIO0	A1	14	IO	CTx9 pad
	CTx10/GPIO3	A1	15	IO	CTx10 pad
	CTx11/GPIO4	B2	16	IO	CTx11 pad
	RDY/GPIO5	C3	17	IO	RDY pad
GPIO	MCLR/GPIO6	A5	20	IO	Active pull-up, 200k resistor to VDD. Pulled low during POR, and MCLR function enabled by default. VPP input for OTP.
I²C	SDA/GPIO1	B4	19	IO	I²C Data
	SCL/GPIO2	A3	18	IO	I²C clock
Power	VDD	C5	1	P	Power supply input voltage
	VREGD	E5	2	P	Internal regulated supply output for digital domain
	VSS	D4	3	P	Analog/Digital Ground
	VREGA	G5	4	P	Internal regulated supply output for analog domain

[ii]Pin Types: I = Input, O = Output, I/O = Input or Output, P = Power

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2.5 Reference Schematic
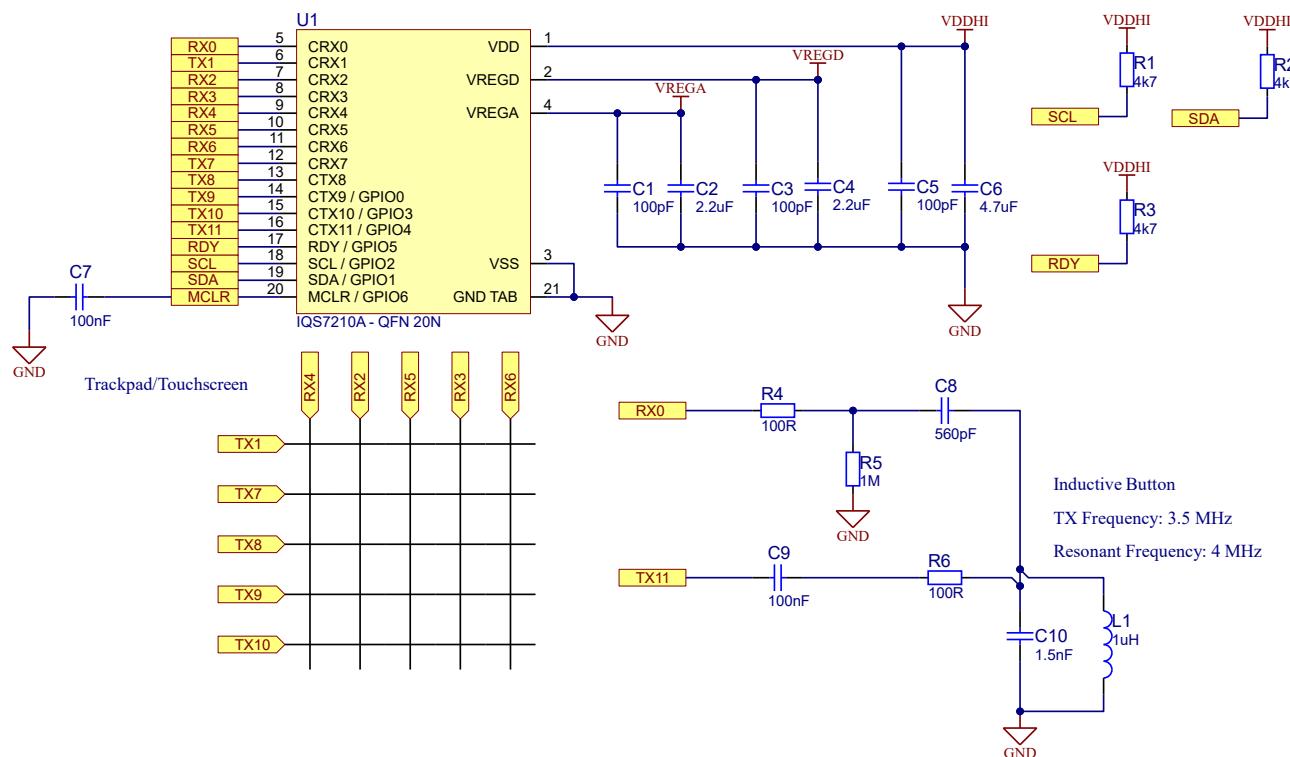
Figure 2.1: Reference Trackpad (5x5) and Inductive Button Schematic

> Sensors Rx0 and Tx11 must be used for an inductive or mutual capacitive button.
> Sensor Rx0 must be used for a self-capacitive button.
> Each cycle can simultaneously sense one channel from Prox block A (Rx0-3) and one from Prox block B (Rx4-7). Make Rx sensor selections accordingly for optimal Cycle Allocations.
> The ALP channel can only be created from Prox block B (Rx4-7).

2.6 Inductive Force Touch

> An embedded or adhesive-based metal plate is fixed to the outer shell of the device
> This metal plate moves closer to a coil on a PCB that is fixed on the inside of the device
> This happens when the user exerts force on the housing to squeeze and deform the outside of the housing.
> The distance (d) between the metal plate and coil becomes smaller under such force and the movement affects the inductance in a measurable way
> This measurement is not affected by capacitive effects like other known force detection technologies
> Typical measurable changes are $\Delta d < 50\mu m$ and causes >10% signal change (dependent on hardware implementation)
> The same metal plate can also be used as an electrode for capacitive proximity or touch detection on one or both sides of the housing.
> The force touch channel will also effectively respond from the lowest power mode because of the typical time required for a "force-based" event (>200ms).

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Figure 2.2: 3D representation of inductive force touch PCB showing orientation and detail

2.7 Inductive Tactile Button

> A metal snap dome that deforms to move closer to a coil on a PCB when the user exerts force on the dome
> This technique requires no electrical contact between the coil and dome
> Force on the dome creates a "snap" with characteristic user feedback
> The "snap" action presents a significant movement of metal that is detected via the coil on the PCB as a change in inductance
> This technology is not affected by capacitive effects (touch or water) and offers a waterproof switch with tactile feedback
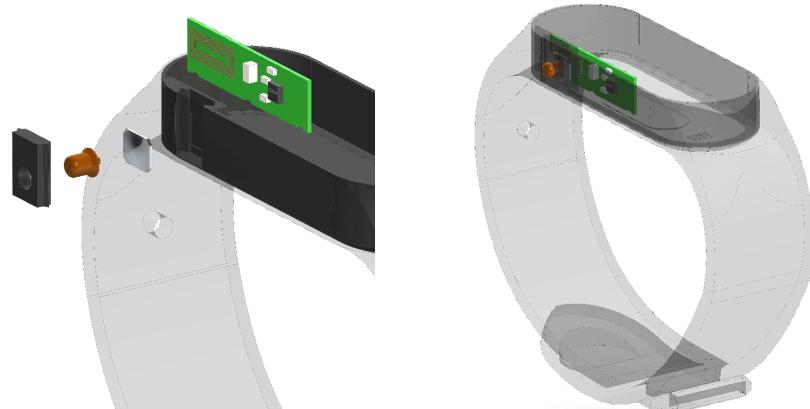
Figure 2.3: 3D representation of inductive tactile button PCB showing orientation and detail

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3 Electrical Characteristics

3.1 Absolute Maximum Ratings

Table 3.1: Absolute Maximum Ratings

	Min	Max	Unit
Voltage applied at VDD pin to VSS	1.71	3.5	V
Voltage applied to any ProxFusion® pin	−0.3	VREGA	V
Voltage applied to any other pin (referenced to VSS)	−0.3	VDD + 0.3 (3.5 V max)	V
Storage temperature, T_{stg}	−40	85	°C

3.2 Recommended Operating Conditions

Table 3.2: Recommended Operating Conditions

Recommended operating conditions		Min	Nom	Max	Unit
VDD	Supply voltage applied at VDD pin: F_{OSC} = 14 MHz F_{OSC} = 18 MHz	1.71 2.2		3.5 3.5	V
VREGA	Internal regulated supply output for analog domain: F_{OSC} = 14 MHz F_{OSC} = 18 MHz	1.49 1.7	1.53 1.75	1.57 1.79	V
VREGD	Internal regulated supply output for digital domain: F_{OSC} = 14 MHz F_{OSC} = 18 MHz	1.56 1.75	1.59 1.8	1.64 1.85	V
VSS	Supply voltage applied at VSS pin		0		V
T_A	Operating free-air temperature	−40	25	85	°C
C_{VDD}	Recommended capacitor at VDD	$2{\times}C_{VREGA}$	$3{\times}C_{VREGA}$		µF
C_{VREGA}	Recommended external buffer capacitor at VREGA, ESR $\leq$ 200 mΩ	2	4.7	10	µF
C_{VREGD}	Recommended external buffer capacitor at VREGD, ESR $\leq$ 200 mΩ	2	4.7	10	µF
$Cx_{SELF-VSS}$	Maximum capacitance between ground and all external electrodes on all ProxFusion® blocks (self-capacitance mode)	1	-	400[i]	pF
$Cm_{CTx-CRx}$	Capacitance between Receiving and Transmitting electrodes on all ProxFusion® blocks (mutual-cap mode)	0.2	-	9[i]	pF
$Cp_{CRx-VSS-1M}$	Maximum capacitance between ground and all external electrodes on all ProxFusion® blocks (mutual-capacitance mode @f_{xfer} = 1 MHz)			100[i]	pF
$Cp_{CRx-VSS-4M}$	Maximum capacitance between ground and all external electrodes on all ProxFusion® blocks (mutual-capacitance mode @ f_{xfer} = 4 MHz sensing)			25[i]	pF
$\frac{Cp_{CRx-VSS}}{Cm_{CTx-CRx}}$	Capacitance ratio for optimal SNR in mutual capacitance mode[ii]	10		20	n/a
$RCx_{CRx/CTx}$	Series (in-line) resistance of all mutual capacitance pins (Tx & Rx pins) in mutual capacitance mode	0[iii]	0.47	10[iv]	kΩ
RCx_{SELF}	Series (in-line) resistance of all self capacitance pins in self capacitance mode	0[iii]	0.47	10[iv]	kΩ

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3.3   ESD Rating

Table 3.3: ESD Rating

		Value	Unit
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[v]	±4000	V

---

[i]RCx = 0 Ω

[ii]Please note that the the maximum values for Cp and Cm are subject to this ratio

[iii]Nominal series resistance of 470 Ω is recommended to prevent received and emitted EMI effects. Typical resistance also adds additional ESD protection

[iv]Series resistance limit is a function of f_{xfer} and the circuit time constant, RC. $R_{max} \times C_{max} = \frac{1}{(6 \times f_{xfer})}$ where C is the pin capacitance to VSS.

[v]JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ±4000 V may actually have higher performance.

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3.4   Current Consumption

The specific parameters configured on varying designs have a great impact on the obtained current consumption. Due to this, the following table is purely illustrative of the expected consumption[vi] for similar configurations. The device configurations used below are examples of practical setups expected in applications. The main oscillator frequency was set to 14MHz for all measurements.

Table 3.4: Current Consumption

Power mode	Active channels	Report rate [ms]	Auto-prox cycles	Setup	Current [μA]
Active Mode	Trackpad (25 Channel) + Inductive Button	10	N/A	Configured as a 5x5 trackpad ATI Target of 300 counts 1.4MHz conversion frequency Inductive button 1MHz conversion frequency ATI Target of 200 counts 1 finger touch (8mm diameter) active Streaming data 0x0A - 0x15 (24 bytes)	1700
Idle Mode	Trackpad (25 Channel) + Inductive Button	50	N/A	Same as above but no touch, and no I^{2}C	220
Low Power 1 Low Power 2	Wake-up on Trackpad	100	4	ALP configured with ATI Target of 200 counts 3 Rxs and 5 Txs active 1.4MHz conversion frequency No user interaction / No comms (event mode)	10
Low Power 1 Low Power 2	Inductive Button	100	4	Button configured with ATI Target of 200 counts ALP disabled 1MHz conversion frequency No user interaction / No comms (event mode)	10
Low Power 1 Low Power 2	Wake-up on Trackpad & Inductive Button	100	None	Both configured with ATI Target of 200 counts 3 Rxs and 5 Txs active 1.4MHz and 1MHz conversion frequency No user interaction / No comms (event mode)	20
Low Power 1 Low Power 2	Wake-up on Trackpad	200	32	ALP configured with ATI Target of 200 counts 3 Rxs and 5 Txs active 1.4MHz conversion frequency No user interaction / No comms (event mode)	5
Low Power 1 Low Power 2	Inductive Button	200	32	Button configured with ATI Target of 200 counts ALP disabled 1MHz conversion frequency No user interaction / No comms (event mode)	5
Low Power 1 Low Power 2	Wake-up on Trackpad & Inductive Button	200	None	Both configured with ATI Target of 200 counts 3 Rxs and 5 Txs active 1.4MHz and 1MHz conversion frequency No user interaction / No comms (event mode)	10

[vi]Bench measurements, not characterised over volume.

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4 Timing and Switching Characteristics

4.1 Reset Levels

Table 4.1: Reset Levels

Parameter		Min	Typ	Max	Unit
V_{VDD}	Power-up/down level (Reset trigger) – slope $>$ 100 V/s	1.040	1.353	1.568	V
V_{VREGD}	Power-up/down level (Reset trigger) – slope $>$ 100 V/s	0.945	1.122	1.304	V

4.2 MCLR Pin Levels and Characteristics

Table 4.2: MCLR Pin Characteristics

Parameter		Conditions	Min	Typ	Max	Unit
$V_{IL(MCLR)}$	MCLR Input low level voltage	VDD = 3.3 V	VSS – 0.3	-	1.05	V
		VDD = 1.7 V			0.75	
$V_{IH(MCLR)}$	MCLR Input high level voltage	VDD = 3.3 V	2.25	-	VDD + 0.3	V
		VDD = 1.7 V	1.05			
$R_{PU(MCLR)}$	MCLR pull-up equivalent resistor		180	210	240	kΩ
$t_{PULSE(MCLR)}$	MCLR input pulse width – no trigger	VDD = 3.3 V	-	-	15	ns
		VDD = 1.7 V			10	
$t_{TRIG(MCLR)}$	MCLR input pulse width – ensure trigger		250	-	-	ns
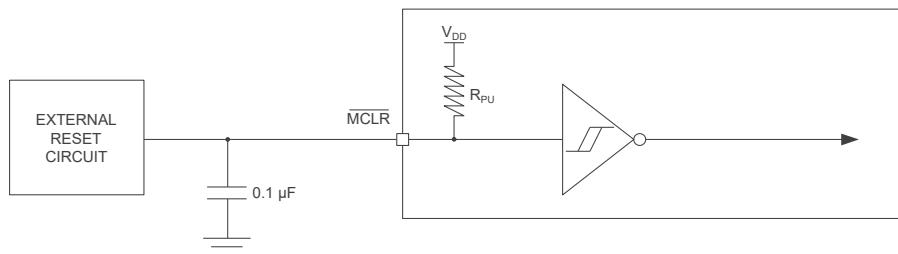
Figure 4.1: MCLR Pin Diagram

4.3 Miscellaneous Timings

Table 4.3: Miscellaneous Timings

Parameter		Min	Typ	Max	Unit
f_{xfer}	Charge transfer frequency (derived from f_{OSC})	42	500 – 1500	4500	kHz
f_{OSC}	Master CLK frequency tolerance 14 MHz	13.23	14	14.77	MHz
f_{OSC}	Master CLK frequency tolerance 18 MHz	17.1	18	19.54	MHz

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4.4 Digital I/O Characteristics

Table 4.4: Digital I/O Characteristics

Parameter		Test Conditions	Min	Typ	Max	Unit
V_{OL}	GPIO1 & GPIO2 Output low voltage	I_{sink} = 20 mA			0.3	V
V_{OL}	GPIO0, 3, 4, 5 Output low voltage	I_{sink} = 10 mA			0.15	V
V_{OH}	Output high voltage	I_{source} = 20 mA	VDD – 0.2			V
V_{IL}	Input low voltage		VDD × 0.3			V
V_{IH}	Input high voltage				VDD × 0.7	V
C_{b_max}	GPIO1 & GPIO2 maximum bus capacitance				550	pF

4.5 I²C Characteristics

Table 4.5: I²C Characteristics

Parameter		VDD	Min	Typ	Max	Unit
f_{SCL}	SCL clock frequency	1.8 V, 3.3 V			1000	kHz
$t_{HD,STA}$	Hold time (repeated) START	1.8 V, 3.3 V	0.26			µs
$t_{SU,STA}$	Setup time for a repeated START	1.8 V, 3.3 V	0.26			µs
$t_{HD,DAT}$	Data hold time	1.8 V, 3.3 V	0			ns
$t_{SU,DAT}$	Data setup time	1.8 V, 3.3 V	50			ns
$t_{SU,STO}$	Setup time for STOP	1.8 V, 3.3 V	0.26			µs
t_{SP}	Pulse duration of spikes suppressed by input filter	1.8 V, 3.3 V	0		50	ns
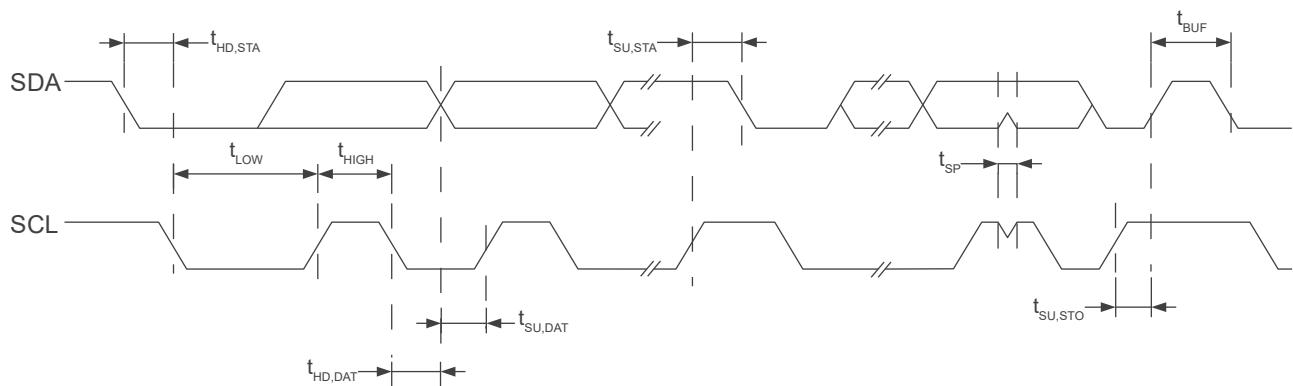
Figure 4.2: I²C Mode Timing Diagram

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5   Proxfusion® Module

The IQS7210A contains a ProxFusion® module that uses patented technology to measure and process the capacitive sensor data. The channel touch output is the primary output from the sensors. These are processed further to provide secondary trackpad outputs that include finger position, finger size as well as on-chip gesture recognition.

5.1   Trackpad Channels

On a trackpad sensor (typically a diamond shape pattern), each intersection of an Rx and Tx row/column forms a mutual-capacitive sensing element which is referred to as a *channel*. Each channel has an associated count value, reference value and touch status.

5.1.1   Channel Numbers

Trackpad channels are numbered from 0 to *(TotalRxs * TotalTxs)* - 1. They are assigned from the top-left corner, first along the Rxs before stepping to the next Tx. The channel number must be known for some settings such as allocating channels into sensing cycles (timeslots). Here is an example of a 4x3 trackpads′ channel numbers:

Table 5.1: Channel Number Assignment

	Rx1 (Column 0)	Rx4 (Column 1)	Rx2 (Column 2)	Rx5 (Column 3)
Tx8 (Row 0)	0	1	2	3
Tx10 (Row 1)	4	5	6	7
Tx3 (Row 2)	8	9	10	11

5.2   Alternate Low-Power Channel (ALP)

To provide lower power consumption, the trackpad can be configured as a single sensor in LP1 and LP2 *(ALP Active in LP)*, instead of sensing the individual trackpad channels. This channel has a lot of setup flexibility:

> *Sensing method:* mutual capacitive or self-capacitive *(Sensor Type)*.
> *Multiple electrode selection:* which Rxs *(Rx EN)* / Txs *(ALP Tx Enable)* are active during conversions.
> *Auto-prox:* if only the ALP Channel is enabled for LP1/LP2, then auto-prox can be utilised. This allows autonomous sensing cycles while core is asleep *(LPX Auto Prox Cycles)* giving further power saving, but similar wake-up capability.
> *Count value filtering (ALP Filter):* gives reliable proximity detection in noisy environments.
> *Single channel:* since the alternate channel is processed as only a single channel, much less processing is done, allowing for lower overall power consumption.

5.3   Button Channel

The main addition to the IQS7210A product compared to the IQS7211A is that of the additional button channel. This is a separate sensor that is active in all trackpad modes, and optionally also in LP1 and LP2 *(Button Active in LP)*.

> *Sensing method:* inductive, mutual capacitive or self-capacitive *(Sensor Type)*.

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> *Fixed electrode allocation:* Rx0 and Tx11 must be used for inductive or mutual capacitive, self-capacitive must use Rx0.
> *Auto-prox:* if only the button is enabled for LP1/LP2, then auto-prox can be utilised. This allows autonomous sensing cycles while core is asleep *(LPX Auto Prox Cycles)* giving further power saving, but similar wake-up capability.
> *Count value filtering (Button Filter):* gives reliable proximity detection in noisy environments.

5.4 Count Value

The capacitive sensing measurement returns a *count value* for each channel. Count values are inversely proportional to capacitance, and all outputs are derived from this.

5.4.1 Trackpad Count Values

The individual trackpad channel count values *(Count values)* are unfiltered.

5.4.2 ALP Count Values

A count value filter is implemented on this channel to give stable proximity output for system wake-up from low-power mode. It is recommended to leave this count filter enabled *(ALP Count Filter)* The amount of filtering can be modified *(ALP count beta)* if required. This beta is used as follows to determine the damping factor of the filter:

$$\text{Count damping factor} = (8*\text{Beta} - 7)/2048$$

If the beta is small, the filtering is stronger (filtered count follows raw count slower), and if the beta is larger, the filtering is weaker (filtered count follows raw count faster).

5.4.3 Button Count Values

A count value filter is implemented on this channel to give stable proximity output for system wake-up from low-power mode. It is recommended to leave this count filter enabled *(Button Count Filter)* The amount of filtering can be modified *(Button count beta)* if required. This beta is used as follows to determine the damping factor of the filter:

$$\text{Count damping factor} = (8*\text{Beta} - 7)/2048$$

If the beta is small, the filtering is stronger (filtered count follows raw count slower), and if the beta is larger, the filtering is weaker (filtered count follows raw count faster).

5.4.4 Max Count

Each channel is limited to having a count value smaller than the configurable limit *(Max Count)*. If the ATI setting or hardware causes measured count values higher than this, the conversion will be stopped, and the max value will be read for that relevant count value.

5.4.5 Trackpad Delta Value

The signed delta values *(Trackpad delta values)* are simply:

$$\text{Delta} = \text{Count} - \text{Reference}$$

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5.5 Reference Value/Long-Term Average (LTA)

User interaction is detected by comparing the measured count values to some reference value. The reference value/LTA of a sensor is slowly updated to track changes in the environment and is not updated during user interaction.

5.5.1 Trackpad References

The trackpad _reference values_ are a two-cycle average of the count value, stored during a time of no user activity, and thus is a non-affected reference. The trackpad reference values are only updated from LP1 and LP2 mode when modes are managed automatically, where no user interaction is assumed. Thus, if the system is controlled manually, the reference must also be managed and updated manually by the host.

The reference value is updated or refreshed according to a configurable interval _(Reference update time)_, in seconds. The Reference update time has a maximum setting of _60 seconds_.

5.5.2 ALP Long-Term Average

The ALP channel does not have a snapshot reference value as used on the trackpad but utilises a filtered long-term average value _(ALP LTA)_. The LTA tracks the environment closely for accurate comparisons to the measured count value, to allow for small proximity deviations to be sensed. The speed of LTA tracking can be adjusted with the _ALP LTA beta_. There is a beta for LP1 and LP2. This is to allow different settings for different report rates, so that the speed of LTA tracking can remain the same.

5.5.3 Button Long-Term Average

Similar to the ALP channel, the button also has a LTA implemented. The button channel has more beta parameters because it is also sensed in Active, Idle-Touch and Idle modes.

The speed of LTA tracking can be adjusted with the _Button LTA beta_.

5.5.4 Reseed

Since the _Reference_ (or _LTA_ for Button/ALP channel) is critical for the device to operate correctly, there could be known events or situations which would call for a manual reseed. A reseed takes the latest measured counts, and seeds the _reference/LTA_ with this value, therefore updating the value to the latest environment. A reseed command can be given by setting the corresponding bit _(TP Reseed /_ _Button Reseed / ALP Reseed)_.

5.6 Channel Outputs

5.6.1 Trackpad Touch Output

The trackpad touch output _(Touch status)_ is set when a channel's count value increases by more than the selected threshold.

The touch threshold for a specific channel is calculated as follows:

$$\text{Threshold} = \text{Reference x } (1 + \text{Multiplier} / 128)$$

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where *Multiplier* is an 8-bit unsigned value for both the 'set' and 'clear' threshold, allowing a hysteresis to provide improved touch detection. A smaller fraction will thus be a more sensitive threshold.

5.6.2   ALP Output

This output *(ALP Output Status)* is set when a channel's count value deviates from the LTA value by more than the selected threshold - thus a delta setting *(ALP output threshold)*. This can be used to implement a proximity or touch detection, depending on the threshold used.

The user can select whether an increase *(ALP Detect Up)* in counts, and/or a decrease *(ALP Detect Down)* will trigger an ALP output. Since the ALP is mostly implemented to wake the trackpad when any user activity is sensed, it is recommended to detect in both directions.

5.6.3   Button Proximity and Touch Output

The bit *(Button Prox Status)* is set when the channel's count value deviates from the LTA value by more than the selected threshold for proximity. The threshold *(Button prox threshold)* is thus a delta setting.

The bit *(Button Touch Status)* is set when a channel's count value increases by more than the selected threshold. The touch threshold is different from the prox threshold, and is determined by:

$$\text{Threshold} = \text{Reference} \times (1 + \underline{Multiplier} / 128)$$

where *Multiplier* is an 8-bit unsigned value for both the 'set' and 'clear' threshold, allowing a hysteresis to provide improved touch detection. A smaller fraction will thus be a more sensitive threshold.

The user can select whether an increase *(Button Detect Up)* in counts, and/or a decrease *(Button Detect Down)* will trigger a button prox and touch output. For example a self-capacitive button will detect down, a mutual-capacitive button up, and an inductive button will depend on whether moving the object to (detect up) or from (detect down) the coil.

A button timeout has been implemented to prevent a stuck output on the channel. If a proximity or touch occurs for longer than the *Button timeout* (in seconds), then a reseed will trigger on the button to remove the possibly faulty scenario. A timeout value of 0 will result in a 'never' timeout condition, and a maximum of *60 seconds* can be configured.

5.6.4   Output Debounce

There is no debounce on the trackpad touch detection (or release). This is because debouncing adds too much delay, and fast movements on the touch panel cannot be debounced fast enough to provide reliable XY output data.

Debounce on the ALP output is however done, to allow for stable proximity detection if needed. An 8-bit unsigned value is used for the set and clear debounce parameter *(ALP set/clear debounce)*.

There is also debounce on the proximity detection (or release) on the button channel. An 8-bit unsigned value is used for the set and clear debounce parameter *(Button set/clear debounce)*. There is however no debounce on the touch detection, only hysteresis. This is because debouncing adds too much delay.

5.7 Automatic Tuning Implementation (ATI)

The ATI is a sophisticated technology implemented in the new ProxFusion ® devices to allow optimal performance of the devices for a wide range of sensing electrode capacitances, without modification to external components. The ATI settings allow tuning of various parameters.

The main advantage of the ATI is to balance out small variations between trackpad hardware and IQS7210A variation, to give similar performance across devices and temperature.

For a detailed description of ATI, please contact Azoteq.

5.7.1 ATI Coarse Divider/ Multiplier

The *ATI coarse divider / multiplier* can be used to configure the base value for the trackpad, button and ALP channels. There is one global setting parameter for all the active trackpad channels for the course divider and one for the course multiplier. The divider is a 5-bit setting (0-31) and the multiplier a 4-bit setting (0-15).

5.7.2 ATI Fine Divider

The *ATI fine divider* is also used to configure the trackpad, button and ALP base value. There is one global setting parameter for all the active trackpad channels for the fine divider. The divider is a 5-bit setting (0-31).

5.7.3 ATI Base Target (Button and ALP Channel)

The ATI process adjusts four parameters when *full ATI* is selected for the Button/ALP channel. These ATI parameters (Coarse divider and multiplier, Fine divider and Compensation) are set by the ATI process using two parameters (*ATI base target* and ATI target).

When *partial ATI* is selected, only the Compensation is set by the ATI process (using the ATI target parameter), the others are configured by the user settings.

ATI Base Target = *ATI base target value* *** 8**)

5.7.4 ATI Compensation (and ATI Target)

The ATI Compensation value for each channel *(ATI compensation)* and *(Button compensation)* / *(ALP ATI compensation)* is set by the ATI procedure, and is chosen so that each count value is close to the selected target value *(TP ATI target / Button ATI target / ALP ATI target)*. The algorithm is queued using *TP / ALP / Button Re-ATI*.

The *TP / ALP / Button Re-ATI* bits clear automatically on chip when the algorithm has completed.

The queued re-ATI routine will execute as soon as the corresponding channels are sensed. For example, the trackpad re-ATI when the system is in Active, Idle-Touch or Idle mode, and the ALP re-ATI when the system is in LP1 or LP2. The button re-ATI when the system is in any of these modes.

This routine will only execute after the communication window is terminated, and the I2C communication will only resume once the ATI routine has completed.

ATI compensation is 10-bit value, thus 0 to 1023.

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5.7.5 ATI Divider

The ATI Compensation can be scaled by means of the *Trackpad ATI compensation divider* / *Button ATI compensation divider* / *ALP ATI compensation divider*. Since the 'size' of compensation is scaled, a small divider value will relate to large compensation, meaning the step size of each compensation unit increase will be larger. For smaller more accurate compensation steps, a larger divider is selected, but the 'range' of compensation is then reduced.

5.8 Automatic Re-ATI

5.8.1 Description

When enabled *(TP Re-ATI EN)* or *(Button / ALP Re-ATI EN)* a re-ATI will be triggered if certain conditions are met. One of the most important features of the re-ATI is that it allows easy and fast recovery from an incorrect ATI, such as when performing ATI during user interaction with the sensor. This could cause the wrong ATI Compensation to be configured, since the user affects the capacitance of the sensor. A re-ATI would correct this. It is recommended to always have this enabled. When a re-ATI is performed on the IQS7210A, a status bit will set momentarily to indicate that this has occurred *(TP / Button / ALP Re-ATI Occurred)*.

5.8.2 Conditions for Re-ATI to activate

1. Reference drift

A re-ATI is performed when the reference of a channel drifts outside of the acceptable range around the ATI Target. The boundaries where re-ATI occurs for the trackpad, button and ALP channels are independently set via the drift threshold value *(Reference drift limit / Button/ALP LTA drift limit)*. The re-ATI boundaries are calculated from the delta value as follows:

Re-ATI Boundary = ATI target $\pm$ Drift limit

For example, assume that the ATI target is configured to 800 and that the reference drift value is set to 50. If re-ATI is enabled, the ATI algorithm will be repeated under the following conditions:

Reference $>$ 850 or Reference $<$ 750

The ATI algorithm executes in a short time, so goes unnoticed by the user.

2. Decreased Count Value

This condition is only valid for trackpad channels. A considerable decrease in the count value of a channel is abnormal since user interaction increases the count value. Therefore, if a decrease larger than the configurable threshold *(Trackpad minimum count re-ATI value)* is seen on such a channel, it is closely monitored. If this is continuously seen for 15 cycles, it will trigger a re-ATI.

5.8.3 ATI Error

After the ATI algorithm is performed, a check is done to see if there was any error with the algorithm. An ATI error is reported if one of the following is true for any channel after the ATI has completed:

> ATI Compensation = 0 (min value)
> ATI Compensation = 1023 (max value)
> Count is already outside the re-ATI range upon completion of the ATI algorithm

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If any of these conditions are met, the corresponding error flag will be set *(ATI Error / ALP ATI Error)*. The flag status is only updated again when a new ATI algorithm is performed.

Re-ATI will not be repeated immediately if an ATI Error occurs. A configurable time *(Re-ATI retry time)* will pass where the re-ATI is momentarily suppressed. This is to prevent the re-ATI repeating indefinitely. An ATI error should however not occur under normal circumstances. The Re-ATI retry time has a maximum setting of *60 seconds*.

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6 Sensing Modes

The IQS7210A automatically switches between different charging modes dependent on user interaction and other aspects. This is to allow for fast response, and low power consumption when applicable. The current mode can be read from the device *(Charging Mode)*.

The modes are best illustrated by means of the following state diagram.
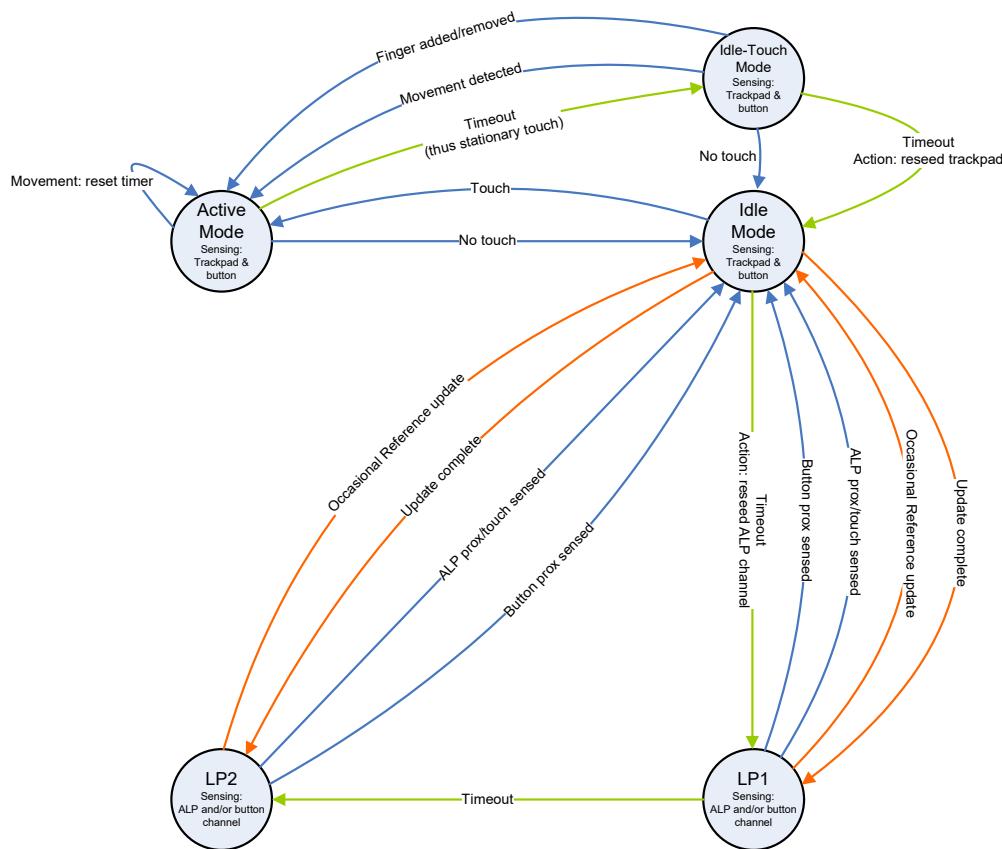
Figure 6.1: System Mode State Diagram

6.1 Report Rate

The report rate for each mode can be adjusted as required by the design. A faster report rate will have a higher current consumption but will give faster response to user interaction. *Active mode* typically has the fastest report rate, and the other modes are configured according to the power budget of the design, and the expected response time.

The report rate is configured by selecting the cycle time (in milliseconds) for each mode:

> *Report rate Active mode*
> *Report rate Idle touch mode*
> *Report rate Idle mode*
> *Report rate LP1 mode*
> *Report rate LP2 mode*

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6.2 Mode Timeout

The timeout values can be configured, and once these times have elapsed, the system will change to the next state according to the state diagram. These times are adjusted by selecting a desired value (in seconds), for the specific timeout:

> *Timeout - Active mode*
> *Timeout - Idle touch mode*
> *Timeout - Idle mode*
> *Timeout - LP1 mode*

A timeout value of 0 will result in a 'never' timeout condition.

6.3 Manual Control

The default method (manual control disabled) allows the IQS7210A to automatically switch between modes and update reference values as shown in Figure 6.1. This requires no interaction from the master to manage the device.

The master can manage various states and implement custom power modes when *Manual Control* is enabled. The master needs to control the mode *(Mode Select)*, and also manage the reference values by reseeding *(TP Reseed)* or manually writing to the reference registers *(Reference values)*.

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7 Trackpad

7.1 Configuration

7.1.1 Size Selection

The total number of Rx and Tx channels used for trackpad purposes must be configured *(Total Rxs/ Total Txs)*. This gives a rectangular area of channels, formed by rows and columns of Rx and Tx sensors.

7.1.2 Cycle Setup

The trackpad channels need to be packed into cycles. The Azoteq PC GUI can be used to assist with this setup. Each cycle can simultaneously sense one channel from Prox block A (Rx0-3) and one from Prox block B (Rx4-7). They must be for the same Tx, and the channel numbers are packed into the cycle numbers *(Cycle allocation registers)* accordingly. A value of 255 for the channel number indicates no channel is allocated.

It is best to select the Rxs as the even numbered sensors, so that optimal cycles/timeslot usage occurs. Similarly, a balanced number of sensors from A and B are optimal. Remember only sensors from B can be used to configure the ALP, which is designed to wake the trackpad from low-power.

7.1.3 Trackpad/ Cycle Size Limitations

This product is limited to 25 channels, and 16 cycles. Any trackpad size that fits into these limits are possible to implement. Refer to Table 1.3 for more information.

7.1.4 Individual Channel Disabling

If the sensor is not a complete rectangle (this could be due to mechanical cut-outs or trackpad shape), there will be some channels that fall within the *Total Rxs/Total Txs* rectangle but do not exist. They must simply not be allocated to a sensing cycle *(see Section 7.1.2)*. The channel numbers are however still allocated for the complete rectangle *(see Section 5.1.1)*.

7.1.5 Rx/Tx Mapping

The Rxs and Txs of the trackpad can be assigned to the trackpad in any order to simplify PCB layout and design. The *Rx/Tx mapping* configures which actual Rx and Tx electrodes are used for the track-pad. The Rxs are specified first, up until the number of Rxs as defined by the *Total Rxs*, then the Txs follow immediately.

Following the example in Table 5.1, the *Rx/Tx mapping* settings will be as follows:

RxTxMapping[0] = 1
RxTxMapping[1] = 4
RxTxMapping[2] = 2
RxTxMapping[3] = 5
RxTxMapping[4] = 8
RxTxMapping[5] = 10
RxTxMapping[6] = 3
RxTxMapping[7..11] = n/a

7.2 Trackpad Outputs

The channel count variation (deltas) and touch status outputs are used to calculate finger location data.

7.2.1 Number of Fingers

This gives an indication of the number of active finger inputs on the trackpad *(No of fingers)*.

7.2.2 Relative XY

If there is only one finger active, a *Relative X* and *Relative Y* value is available. This is a signed 2's complement 16-bit value. It is a delta of the change in X and Y, in the scale of the selected output resolution.

7.2.3 Absolute XY

For all the multi-touch inputs, the absolute finger position *(Absolute X/Y)*, in the selected resolution *(Resolution X/Y)* of the trackpad, is available.

7.2.4 Touch Strength

This value *(Touch strength)* indicates the strength of the touch by giving a sum of all the deltas associated with the finger, and therefore varies according to the sensitivity setup of the sensors.

7.2.5 Area

The number of channels associated with a finger is provided here. This area is usually equal to or smaller than the number of touch channels under the finger. *(Finger 1 area)* / *(Finger 2 area)*.

7.2.6 Tracking Identification

The fingers are tracked from one cycle to the next, and the same finger will be in the same position in the memory map. The memory location thus identifies the finger.

7.3 Maximum Number of Multi-touches

The maximum number of allowed multi-touches is configurable *(Max multi-touches)* up to 2 points. If more than the selected value is sensed, a flag is set *(Too Many Fingers)* and the XY data is cleared.

7.4 XY Resolution

The output resolution for the X and Y coordinates are configurable *(X/Y Resolution)*. The on-chip algorithms use 256 points between each row and column. The resolution is defined as the total X and total Y output range across the complete trackpad.

7.5 Stationary Touch

A stationary touch is defined as a point that does not move outside of a certain boundary within a specific time. This movement boundary or threshold can be configured *(Stationary touch movement threshold)* and is defined as a movement in either X or Y in the configured resolution.

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The device will switch to *Idle-Touch* mode when a stationary point is detected for the active mode timeout period, where a lower duty cycle can be implemented to save power in applications where long touches are expected.

If movement is detected, a status flag *(TP Movement)* is set.

7.6 Multi-touch Finger Split

The position algorithm looks at areas (polygons) of touches and calculates positional data from this. Two fingers near each other could have areas touching, which would merge them incorrectly into a single point. A finger split algorithm is implemented to separate these merged polygons into multiple fingers. There is a *Finger split factor* which can be adjusted to determine how aggressive this finger splitting must be implemented. A value of '0' will not split polygons, and thus merge any fingers with touch channels adjacent (diagonally also) to each other.

7.7 XY Output Flip & Switch

By default, X positions are calculated from the first column to the last column. Y positions are by default calculated from the first row to the last row. The X and/or Y output can be flipped *(Flip X / Flip Y)*, to allow the [0, 0] co-ordinate to be defined as desired. The X and Y axes can also be switched *(Switch XY Axis)* allowing X to be the Txs, and Y to be along the Rxs. *Note: The channel numbers are still assigned the same way, first along the Rxs, then to the next Tx, it is not affected by this setting.*

7.8 XY Position Filtering

Stable XY position data is available due to two on-chip filters, namely the Moving Average (MAV) filter, and the Infinite Impulse Response (IIR) filter. The filters are applied to the raw positional data. It is recommended to keep both filters enabled for optimal XY data.

7.8.1 MAV Filter

If enabled *(MAV Filter)*, raw XY points from the last two cycles are averaged to give the filter output.

7.8.2 IIR Filter

The IIR filter, if enabled *(IIR Filter)*, can be configured to select between a dynamic and a static filter *(IIR Static)*.

$$\text{Damping factor} = \text{Beta} / 256$$

Dynamic Filter

Relative to the speed of movement of a co-ordinate, the filter dynamically adjusts the amount of filtering (damping factor) performed. When fast movement is detected, and quick response is required, less filtering is done. Similarly, when a co-ordinate is stationary or moving at a slower speed, more filtering can be applied.

The damping factor is adjusted depending on the speed of movement. Three of these parameters are adjustable to fine-tune the dynamic filter if required:

> *XY dynamic filter - bottom speed*
> *XY dynamic filter - top speed*

> *Dynamic filter bottom beta*

The speed is defined as the distance (in the selected resolution) travelled in one cycle (pixels/cycle).
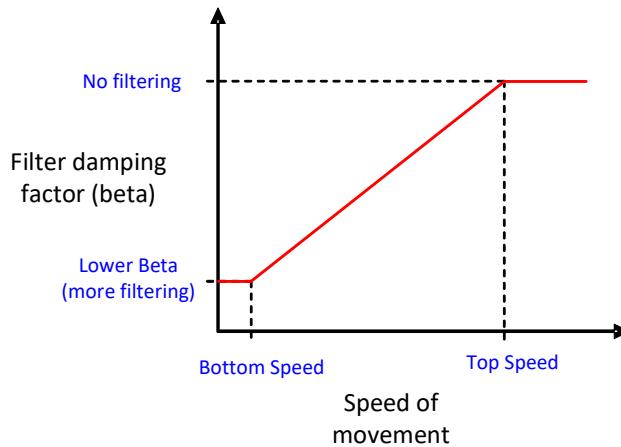
Figure 7.1: Dynamic Filter Parameters

Static Filter

Co-ordinates filtered with a fixed but configurable damping factor *(XY static beta)* are obtained when using the static filter *(IIR Static)*. It is recommended that the dynamic filter is used due to the advantages of a dynamically changing damping value.

7.9   X & Y Trim

Due to boundary conditions at the edges of the trackpad, it is unlikely that the X and Y extreme values will be achievable (0 and X/Y Resolution). To be able to achieve this, the edges can be trimmed with configurable amount *(X Trim / Y Trim)* on-chip. For example, say *X Trim* is set to 0, and a finger on the left of the trackpad gives a minimum X output of 48, and a maximum of 960 for a finger to the far right (for X resolution set to 1000). Then an X Trim = 50 could be used to trim away the 'dead' area, and the full 0 to 1000 range will be achievable.

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8 Gestures

The following on-chip gestures are available:

> 1 finger gestures *(Gestures)*
>> • A single tap
>> • A press and hold
>> • Swipe X+
>> • Swipe X-
>> • Swipe Y+
>> • Swipe Y-

Each single finger gesture can individually be enabled and disabled by setting or clearing the corresponding bits in the register *Gesture Enable*.

All gestures are calculated relative to their starting coordinates, i.e., the first coordinate at which the touch was detected. Furthermore, if at any time during a gesture, more than the required number of touches is detected, the gesture will be invalidated.

8.1 Single Tap

The single tap gesture requires that a touch is made and released in the same location and within a short period of time. Some small amount of movement from the initial coordinate must be allowed to compensate for shift in the finger coordinate during the release. This bound is defined in register *Tap distance*, which specifies the maximum deviation in pixels the touch can move before a single tap gesture is no longer valid.

Similarly, the *Tap time* register defines the maximum duration (in ms) that will result in a valid gesture. That is, the touch should be released before the time in *Tap time* is reached.

A valid single tap gesture will be reported *(Single Tap)* in the same processing cycle as the touch release was detected and will be cleared on the next cycle. No movement will be reported in the relative XY registers *(Relative X* and *Relative Y)* during this gesture

Since the gesture reports after the finger is removed, the location of the tap gesture is placed in the *Absolute X/Y* registers of finger 1 at this time. With *No of fingers* set to 0, this will not look like an active finger, and is just a repetition of the location of the tap that has occurred for the main controller to utilise.

8.2 Press and Hold

The same register that defines the bounds for the single tap gesture *(Tap distance)* is used for the press and hold gesture. If the touch deviates more than the specified distance, the gesture is no longer valid. However, if the touch remains within the given bound for longer that the period (in ms), defined as the sum of the register values in *Tap time* and *Hold time*, a press and hold gesture will be reported *(Press and hold)*. The gesture will continue to be reported until that specific finger is released.

No data will be reported in *Relative X* and *Relative Y* before the defined maximum hold period is reached, however, the relative data will be reported thereafter. This allows for features such as drag-n-drop.

8.3 Swipe (X-, X+, Y-, Y+)

All four swipe gestures work in the same manner and are only differentiated in their direction. The direction is defined with respect to the origin (0, 0) of the trackpad (Channel 0). If the touch is moving away from the origin, it is considered a positive swipe (+) and if it is moving towards the origin, it is a negative swipe (-). Whether the swipe is of the type X or Y is defined by which axis the touch is moving approximately parallel to. A swipe gesture event is only reported when a moving touch meets all three of the following conditions:

1. A minimum distance is travelled from its initial coordinates, as defined in pixels by the value in registers *Swipe x distance* and *Swipe y distance*.
2. The distance in (1) is covered within the time specified in *Swipe time* (in ms).
3. The angle of the swipe gesture, as determined by its starting coordinate and the coordinate at which conditions (1) and (2) were first met, does not exceed the threshold in *Swipe angle* with regards to at least 1 of the axes. The value in register *Swipe angle* is calculated as $64 \tan\theta$, where θ is the desired angle (in degrees).

The respective swipe gesture will be reported for 1 cycle *(Swipe X-, X+, Y- Y+)* when all these conditions are met. The relative distance travelled will be reported in registers *Relative X* and *Relative Y* throughout.

8.4 Switching Between Gestures

For all single finger gestures, it is necessary to release all touches before any new gesture can be made and validated.

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9   Hardware Settings

Settings specific to hardware and the ProxFusion® Module charge transfer characteristics can be changed.

Below some are described, the other hardware parameters are not discussed as they should only be adjusted under guidance of Azoteq support engineers.

9.1   Main Oscillator

The main oscillator frequency can be configured to 14MHz or 18MHz *(14MHz/18MHz)*. When 18MHz is selected the minimum VDD allowed increases, please see Section 3.2 for details.

Smaller adjustments to incrementally decrease the main oscillator can be made *(Main Osc Adj)*.

9.2   Charge Transfer Frequency

The charge transfer frequency (f_{xfer}) can be configured using the product GUI, and the relative parameters *(Charge Transfer Frequency)* will be provided. For high resistance sensors (such as ITO), it might be needed to decrease f_{xfer}.

9.3   Reset

9.3.1   Reset Indication

After a reset, the *Show Reset* bit will be set by the system to indicate the reset event occurred. This bit will clear when the master sets the *Ack Reset*, if it becomes set again, the master will know a reset has occurred, and can react appropriately.

Note that *Event Mode* will not work until the Ack Reset has been used to clear the Show Reset bit. This allows I²C to always become active again if an unexpected reset has occurred, allowing the master to react accordingly to the Show Reset flag, such as writing the start-up settings if needed.

9.3.2   Software Reset

The IQS7210A can be reset by means of an I²C command *(SW Reset)*. This reset will take effect shortly after the SW Reset bit has been set and the I²C communication window terminated.

9.3.3   Hardware Reset

The MCLR/GPIO6 pin (active LOW) can be used to reset the device. For more details see Section 4.2.

10   Additional Features

10.1   GUI for Parameter Setup

The Azoteq product GUI can be utilised to configure the optimal settings required for the specific hard-ware. The device performance can be easily monitored and evaluated in the graphical environment until the optimal configuration is obtained. Once these parameters have been finalised, there are two options for production, namely to program the IC with the firmware integrated with the specific set-tings/parameters, or to use a default configured IC and then perform the device setup over I^{2}C after power-up.

10.1.1   Automated Start-up

If the IC is programmed with the application firmware bundled with settings specifically configured for the current hardware, then an automated start-up is achieved. These parameters are used as the default values without requiring any setup from the master. After power-up the device will automatically use the settings and perform the configuration/setup accordingly.

The firmware with design specific defaults can be obtained from the GUI by configuring the device and then exporting a HEX file. This file is then used to program the blank IQS721xy device. For large volume orders Azoteq can provide pre-programmed devices with customer specific firmware.

Two bytes *(Settings version number)* are available so that the designer can label and identify the user selected default start-up settings. This allows the master to verify if the device firmware has the intended configuration as required.

10.1.2   Manual Start-up

If the device is not programmed with customer specific settings, then they need to be configured by the master via I^{2}C. The parameters can still be obtained using the GUI, but then these need to be configured in the memory map accordingly.

The device will thus be programmed with defaults not necessarily applicable to the current application. It is recommended that the whole memory map is overwritten to be sure all settings are as intended. Once this has been done set the re-ATI bits for the trackpad and ALP channel, so that the ATI can be executed on the intended settings.

10.2   Suspend

The IQS7210A can be placed into a suspended state, where no processing is performed, minimal power is consumed ($<1.5\mu$A), and the device retains existing data. This state is entered after the communication session that sets the *Suspend* bit.

The device can be woken from suspend by forcing I^{2}C communication (see Section 11.9.2) and clear-ing the suspend bit in that communication session. An automatic reseed of the trackpad and button is triggered after the device is woken from suspend, since it cannot be guaranteed that the reference values/LTA are still relevant.

10.3   Watchdog Timer (WDT)

A software watchdog timer is implemented to improve system reliability.

The working of this timer is as follows:

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> A software timer t_{WDT} is linked to the LFTMR (Low frequency timer) running on the "always on" Low Frequency Oscillator (10 kHz).
> This timer is reset at a strategic point in the main loop.
> Failing to reset this timer will cause the appropriate ISR (interrupt service routine) to run.
> This ISR performs a software triggered POR (Power on Reset).
> The device will reset, performing a full cold boot.

10.4   RF Immunity

The IQS7210A has immunity to high power RF noise. To improve the RF immunity, extra decoupling capacitors are suggested on V_{REGA}, V_{REGD} and V_{DD}.

Place a 100pF in parallel with the 2.2μF ceramic on V_{REGA}, V_{REGD} and V_{DD}. All decoupling capacitors should be placed as close as possible to the V_{DD} and V_{REG} pads.

If needed, series resistors can be added to Rx electrodes to reduce RF coupling into the sensing pads. Normally these are in the range of 470Ω-$1k\Omega$. PCB ground planes also improve noise immunity.

10.5   Additional Non-Trackpad Channels

Unused mutual capacitive channels can be used to design additional buttons or sliders. Note that the channels will still provide XY data output, which can be ignored (or utilised) by the master.

10.6   Version Information

See Table A.1

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11   I²C Interface

11.1   I²C Module Specification

The device supports a standard two wire I²C interface with the addition of an RDY (ready interrupt) line. The communications interface of the IQS7210A supports the following:

> *Fast-mode-plus* standard I²C up to 1MHz.
> Streaming data as well as event mode.
> The master may address the device at any time according to the comms request setting *(see Section 11.9.2)*. However for optimal usage, such as power consumption, the RDY is strongly recommended.
> The provided interrupt line (RDY) is an open-drain active low implementation and indicates a communication window.

The IQS7210A implements 8-bit addressing with 2 bytes at each address. Two consecutive read-/writes are required in this memory map structure. The two bytes at each address will be referred to as "byte 0" and "byte 1".

11.2   I²C Address

The IQS7210A has a fixed I²C address of 0x56.
Other address options exist on special request. Please contact Azoteq.

11.3   I³C Compatibility

This device is not compatible with an I³C bus due to clock stretching allowed for data retrieval.

11.4   Memory Map Addressing

11.4.1   8-bit Address

Most of the memory map implements an 8-bit addressing scheme for the required user data. For all application requirements this should be adequate.

11.4.2   Extended 16-bit Address

For development purposes larger blocks of data (such as the trackpad 16-bit channel count values) are found in an extended 16-bit memory addressable location. It is possible to only address each Block as an 8-bit address, and then continue to clock into the next address locations. For example, address 0xE000 is where the trackpad count values are located. If you thus do the following, you will read the count values from address 0xE000 to 0xE003:

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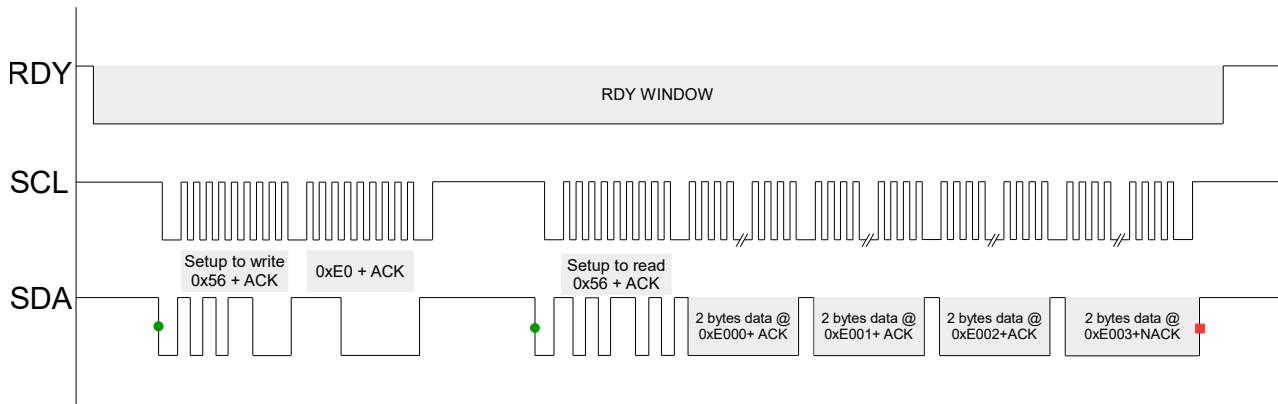
Figure 11.1: Extended Addressing Comms Diagram

However, if you need to address a specific byte in that extended memory map space, then you will need to address using the full 16-bit address (note the 16-bit address is high byte first, unlike the data which is low byte first):
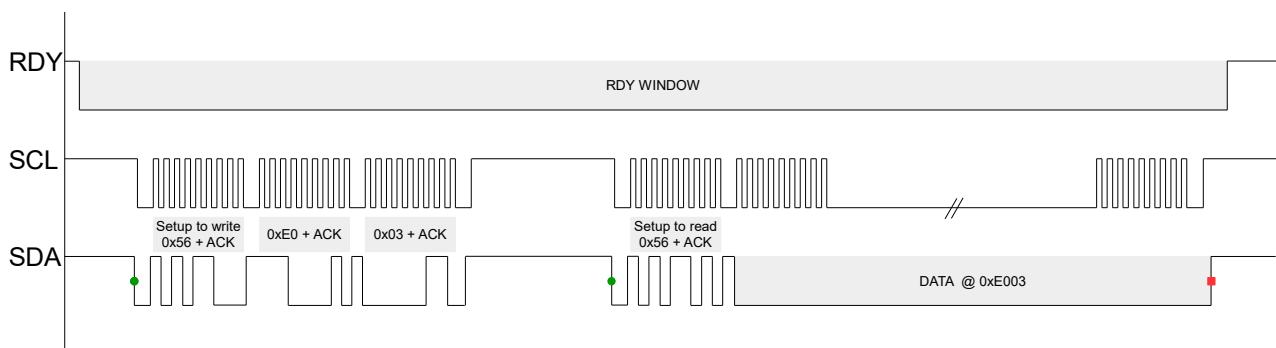

Figure 11.2: Extended Addressing Comms Diagram (Specific Channel)

11.5   Data

The data is 16-bit words, meaning that each address obtains 2 bytes of data. For example, address 0x10 will provide two bytes, then the next two bytes read will be from address 0x11. The 16-bit data is sent in little endian byte order (least significant byte first).

11.6   I^{2}C Timeout

If the communication window is not serviced within the _I^{2}C timeout period_ (in milliseconds), the session is ended (RDY goes HIGH), and processing continues as normal. This allows the system to continue and keep reference values up to date even if the master is not responsive, however the corresponding data was missed/lost, and this should be avoided.

11.7   Terminate Communication

With the comms end setting cleared _(Comms End Cmd)_, a standard I^{2}C STOP ends the current communication window. If multiple I^{2}C transactions need to be done, then they should be strung together using repeated-start conditions instead of giving a STOP. This will allow the communication to occur in the same session.

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The alternative option with comms end setting set, is that an I^{2}C command is needed to terminate the communication window. This can be done by writing 0x00 to address 0xFF, followed by a STOP as follows:
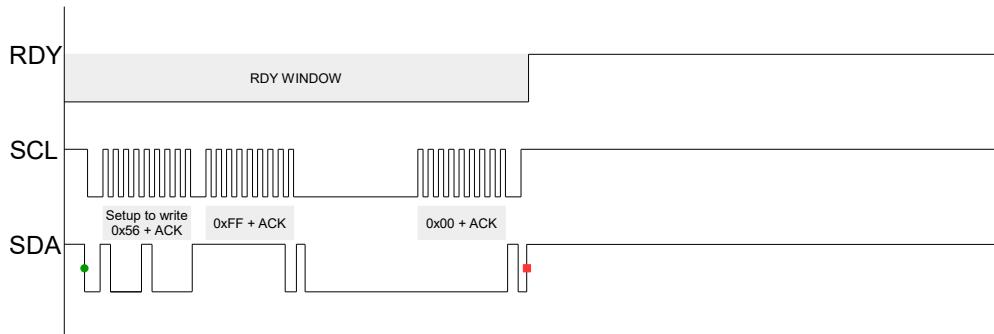
11.8 RDY/IRQ

The communication has an open-drain active-LOW RDY signal to inform the master that updated data is available. It is optimal for the master to use this as an interrupt input and obtain the data accordingly. It is also useful to allow the master MCU to enter low-power/sleep allowing wake-up from the touch device when user presence is detected.

11.9 Event Mode Communication

The device can be set up to bypass the communication window when no activity is sensed *(Event Mode)*. This is usually enabled since the master does not want to be interrupted unnecessarily during every cycle if no activity occurred. The communication will resume (RDY will indicate available data) if an enabled event occurs. It is recommended that the RDY be placed on an interrupt-on-pin-change input on the master.

Note that Event Mode will only implement if *Show Reset* has been cleared, see Section 9.3.1.

11.9.1 Events

Numerous events can be individually enabled to trigger communication, they are:

> Gesture events *(Gesture Event)*: *enabled gestures* will trigger event.
> Trackpad events *(TP Event)*: event triggered if there is a change in X/Y value, or if a finger is added or removed from the trackpad.
> Touch events *(TP Touch Event)*: event only triggers if a channel has a change in a touch state. This is mostly aimed at channels that are used for traditional buttons, where you want to know only when a status is changed.
> Re-ATI *(Re-ATI Event)*: one communication cycle is given to indicate the re-ATI occurred *(TP / ALP / Button Re-ATI Occurred)*.
> Proximity/Touch on Button *(Button Event)*: event given on state change.
> Proximity/Touch on ALP *(ALP Event)*: event given on state change.

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11.9.2 Force Communication/Polling

The master can initiate communication even while RDY is HIGH (inactive). The default method (*comms request en* set to 0) is that the IQS7210A will clock stretch until an appropriate time to complete the I^{2}C transaction. The master firmware will not be affected (if clock stretching is correctly handled).

If the associated clock stretching cannot be allowed, then an alternative comms request method can be enabled *(Comms Request EN)*. To achieve this, the master will do communication when RDY is not active (thus forcing comms), and it will write a comms request to the device. This comms request is as follows:
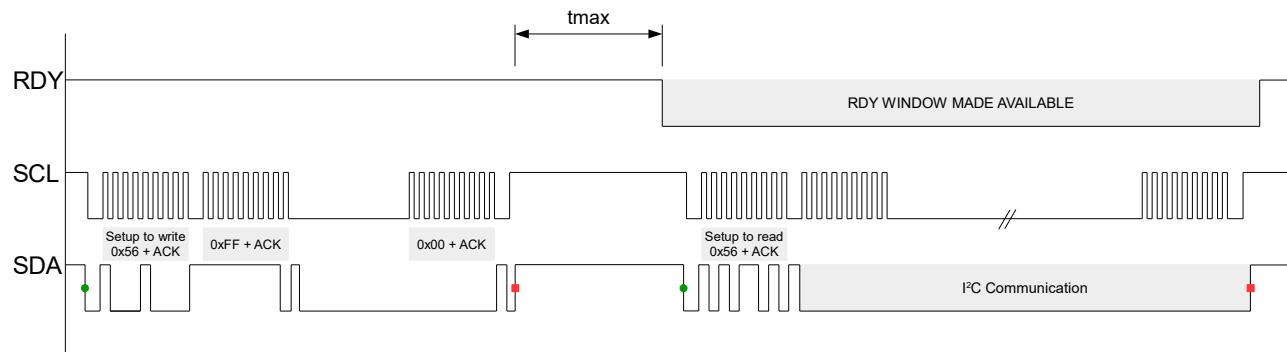
Figure 11.4: Force Comms Diagram

After this request for communication has been sent, then the next available communication window will become available as normal (thus RDY going LOW).

For optimal program flow, it is suggested that RDY is used to sync on new data. The forced/polling method is only recommended if the master must perform I^{2}C and Event Mode is active.

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12   I²C Memory Map - Register Descriptions

For a more detailed description please see *Appendix A*

Address	Data (16bit)		Notes
	Start of Read Only Section		
0x00 - 0x09	Version details		See Table A.1
0x0A	Info flags		See Table A.2
0x0B	Trackpad and gesture flags		See Table A.3
0x0C	Relative X		See Section 7.2.2
0x0D	Relative Y		
0x0E	Finger 1 X-coordinate		See Section 7.2.3
0x0F	Finger 1 Y-coordinate		
0x10	Finger 1 touch strength		See Section 7.2.4
0x11	Finger 1 area		See Section 7.2.5
0x12	Finger 2 X-coordinate		See Section 7.2.3
0x13	Finger 2 Y-coordinate		
0x14	Finger 2 touch strength		See Section 7.2.4
0x15	Finger 2 area		See Section 7.2.5
0x16	Touch status ⟨CH15..CH0⟩		See Table A.4
0x17	Touch status ⟨CH24..CH16⟩		
0x18	Button channel count		See Section 5.4.3
0x19	Button channel LTA		See Section 5.5.3
0x1A	ALP channel count		See Section 5.4.2
0x1B	ALP channel LTA		See Section 5.5.2
	End of Read Only Section		
	(HIGH byte)	(LOW byte)	
	Start of Read/Write Section		
0x1C	Button ATI compensation		See Section 5.7.4
0x1D	ALP ATI compensation		
0x1E	Trackpad ATI multiplier/dividers (Global)		See Table A.5
0x1F	Trackpad reference drift limit	Trackpad ATI compensation divider (Global)	See Section 5.8.2 and 5.7.5
0x20	Trackpad ATI target		See Section 5.7.4
0x21	Trackpad minimum count re-ATI value		See Section 5.8.2
0x22	Button ATI multiplier/dividers		See Table A.5
0x23	ALP ATI multiplier/dividers		
0x24	ALP ATI compensation divider	Button ATI compensation divider	See Section 5.7.5
0x25	ALP LTA drift limit	Button LTA drift limit	See Section 5.8.2
0x26	ALP base target	Button base target	See Section 5.7.3
0x27	Button ATI target		See Section 5.7.4
0x28	ALP ATI target		
	(HIGH byte)	(LOW byte)	
0x29	Active mode report rate (ms)		See Section 6.1
0x2A	Idle-Touch mode report rate (ms)		
0x2B	Idle mode report rate (ms)		
0x2C	LP1 mode report rate (ms)		
0x2D	LP2 mode report rate (ms)		
0x2E	Active mode timeout (s)		
0x2F	Idle-Touch mode timeout (s)		

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0x30	Idle mode timeout (s)		See Section 6.2
0x31	LP1 mode timeout (s)		
0x32	Reference update time (s)	Re-ATI retry time (s)	See Section 5.5.1 and 5.8.3
0x33	I²C timeout (ms)		See Section 11.6
0x34	Reserved	Button timeout	See Section 5.6.3
0x35	System control		See Table A.6
0x36	Config settings		See Table A.7
0x37	Button and ALP settings		See Table A.8
0x38	Other settings		See Table A.9
0x39	ALP Rx enable		See Table A.10
0x3A	ALP Tx enable		See Table A.11
	(HIGH byte)	(LOW byte)	
0x3B	Trackpad touch clear multiplier	Trackpad touch set multiplier	See Section 5.6.1
0x3C	Button prox threshold		See Section 5.6.3
0x3D	ALP output threshold		See Section 5.6.2
0x3E	Button touch clear multiplier	Button touch set multiplier	See Section 5.6.3
0x3F	Button clear debounce	Button set debounce	See Section 5.6.4
0x40	ALP clear debounce	ALP set debounce	
	(HIGH byte)	(LOW byte)	
0x41	Button LTA filter beta - Active mode	Button count filter beta - Active mode	See Section 5.4.3 and 5.5.3
0x42	Button LTA filter beta - Idle-Touch mode	Button count filter beta - Idle-Touch mode	
0x43	Button LTA filter beta - Idle mode	Button count filter beta - Idle mode	
0x44	Button LTA filter beta - LP1 mode	Button count filter beta - LP1 mode	
0x45	Button LTA filter beta - LP2 mode	Button count filter beta - LP2 mode	
0x46	ALP LTA filter beta - LP1 mode	ALP count filter beta - LP1 mode	See Section 5.4.2 and 5.5.2
0x47	ALP LTA filter beta - LP2 mode	ALP count filter beta - LP2 mode	
0x48	Trackpad conversion frequency		See Table A.12
0x49	Button conversion frequency		
0x4A	ALP conversion frequency		
0x4B	Trackpad hardware settings		See Table A.13
0x4C	Button hardware settings		
0x4D	ALP hardware settings		
	(HIGH byte)	(LOW byte)	
0x4E	Total Rxs	Trackpad settings	See Section 7.1.1 and Table A.14
0x4F	Max multi-touches	Total Txs	See Section 7.1.1 and 7.3
0x50	X resolution		See Section 7.4
0x51	Y resolution		
0x52	XY dynamic filter - bottom speed		See Section 7.8.2
0x53	XY dynamic filter - top speed		
0x54	Static filter beta value	Dynamic filter bottom beta	

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0x55	Finger split factor	Stationary touch movement threshold	See Section 7.6 and 7.5
0x56	Y trim value	X trim value	See Section 7.9
	(HIGH byte)	(LOW byte)	
0x57	Settings major version	Settings minor version	See Section 10.1.1
0x58	Gesture enable		See Table A.15
0x59	Tap time (ms)		See Section 8.1
0x5A	Tap distance (pixels)		
0x5B	Hold time (ms)		See Section 8.2
0x5C	Swipe time (ms)		
0x5D	Swipe x-distance (pixels)		See Section 8.3
0x5E	Swipe y-distance (pixels)		
0x5F	Reserved	Swipe angle (64tan(deg))	

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0x60	RxTx mapping <1..0>		
0x61	RxTx mapping <3..2>		
0x62	RxTx mapping <5..4>		See Section 7.1.5
0x63	RxTx mapping <7..6>		
0x64	RxTx mapping <9..8>		
0x65	RxTx mapping <11..10>		
	(HIGH byte)	(LOW byte)	
0x66	ProxA channel for cycle-0	0x05	
0x67	0x05	ProxB channel for cycle-0	
0x68	ProxB channel for cycle-1	ProxA channel for cycle-1	
0x69	ProxA channel for cycle-2	0x05	
0x6A	0x05	ProxB channel for cycle-2	
0x6B	ProxB channel for cycle-3	ProxA channel for cycle-3	
0x6C	ProxA channel for cycle-4	0x05	
0x6D	0x05	ProxB channel for cycle-4	See Section 7.1.2
0x6E	ProxB channel for cycle-5	ProxA channel for cycle-5	
0x6F	ProxA channel for cycle-6	0x05	
0x70	0x05	ProxB channel for cycle-6	
0x71	ProxB channel for cycle-7	ProxA channel for cycle-7	
0x72	ProxA channel for cycle-8	0x05	
0x73	0x05	ProxB channel for cycle-8	
0x74	ProxB channel for cycle-9	ProxA channel for cycle-9	
	(HIGH byte)	(LOW byte)	
0x75	ProxA channel for cycle-10	0x05	
0x76	0x05	ProxB channel for cycle-10	
0x77	ProxB channel for cycle-11	ProxA channel for cycle-11	
0x78	ProxA channel for cycle-12	0x05	
0x79	0x05	ProxB channel for cycle-12	
0x7A	ProxB channel for cycle-13	ProxA channel for cycle-13	See Section 7.1.2
0x7B	ProxA channel for cycle-14	0x05	
0x7C	0x05	ProxB channel for cycle-14	
0x7D	ProxB channel for cycle-15	ProxA channel for cycle-15	
0xE0[i]	...	Trackpad count values	See Section 5.4.1
0xE1[i]	...	Trackpad reference values	See Section 5.5.1
0xE2[i]	...	Trackpad delta values	See Section 5.4.5
0xE3[i]	...	Trackpad ATI compensation values	See Section 5.7.4
		End of Read/Write Section	

[i]extended memory map

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13 Implementation and Layout

13.1 Layout Fundamentals

13.1.1 Power Supply Decoupling

Azoteq recommends connecting a combination of a 4.7 µF plus a 100 pF low-ESR ceramic decoupling capacitor between the VDD and VSS pins. Higher-value capacitors may be used but can impact supply rail ramp-up time. Decoupling capacitors must be placed as close as possible to the pins that they decouple (within a few millimetres).
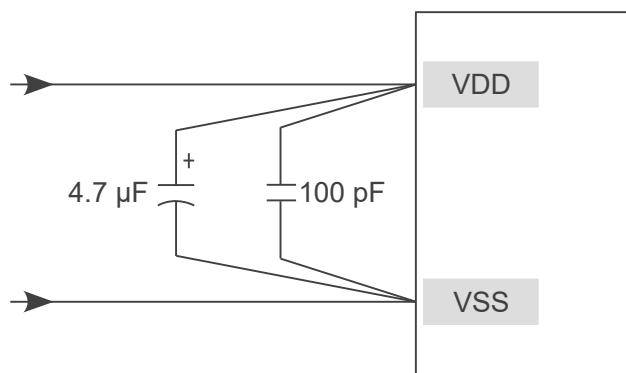

Figure 13.1: Recommended Power Supply Decoupling

13.1.2 VREG

The VREG pin requires a 2.2 µF capacitor to regulate the LDO internal to the device. This capacitor must be placed as close as possible to the microcontroller. The figure below shows an example layout where the capacitor is placed close to the IC.
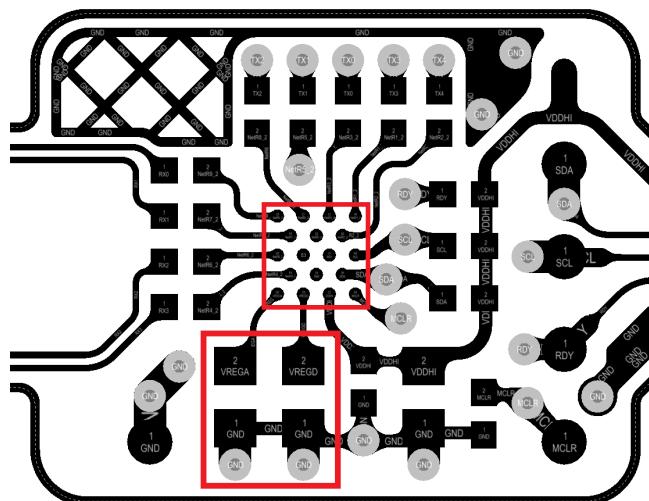

Figure 13.2: VREG Capacitor Placement Close to IC

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13.1.3 WLCSP Light Sensitivity

The CSP package is sensitive to infrared light. When the silicon IC is subject to the photo-electric effect, an increase in leakage current is experienced. Due to the low power consumption of the IC this causes a change in signal and is common in the semiconductor industry with CSP devices.

If the IC could be exposed to IR in the product, then a dark glob-top epoxy material should cover the complete package to block infrared light. It is important to use sufficient material to completely cover the corners of the package. The glob-top also provides further advantages such as mechanical strength and shock absorption.

14 Ordering Information

14.1 Ordering Code

<u>IQS7210A</u>　　　<u>zzz</u>　　　<u>ppb</u>

IC NAME	IQS7210A	=	IQS7210A	
POWER-ON CONFIGURATION	zzz	=	000	Default settings. Setup via I^{2}C.
PACKAGE TYPE	pp	=	CS	WLCSP-18 package
		=	QN	QFN-20 package
BULK PACKAGING	b	=	R	WLCSP-18 Reel (3000pcs/reel)
				QFN-20 Reel (2000pcs/reel)

Figure 14.1: Order Code Description

14.2 Top Marking

14.2.1 WLCSP18 Package

```
IQS
7210A
pppxx

●
```
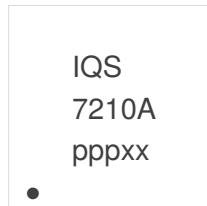
Product Name
ppp = product code
xx = batchcode

14.2.2 QFN20 Package Marking Option 1

```
●

IQS
7210A
pppxx
```
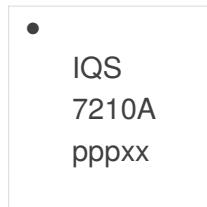
Product Name
ppp = product code
xx = batchcode

14.2.3 QFN20 Package Marking Option 2

```
●

IQS
721xy
pppxx
```
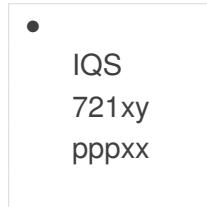
Product Name
ppp = product code
xx = batchcode

15 Package Specification

15.1 Package Outline Description – QFN20

Top View

Bottom View

Side View
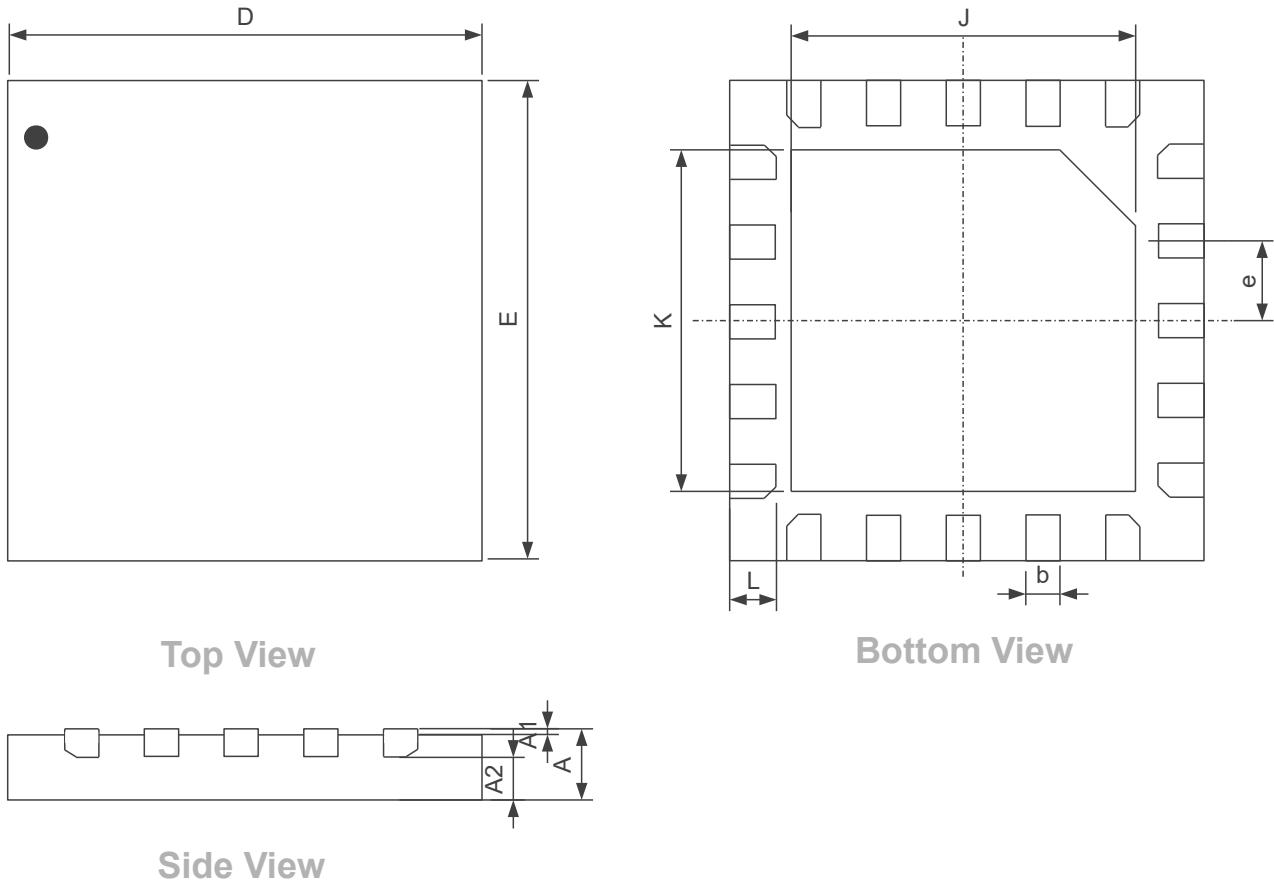
Figure 15.1: QFN (3x3)-20 Package Outline Visual Description

Table 15.1: QFN (3x3)-20 Package Outline Visual Description

Dimension	[mm]	Dimension	[mm]
A	0.5 ± 0.1	E	3
A1	0.035 ± 0.05	e	0.4
A2	0.3	J	1.7 ± 0.1
A3	0.203	K	1.7 ± 0.1
b	0.2 ± 0.05	L	0.4 ± 0.05
D	3		

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15.2 Package Outline Description – WLCSP18
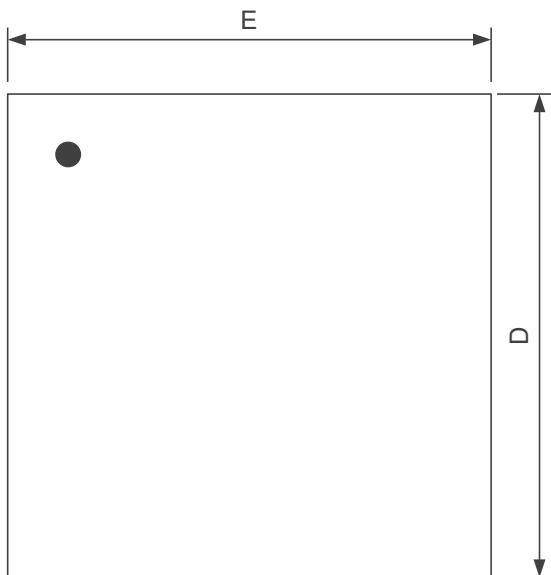
Top Side View
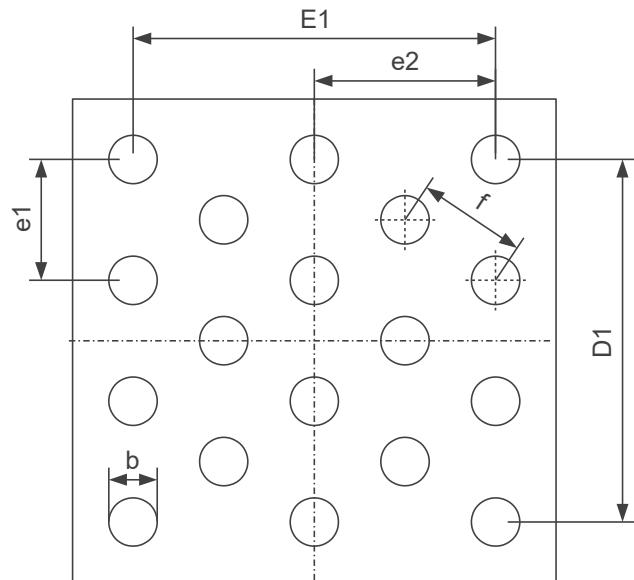
Bottom (Ball Side) View
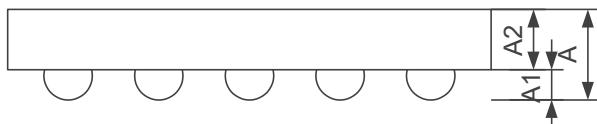
Side View

Figure 15.2: WLCSP (1.62x1.62)-18 Package Outline Visual Description

Table 15.2: WLCSP (1.62x1.62)-18 Package Outline Visual Description

Dimension	[mm]	Dimension	[mm]
A	0.525 ± 0.05	E	1.620 ± 0.015
A1	0.2 ± 0.02	E1	1.2
A2	0.3 ± 0.025	e1	0.4
b	0.260 ± 0.039	e2	0.6
D	1.620 ± 0.015	f	0.36
D1	1.2		

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15.3   Tape and Reel Specifications

REEL DIMENSIONS
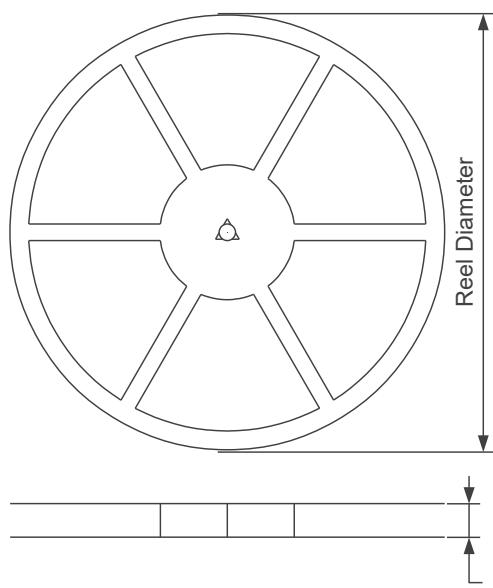
TAPE DIMENSIONS
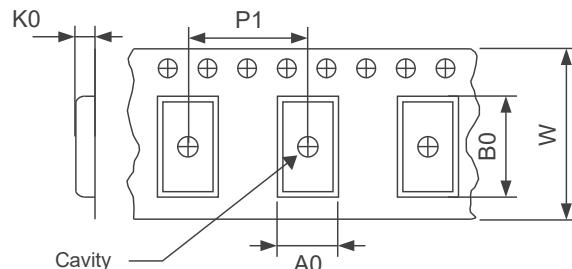
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**
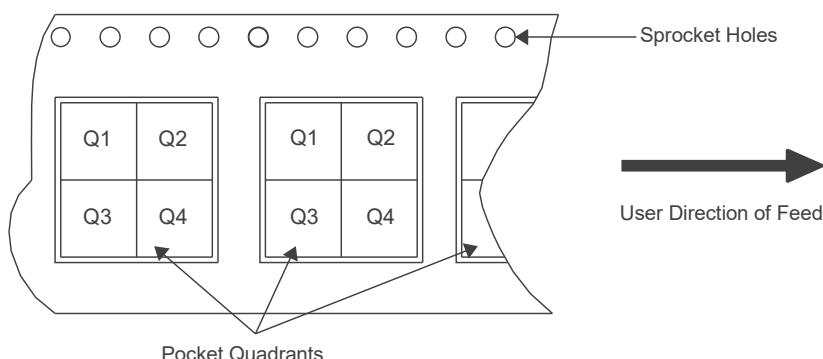
Figure 15.3: Tape and Reel Specification

Table 15.3: Tape and reel Specifications

Package Type	Pins	Reel Diameter (mm)	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
QFN20	20	180	12.4	3.3	3.3	0.8	8	12	Q2
WLCSP18	18	179	8.4	1.78	1.78	0.69	4	8	Q1

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15.4   Moisture Sensitivity Levels

Package	MSL
QFN20	1
WLCSP18	1

15.5   Reflow Specifications

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16   Revision History

Release	Date	Comments
v1.1	2022/01/28	Changed value of capacitor C6 in the reference schematic (2.5) Added button timeout (5.6.3) If the Show Reset bit is not cleared, then event mode will not activate (11.9) Added suspend mode (10.2) Appendix A: _Gesture Enable_ descriptions revised Appendix A: _Version Information_ updated Added comms diagrams for extended MM addressing and force/terminate comms (11.4.2) Fixed hyperlinks Added WLCSP Light Sensitivity section (13.1.3) Added Tape and Reel Specifications and MSL ratings (15.3) Other minor formatting
v1.0	2021/10/13	Initial document released

A   Memory Map Descriptions

Table A.1: Version Information

Register:	0x00 - 0x09		
Address	**Category**	**Name**	**Value**
0x00		Product Number	944
0x01		Major Version	1
0x02	Application Version Info	Minor Version	0
0x03		Patch Number (Commit hash)	Value between 0 and 65536
0x04			
0x05 - 0x09		Reserved	

Table A.2: Info Flags (0x0A)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Show Reset	Reserved	TP ReATI Occured	TP ATI Error	Reserved	ALP Output Status	ALP ReATI Occured	ALP ATI Error	Reserved	Charging Mode			Button Touch Status	Button Prox Status	Button ReATI Occured	Button ATI Error

> Bit 15: **Show Reset**- Indicates a reset
>   • 0: Reset indication has been cleared by host, writing to *Ack Reset*
>   • 1: Reset has occurred and indication has not been cleared by host
> Bit 14: Unused
> Bit 13: **TP Re-ATI Occurred**- Trackpad re-ATI status
>   • 0: No re-ATI
>   • 1: Re-ATI has just completed on the trackpad
> Bit 12: **TP ATI Error**- Error condition seen on latest trackpad ATI procedure
>   • 0: Most recent ATI process was successful
>   • 1: Most recent ATI process was unsuccessful
> Bit 11: Unused
> Bit 10: **ALP Output Status**- Output status of ALP channel
>   • 0: No prox/touch detected
>   • 1: Prox/Touch detected
> Bit 9: **ALP Re-ATI Occurred**- Alternate Low Power channel re-ATI Status
>   • 0: No re-ATI
>   • 1: Re-ATI has just completed on alternate LP channel
> Bit 8: **ALP ATI Error**- Alternate Low Power ATI error status
>   • 0: Most recent ATI process was successful
>   • 1: Most recent ATI process was unsuccessful
> Bit 7: Unused
> Bit 6-4: **Charging Mode**: Indicates current mode
>   • 000: Active mode
>   • 001: Idle-touch mode
>   • 010: Idle mode
>   • 011: LP1 mode
>   • 100: LP2 mode
> Bit 3: **Button Touch Status**- Touch detection status of Button channel
>   • 0: No touch detected
>   • 1: Touch detected
> Bit 2: **Button Prox Status**- Prox detection status of Button channel
>   • 0: No prox detected
>   • 1: Prox detected
> Bit 1: **Button Re-ATI Occurred**- Button channel re-ATI Status
>   • 0: No re-ATI

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- 1: Re-ATI has just completed on Button channel
> Bit 0: **Button ATI Error**- Button ATI error status
  - 0: Most recent ATI process was successful
  - 1: Most recent ATI process was unsuccessful

Table A.3: Trackpad and Gesture Flags (0x0B)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Reserved				Too Many Fingers	TP Move-ment	No of Fingers		Reserved		Swipe Y-	Swipe Y+	Swipe X+	Swipe X-	Press and Hold	Single Tap

> Bit 15-12: Unused
> Bit 11: **Too Many Fingers**- Indicates more than allowed fingers detected
  - 0: Number of fingers within maximum selected value
  - 1: Number of fingers exceeds maximum selected value
> Bit 10: **TP Movement**- Trackpad finger movement detected
  - 0: No touches, or all touches stationary *(see Section 7.5)*
  - 1: Movement of finger(s) detected on trackpad
> Bit 9-8: **No of Fingers**- Number of fingers detected on trackpad
  - 00: No fingers on trackpad
  - 01: 1 finger active
  - 10: 2 fingers active
> Bit 7-6: Unused
> Bit 5: **Swipe Y-** - Swipe in negative Y direction
  - 0: No gesture
  - 1: Swipe in negative Y direction occurred
> Bit 4: **Swipe Y+** - Swipe in positive Y direction
  - 0: No gesture
  - 1: Swipe in positive Y direction occurred
> Bit 3: **Swipe X+** - Swipe in positive X direction
  - 0: No gesture
  - 1: Swipe in positive X direction occurred
> Bit 2: **Swipe X-** - Swipe in negative X direction
  - 0: No gesture
  - 1: Swipe in negative X direction occurred
> Bit 1: **Press and Hold**- Indicates a Press and hold gesture
  - 0: No gesture
  - 1: Press and hold occurred
> Bit 0: **Single Tap**- Indicates a single tap gesture
  - 0: No gesture
  - 1: Single tap occurred

Table A.4: Touch Status <RowZ> (0x16 / 0x17)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Touch Status <0>															
CH15	CH14	CH13	CH12	CH11	CH10	CH9	CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH0
Touch Status <1>															
~	~	~	~	~	~	~	CH24	CH23	CH22	CH21	CH20	CH19	CH18	CH17	CH16

> Touch Flags for CH0 - CH24
  - 0: No touch detected
  - 1: Touch detected

Table A.5: Trackpad, Button and ALP Multipliers/Divider (0x1E / 0x22 / 0x23)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Reserved		Fine Divider					Coarse Multiplier				Coarse Divider				

> Bit 15-14: Unused
> Bit 13-9: **Fine Fractional Divider**
  - 5-bit value between 1 and 31
> Bit 8-5: **Coarse Multiplier**
  - 4 bit value between 1 and 15
> Bit 4-0: **Coarse Fractional Divider**
  - 5 bit value between 1 and 31

Table A.6: System Control (0x35)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Tx test	SW Reset	TP ReATI	TP Re-seed	Sus-pend	Res-erved	ALP ReATI	ALP Re-seed	Ack Reset	Mode Select			Reserved		Button ReATI	Button Re-seed

> Bit 15: **Tx test**- Tx short test
  - 0: Normal operation
  - 1: Enable Tx short test configuration
> Bit 14: **SW Reset**- Reset the device
  - 0: No action
  - 1: Reset device after communication window terminates
> Bit 13: **TP Re-ATI**- Queue a re-ATI on trackpad channels
  - 0: No action
  - 1: Perform re-ATI when trackpad channels are sensed again
> Bit 12: **TP Reseed**- Reseed trackpad channels
  - 0: No action
  - 1: Reseed reference values of trackpad
> Bit 11: **Suspend**- Suspend IQS7210A
  - 0: No action
  - 1: Place IQS7210A into suspend after the communication window terminates
> Bit 10: Unused
> Bit 9: **ALP Re-ATI**- Queue a re-ATI on ALP channel
  - 0: No action
  - 1: Perform re-ATI when ALP channel is sensed again
> Bit 8: **ALP Reseed**- Reseed alternate low power channel
  - 0: No action
  - 1: Reseed the LTA of the alternate LP channel
> Bit 7: **Ack Reset**- Acknowledge a reset
  - 0: No action
  - 1: Acknowledge the reset by clearing *Show Reset* flag
> Bit 6-4: **Mode Select**- Select mode (only applicable in *Manual Mode*)
  - 000: Active mode
  - 001: Idle-Touch mode
  - 010: Idle mode
  - 011: LP1 mode
  - 100: LP2 mode
> Bit 3-2: Unused
> Bit 1: **Button Re-ATI**- Queue a re-ATI on Button channel
  - 0: No action
  - 1: Perform re-ATI when the button channel is sensed again

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> Bit 0: **Button Reseed**- Reseed button channel
>> ● 0: No action
>> ● 1: Reseed the LTA of the button channel

Table A.7: Config Settings (0x36)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Res-erved	TP Touch Event	ALP Event	Button Event	ReATI Event	TP Event	Gesture Event	Event Mode	Reserved			WDT EN	Manual Con-trol	Comms End Cmd	Comms Re-quest EN	TP ReATI EN

> Bit 15: Unused
> Bit 14: **TP Touch Event**- Enable trackpad touch triggering event
>> ● 0: Toggle of trackpad touch status does not trigger an event
>> ● 1: Toggle of trackpad touch status triggers an event
> Bit 13: **ALP Event**- Enable alternate LP channel detection triggering event
>> ● 0: Toggle of alternate channel prox/touch status does not trigger an event
>> ● 1: Toggle of alternate channel prox/touch status triggers an event
> Bit 12: **Button Event**- Enable button channel detection triggering event
>> ● 0: Toggle of button channel prox/touch status does not trigger an event
>> ● 1: Toggle of button channel prox/touch status triggers an event
> Bit 11: **Re-ATI Event**- Enable re-ATI generating an event
>> ● 0: Re-ATI occurring does not trigger an event
>> ● 1: Re-ATI occurring triggers an event
> Bit 10: **TP Event**- Enable trackpad events
>> ● 0: Trackpad finger movement or finger up/down will not trigger event
>> ● 1: Trackpad finger movement or finger up/down will trigger event
> Bit 9: **Gesture Event**- Enable gesture events
>> ● 0: Gestures will not trigger event
>> ● 1: Gestures will trigger event
> Bit 8: **Event Mode**- Enable event mode communication
>> ● 0: I^2C is presented each cycle (except auto-prox cycles)
>> ● 1: I^2C is only initiated when an enabled event occurs
> Bit 7-5: Unused
> Bit 4: **WDT EN**- Watchdog timer enable
>> ● 0: Watchdog is disabled
>> ● 1: Watchdog is enabled
> Bit 3: **Manual Control**- Override automatic mode switching
>> ● 0: Modes are automatically controlled by firmware
>> ● 1: Manual control of modes are handled by host
> Bit 2: **Comms End Cmd**- Alternative method to terminate comms
>> ● 0: I^2C stop ends comms
>> ● 1: Write one or two bytes (any data) to the address 0xFF followed by a STOP to end comms
> Bit 1: **Comms Request EN**- Alternative polling method (while RDY not LOW)
>> ● 0: Forcing comms will clock stretch until a comms window
>> ● 1: A comms window must be requested with a command (no stretching) (Section 11.9.2)
> Bit 0: **TP Re-ATI EN**- Automatic re-ATI on trackpad
>> ● 0: Re-ATI is disabled for trackpad channels
>> ● 1: Re-ATI is enabled for trackpad channels

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Table A.8: Button and ALP Settings (0x37)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
ALP Full ATI	ALP Re-ATI EN	ALP Detect Down	ALP Detect Up	ALP Active in LP	ALP Count Filter	ALP Sensor Type		Button Full ATI	Button Re-ATI EN	Button Detect Down	Button Detect Up	Button Active in LP	Button Count Filter	Button Sensor Type	

- Bit 15: **ALP Full ATI**- ATI algorithm
    - 0: Partial ATI (Compensation only) enabled for ALP channel
    - 1: Full ATI (Mirrors and Compensation) enabled for ALP channel
- Bit 14: **ALP Re-ATI EN**- Automatic re-ATI on ALP channel
    - 0: Re-ATI is disabled for ALP channel
    - 1: Re-ATI is enabled for ALP channel
- Bit 13: **ALP Detect Down**- Detect outputs for counts decreasing
    - 0: Disabled
    - 1: Enabled
- Bit 12: **ALP Detect Up**- Detect outputs for counts increasing
    - 0: Disabled
    - 1: Enabled
- Bit 11: **ALP Active in LP**- Enable ALP for LP1/LP2 mode
    - 0: ALP is not sensed in LP
    - 1: ALP is active in LP
- Bit 10: **ALP Count Filter**- ALP count filter
    - 0: ALP count value is unfiltered
    - 1: ALP count filter enabled
- Bit 9-8: **ALP Sensor Type**- ALP sensing method
    - 00: ALP is setup for self-capacitive sensing
    - 01: ALP is setup for mutual-capacitive sensing
    - 10: ALP is setup for inductive sensing
- Bit 7: **Button Full ATI**- ATI algorithm
    - 0: Partial ATI (Compensation only) enabled on button channel
    - 1: Full ATI (Mirrors and Compensation) enabled on button channel
- Bit 6: **Button Re-ATI EN**- Automatic re-ATI on button channel
    - 0: Re-ATI is disabled for button channel
    - 1: Re-ATI is enabled for button channel
- Bit 5: **Button Detect Down**- Detect outputs for counts decreasing
    - 0: Disabled
    - 1: Enabled
- Bit 4: **Button Detect Up**- Detect outputs for counts increasing
    - 0: Disabled
    - 1: Enabled
- Bit 3: **Button Active in LP**- Enable for LP1/LP2 mode
    - 0: Button is not sensed in LP
    - 1: Button is active in LP
- Bit 2: **Button Count Filter**- Button count filter
    - 0: Button count value is unfiltered
    - 1: Button count filter enabled
- Bit 1-0: **Button Sensor Type**- Button sensing method
    - 00: Button is setup for self-capacitive sensing
    - 01: Button is setup for mutual-capacitive sensing
    - 10: Button is setup for inductive sensing

Table A.9: Other Settings (0x38)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
					Reserved						14MHz / 18MHz		Main Osc Adj		

> Bit 15-5: Unused
> Bit 4: **14MHz/18MHz**- Main oscillator selection
  - 0: Main oscillator is 14MHz
  - 1: Main oscillator is 18MHz
> Bit 3-0: **Main Osc Adj**- Small main oscillator adjustment setting
  - 4-bit value
  - 0-15: 0 = No adjustment .. 15 = Maximum adjustment

Table A.10: ALP Rx Enable (0x39)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
				Reserved				Rx7_EN	Rx6_EN	Rx5_EN	Rx4_EN		Reserved		

> Bit 15-8: Unused
> Bit 7-4: **RX_EN**- ALP Rx electrodes
  - 0: Rx disabled (not used for ALP)
  - 1: Rx enabled (forms part of ALP sensor)
> Bit 3-0: Unused

Table A.11: ALP Tx Enable (0x3A)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	Reserved			Tx11_EN	Tx10_EN	Tx9_EN	Tx8_EN	Tx7_EN	Tx6_EN	Tx5_EN	Tx4_EN	Tx3_EN	Tx2_EN	Tx1_EN	Tx0_EN

> Bit 15-12: Reserved
> Bit 11-0: **TX_EN**- ALP Tx electrodes
  - 0: Tx disabled (not used for ALP)
  - 1: Tx enabled (forms part of ALP sensor)

Table A.12: Conversion Frequency (0x48 / 0x49 / 0x4A)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Conversion Frequency Fraction								Conversion Frequency Period							

> Bit 15-8: **Frequency Fraction**
  - $256 * \frac{f_{conv}}{f_{clk}}$
  - Range: 0 - 255
> Bit 7-0: **Conversion Period**
  - $\frac{128}{FrequencyFraction} - 2$
  - Range: 0 - 127
> Note: if Frequency fraction is fixed at 127, the following values of the conversion period will result in the corresponding charge transfer frequencies:
  - 1: 2MHz
  - 5: 1MHz
  - 12: 500kHz
  - 17: 350kHz
  - 26: 250kHz
  - 53: 125kHz

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Table A.13: Trackpad, Button and ALP Hardware Settings (0x4B / 0x4C / 0x4D)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
NM In Static	CS_0v5 Discharge	RF Filter	CS Cap Select	Opamp Bias		Max Count		LP2 Auto Prox Cycles (only registers 0x4C/0x4D)			LP1 Auto Prox Cycles (only registers 0x4C/0x4D)			Init Delay	

> Bit 15: **NM In Static**- NM In Static
>   - 0: Disabled
>   - 1: Enabled (recommended)
> Bit 14: **CS 0v5 Discharge**- Select internal Cs discharge voltage
>   - 0: Discharge to 0V (recommended for most cases)
>   - 1: Discharge to 0.5V
> Bit 13: **RF Filter**- Internal RF filters
>   - 0: RF filters disabled
>   - 1: RF filters enabled
> Bit 12: **CS Cap Select**- Internal pool capacitor size
>   - 0: Internal capacitor is 40pF
>   - 1: Internal capacitor is 80pF (recommended)
> Bit 11-10: **Opamp Bias**- Projected opamp bias
>   - 00: 2μA
>   - 01: 5μA
>   - 10: 7μA
>   - 11: 10μA
> Bit 9-8: **Max Count**- Count upper limit (count value stops conversion after reaching this)
>   - 00: 1023
>   - 01: 2047
>   - 10: 4095
>   - 11: 16384
> Bit 7-5: **LP2 Auto Prox Cycles**- Number of LP2 auto-prox cycles
>   - 000: 4
>   - 001: 8
>   - 010: 16
>   - 011: 32
>   - 1xx: Auto-prox disabled
> Bit 4-2: **LP1 Auto Prox Cycles**- Number of LP1 auto-prox cycles
>   - 000: 4
>   - 001: 8
>   - 010: 16
>   - 011: 32
>   - 1xx: Auto-prox disabled
> Bit 1-0: **Init Delay**- Initial cycles delay
>   - 00: 4
>   - 01: 16
>   - 10: 32
>   - 11: 64

Table A.14: Trackpad Settings (0x4E)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Total Rxs								Reserved		MAV Filter	IIR Static	IIR Filter	Switch XY Axis	Flip Y	Flip X

> Bit 15-8: **Total Rxs**- used for trackpad

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- Bit 7-6: Unused
- Bit 5: **MAV Filter**- Moving averaging filter
  - 0: XY MAV filter on touch position disabled
  - 1: XY MAV filter on touch position enabled (recommended)
- Bit 4: **IIR Static**- IIR filtering method for the XY data points
  - 0: Damping factor for IIR filter is dynamically adjusted relative to XY movement (recommended)
  - 1: Damping factor for IIR filter is fixed
- Bit 3: **IIR Filter**- IIR filter
  - 0: XY IIR filter disabled
  - 1: XY IIR filter enabled (recommended)
- Bit 2: **Switch XY Axis**- Switch X and Y axes
  - 0: Rxs are arranged in trackpad columns (X), and Txs in rows (Y)
  - 1: Txs are arranged in trackpad columns (X), and Rxs in rows (Y)
- Bit 1: **Flip Y**- Flip Y output values
  - 0: Keep default Y values
  - 1: Invert Y output values
- Bit 0: **Flip X**- Flip X output values
  - 0: Keep default X values
  - 1: Invert X output values

Table A.15: Gesture Enable (0x58)

Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Reserved										Swipe Y-	Swipe Y+	Swipe X+	Swipe X-	Press and Hold	Single Tap

- Bit 15-6: Unused
- Bit 5: **Swipe Y-** - Swipe in negative Y direction
  - 0: Gesture disabled
  - 1: Gesture enabled
- Bit 4: **Swipe Y+** - Swipe in positive Y direction
  - 0: Gesture disabled
  - 1: Gesture enabled
- Bit 3: **Swipe X+** - Swipe in positive X direction
  - 0: Gesture disabled
  - 1: Gesture enabled
- Bit 2: **Swipe X-** - Swipe in negative X direction
  - 0: Gesture disabled
  - 1: Gesture enabled
- Bit 1: **Press and Hold** - Press and hold gesture
  - 0: Gesture disabled
  - 1: Gesture enabled
- Bit 0: **Single Tap** - Single tap gesture
  - 0: Gesture disabled
  - 1: Gesture enabled

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