IQS231 Datasheet

Single Channel Capacitive Proximity/Touch Controller for SAR applications

NOT RECOMMENDED FOR NEW DESIGNS - SEE IQS231A

Features

- **Pin compatible** with IQS127/128/227/228/211
- **Replacement solution for the IQS128** to meet SAR regulations (failsafe & long-term activation testing) and improve performance
- Improved **IQS128 DYCAL™** operation with **quick release detection** for improved SAR safety
- Human detection options for start-up detection and improved user experience (non-default, FCC approval pending)
- **1.75V to 3.6V** Input voltage, trimmed to use proximity detection with 1.8V digital interface
- **External threshold adjustment** pin (minimize need for pre-empted OTP adjustments)
- **Minimal external components** (direct input strap)
- Standalone failsafe mode (backwards compatible failsafe output, short pulses on output to indicate operational device)
- **Default** OTP options focus on **safety and passing SAR lab qualification**, OTP changes offer performance advantages
- **Quick release detection –** effectively prevent false triggers

RoHS2 Compliant

6 pin **TSOT23-6**
Representations only, not actual markings

- Quick release **sensitivity options**
- **Projected capacitive sensing** option (self-capacitance by default)
- **I2C interface option** (improved compatibility)
- **Extended controls in I²C mode** (setup in I²C, runtime with standalone output)
- **Hand-held power on detection** (safety back-off feature using user interaction)
- **Optional input for synchronized implementations** (input to instruct IC when to sense)
- **Synchronization output** – failsafe pulses may be used by the master to synchronize on. Sensing is done after each pulse
- **Synchronization input** – Sensing is only done while Sync input is low
- Low power sensing: 30Hz (default), 100Hz
- **Constant sampling rates during all power modes with rapidly debounced output changes**

Applications

- SAR Sensor
- Integrated hybrid designs (RF and capacitive sensing combined)
- Movement sensing applications (user interaction detection, anti-theft)
- Hold detection for screen activation
- On-ear detection

T_A	TSOT23-6
-40°C to 85°C	IQS231

NOT RECOMMENDED FOR NEW DESIGNS - SEE IQS231A

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1 Summary: Packaging and Pin-Out

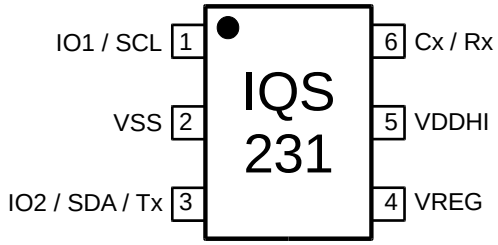


Figure 1.1 IQS231 pin-out (TSOT23-6 package)

Table 1.1 Pin-out description

IQS231 in TSOT23-6			
Pin	**Name**	**Type**	**Function**
1	PRIMARY I/O	Digital Input/Output	Multifunction **IO1** / **SCL** (I^2C Clock signal)
2	VSS	Signal GND	
3	SECONDARY I/O / Tx	Digital Input/Output	Multifunction **IO2 / SDA** (I^2C Data output) / Tx
4	VREG	Regulator output	Requires external capacitor
5	VDDHI	Supply Input	Supply:1.75V – 3.6V
6	Cx	Sense electrode	Connect to conductive area intended for sensor

Table 1.2 Multifunction pin descriptions

Multifunction pin name	Multifunction pin option
IO1	Proximity output / Proximity output with heartbeat
IO2	Sensitivity input / Synchronization input / Movement output / Touch output

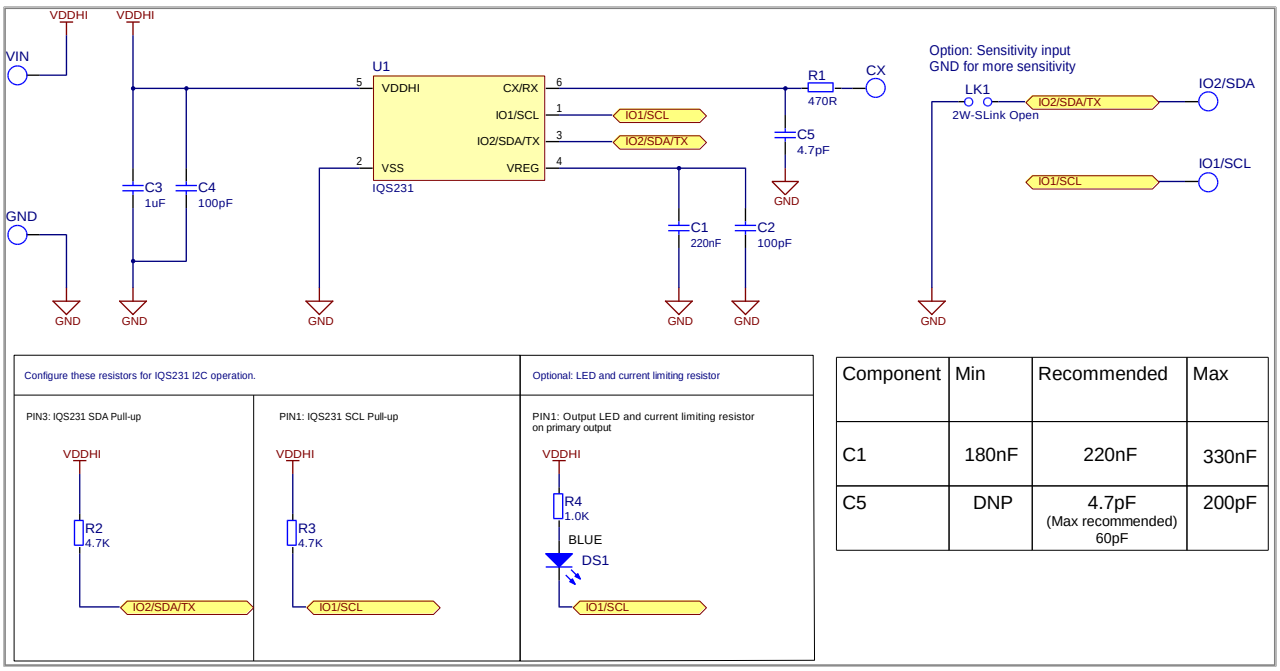


Figure 1.2 IQS231 reference schematic

2 Summary: One-Time-Programmable (OTP) options

OTP bank 0				IQS231 000000**xx** TSR			
Bit7	6	5	4	3	2	1	Bit 0
Movement time-out		Movement threshold		Quick release threshold		Quick release beta	
Prox no mov UI 00 - 2s 01 - 5s 10 - 10s 11 - Disabled (0s) Prox&Mov UIs 00 - 10s 01 - 30s 10 - 60s 11 - 10min		00 – 4 counts 01 – 6 10 – 8 11 – 10		00 – moderate 01 – strict 10 – relaxed 11 - very strict	100 counts 150 50 250	00 – 2 (fast following) 01 - 3 10 - 4 11 – 5 (slow following)	
OTP Bank 1				**IQS231 0000xx00 TSR**			
Bit7	6	5	4	3	2	1	Bit 0
Filter halt threshold	Proximity Threshold (low/high)			AC Filter	Hand-held power on detection	Touch threshold	
0 – 3 counts 1 – 6 Filter halt time-out fixed at 5 seconds	Sensitivity input low / Sync input active / Mov output / Touch output 000 – 20 counts 100 – 52 001 – 28 101 – 68 010 – 36 110 – 68 011 – 44 111 – 132 Sensitivity input high (internal 20kΩ pull-up) 000 – 40 counts 100 – 104 001 – 56 101 – 136 010 – 72 110 – 195 011 – 88 111 – 264			0 – Increased 1 – Normal	0 – Disabled 1 – Enabled	00 – 32 counts 01 – 64 10 – 256 11 – 320	
OTP Bank 2				**IQS231 00xx0000 TSR**			
Bit7	6	5	4	3	2	1	Bit 0
Reserved	Target	Base value		Failsafe	Quick release	User interface	
n/a	0 = 1200 / 1096 (movement) 1 = 768	00 – 100 counts 01 – 75 10 – 150 11 – 200		0 – Disabled 1 – Enabled	0 – Enabled 1 – Disabled	00 - Prox / No movement 01 - Prox with movement 10 - Prox with movement / Touch with no movement 11 - Same as '10', touch output forced on IO2	
OTP Bank 3				**IQS231 xx000000 TSR**			
Bit7	6	5	4	3	2	1	Bit 0
Reserved		Projected sensing	IO2 function		IC mode	Reserved	Sample rate
n/a		0 – Self capacitance 1 – Projected capacitance	00 - Sensitivity input (proximity threshold adjust) 01 - Sync input 10 - Movement output 11 - Ignore input, no output		0 – Standalone 1 – I^2C		Sample-to-sample time (Response time) Includes 6 sample debounce burst of 24ms 0 – 30 Hz (57ms) 1 – 100 Hz (34ms)

Recommended base configurations: IQS128 replacement: **IQS231 00000000** TSR | Full featured: **IQS231 000A0600 TSR** | Shared electrode: **IQS231 08000000 TSR** | I^2C mode (optional: jump to standalone): **IQS231 04000000 TSR**

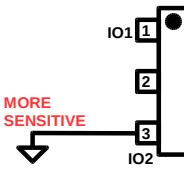
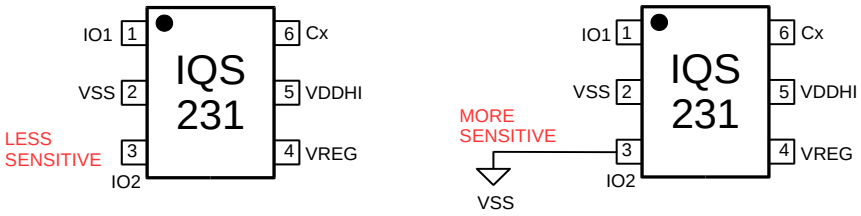
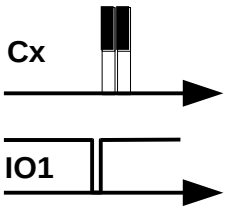
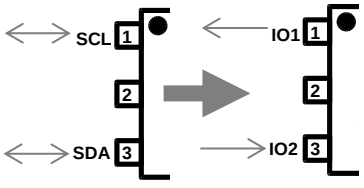
3 Summary: Programming reference (I²C memory map)

I2C Communications Layout											
Address/ Command/ Byte	**Register name/s**	**R/W**	**Default Value**	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
xxH	MAIN_EVENTS	R	n/a		DEBUG	SENSING DISABLED	WARM BOOT	COLD BOOT	RELEASE	TOUCH	PROX
Each read instruction returns 'MAIN_EVENTS' byte as first byte, followed by the data at the specified address											
00H	PRODUCT_NUMBER	R	0x40	0x40							
01H	SOFTWARE_VERSION	R	0x04	0x04							
02H	DEBUG_EVENTS	R	n/a	RESERVED	ATI_ERROR	CH0_ATI	RESERVED	QUICK RELEASE	EXIT MOV DETECT	ENTER MOV DETECT	MOVEMENT
03H	EVENTS_ENABLED	R/W	0x03F	RESERVED	DEBUG	SENSING DISABLED	WARM BOOT	COLD BOOT	RELEASE	TOUCH	PROX
04H	COMMANDS	R/W	0x00	ATI_CH0	DISABLE SENSING	ENABLE SENSING	TOGGLE AC FILTER	TOGGLE MOVEMENT ALGORITHM	TOGGLE ULP MODE	TOGGLE EVENT MODE	WARM BOOT
05H	OTP Bank 1	R/W	0x00	Filter halt	Proximity threshold Read only			AC Filter	Hand-held power on detection	Touch threshold Read only	
06H	OTP Bank 2	R/W	0x00	RESERVED	Target	Base value		Failsafe	Quick release	User interface selection	
07H	OTP Bank 3	R/W	0x00	RESERVED	RESERVED	Projected sensing	IO2 Function		IC mode (Standalone / I2C)	RESERVED	Sample rate
08H	QUICK RELEASE	R/W	0x00	Quick release threshold LUT				Quick release beta			
				0xC = 500 0xD = 750 0xE = 850 0xF = 1000	0x8 = 75 0x9 = 200 0xA = 300 0xB = 400	0x4 = 10 0x5 = 20 0x6 = 25 0x7 = 30	0x0 = 100 0x1 = 150 0x2 = 50 0x3 = 250				
09H	MOVEMENT	R/W	0x30 (2s, 4)	Filter halt time				Movement threshold = (Value × 2) + 4 Available range: 4 – 34			
				0xC = 10min 0xD = 30min 0xE = 60min 0xF = 90min	0x8 = 30s 0x9 = 1min 0xA = 2min 0xB = 5min	0x4 = 4s 0x5 = 5s 0x6 = 10s 0x7 = 20s	0x0 = 0s 0x1 = 0.5s 0x2 = 1s 0x3 = 2s				
0AH	TOUCH THRESHOLD	R/W	0x07 (32)	Touch threshold = (Value × 4) + 4 Available range: 4 – 1024							
0BH	PROXIMITY THRESHOLD	R/W	0x00	Reserved				Reserved	Proximity threshold = (OTP value +1) x 4 x2 if IO2 is high in standalone Available range: 20 – 132 (IO2 low) Available range: 40 – 264 (IO2 high)		
0CH	RESERVED	R/W	n/a	n/a							
0DH	CH0 Multipliers	R/W	n/a	Reserved	Reserved	CH0 Sensitivity Multiplier		CH0 Compensation multiplier			
						0 – 3		0 – 15			
0EH	CH0 Compensation	R/W	n/a	0 – 255							
0FH	CH1 Multipliers	R/W	n/a	Reserved	Reserved	CH1 Sensitivity Multiplier		CH1 Compensation multiplier			
						0 – 3		0 – 15			
10H	CH1 Compensation	R/W	n/a	0 – 255							
11H	System flags	R	n/a	AC FILTER ACTIVE	Reserved	CH1_ACTIVE	Reserved		CH0_LTA_HALTED	ATI_MODE	ZOOM MODE
12H	UI flags	R	n/a	Reserved		ULP_MODE	Reserved	HAND_HELD PWR ON	QUICK_RELEASE	Reserved	OUTPUT ACTIVE
13H	ATI flags	R	n/a	Reserved							
14H	Event flags	R	n/a	CH1_ATI ERROR	Reserved		CH1 MOVEMENT	CH0_ATI ERROR	CH0 UNDEBOUNCED	CH0_ TOUCH	CH0_PROX
15H	CH0 ACF_H	R	n/a	Proximity channel: Filtered count value 0 – 2000							
16H	CH0 ACF_L	R	n/a								
17H	CH0 LTA_H	R	n/a	Proximity channel: Reference count value (Long term average) 0 – 2000							
18H	CH0 LTA_L	R	n/a								
19H	CH0 QRD_H	R	n/a	Proximity channel: Quick release detect reference value 0 – 2000							
1AH	CH0 QRD_L	R	n/a								
1BH	CH1 ACF_H	R	n/a	Movement channel: Filtered count value 0 – 2000							
1CH	CH1 ACF_L	R	n/a								
1DH	CH1 UMOV_H	R	n/a	Movement channel: Upper reference count value 0 – 2000							
1EH	CH1 UMOV_L	R	n/a								
1FH	CH1 LMOV_H	R	n/a	Movement channel: Lower reference count value 0 – 2000							
20H	CH1 LMOV_L	R	n/a								
21H	HALT_TIMER_H	R	n/a	Countdown timer to give active feedback on the time-out. Movement events will reset this timer (0 – 255) × 100ms | Timer range: 0 – 90min							
22H	HALT_TIMER_L	R	n/a								
23H	TIMER.ATI_CH0	R	n/a	Countdown timer to give active feedback on the time until re-calibration is attempted after ATI-error (0 – 255) × 100ms | Timer range: 0 – 25s							
24H	TIMER.ATI_CH1	R	n/a	Countdown timer to give active feedback on the time until re-calibration is attempted after ATI-error (0 – 255) × 100ms | Timer range: 0 – 25s							

4 Summary: Features

 Pin compatibility	Many older designs using the IQS128 will benefit from a “drop-in” replacement on a production device for evaluation.
 **DYCAL / Quick release**	A DYCAL-type implementation (referring to dynamic threshold calibration) is recommended as main stability feature for the latest SAR user interface. Passing the device SAR qualification with this type of interface has been proven successful. “Quick release” detection is the improved “DYCAL”-type implementation and focusses on a release characteristic within a time window. Movement features add a second level of protection against stuck conditions with the quick release detection. The quick release will be detected on the proximity channel (not the secondary movement channel) and the signal slope will be monitored to enable the quick release. A single action from a touch/proximity state will trigger the quick release event and the event will only remain as long the proximity state holds.
UI **User interface selection**	The device offers 3 main UIs intended for SAR use. These are: • Proximity UI, no continuous movement sensing • Proximity UI, continuous movement sensing • Proximity & touch UI, continuous movement sensing during proximity, no movement sensing during touch (No time-out during long duration stationary SAR tests) In all cases the use of the quick release feature is recommended to prevent typical non-human activations from remaining. In all cases “no movement” and “movement sensing” refers to the capacitive movement sensing during normal activation. “Hand held detection” and “quick release” features will enable movement sensing with a no-movement time-out, irrespective of which UI is selected.

Summary: Features (Continued 1…)

 **Movement detection**	Movement detection is designed to function as human presence detection in a localized area. This device can't be used to fulfil an accelerometer function ("G-sensor" function). Human presence detection requires an exception in SAR testing because the qualification testing only uses stationary "phantom bodies". Optimized human detection is offered through an integrated separate channel, dedicated towards human detection.
 **Sensitivity adjustment**	 Default input use: internal pull-up (20kΩ) by default, tie directly to GND for more sensitive option. Apart from the simple external adjustment, an external capacitor is recommended for sensitivity adjustments. 1pF is considered a small change in sensitivity, while 10pF changes are considered large. A maximum of 60pF load is recommended for effective proximity sensing.
 **Failsafe heartbeat**	A single pulse of 500µs is integrated on IO1. This pulse is the failsafe heartbeat, sent on each sensing event. This pulse will be sent during the "stabilize time" as shown in Figure 8.1. The failsafe indicator signal will precede the conversions (sampling). The failsafe signal will be repeated during burst mode in order to offer synchronization output to the master, indicating exactly when sensitive measurements are done. Measurement times have a fixed maximum which the user can implement. The failsafe signal is disabled by default and may be enabled via OTP option or I²C initialize with standalone setup.
 High configurability	Through I²C the IQS231 can be used in many different ways and the configuration can be updated during later stages of development than with the OTP route.
 **Switch I²C to standalone**	Configure the device via a dedicated I²C type connection and switch to any standalone mode for runtime operation. This minimises the processor load and spurious content from communication signals. The failsafe heartbeat is integral to detecting an unexpected reset event. When the heartbeat disappears, default state is assumed and the master device should reconfigure the device through I²C.

Summary: Features (Continued 2…)

Self / Projected Sensing	Projected is offered for future implementations with advantages in proximity detection for SAR and on-ear. Electrode design is a major design element in such application. Projected sensing is permanently disabled when I^2C mode is chosen.
Hand-held detection during power-on	Movement detection information will be used for power-on safety detection. During the start-up period, the threshold detection cannot be accurately used due to calibration at this time. Human movement characteristics are used as an alternative. A touch event is considered a more substantial indication of actual threshold trigger and therefore this will clear the hand-held detection state when a proximity & touch UI is selected.
Sync input	In order to ensure a stable sensing environment, sensing may be done in strategic time windows controlled by a master device.
Automatic tuning (ATI)	The Automatic tuning implementation (ATI) ensures optimal sensitivity during runtime for various sensor environments. Two channels are calibrated (proximity channel and movement channel). Both run on the same Cx pin in different time slots. An ATI-block time is defined to prevent re-ATI loops during touch release events. The ATI-block is fixed for the movement channel, and fixed for the standard touch/proximity channel
Reference signal behaviour	Long-term-average (LTA: signal reference) behavior is optimized for SAR where trigger tests are important in product qualification. The LTA will therefore be slow while still able to prevent typical temperature drift from causing activations.
 **Improved I^2C interface**	Standard I^2C polling for: • Debugging & normal use • Device polling optimized for guaranteed response (within $t_{CLK\_stretch}$ – clock stretching will be applied to the bus SCL line)

5 Features: Extended details

5.1 ATI (Automatic Tuning Implementation)

External sensor connections are calibrated in the following ways:

- Power On Reset (proximity channel is calibrated at each POR)
- Movement channel is only calibrated with POR when hand-held detection is enabled
- Proximity & movement channel is calibrated when the reference is out of bounds (1/8 of target counts). The reference of the proximity channel is rapidly adapted when capacitance moves away from the trigger threshold OR when an automatic “reseed” is done (Reseed: reference = actual sensor value). The reference of the movement channel is rapidly adapted in any direction of capacitive changes.
- Redo-ATI of the proximity channel can be initiated by the user in I^2C mode using an I^2C command.

During each proximity channel ATI event, the proximity output is activated to indicate the event and ensure a safe output during the event and in the case of an ATI-error.

Known issues: When 125 kHz charge transfer frequency selected for large capacitive and resistive loads, the calibration has instability around the ATI boundaries.

5.2 Sensitivity adjustment

Apart from the simple external adjustment, an external capacitor is recommended for sensitivity adjustments. 1pF is considered a small change in sensitivity, while 10pF changes are considered large. A maximum of 60pF load is recommended for effective proximity sensing.

6 Recommended SAR configurations

Configuration name	Configuration	Details
IQS128 replacement	**IQS231 00000000 TSR**	Backwards compatible / with quick release
Full-feature (base)	**IQS231 000A0600 TSR**	Touch threshold, Hand-held power on detect, quick-release, failsafe, prox&touch UI,
Full-feature (no failsafe heartbeat)	**IQS231 00020600 TSR**	Touch threshold, Hand-held power on detect, quick-release, prox&touch UI
Shared electrode	**IQS231 08000000 TSR**	Synchronization input
I^2C Mode	**IQS231 04000000 TSR**	I^2C enabled

See below sections for details on recommended configurations.

6.1 IQS128 replacement configuration

The IQS128 replacement mode is the default OTP configuration:

- DYCAL release is replaced with the quick release (enabled by default)
- The available input (IO2) may be used floating (has internal pull-up)
    - Float / pull high: Less sensitive proximity threshold of 8 counts
    - Shorting this pin to GND: More sensitive proximity threshold of 4 counts.
- The default base value of the IQS231 is decreased (100 compared to IQS128 @ 200) to give more sensitivity for a lower target count
    - add a larger Cx capacitance if this sensitivity boost is applied in an environment with a low signal-to-noise ratio.
- The default quick release settings make the feature function towards the safe side. A design with 20mm trigger distance should activate the feature if a quick release action is done from a deep touch on the electrode.
- Reference part number: **IQS231 00000000 TSR**

6.2 Full feature configuration

With the standalone mode using movement, all important features of the IQS231 are recommended to enable:

- Enable hand held detection: This feature offers improved user protecting when powering up the device in-hand.
- Enable failsafe output: This feature will place short pulses on the output which can easily be ignored by a debounce algorithm and detected by an interrupt. When failsafe pulses disappear, the output IQS231 output should be ignored and the device should enter a safe state.
- Enable the proximity & touch UI with movement. This UI will effectively time-out when a proximity state is activated, but with no user interaction (device placed on table / in bag etc.). When in a touch state, no time-out will occur. This time-out blocking is beneficial for the long term SAR qualification testing.
- When the touch UI is enabled the touch level becomes active. Select a touch threshold
- Keep quick release enabled. The feature will improve user experience with a quick 2 second no-movement time-out. The time-out is fixed (2 sec) when any proximity & movement UI is chosen.
- Reference part number: **IQS231 000A0600 TSR (or IQS231 00020600 TSR no failsafe heartbeat)**

6.3 Shared electrode with RF antenna

When using the device in an advanced implementation using the RF antenna as sensing electrode, the following settings are recommended:

- Enable the synchronization input to take control of when sensing is allowed (pull IO2 low) and when sensing is paused (IO2 high with internal pull-up). This feature may be used to multiplex RF transmit, receive and capacitive sensing. Sensing requires a minimum IO2 low time of 10ms to do a proper charge transfer. The proximity threshold will default to the low option.
- Use the mode described next: "I^2C setup with standalone output in runtime". This mode will ensure full control of settings while offering a connection to the RF module without the frequency harmonics produced by I^2C communications.
- Reference part number: **IQS231 08000000 TSR**

6.4 I²C setup with standalone output in runtime

For full control of the settings, an I²C device may be used (I²C enabled with OTP) to do the IC setup, while runtime offers a standalone output. The advantage is that detailed settings can be flexible and determined separately from the procurement phase (OTPs are required to be fixed early enough to satisfy the lead-time for an OTP-specific solution). Details about this mode are as follows:

- From about 20ms from power-up, the device may be polled by address.
- The device will acknowledge the correct address within about 5ms from any R/W event (expect clock stretching during IQS231 wake-up)
- Send write commands via I²C until all the required settings are written
- Send the mode switch bit “IC mode” -> “Standalone” only after all settings are written. After writing this setting, the next I²C stop sent will automatically instruct a soft reset to put the IC in standalone mode, keeping all the settings written through I²C. A soft reset will also ensure that a recalibration is done.
- Quick reference to switch modes: Clear register 0x07 (OTP Bank 3) bit 2 to enter standalone mode.
- Reference part number: **IQS231 04000000 TSR**

7 I²C Programming Guide (Summary)

The IQS231 device interfaces to a master controller via a 2-wire (SDA and SCL) serial interface bus that is I²C™ compatible, with a maximum communication speed of 400kbit/s.

The protocol acknowledges an address request independently. The I²C hardware module is awake for address recognition while the IQS231 is in sleep mode, giving the ability to wake the device at any time and effectively communicate via serial interface. This is different compared to other ultra-low power Azoteq solutions where the communications module also sleeps during standard IC sleep times. Repeated polling requests where required in such case.

7.1 Add I2C connection

When using I²C mode, ensure the connections as shown in Figure 1.1. Internal pull-up resistors are sufficient for communication speeds up to 100kbits/s with low capacitance on the lines (<15pF). For 400kbit/s, be sure to place pull-up resistors (4.7kΩ recommended)

7.2 I2C command structure

By writing to address 0x04, commands can be sent to the device. The commands are as follows:

Table 7.1 I²C command structure

Reg 0x04 Bit	Name	Description	Toggle (yes/no)
0	WARM BOOT	Soft reset, all registers remain as written, UI resets	No
1	RESERVED	n/a	n/a
2	ULP MODE	Ultra low power mode enable (512ms)	Yes
3	RESERVED	n/a	n/a
4	AC FILTER	Toggle between option available in OTP	Yes
5	DISABLE SENSING	Disables all conversions	No
6	ENABLE SENSING	Enable capacitive sensing	No
7	ATI CH0	Perform re-calibration on proximity channel	No

7.3 Control Byte

The Control byte indicates the 7-bit device address (44H default) and the Read/Write indicator bit. The structure of the control byte is shown in Figure 7.1.

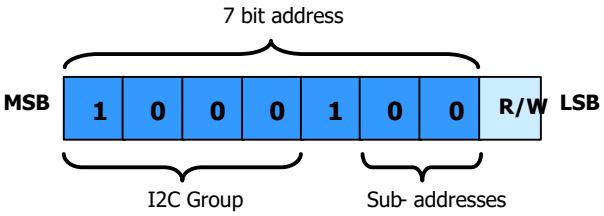


Figure 7.1 IQS231 control byte

The I²C device has a 7 bit Slave Address (default 0x44H) in the control byte as shown in Figure 7.1. To confirm the address, the software compares the received address with the device address. Sub-address values can be set by OTP programming options.

The IQS231 has no alternate slave address options.

7.4 Test mode (address 0x45)

During the power-on period (approx. 20ms), the device will respond to polling requests on address **0x45** (test-mode address). Test-mode is used during IC production and OTP configuration.

With another device on the I²C bus with address 0x45, power-up sequence and communication timing should be considered.

7.5 I2C typical setup

The typical I^2C setup would adjust the following registers:

- Quick release beta
- Quick release threshold
- Movement threshold
- Touch threshold
- Proximity threshold
- Filter halt time
- User interface
- IC mode

The rest of the settings will only require adjustment with specific requirement.

7.6 I2C read (Event register)

Each I2C read will always return the event register as the first byte. When reading from a specific register (write address before read), 2x reads should be done. See memory map first line for detail on the event register.

8 Configuration Options

The IQS231 offers various user selectable options. These options may be defined via I^2C setup or **one-time programmable (OTP)** configuration. OTP configured devices may be ordered pre-programmed for bulk orders or in-circuit programming techniques may be implemented during the product testing phase. I^2C setup allows access to all device settings while entering direct output mode when selected by the MCU.

Azoteq offers a Configuration Tool (CT210 or later) and associated software that can be used to program the OTP user options for prototyping purposes. For further information regarding this subject, please contact your local distributor or submit enquiries to Azoteq at: ProxSenseSupport@azoteq.com

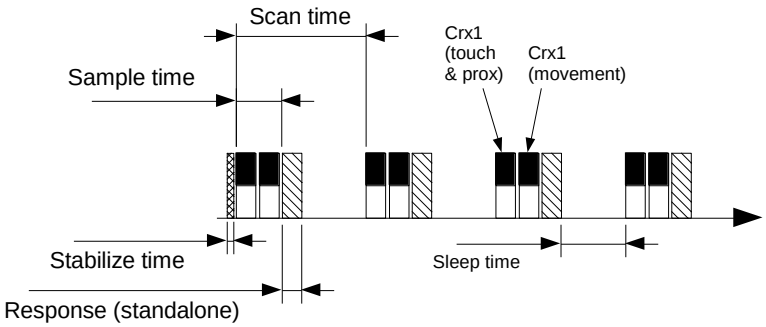
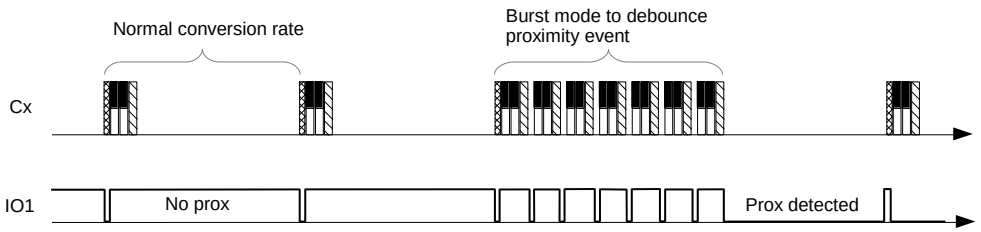
8.1 OTP Details: Bank 0

Movement time-out **(bit 7:6)**	When no movement is detected within a time period, a movement time-out occurs. The reference is halted until the timer clears. After the timer clears, the reference signal is made equal to the actual signal, nullifying any signal delta that may have caused a proximity or touch event. The timer is reloaded with every movement event detected.
Movement threshold **(bit 5:4)**	A low count threshold region is defined for a movement signal internally stored. Movement characteristics accumulate and triggers as soon as it reaches the threshold. The accumulated effect is nullified and accumulation is restarted in order to detect the next possible movement event.
Quick release threshold **(bit 3:2)**	The quick release feature will operate according to the parameters as specified in: • DYCAL / Quick release definition • Quick release beta • Quick release threshold The quick release threshold defines the trigger point for the feature where the counts deviate from a quick release moving average in a certain direction. The direction is determined by the projected sensing enabled/disabled bit: • With projected disabled (default) the direction is with increasing counts • With projected enabled the direction is with decreasing counts
Quick release beta **(bit 1:0)**	The quick release beta forms part of the quick release feature and is the filter intensity of the reference value which follows the actual counts. The quick release is triggered according to the difference between this reference value and the actual counts. When this value is large, the quick release will trigger for a variety of release types from slow to fast releases. When this value is small, the quick release will only trigger for fast releases.

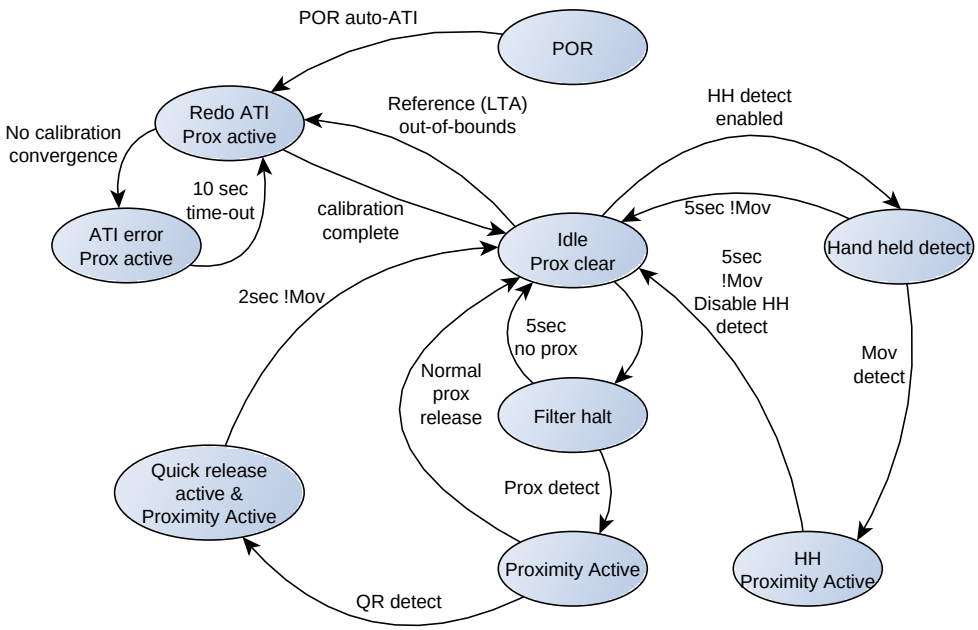
8.2 OTP Details: Bank 1

Filter halt threshold **(bit 7)**	The filter halt is a separate threshold that is intended to be more sensitive than the proximity threshold. While in no proximity detected state, the reference of the IQS231 will follow the actual signal to prevent environmental effects such a temperature drift. A filter halt feature is implemented to "freeze" the reference and allow slow proximity trigger approaches to still be effective without adapting. The time-out is t_{filter_halt} when a filter halt does not result in a proximity event.
Proximity Threshold (low/high) **(bit 6:4)**	By default this is the only trigger threshold in the system (touch also threshold available). The threshold is adjustable in actual counts values (count values can be seen when streaming I2C value through the IQS231 GUI). The threshold is the amount of counts the actual signal **falls below** (projected disabled) | **rises above** (projected enabled) the reference signal (long-term average) In the default configuration the input pin IO2 will be active. IO2 = VSS will enable the chosen option in the OTP (20-132 counts) IO2 = VDDHI (40-264 counts) The system will default to the IO2 = VSS option when sync input or movement output is enabled.
AC Filter **(bit 3)**	Incoming samples are filtered by default. This option gives the ability to significantly decrease the filter strength. Default is an IIR (infinite impulse response) filter of 2 (2^3). This "increased" option enables an IIR filter of 8 (2^3). The filter can be changed to 2^1 by setting this bit.
Hand-held power on detection **(bit 2)**	Standalone operation involves the detection of user interaction (movement) during power-on. When enabled, the slightest interaction detected during $t_{pwrcheck}$ will result in a safe output along with resetting the timer that times out at $t_{pwrcheck}$. This allows for a safe period during power-up before starting with normal threshold based sensing. The "movement" parameters used for this feature will be as follows: • $t_{pwrcheck}$ = "**Movement time-out"** when UI is set to any proximity with movement selection • $t_{pwrcheck}$ = 5 seconds when **UI** is set to proximity with no movement enabled • Movement trigger threshold = Movement threshold register • Filtering = AC Filter bit
Touch threshold **(bit 1:0)**	Threshold in counts that defines the level below the proximity threshold that cancels a quick release event and disables any active movement detection.

8.3 OTP Details: Bank 2

Target **(bit 6)**	The target count is an offset value of the actual system capacitance. The actual signal (expressed in counts) will be calibrated as close as possible to this value. A larger target optimizes sensitivity at the cost of charge transfer time. A lower target offers more stability, but less sensitivity.
Base value **(bit 5:4)**	The base value is a lower target value for the actual signal and implies the system gain. A base value of 100 and target of 1000 implies a x10 gain, while base value of 200 and target of 1000 implies a x5 gain.
Failsafe **(bit 3)**	This bit is only has an effect when User interface is set to Standalone. Default is to always have 500us pulses on output, separated by the sampling period. A pulse will be on output every time a capacitive conversion is done. Conversion rate and debounce events may be debugged through this output.  **Figure 8.1 Conversion signal on Cx timing description**  **Figure 8.2 Conversion diagram with failsafe output signal**

OTP Details: Bank 2 (...continued)

Quick release **(bit 2)**	The quick release feature can be disabled here. It is enabled by default. The quick release feature offers improved user experience and does not influence trigger testing. The feature is mainly directed at SAR applications, but also has significant benefits for on-ear detection applications. The touch depth and speed of release is used to detect the instance where the user interaction implies a release condition. This is required for cases where the normal threshold release is not triggered for any of the following reasons: • Device placed on table while releasing the hand (the capacitive influence of the table remains) • Place device inside a bag while releasing the hand (the capacitive influence of the bag remains) • Fit a protective cover during use (the capacitive influence of the cover remains) • Extreme temperature (cool down) shift causes a shift in capacitive environment • Capacitance impulse recovery (drop test, transient bursts etc)
User interface **(bit 1:0)**	When movement Uis are enabled, the timeout is only active in the proximity region. When in touch, only quick release can get the IC out of a stuck condition. In such case no movement time-out for quick release is fixed at 2sec and no-movement time-out for proximity is as defined in OTPs  **Figure 8.3 Proximity UI no movement**

OTP Details: Bank 2 (...continued)

User interface (bit 1:0) (continued..)

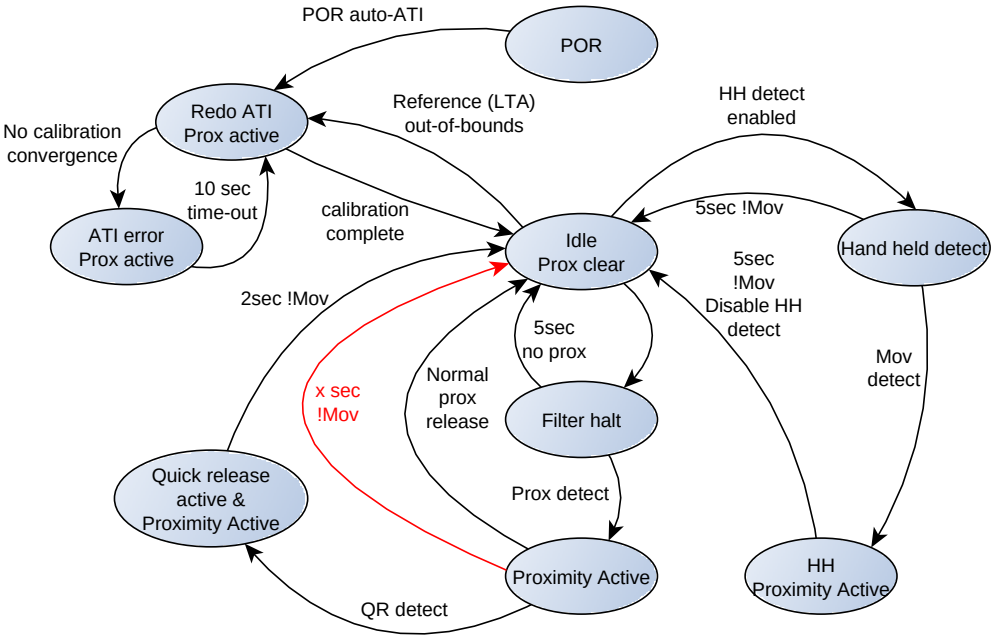


Figure 8.4 Proximity UI with movement

User interface (bit 1:0) (continued..)

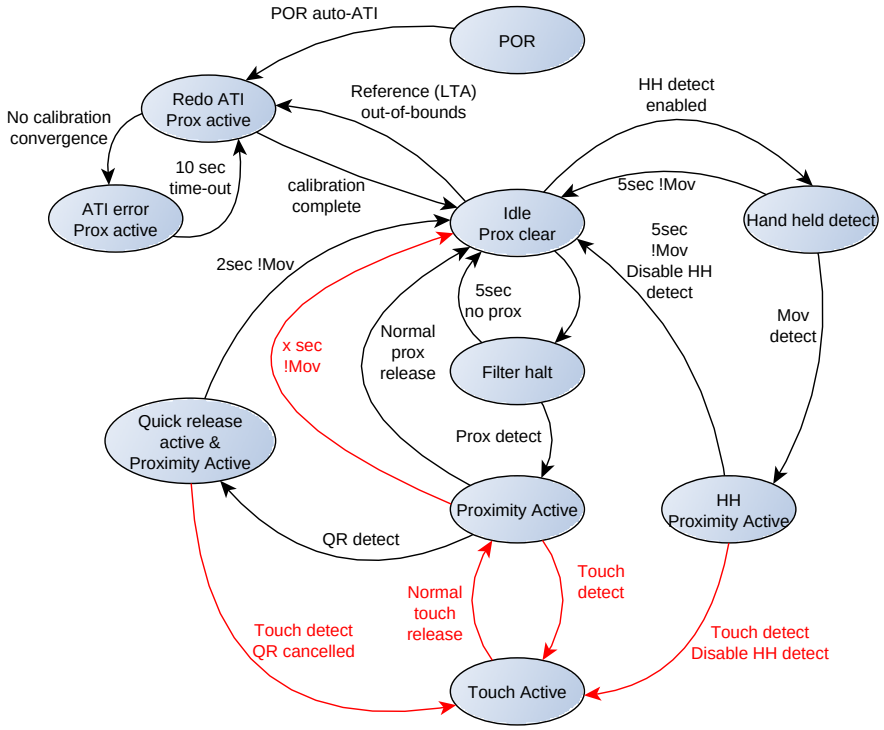
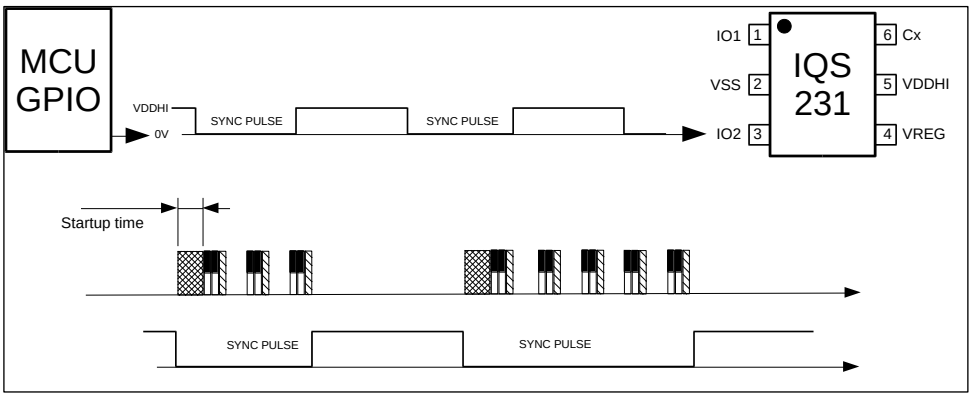


Figure 8.5 Proximity & touch UI (with movement enabled in proximity & movement disabled in touch)

8.4 OTP Details: Bank 3

Projected sensing (bit 5)	When disabled (default) self-capacitance technology is used. When enabled, projected capacitance technology is used. In this case Input (IO2) becomes a transmit signal and the Cx pin (pin 6) becomes the receive pin. In this mode any other I/O function defined on IO2 will be cancelled automatically.
IO2 function (bit 4:3)	By default IO2 will be a sensitivity adjustment input. An internal pull-up ($R_{internal}$) will by default select a less sensitive option (IO2 = VDDHI). By strapping then pin directly to Vss, a more sensitive option is selected (IO2 = VSS). When the movement output is enabled, the input defaults to the “more sensitive option” as shown with IO2 = VSS With the output enabled the movement events are shown on IO2. The output is in an active low, open drain configuration. The output will remain low for t_{awake} when movement is detected and this will occur during the sample time after the movement trigger occurs (the movement trigger is delayed with the sample rate) Sync input: The input (pin IO2) may be used to detect when to sense and when to halt the sensing.  **Figure 8.6 Sync input of the IQS231**
IC mode (bit 2)	Standalone (default), or I2C The advantage of this option is explained in the Switch I^2C to standalone section of the features summary.
Sample rate (bit 1:0)	The various sample rates offered are mainly given for the user to determine an ideal balance between power consumption and response time. Overall response times of the IQS231 are improved with SAR trigger testing in mind.

9 Full programming reference

A detailed list of the I²C registers follows and follows the structure of the memory map summary on page 6.

ADDR	Register name	Bit	Description
xxH	MAIN_EVENTS	7	n/a
		6	DEBUG – Debug events are disabled by default. In order to report debug events, enable debug events in register 0x03 and read debug event in register 0x02 when this bit is set.
		5	SENSING DISABLED – An indication of forced or implied times when no sensing signals are applied to the sense pin. When this bit is set and bit 2 is cleared, sensing is disabled. When this bit and bit 2 is set, sensing is enabled again.
		4	WARM BOOT – A software reset command in register 0x04 will lead to a warm boot. This will imply a reset for the user interface, re-calibration, and hand-held power on detection will be forced if enabled.
		3	COLD BOOT – A hard reset (power supply cycle) will cause all registers to return to a default value. This indicator will imply the need to re-initialize the device.
		2	RELEASE – A touch, prox or sensing event may be paired with a release indication to show an exit of the flagged event.
		1	TOUCH – Disabled by default, this bit will be active when a touch and prox user interface is chosen.
		0	PROX - The main feedback bit to indicate an activation
00H	PRODUCT_ NUMBER	n/a	The product number is fixed at 0x40
01H	SOFTWARE_ VERSION	n/a	The only software version released is 0x04
02H	DEBUG_ EVENTS	7	n/a
		6	ATI_ERROR – when a recalibration cannot converge, due to external tampering or instability, this bit will indicate the error and implies that the calibration does not offer optimal sensitivity. The PROX event in the main events register will be set along with this bit in such case.
		5	CH0_ATI – An indication that a recalibration of the proximity sensing channel has occurred. With calibration, the PROX output in main events will be set and after calibration, the PROX output will release.
		4	n/a
		3	QUICK RELEASE – The quick release feature is a single event that is indicated here. This event will always imply an “ENTER MOV DETECT”, but is not the only event that causes movement detection to be activated.
		2	EXIT MOV DETECT – The user interface dictates when the movement channel is deactivated. The deactivation of movement sensing will be reported in this bit.
		1	ENTER MOV DETECT – Movement detection is user interface dependant and not continually active. Movement detection implies that a separate movement channel is activated. This activation will be reported in this bit.

ADDR	Register name	Bit	Description
		0	MOVEMENT – Each trigger detected by the movement algorithm is reported as an event that resets along with each read operation.
03H	EVENTS_ENABLED	n/a	ENABLE (set) or DISABLE (clear) events that are reported in the MAIN_EVENTS register. Each read operation is preceded by the MAIN_EVENTS byte. The bit order from the MAIN_EVENTS register can be used to determine a required event mask
04H	COMMANDS	7	ATI_CH0 – Recalibrate the proximity channel. Only after closing the communications window, a recalibration of the proximity sensing electrode will be started.
		6	DISABLE SENSING – Sensing can be disabled to save power or synchronize sensing in a more complex system and limit certain signals from affecting the measurement.
		5	ENABLE SENSING – Sensing can be enabled at strategic times to limit interference in the sensitive measurement environment. ENABLE / DISABLE sensing will be reflected in the MAIN_EVENTS register. ENABLE sensing will result in a “SENSING DISABLED” and “RELEASE” bit being set simultaneously.
		4	TOGGLE AC FILTER – The AC Filter as defined in OTP Bank 1 can be toggled through a command and read in register 0x05 (OTP Bank 1)
		3	RESERVED
		2	TOGGLE ULP MODE - An ultra low power mode is defined to limit power consumption to a maximum with a 512ms sensing period. The IQS231 debounce will give a sub-550ms response time.
		1	RESERVED
		0	WARM BOOT – A warm boot implies a user interface restart while keeping all register changes made. Sending the command will execute as soon as the communications window is closed. The event will be flagged in the MAIN_EVENTS register.
05H	OTP Bank 1	7	Filter halt threshold (see OTP bank definition)
		6	Proximity Threshold (low/high) read only For reading OTP setting only. Note that the actual proximity threshold is defined in register 0x0B.
		5	
		4	
		3	AC Filter (see OTP bank definition)
		2	Hand-held power on detection (see OTP bank definition)
		1	Touch threshold (read only) For reading OTP setting only. Note that the actual touch threshold is defined in register 0x0A.
		0	
06H	OTP Bank 2	7	Reserved
		6	Target (see OTP bank definition)
		5	Base value (see OTP bank definition)
		4	
		3	Failsafe (see OTP bank definition)
		2	Quick release (see OTP bank definition)
		1	User interface (see OTP bank definition)
		0	
07H	OTP Bank 3	7	RESERVED

ADDR	Register name	Bit	Description
		6	RESERVED
		5	Projected sensing (see OTP bank definition)
		4	IO2 function (see OTP bank definition)
		3	
		2	IC mode – I^2C or standalone. This powerful feature enables the designer to configure the device in I^2C mode and thereafter reduce the I^2C overhead and related EMI by switching to standalone for runtime. The actual mode switch occurs as soon as the communications window is closed with a stop command. It is recommended to enable the failsafe heartbeat when going from I^2C mode to standalone. The absence of the heartbeat should be used to indicate an unexpected reset event, implying the need for I^2C reconfiguration.
		1	Sample rate (see OTP bank definition)
		0	
08H	QUICK RELEASE	7	The OTP options for quick release (see Quick release threshold in OTP Bank 0) is extended in I^2C mode to enable a very specific release characteristic. Quick release threshold look-up table: 0x0 = 150 counts 0x1 = 100 0x2 = 50 0x3 = 250 0x4 = 10 0x5 = 20 0x6 = 25 0x7 = 30 0x8 = 75 0x9 = 200 0xA = 300 0xB = 400 0xC = 245 0xD = 230 0xE = 335 0xF = 500
		6	
		5	
		4	
		3	Quick release beta – This beta value is an indication of the filter strength used to track the characteristic of the release signal. The faster the tracking, the less likely the release will be detected (only very quick events will be detected). The slower the tracking, the more likely the quick release occur (quick events and slow events will be detected as a quick release) Practical values for the beta range between: 0 (fast events only) and 4 (fast and slow events) The maximum of 0xF is impractical and high values are not recommended.
		2	
		1	
		0	
09H	MOVEMENT	7	MOVEMENT TIME-OUT – Depending on the user interface, a movement detection channel may be started along with specific events (proximity / quick release). The timer is set and cleared as mentioned in Movement time-out (OTP Bank 0).
		6	
		5	
		4	

ADDR	Register name	Bit	Description
			No movement time-out value: 0x0 = 0s 0x1 = 0.5s 0x2 = 1s 0x3 = 2s 0x4 = 4s 0x5 = 5s 0x6 = 10s 0x7 = 20s 0x8 = 30s 0x9 = 1min 0xA = 2min 0xB = 5min 0xC = 10min 0xD = 30min 0xE = 60min 0xF = 90min
		3 2 1 0	MOVEMENT THRESHOLD. Movement threshold = (Value × 2) + 4 Available range: 4 – 34 For description see Movement threshold in OTP Bank 0. Note that the movement threshold in OTP Bank 1 is loaded in this register at start up and the OTP setting becomes read only. All movement threshold adjustments are performed in this register.
0AH	TOUCH THRESHOLD	n/a	Touch threshold = (Value × 4) + 4 Available range: 4 – 1024 For details on the touch threshold operation and uses see Touch threshold in OTP Bank 1. Note that the touch threshold in OTP Bank 1 is loaded in this register at start up and the OTP setting becomes read only. All touch threshold adjustments are performed in this register.
0BH	PROXIMITY THRESHOLD	7 6 5 4 3	Reserved
		2 1 0	Proximity threshold = (OTP value +1) x 4 x2 if IO2 is high in standalone Available range: 20 – 132 (IO2 low) Available range: 40 – 264 (IO2 high) For details on the proximity threshold operation and uses see Proximity Threshold (low/high) in OTP Bank 1. Note that the proximity threshold in OTP Bank 1 is loaded in this register at start up and the OTP setting becomes read only. All proximity threshold adjustments are performed in this register.
0CH	RESERVED	n/a	n/a
0DH	CH0 Multipliers	7 6	Reserved
		5 4	CH0 Sensitivity Multiplier (Values: 0 – 3)
		3	CH0 Compensation multiplier (Values: 0 – 15)

ADDR	Register name	Bit	Description
		2	
		1	
		0	
0EH	CH0 Compensation	n/a	0 – 255
0FH	CH1 Multipliers	7	Reserved
		6	
		5	CH1 Sensitivity Multiplier (Values: 0 – 3)
		4	
		3	CH1 Compensation multiplier (Values: 0 – 15)
		2	
		1	
		0	
10H	CH1 Compensation	n/a	0 – 255
11H	System flags	7	AC FILTER ACTIVE – Indicates if the function selected in register 0x05 is currently active.
		6	Reserved
		5	CH1 ACTIVE – Indicates if the movement channel (CH1) is activated and busy with movement detection
		4	Reserved
		3	
		2	CH0 LTA HALTED – Indicates that some proximity shift has been detected according to the threshold in register 0x05 bit 7. This event automatically clears if a proximity is not detected within $t_{filter\ halt}$
		1	ATI MODE – Indicates that CH0 or CH1 is busy with the recalibration routine. Read the ATI in flags in register 0x13 for more information
		0	ZOOM MODE – At each threshold of the proximity channel (proximity & touch threshold), a signal “debounce” is done rapidly. During this rapid event, this bit will be set.
12H	UI flags	7	Reserved
		6	
		5	ULP MODE – When ULP mode is entered by the command in register 0x04 bit 2, the power mode will be flagged here.
		4	Reserved
		3	Hand held power on – Indicates the hand held power on feature is active/inactive after power on or WARM BOOT.
		2	Quick release – Indicates when a quick release action has been detected
		1	Reserved
		0	Output active – Indicates an active proximity detection
13H	ATI flags	n/a	Reserved
14H	Event flags	7	CH1_ATI ERROR – This will indicate that the movement channel is not operating under optimal sensitivity and the calibration will automatically be redone in $t_{redoATI}$. The count-down time until next attempt can be read in register 0x25 and 0x26.
		6	Reserved
		5	

ADDR	Register name	Bit	Description
		4	CH1 MOVEMENT
		3	CH0_ATI ERROR – Because of external interference, strong EMI or extreme capacitive load conditions the calibration will not be able to reach the target sensitivity (target count – as defined in register 0x06 bit 6). The proximity output will be set in such case in order to fail towards the safe side. The calibration will automatically be redone in $t_{redoATI}$. The count-down time until next attempt can be read in register 0x23 and 0x24.
		2	CH0 UNDEBOUNCED – An indication that a proximity event has been detected before a debounce operation has been done.
		1	CH0_ TOUCH – The touch event is flagged here for the duration of the touch
		0	CH0_PROX – The proximity event is flagged here for the duration of the proximity
15H	CH0 ACF_H	n/a	Proximity channel: Filtered count value 0 – 2000 This count value is related to an offset actual capacitive load. The offset is done though calibration and ensures system sensitivity.
16H	CH0 ACF_L		
17H	CH0 LTA_H	n/a	Proximity channel: Reference count value (Long term average) 0 – 2000
18H	CH0 LTA_L		
19H	CH0 QRD_H	n/a	Proximity channel: Quick release detect reference value 0 – 2000
1AH	CH0 QRD_L		
1BH	CH1 ACF_H	n/a	Movement channel: Filtered count value 0 – 2000
1CH	CH1 ACF_L		
1DH	CH1 UMOV_H	n/a	Movement channel: Upper reference count value 0 – 2000
1EH	CH1 UMOV_L		
1FH	CH1 LMOV_H	n/a	Movement channel: Lower reference count value 0 – 2000
20H	CH1 LMOV_L		
21H	HALT_TIMER_H	n/a	Countdown timer to give active feedback on the time-out. Movement events will reset this timer (0 – 255) × 100ms | Timer range: 0 – 90min
22H	HALT_TIMER_L		
23H	TIMER.ATI_CH0	n/a	Channel 0 countdown timer to give active feedback on the time until re-calibration is attempted after ATI-error (0 – 255) × 100ms | Timer range: 0 – 25s
24H	TIMER.ATI_CH1	n/a	Channel 1 countdown timer to give active feedback on the time until re-calibration is attempted after ATI-error (0 – 255) × 100ms | Timer range: 0 – 25s

10 Specifications

10.1 Absolute maximum ratings

The following absolute maximum parameters are specified for the device:

Exceeding these maximum specifications may cause damage to the device.

• Operating temperature	-40°C to 85°C
• Supply Voltage (VDDHI – VSS)	3.6V
• Maximum pin voltage	VDDHI + 0.5V (may not exceed VDDHI max)
• Maximum continuous current (for specific Pins)	10mA
• Minimum pin voltage	VSS – 0.5V
• Minimum power-on slope	100V/s
• ESD protection	±8kV (Human body model)
• Package Moisture Sensitivity Level (MSL)	1

Table 10.1 IQS231 General Operating Conditions

DESCRIPTION	Conditions	PARAMETER	MIN	TYP	MAX	UNIT
Supply voltage		V_{DDHI}	1.75	n/a	3.6	V
Internal regulator output	1.75 ≤ V_{DDHI} ≤ 3.6	V_{REG}	1.62	1.65	1.72	V
Default Operating Current	3.3V, Scan time = 30ms	$I_{IQS231LP30}$		33		µA
Full Power Setting	3.3V, Scan time =9ms	$I_{IQS231FP}$		80		µA
Halt charge				1		uA

Table 10.2 Start-up and shut-down slope Characteristics

DESCRIPTION	Conditions	PARAMETER	MIN	MAX	UNIT
Power On Reset	V_{DDHI} Slope ≥ 100V/s @25°C	POR	1.2	1.6	V
Brown Out Detect	V_{DDHI} Slope ≥ 100V/s @25°C	BOD	1.15	1.6	V

Table 10.3 Various IQS231 characteristics

DESCRIPTION	MIN	TYP	MAX	UNIT
$t_{comms\_timeout}$	-	20	-	ms
$t_{CLK\_stretch}$		5		ms
t_{filter_halt}		5		s
$t_{pwrcheck}$		5		s
$t_{redoATI}$		10		s
t_{awake}		9		ms
$R_{internal}$		20		kΩ
$f_{sampling}$		500		kHz

Table 10.4 Digital input trigger levels

DESCRIPTION	Conditions	PARAMETER	MIN	TYPICAL	MAX	UNIT
All digital inputs	VDDHI = 3.3V	Input low level voltage	1.19	1.3	1.3	V
All digital inputs	VDDHI = 1.8V	Input low level voltage	0.54	0.6	0.76	V
All digital inputs	VDDHI = 1.8V	Input high level voltage	0.9	1.0	1.2	V
All digital inputs	VDDHI = 3.3V	Input high level voltage	1.90	2.1	2.20	V

Table 10.5 Digital output levels

DESCRIPTION	Conditions	PARAMETER	@1mA*	@10mA*	UNIT
Output voltage low	VDDHI = 3.3V	V_{OL}	0.01	0.1	V
Output voltage high	VDDHI = 3.3V	V_{OH}	n/a**	n/a**	V

* Current sinked into output pin

** Only open drain output offered. Pull-up resistor to VDDHI recommended

11 Package information

11.1 TSOT23-6

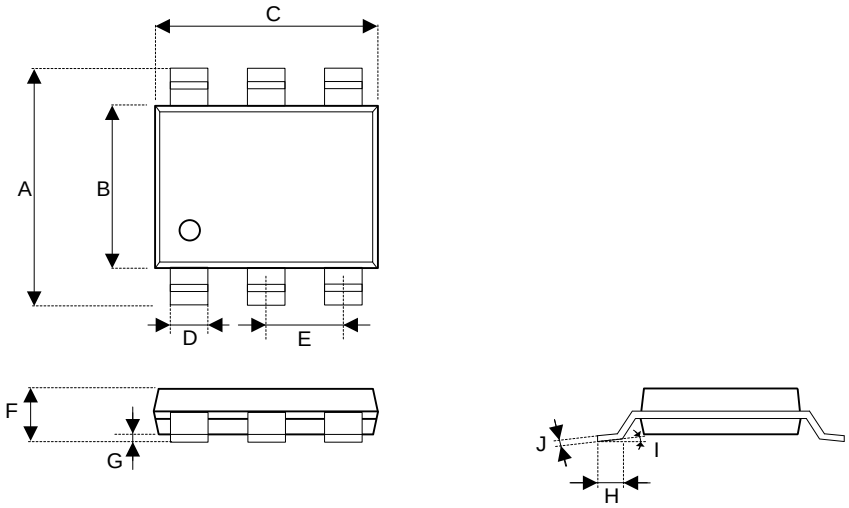


Figure 11.1 TSOT23-6 Packaging[i]

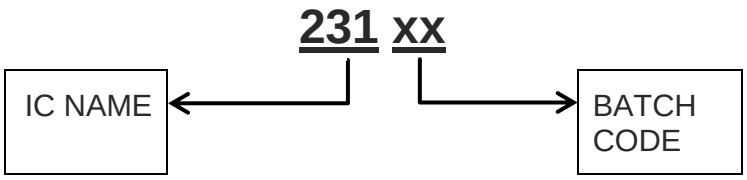
Table 11.1 TSOT23-6 Dimensions

Dimension	Min (mm)	Max (mm)
A	2.60	3.00
B	1.50	1.70
C	2.80	3.00
D	0.30	0.50
E	0.95 Basic	
F	0.84	1.00
G	0.00	0.10
H	0.30	0.50
I	0°	8°
J	0.03	0.20

[i] Drawing not on Scale

11.2 Device packaging convention

11.2.1 Top



IC name	231
Batch	xx

11.2.2 Bottom

No bottom marking present

11.3 MSL Level

Moisture Sensitivity Level (MSL) relates to the packaging and handling precautions for some semiconductors. The MSL is an electronic standard for the time period in which a moisture sensitive device can be exposed to ambient room conditions (approximately 30°C/85%RH see J-STD033C for more info) before reflow occur.

Package	Level (duration)
TSOT23-6	MSL 1 (Unlimited at ≤30 °C/85% RH) Reflow profile peak temperature < 260 °C for < 30 seconds

12 Ordering and Part-number Information

12.1 Ordering Information

Please check stock availability with your local distributor.

CONFIGURATION	zzzzzzzz	=	IC configuration (hexadecimal) **Default 00000000** (other configurations available on request)
PACKAGE TYPE	TS	=	TSOT23-6 package
BULK PACKAGING	R	=	Reel (3000pcs/reel) – MOQ = 3000pcs MOQ = 1 reel (orders shipped as full reels)

Example ordering code for default device: **IQS231 00000000 TS R**

12.2 Device Numbering Convention

REVISION	x	=	IC Revision Number
TEMPERATURE RANGE	t	=	-40°C to 85°C (Industrial)
DATE CODE	P	=	Internal use
	WWYY	=	Batch number

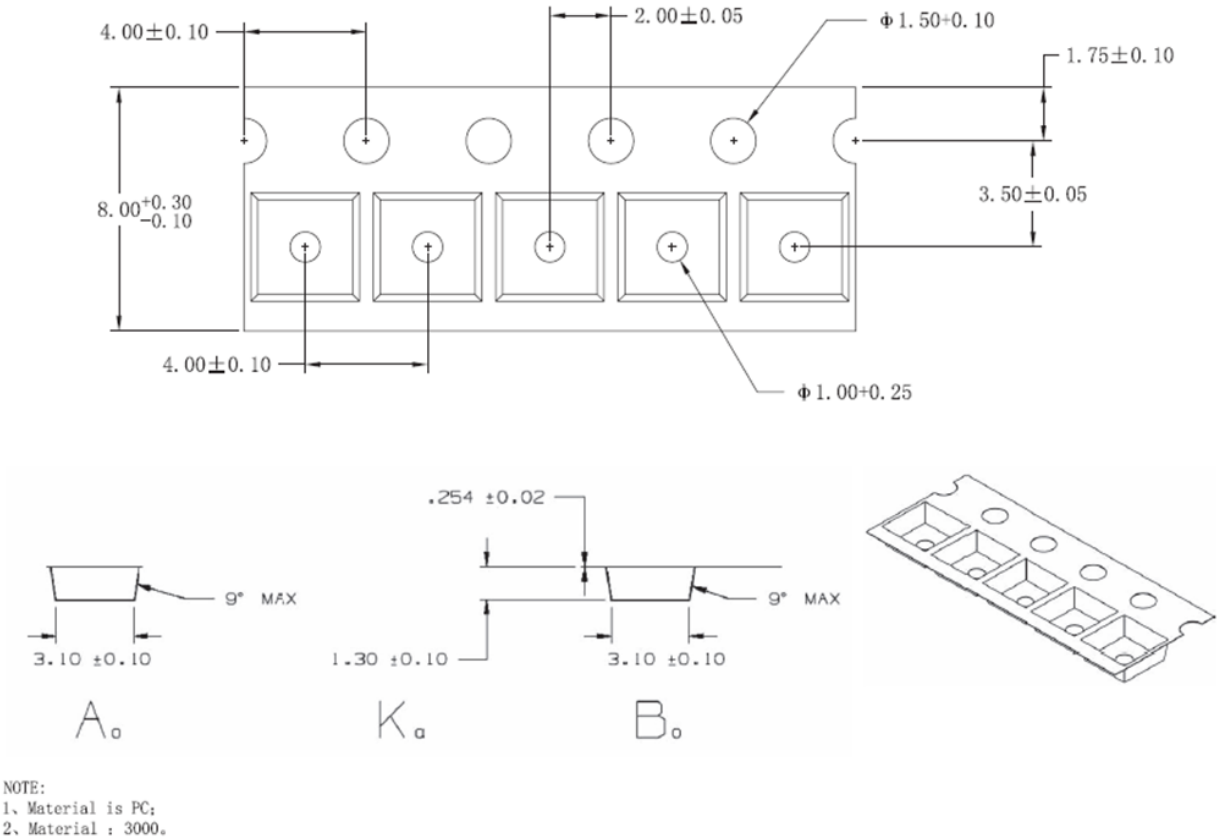


Figure 12.1 TSOT23-6 Tape Specification

13 Revision History

Revision Number	Description	Date of issue
v1.0	IC release version	12 August 2015
v1.1	Figure 1.2 updated – load capacitor moved AC filter is increased by default Large quick release thresholds adapted Known issues and workarounds: Proximity threshold Low frequency sensing mode omission	9 October 2015
V1.2	Typing error on proximity threshold OTP in bank1 should be 110 – 195 not 136	
V1.3	Device package marking detail added	13 November 2015
V1.4	Output voltage levels added	8 March 2016
V1.5	Example schematic updated with C1 capacitor guide added Low power references removed	4 May 2016

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