AZD130 - Keyboard Proximity Design Guide

Design guide for capacitive keyboard proximity sensors offered by Azoteq's ProxFusion® range.
Description of design and production specification.

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1 Introduction

The aim of this document is to give a step-by-step guide on how to design capacitive sensors for keyboard proximity applications. The Azoteq technology used for this application provides an intuitive low power proximity solution.

A summary of the design process is shown below:

Figure 1.1: Design Process Summary

The result of this process is to achieve the required proximity performance for the specific keyboard application.

The document is structured as follows: Chapter 2 outlines the design specifications for Azoteq's capacitive proximity sensing. Chapter 3 describes the capacitive proximity solution offered by Azoteq. Chapter 4 provides various resources to aid in the design of keyboard proximity solutions. Chapter 5 demonstrates an example design of a keyboard with proximity sensing utilizing the IQS7223C. Chapter 6 provides a process for validating the keyboard proximity design to ensure the requirements are met. Chapter 7 describes the interface between the master MCU and the proximity sensor. Chapter 8 discusses important considerations for moving the proximity enabled keyboard into production.

2 Design Specification / Product Requirements

This chapter outlines the key specifications for the keyboard proximity sensor that needs to be considered during the design process.

2.1 Mechanical Specification

A minimum distance of 3.5 mm between the metal plate electrode and ground plane is required for self-capacitive proximity sensing applications. A distance < 3.5 mm will require a mutual capacitive design.

2.2 Electrical Interface Specification

The specifications for sensor electrical and interface design are listed in the table below.

Table 2.1: Electrical Specifications

Specification	Requirement
Supply Voltage (V_{DD})	1.8V - 3.3V
Internal Regulation (V_{REG})	Digital and analogue domains (requires external decoupling capacitors)
Communication Interface	I^2C (SCL & SDA) + interrupt / data-ready (RDY active-low) for event indication
Master Reset Control	MCLR (some devices time share functionality on the same pin as RDY)
Additional Outputs	Optional, Up to 3x outputs with custom configurable logic and output assignment
ESD protection	HBM up to class 3A and -B or IEC 61000-4-2 standard level 4 (contact and air discharge) System level qualification of finished product with the necessary protection can be achieved with the recommended series resistance on sensor (CRX) pins and the use of exposed ground traces and pours/floods for safe discharge. Extreme measures incorporates the use of TVS diodes to clamp nodes when and where necessary.
Radiated noise immunity	IEC 61000-4-3 standard test level 2 and 3 (3 V/m – 10 V/m) Appropriate capacitive decoupling and sensor series resistive elements (low-pass filter) component implementation and the placement thereof towards effective decoupling ground sites which are sufficiently stitched and commonly connected in a system are crucial for improved radiated immunity. Consider antenna placement and feed lines with higher energy flow
Current consumption	Application use of different sensors, UIs and response rate requirements may influence the current budget minimum allocation and brief periods of increased consumption. Optimisation of low power (sleep) current drawn should be minimised for extended idle periods. Current consumption for keyboard proximity applications are dependent on the response rate. A higher response rate requires higher current consumption and vice versa. It is possible to achieve sufficient performance below 10 µA in some cases.

2.3 Operational Environment Specification

The specifications for sensor operational environments are listed in the table below.

Table 2.2: Operational Environment Specifications

Specification	Self-capacitive	Mutual capacitive
Typical product temperature range	-10°C to +60°C	-10°C to +60°C
Product operational relative humidity range	30- to 70 %RH	30- to 70 %RH
Usable charge transfer frequency range	125 kHz – 1 MHz	500 kHz – 4 MHz

2.4 Sensing Range

A capacitive proximity sensor gives an indication when a user is within a specific range of the product. A sensing range of 2-3 cm from the surface of the keyboard is recommended to prevent any undesired proximity activations.

2.5 Report Rate and Wake-up Response Time

Table 2.3: Report Rate and Wake-up Response Time

Specification	Requirement
Sensor Configuration Start Up Time	$<$ 1000 ms
Active Mode Report Rate	$\geq$ 50 ms[i]
Low Power Mode Report Rate	$\leq$ 160 ms
Activation Timeout	$>$ 5000 ms

The activation timeout is required to allow the device to recalibrate when the environment is changed.

2.6 Communication Interface

"Event Mode" should be used to interrupt the master only when an event is detected. Channel proximity flags should be read once an event is generated to determine whether the device is in "Prox".

2.7 Test Points

Exposed copper test points are required for VDD, GND, SDA, SCL and RDY. The test points are used during production testing for rapid debugging of the proximity sensor.

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[i] A higher report rate can be set to achieve better responsiveness but with an increased current consumption.

3 Proposed Solution

This chapter provides a high-level overview of Azoteq's keyboard proximity sensing solutions, including a a brief overview of the different sensing methods, system diagram, a mechanical stack-up, and a list of recommended Azoteq part numbers.

3.1 Keyboard Types

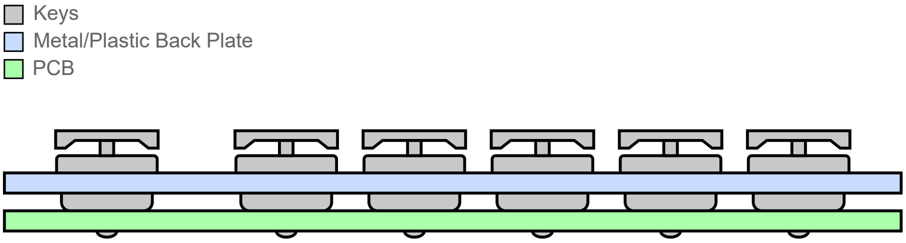

Figure 3.1: Keyboard Back Plate

A keyboard would either have a conductive metal back plate or non-conductive plastic back plate as seen in figure 3.1. The conductive metal back plate of the keyboard can be used as a sensor electrode, thereby simplifying the proximity sensor design.

An alternative sensing electrode should be used where a non-conductive plastic back plate is used. Different sensing methods for both cases are discussed in the following section.

3.2 Sensing Methods for Various Keyboard Types

We recommend using the metal back plate of the keyboard as a self-capacitive sensing electrode. This configuration can be seen in figure 3.2 below. The sensor will detect the user once they are within the sensing range from the metal back plate.

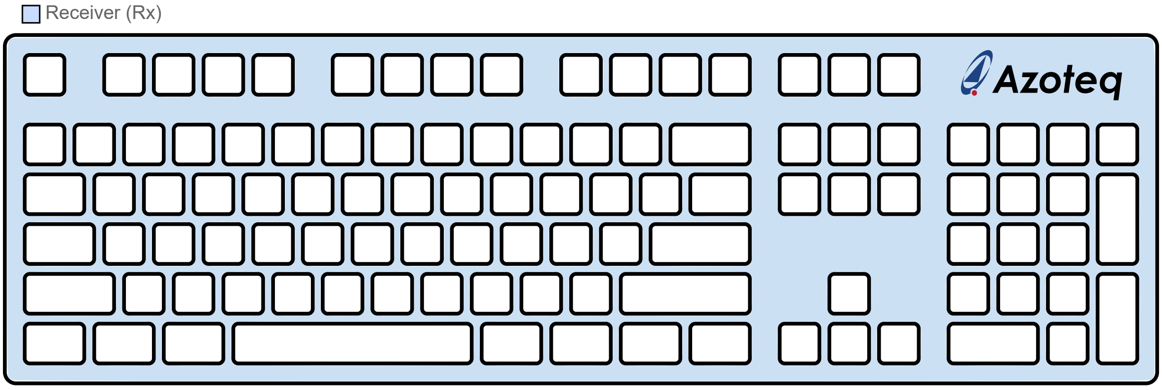

Figure 3.2: Self-Capacitive Keyboard Proximity Solution

This sensing method has a simple design that offers great performance. However, it should be noted that the performance is dependent on the parasitic capacitance of the electrode. This parasitic capacitance is mainly determined by the spacing between the electrode and the ground plane. The smaller the spacing between the electrode and the ground plane, the higher the parasitic capacitance. A higher parasitic capacitance will result in a smaller sensing range as the influence of the user decreases. It is recommended to keep a distance of at least 3.5 mm between the electrode plate and the ground plane for a self-capacitive configuration.

Alternative sensing methods are available where desired performance cannot be achieved due to electrode and ground plane spacing. A mutual capacitive configuration is recommended in such cases. This configuration can be seen in figure 3.3 and 3.4 below, where the metal plate is used as a transmitter electrode and a slim wire/trace used as the receiver electrode below the transmitter. The receiver trace should have a ground plane cutout behind the trace to prevent undesired performance.

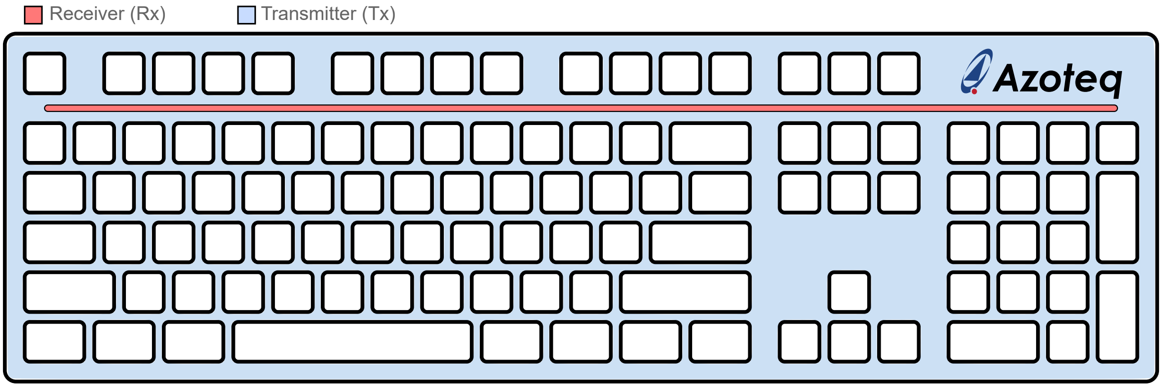

Figure 3.3: Mutual Capacitive Keyboard Proximity Solution Top View

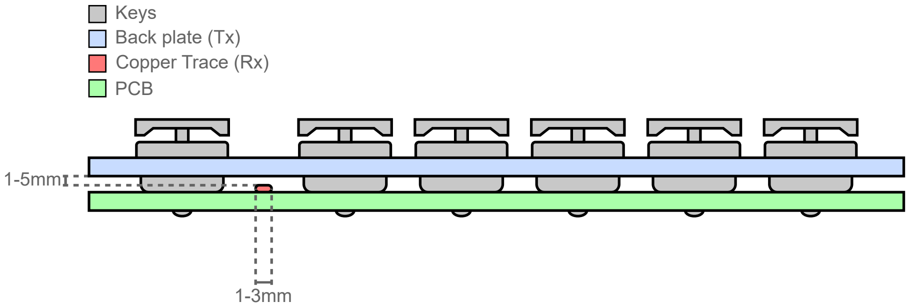

Figure 3.4: Mutual Capacitive Keyboard Proximity Solution Side View

This configuration is only recommended for an isolated battery system as the sensing will not work for a grounded system (for example: when plugged into USB power). In this case, it is recommended to keep the keyboard backlighting on when not on battery power. If performance remains inadequate, please contact Azoteq.

If the metal back plate is unavailable as an electrode, a simple wire or trace around the edge of the keyboard can be used as the sensor electrode as seen in figure 3.5 below.

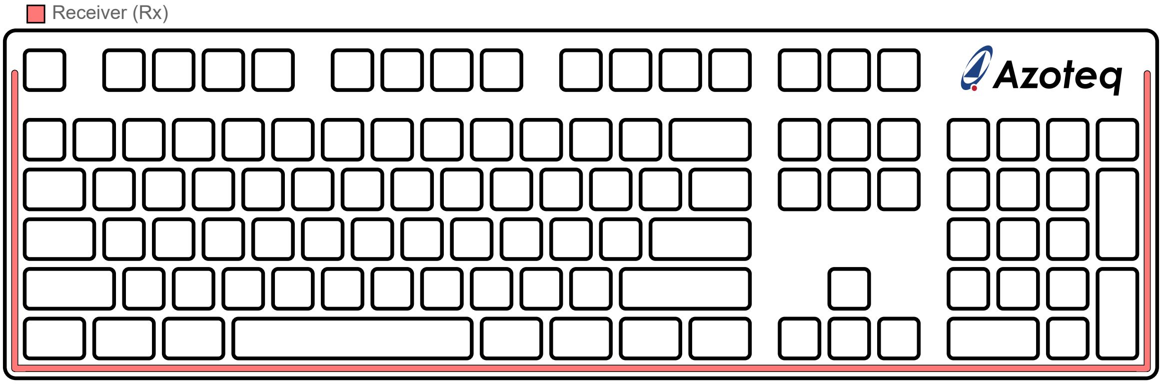

Figure 3.5: Self-Capacitive Keyboard Proximity Solution (Wire/Trace)

The same applies for a mutual capacitive configuration where the metal back plate is unavailable.

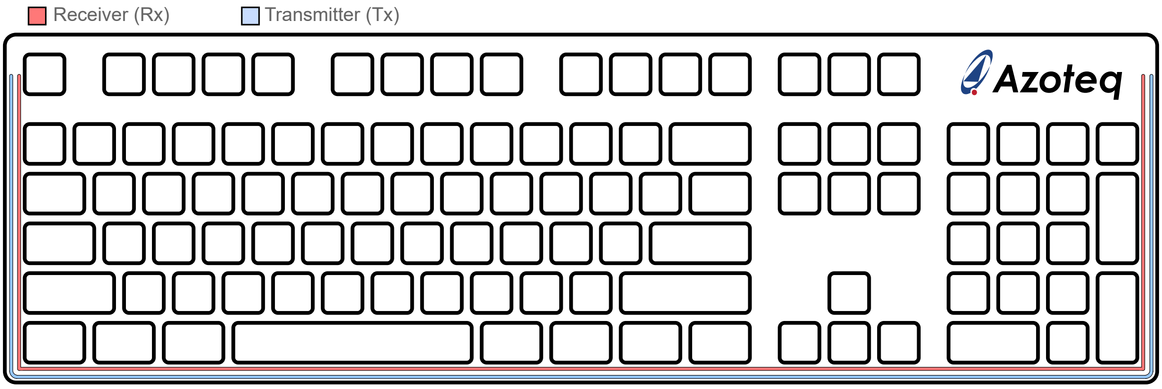

Figure 3.6: Mutual Capacitive Keyboard Proximity Solution (Wire/Trace)

For the purpose of this document a self-capacitive design using the metal back plate as an electrode will be discussed in detail.

3.3 System Description

On a high level the system overview is comprised of three main sections:

- The user
- The sensor solution
- The host (main controller / processor)

The sensor slave controller (IQS device IC) is required to accommodate customisable setup(s) specific to hardware designs and UI requirements and will operate as required to sense, process and qualify detection of low-level measurement data while also doing the validation for user interaction events. Only when a valid event interaction is registered, the host will be interrupted to service and read the reported event state and detail via the dedicated communication interface, thus minimising the data transfer, latency, processing overhead and service priority (ISR) required so that other more important tasks on the host side can be handled with optimal/required resource allocation.

Figure 3.7 provides a system block diagram of a generic keyboard proximity implementation.

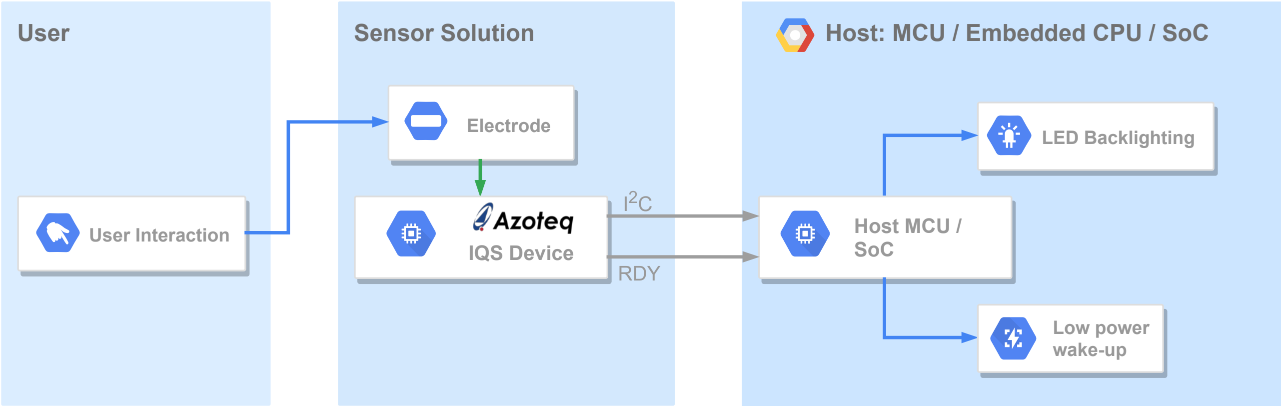

Figure 3.7: System Block Diagram

3.4 Mechanical Stackup

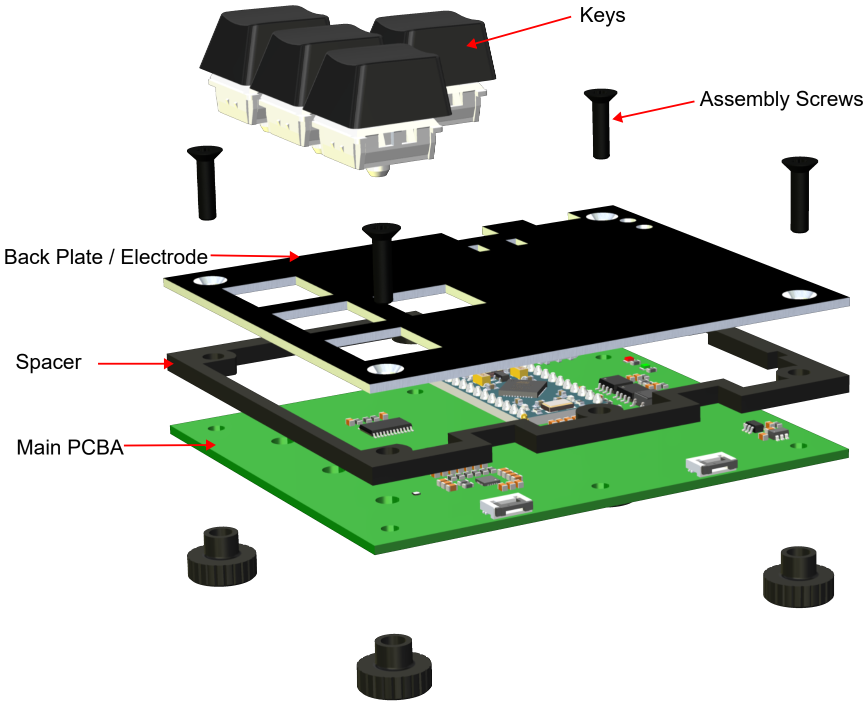

Figure 3.8: Proximity Keyboard Assembly

3.5 Azoteq Device Selection Guide

The following listed devices are Azoteq's recommended keyboard proximity sensing solutions.

- IQS7223C (WLCSP18 [1.62 x 1.62 x 0.5 mm] QFN20 [3 x 3 x 0.5 mm])
  - Up to 4 self-capacitive channels
  - Up to 4 mutual capacitive channels
    - Differential mutual capacitance available
- IQS319 (WLCSP11 [1.48 x 1.08 x 0.345 mm] DFN12 [3 x 3 x 0.75 mm])
  - Single channel self-capacitive sensor
  - Built-in signal processing options:
    - Standalone proximity output
    - Movement user interface
    - Release user interface

4 Design Resources

For all sensor design resources please refer to the Azoteq website: ProxFusion combination sensors

4.1 Datasheets, Application Notes and User Guides

- IQS Device Datasheets
- AZD004 - Azoteq Sensing overview
- AZD044 - Azoteq MSL and Reflow specifications
- AZD125 - Capacitive sensing design guide
- AZD102 - Series resistance limit of self capacitance charge transfers
- IQS7223C GUI setup guide

4.2 Hardware Design Resources

- IQS7223CzzzQNR [QFN20] SCH symbol and PCB footprint[i]
- IQS7223CzzzCSR [WLCSP18] SCH symbol and PCB footprint[i]
- IQS319zzzDNR [DFN12] SCH symbol and PCB footprint[i]
- IQS319zzzCSR [WLCSP11] SCH symbol and PCB footprint[i]

4.3 Software, Tools and Example Code

- Arduino Example code and user guide
- Graphical user interface software and tools
- CT210A Azoteq Configuration tool

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[i] The IQS7223C uses the same PCB footprint as the IQS7222A and the IQS319 uses the PCB footprint as the IQS323.

5 Design Implementation

This chapter describes the design interface of the keyboard with the IQS7223C.

5.1 Sensor Design

The sensor electrode design is dependent on the metal plate of the keyboard. In this case it is a metallic plate with cutouts for the 4 keys. The electrode can be seen in figure 5.1 below.

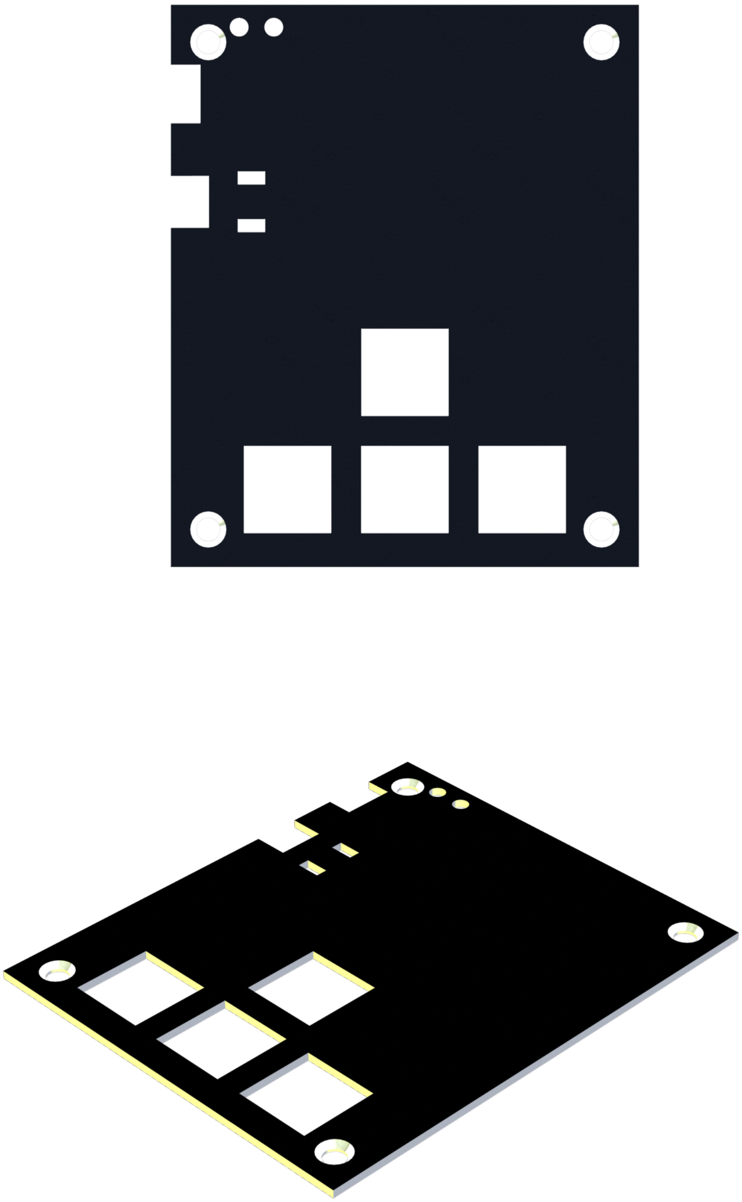

Figure 5.1: Proximity Keyboard Back Plate / Electrode

5.2 Circuit Design

A circuit was designed with the IQS7223C (QFN20 package) and a simplified schematic diagram is shown in figure 5.2 below.

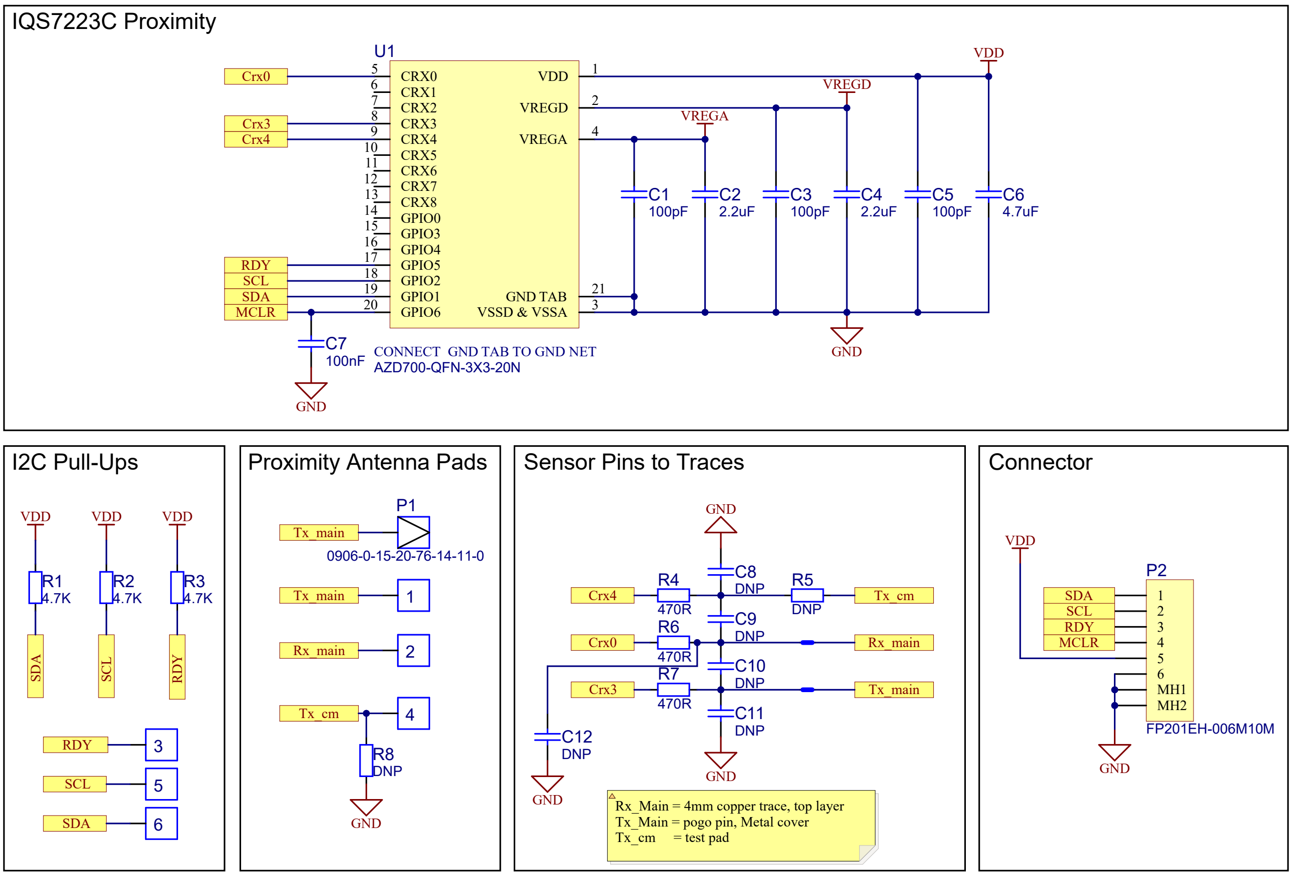

Figure 5.2: Simplified Schematic Design for Keyboard Proximity Solution[i]

5.2.1 Power Supply Decoupling and Regulation

All IQS devices require external decoupling capacitors on their supply (VDD) as well as internal regulation (VREG) pins. Please refer to IQS device specific datasheets for implementation and guidance for optimal component selection, size and placement/routing considerations.

5.2.2 Capacitive Sensor Nodes

All the self-capacitive sensor inputs (CRX) are supplied with a standard series resistance to increase radiated immunity and will sense the connected electrodes accordingly (please refer to AZD125 for fundamental design discussions; AZD015 for considerations of radiated/RF immunity; AZD102 on using resistive paths higher than the recommended). A TVS diode should be added on the sensor inputs to suppress any induced voltage spikes.

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[i] Although this design makes use of self-capacitive sensing, provision is made for mutual capacitive and differential capacitive sensing with additional sensor pads Crx3 and Crx4.

5.2.3 Routing

Digital signals such as PWM signals, I2C or SPI are active during a capacitive measurement, therefore it is recommended that the digital signals be kept a minimum of 4 mm away from the capacitive sensor traces, preferably on the bottom layer of the PCB. Refer to AZD125 for more details on routing.

5.2.4 Connections

The required test point implementations are provided to showcase typical product sub-assembly connections. Test points are convenient for design development, debugging and validation.

5.3 PCB Layout Design

Although this PCBA design consists of both proximity sensing and inductive based keys, proximity sensing will be the focus for this design document.

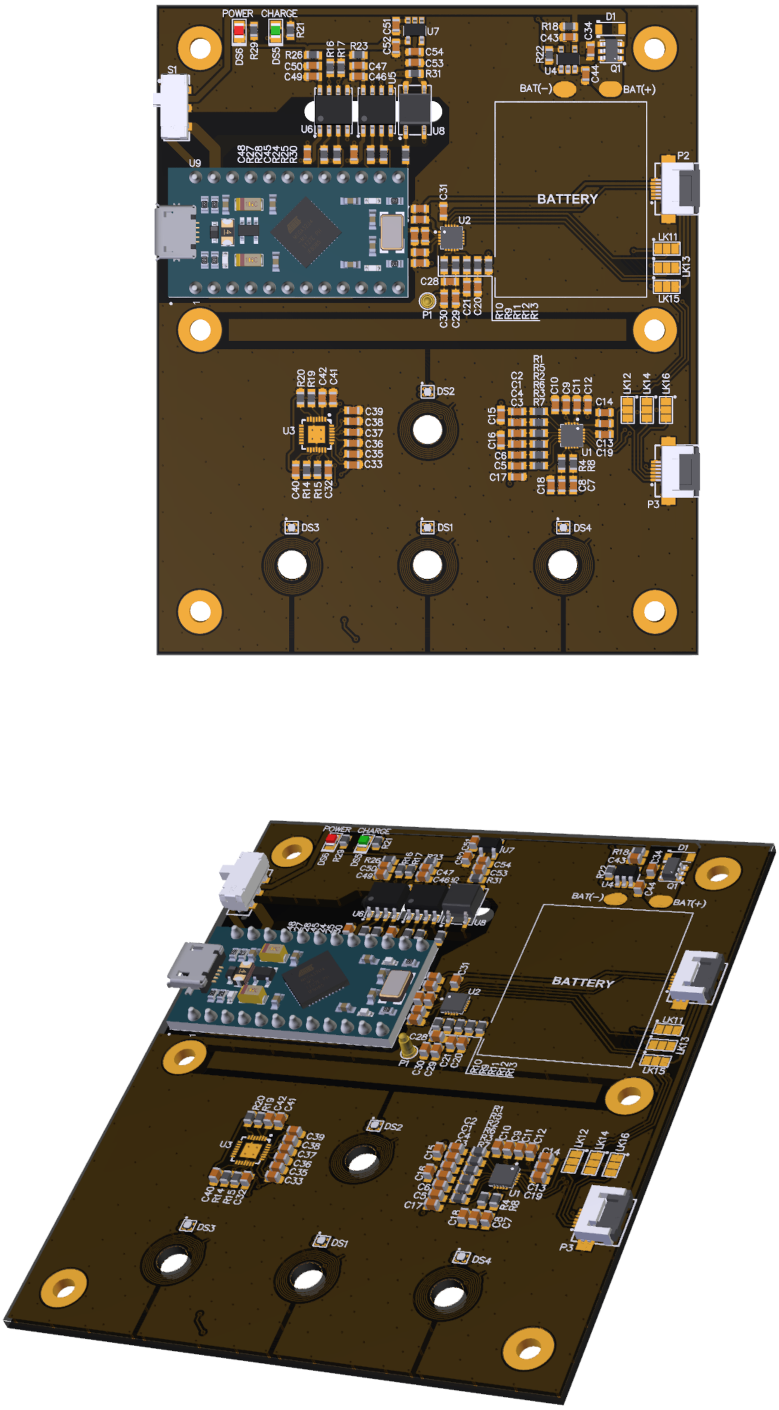


Figure 5.3: Keyboard Proximity Solution PCB

5.4 Mechanical Design

Refer to Appendix B for mechanical assembly drawings generated by computer-aided design (CAD) software for the keyboard proximity design.

5.5 Manufacturing

The following is typical to include in a datapack for manufacturing:

- Bill of Materials (BOM) with part numbers and alternative parts
- Computer Aided Drawings (CAD) - test points for jig, adhesive and overlay .dxf files
- PCB - Gerber files, pdf plots and pick and place file

The BOM for the schematic in figure 5.2 is found in Appendix A.

5.6 IC Setup

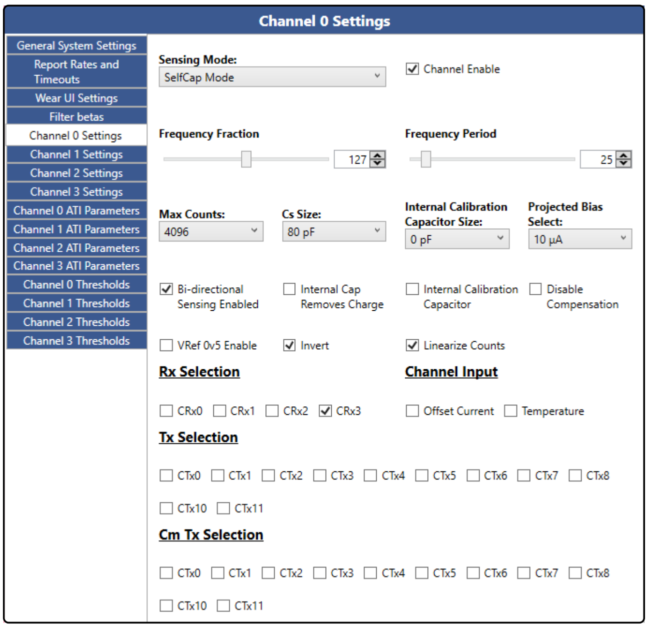
The graphical user interface (GUI) is a powerful support/design tool to simplify the process of configuring the IQS device with the parameters required for optimal performance for customer-specific hardware.

An introduction on how to use Azoteq's debug and display tool can be seen in this video.

The latest GUI can be obtained from the relevant product page on Azoteq's website as listed in Chapter 4.

5.6.1 Channel Settings

For a more in depth setup guide please refer to the IQS7223C GUI setup guide.



Sensing Mode: SelfCap Mode
☑ Channel Enable

Frequency Fraction 127
Frequency Period 25

Max Counts: 4096
Cs Size: 80 pF
Internal Calibration Capacitor Size: 0 pF
Projected Bias Select: 10 µA

☑ Bi-directional Sensing Enabled ☐ Internal Cap Removes Charge ☐ Internal Calibration Capacitor ☐ Disable Compensation

☐ VRef 0v5 Enable ☑ Invert ☑ Linearize Counts

Rx Selection

☐ CRx0 ☐ CRx1 ☐ CRx2 ☑ CRx3

Channel Input

☐ Offset Current ☐ Temperature

Tx Selection

☐ CTx0 ☐ CTx1 ☐ CTx2 ☐ CTx3 ☐ CTx4 ☐ CTx5 ☐ CTx6 ☐ CTx7 ☐ CTx8
☐ CTx10 ☐ CTx11

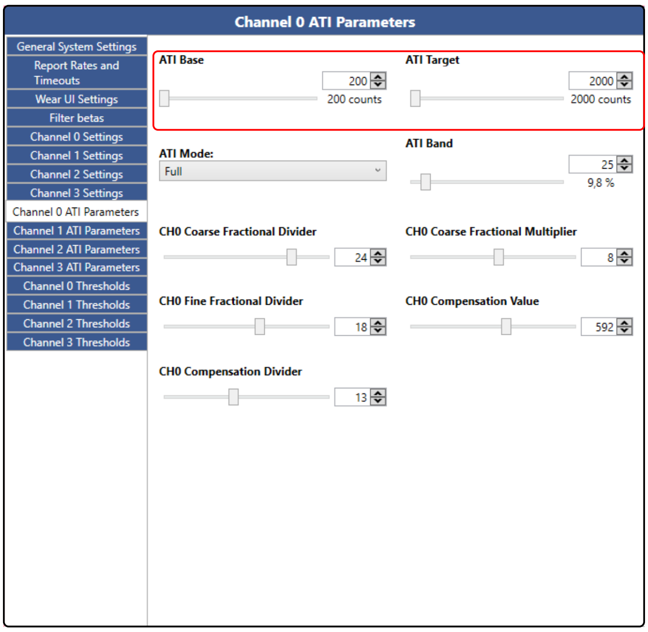
Cm Tx Selection

☐ CTx0 ☐ CTx1 ☐ CTx2 ☐ CTx3 ☐ CTx4 ☐ CTx5 ☐ CTx6 ☐ CTx7 ☐ CTx8
☐ CTx10 ☐ CTx11

Figure 5.4: General Channel Settings

General channel settings can be seen in figure 5.4 above.

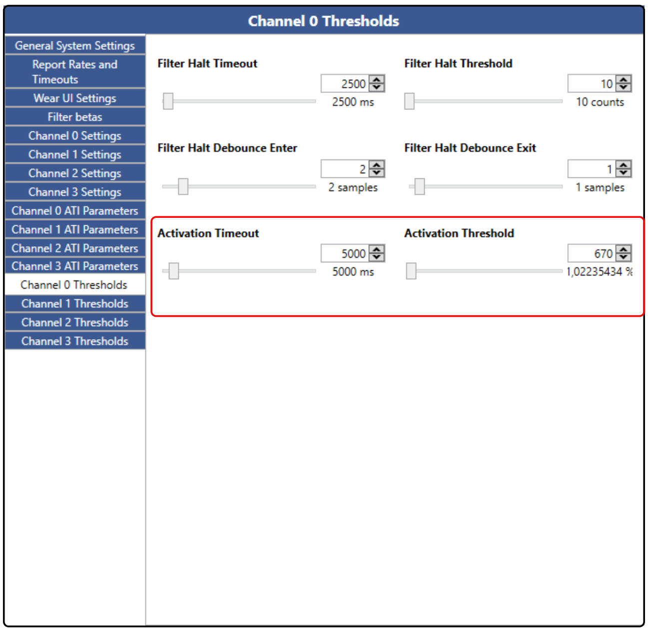
Channel ATI settings can be seen in figure 5.5. The ATI base is set to 200 and target 2000 to provide high sensitivity and range. Please refer to AZD004 for adjusting sensitivity to suit a specific design.


Channel 0 ATI Parameters

ATI Base: 200 (200 counts)
ATI Target: 2000 (2000 counts)
ATI Mode: Full
ATI Band: 25 (9,8 %)
CH0 Coarse Fractional Divider: 24
CH0 Coarse Fractional Multiplier: 8
CH0 Fine Fractional Divider: 18
CH0 Compensation Value: 592
CH0 Compensation Divider: 13

Figure 5.5: Channel ATI Settings

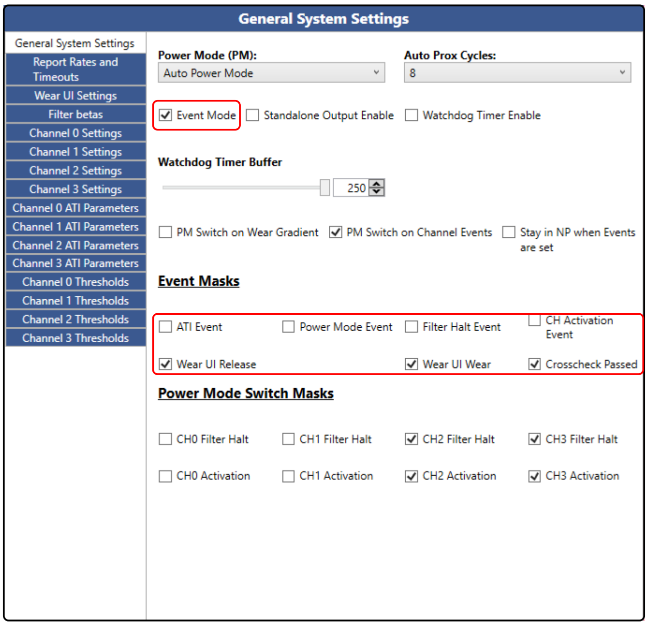
Thresholds can be adjusted to acquire a specific sensing range. A timeout is required to allow the sensor to recalibrate if there is a change in environment.


Channel 0 Thresholds

Filter Halt Timeout: 2500 (2500 ms)
Filter Halt Threshold: 10 (10 counts)
Filter Halt Debounce Enter: 2 (2 samples)
Filter Halt Debounce Exit: 1 (1 samples)
Activation Timeout: 5000 (5000 ms)
Activation Threshold: 670 (1,02235434 %)

Figure 5.6: Channel Threshold Settings

5.6.2 System Settings



Power Mode (PM): Auto Power Mode
Auto Prox Cycles: 8

☑ Event Mode ☐ Standalone Output Enable ☐ Watchdog Timer Enable

Watchdog Timer Buffer: 250

☐ PM Switch on Wear Gradient ☑ PM Switch on Channel Events ☐ Stay in NP when Events are set

Event Masks

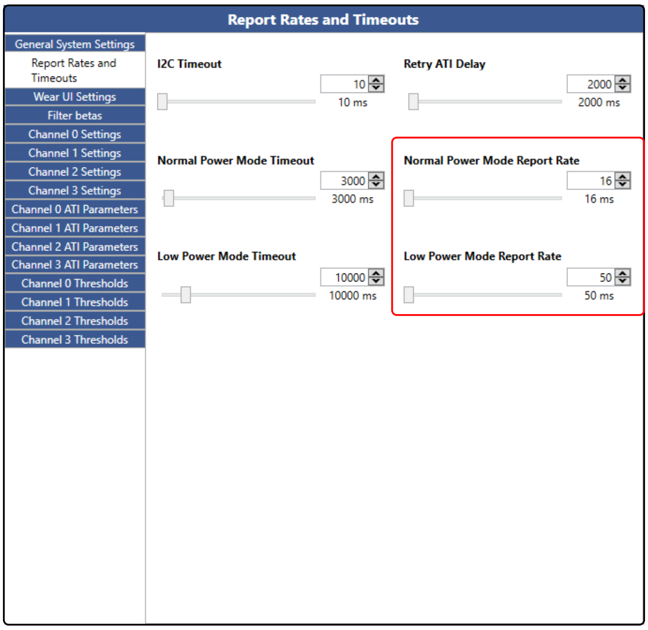
☐ ATI Event ☐ Power Mode Event ☐ Filter Halt Event ☐ CH Activation Event
☑ Wear UI Release ☑ Wear UI Wear ☑ Crosscheck Passed

Power Mode Switch Masks

☐ CH0 Filter Halt ☐ CH1 Filter Halt ☑ CH2 Filter Halt ☑ CH3 Filter Halt
☐ CH0 Activation ☐ CH1 Activation ☑ CH2 Activation ☑ CH3 Activation

Figure 5.7: General System Settings

Event Mode should be enabled to prevent the master MCU from being interrupted unnecessarily. Events that are unused should be selected. In this case the "ATI Event", "Power Mode Event", "Filter Halt Event" and "CH Activation Event" will generate a ready interrupt.



I2C Timeout: 10 (10 ms)
Retry ATI Delay: 2000 (2000 ms)
Normal Power Mode Timeout: 3000 (3000 ms)
Normal Power Mode Report Rate: 16 (16 ms)
Low Power Mode Timeout: 10000 (10000 ms)
Low Power Mode Report Rate: 50 (50 ms)

Figure 5.8: Report Rate and Timeout Settings

The report rate and power mode timeout should be adjusted to meet the response and current consumption specification. A lower report rate will result in higher current consumption and vice-versa.

5.6.3 Event Mode Communication

Firstly, configure which events should be generated in event mode. In this case, the channel activation event will generate an event only when a channel activation occurs due to proximity or touch. Data can be read when a communication window opens due to the event occurring.

Enable the Event Mode bit when the MCU has finished the I^{2}C initialisation process.

6 Design Verification

This chapter describes the general procedure that should be followed to validate whether a design meets the original requirements. This is done during the engineering stage. Using the numerous configurations available on the Azoteq device, small adjustments can be made to optimise and improve the performance to meet the requirements.

With the design verified, similar performance will be expected in mass production due to the on-chip calibration (ATI) technology, an individual verification of each of these items is not needed in mass production testing phase.

6.1 Test Setup

Design verification is done using the product GUI. Connect the power, I^{2}C and RDY lines of the IQS7223C to the CT210A USB dongle as shown in the table and figure below. Now connect the CT210A via an USB-micro cable to an available USB port on a PC.

Table 6.1: CT210A Pin-out

IQS Pins	CT210A Pins
GND	Pin 1
VDD	Pin 3
MCLR	Pin 5
SDA	Pin 7
SCL	Pin 9
RDY	Pin 10

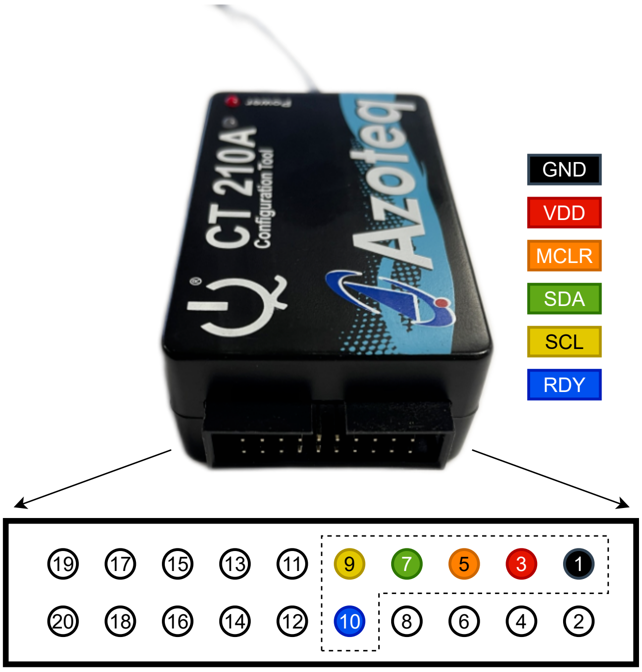


Figure 6.1: CT210A Power, I^{2}C And RDY Connections

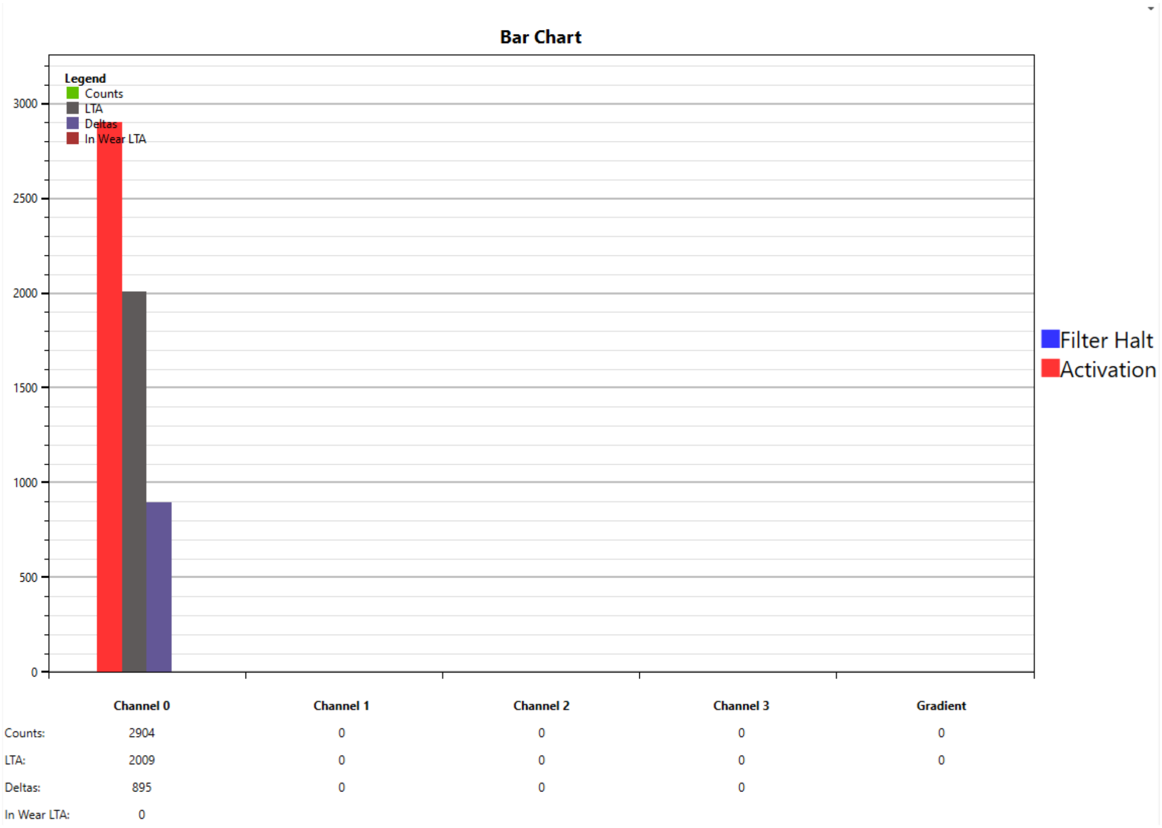
The typical procedure to evaluate a device is as follows:

- Open the device-specific GUI software
- start up the device by clicking the "START STREAMING" button
- Initiate the streaming of device data by clicking the "ACK RESET" button
- Load the application-specific configuration settings using the "IMPORT H FILE" button, or configure the device manually by pressing the "USER SETTINGS" button and using the various options available in the submenus
- Ensure that the ATI algorithm has executed correctly after the changes in the previous step have been applied
- View the channel or system response by means of the bar, scope or event indications
- Specific operating modes (such as low power sampling or event mode operation) can also be induced for example to measure currents or to monitor I^{2}C and RDY logic behaviour and event activities.

For further detailed information on the related device and/or GUI support please consult the necessary documents as listed in Chapter 4.

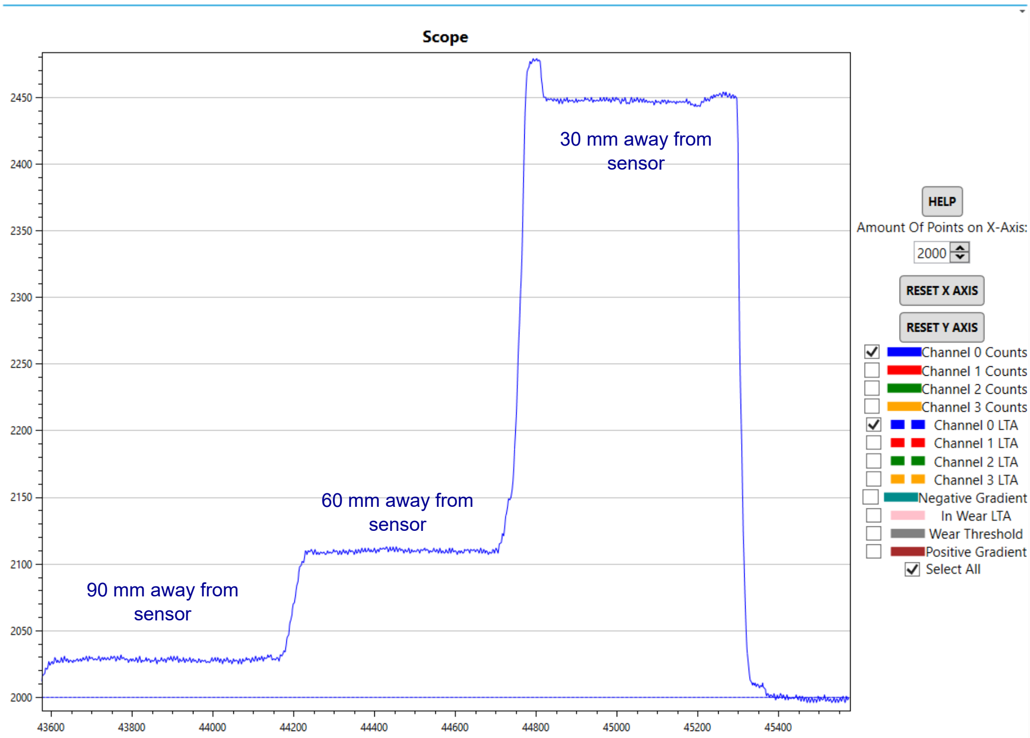
6.2 Response Output

Evaluating the response of a sensor in real-time is beneficial for rapid setup, tuning and prototyping.



	Channel 0	Channel 1	Channel 2	Channel 3	Gradient
Counts:	2904	0	0	0	0
LTA:	2009	0	0	0	0
Deltas:	895	0	0	0	
In Wear LTA:	0				

Figure 6.2: General GUI Bar Output For Count And LTA Data



Amount Of Points on X-Axis: 2000

☑ Channel 0 Counts
☐ Channel 1 Counts
☐ Channel 2 Counts
☐ Channel 3 Counts
☑ Channel 0 LTA
☐ Channel 1 LTA
☐ Channel 2 LTA
☐ Channel 3 LTA
☐ Negative Gradient
☐ In Wear LTA
☐ Wear Threshold
☐ Positive Gradient
☑ Select All

Figure 6.3: General GUI Scope Output For Count And LTA Data

This is a self-capacitive setup where the counts are linearised and an increase in capacitance results in an increase in counts (Unlinearised counts results in a decrease in counts when capacitance is increased).It should be noted that the outputs shown in figure 6.2 and 6.3 are the results while the system ground is referenced to earth ground (USB Powered). The test setup for measuring the proximity range can be seen in figure 6.4 below.

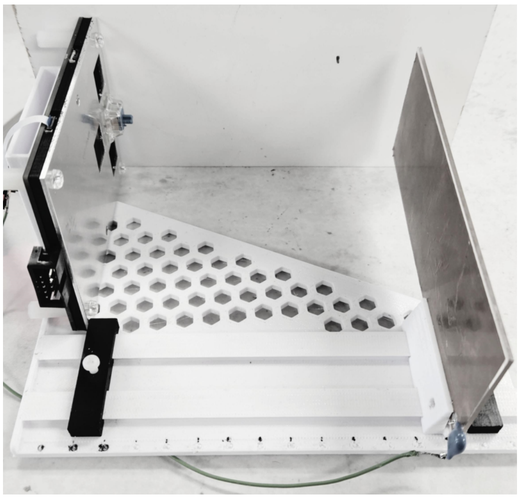


Figure 6.4: Proximity Range Test Setup

To thoroughly evaluate and analyze the response of the sensors, it is recommended to gather sample data through logging sessions. These sessions may involve extended activation periods, temperature or humidity variations, or other stimuli, depending on the specific use case or qualification being examined. To ensure a robust device, sample data should be collected where the keyboard is placed on different surfaces.

6.3 Proximity Verification

It is important to verify the sensing range of the keyboard proximity sensor by relating proximity distance to counts in the GUI. Activation thresholds can be set for a required sensing range.

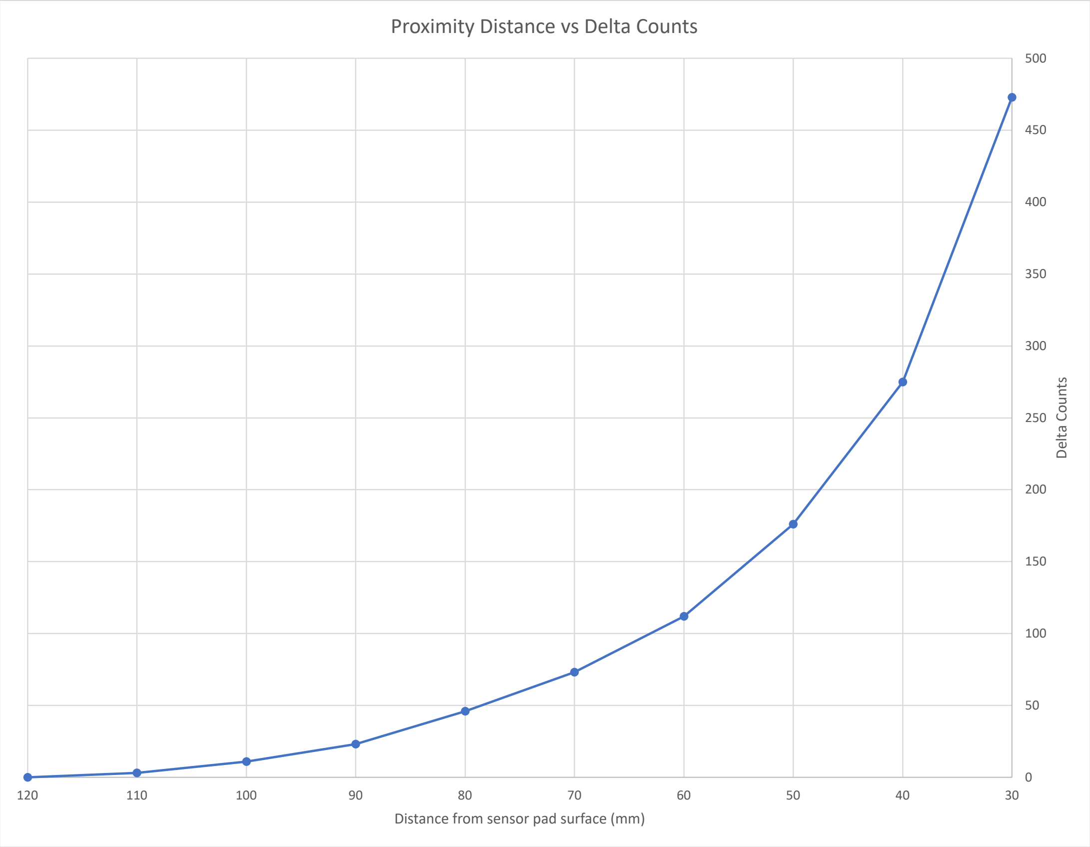


Figure 6.5: Proximity Distance vs Delta Counts (Grounded)

Figure 6.5 shows the delta counts vs range for a grounded self-capacitive sensor. An ATI base of 200 and target of 2000 was selected for this application to provide high sensitivity and thus a higher sensing range. The activation threshold should be higher than any noise experienced by the system to prevent any false triggers.

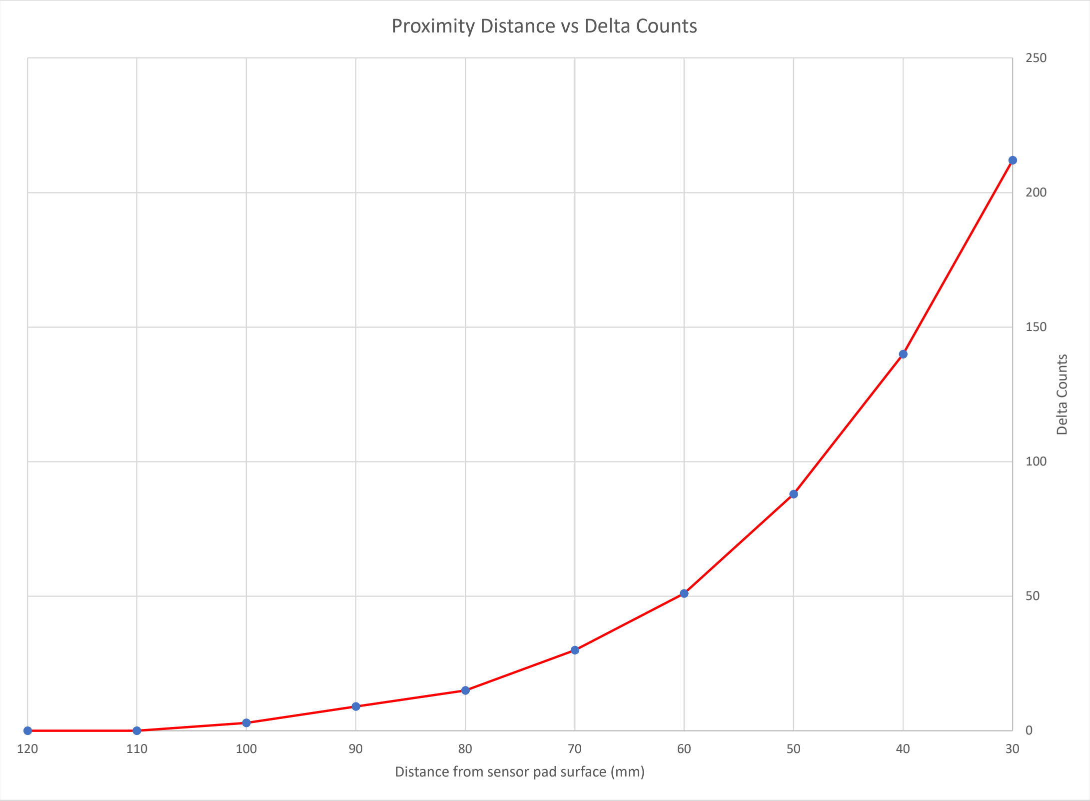


Figure 6.6: Proximity Distance vs Delta Counts (Isolated)

Figure 6.6 shows the delta counts vs range for an isolated system. The delta counts of the isolated system is lower than the ground referenced system, therefore it is imperative that verification be done in both an isolated and grounded system.

6.4 Noise Tests

Normal product noise variation should be evaluated over numerous pre-production units/builds before starting mass production testing in order to gain performance metrics and statistics for establishing the upcoming production limits. An applicable noise failure limit must be considered to reject excessively noisy sensors with presumable quality or assembly issues. Standardised noise tests (whether aimed at radiated and/or conducted noise) as well as other product performance qualifications governed by international standards, should be considered according to the specific underwriting by the IEC body or other known standard body which the product needs to comply with.

6.5 LED Backlighting

The effect of the LED PWM signals should be considered when verifying the proximity performance. It is recommended to evaluate the signal contribution from LED backlighting in order to pre-empt issues possible during production or pre-production. No false proximity activations should occur due to the toggling of the LED backlighting.

7 Interface Description

This chapter provides some high-level information that should be beneficial to a firmware developer who wants to write a driver for one of Azoteq's ICs in a keyboard proximity application. The chapter should be read in conjunction with the relevant device's datasheet.

7.1 Software Implementation

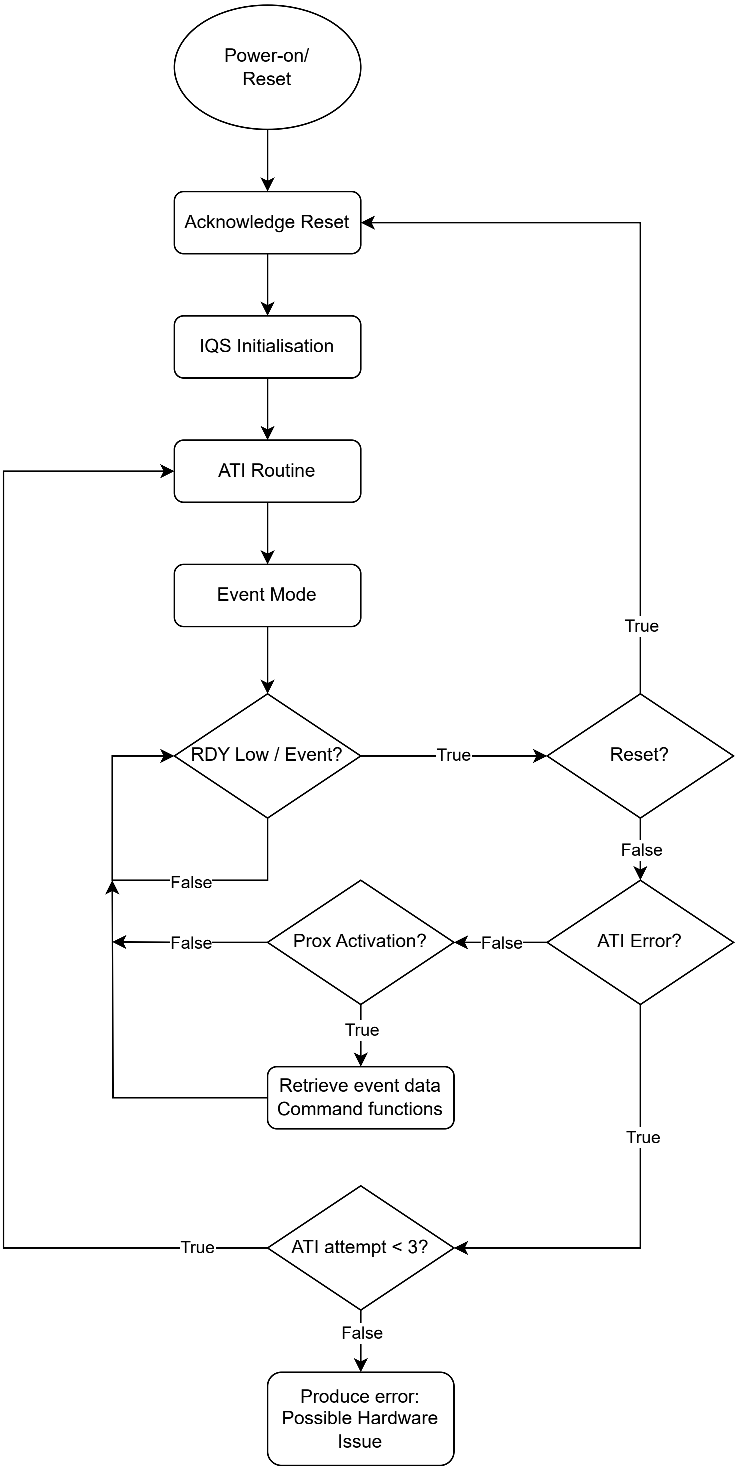


Figure 7.1: Software Flow Diagram

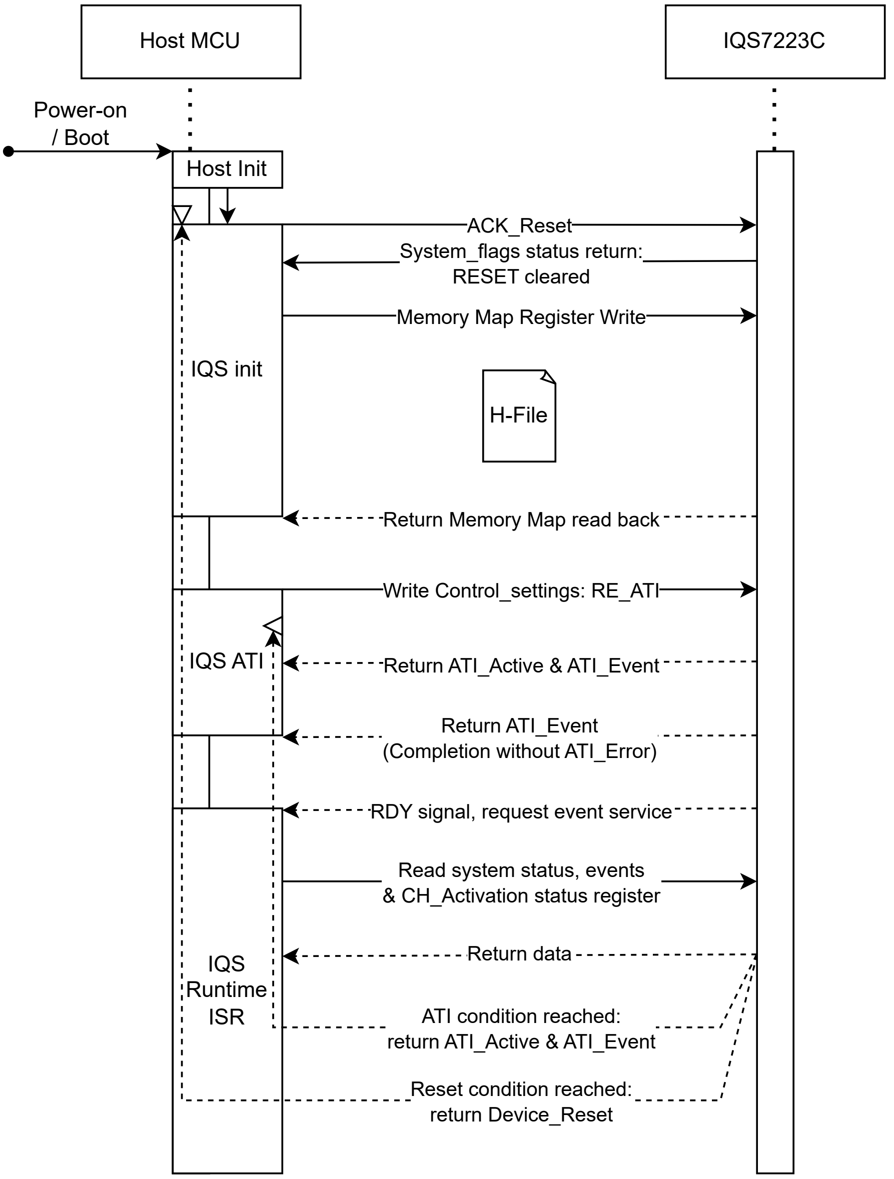


Figure 7.2: Host Software Sequence Diagram

Once the initialisation has been completed, the IQS7223C will notify the master of events by pulling the RDY line LOW. The master can then read the event flags and act accordingly.

7.1.1 Example Host Software Flow

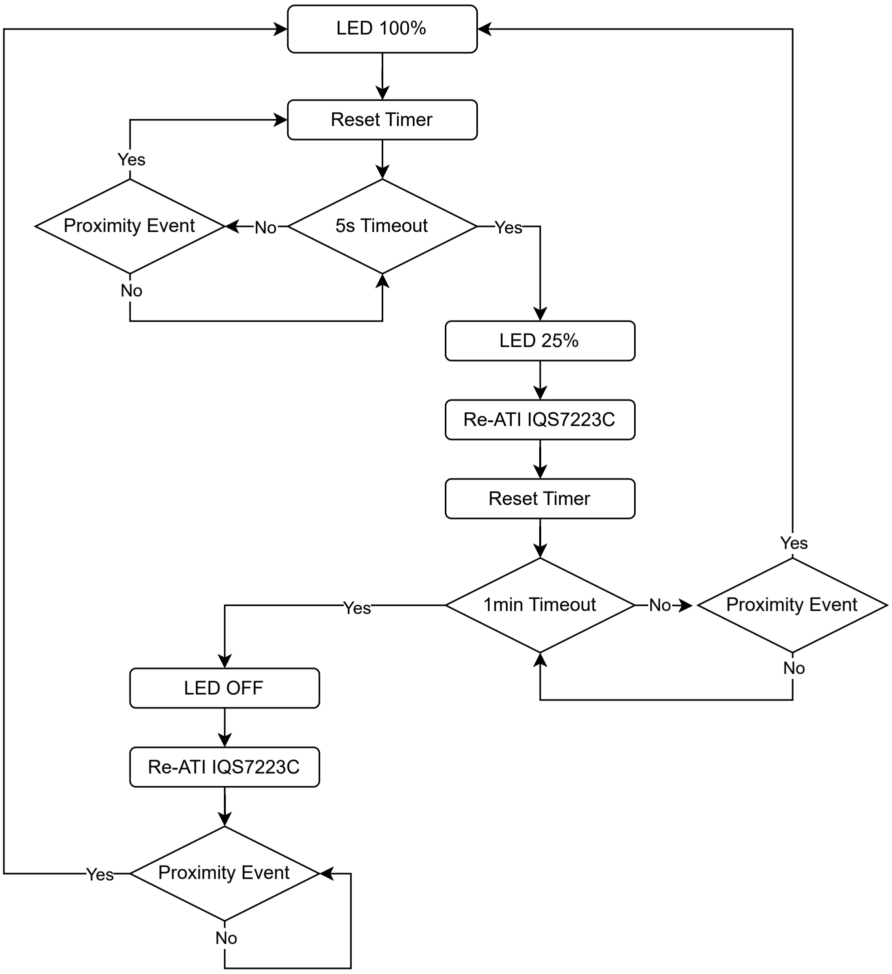


Figure 7.3: Example Host Software Flow

An example flow diagram of the LED backlighting behaviour can be seen in figure 7.3. At startup the LED backlighting would be fully turned on. After 5 seconds with no proximity activation, the LEDs would dim and the IQS7223C would recalibrate. Once the LEDs are dimmed and after 1 minute with no proximity activation, the LEDs would completely turn off and the IQS7223C would recalibrate. If a proximity event occurs at any point the LED backlighting would fully turn on again.

7.1.2 Communication Protocol

For examples of I^2C addressing, read, write, force communication requests and other communications related behaviour, please refer to the relevant device's datasheet I^2C interface section.

8 Mass Production Testing

This chapter provides information concerning testing during mass production.

8.1 In-circuit Testing (ICT)

PCBA testing should ideally be done with the product assembled to determine the effect of all auxillary functions such as the LED backlighting, bluetooth, etc. Ideally test should be done in the typical operating environment of the keyboard. The testing environment should be free of any users or objects that could interfere with the ATI calibration routine.

Testing of the proximity sensor can be done via the on-board MCU. The following test parameters should be considered:

- Version information
  - Check device product number
  - Check device major and minor firmware version info
  - Confirm device communication and clear/acknowledge (*ACK RESET*) flag
- Application settings
  - Written configuration settings can be read back
  - ATI specific parameters are distinct and updated
  - ATI completion reached on all channels without any *ATI error* reported
- Functional testing
  - Procedural exercise of all functionality when sensors are activated (can have a test routine implementation)
  - Induced user activation assessment (signal of known or controlled benchmark for sensitivity and reactivity qualification)
  - Raw signal noise assessment
- Current consumption
  - Average current measurement over long periods is constant for normal device operation
  - The integration time period should be long enough such that starting or ending the measurement midway through an active cycle/conversion does not have a large effect on the measured average current

Pre-production builds of increasing quantities are a general sound practise used to choose applicable tests, gathering test data and establishing limitations thereof. Statistical means, standard deviations and typical outlier criteria may be used to discover and inspect certain units in detail to institute a basis for known risks or critical design aspects which should be evaluated, addressed and improved upon during the preparation leading towards final or mass production.

Testing should also be done where a unit is only battery powered and isolated from earth, and the case where the unit is earthed (example via USB). This is to determine whether satisfactory performance is achieved with all methods of operation.

8.2 Response vs Current Consumption

There exists a trade-off between the responsiveness of a sensor and the average amount of current being consumed to reach a specific response or sampling rate. End-product or UX design may dictate the specification for responsiveness but this ultimately impacts the overall system current consumption. Current measurement during production testing should allow for typical normal power mode operation as well as slower low-power mode current measurements to ensure acceptable consumption requirements are met and guarantee the stability of a specific mode without irregular/erratic behaviour such as unexpected wake-up from low-power modes or excessive high currents (short-circuit assembly issues).

Standard SMT production line practises and guidelines should always be followed with respect to IC device and sub-assembly handling, manufacturing, storage and transport to ensure quality, high yield and reliability.

9 Revision History

Release	Date	Comments
v1.0	2023/07/27	Initial document released

A Bill of Materials

The following Table A.1 provides the bill of material detail for the schematic layout of Figure 5.2.

Table A.1: Bill Of materials

Comment	Description	Designator	Footprint	Manufacturer (P/N)
IQS7223C	IQS7223C-QFN-20N	U1	QFN–20	Azoteq (IQS7223CA001QFR)
100 pF	Capacitor, ceramic, C0G	C1, C3, C5	0603	KEMET (C0603C101J5GACTU)
100 nF	Capacitor, ceramic, X7R	C7	0603	Murata (GCJ188R71H104KA12D)
2.2 µF	Capacitor, ceramic, X5R	C2, C4	0603	TDK (C1608X5R1E225K080AB)
4.7 µF	Capacitor, ceramic, X5R	C6	0603	TDK (C1608X5R1E475K080AC)
4.7k	Resistor, 4700 Ω, 1%, 0.1W	R1, R2, R3	0603	ROHM (SFR03EZPF4701)
470R	Resistor, 470 Ω, 1%, 0.1W	R4, R6, R7	0603	ROHM (SFR03EZPF4700)
DNP	Resistor, DNP	R5, R8	0603	
DNP	Capacitor, DNP	C8, C9, C10, C11, C12	0603	
P1	Pogo Pin	P1	Special	Mill-Max Manufacturing Corp (0906-0-15-20-76-14-11-0)
TP1, -2, -3, -4, -5, -6	Test points	1, 2, 3, 4, 5, 6	⌀1.5 mm Exposed Copper Pad	PCB

B Mechanical Design

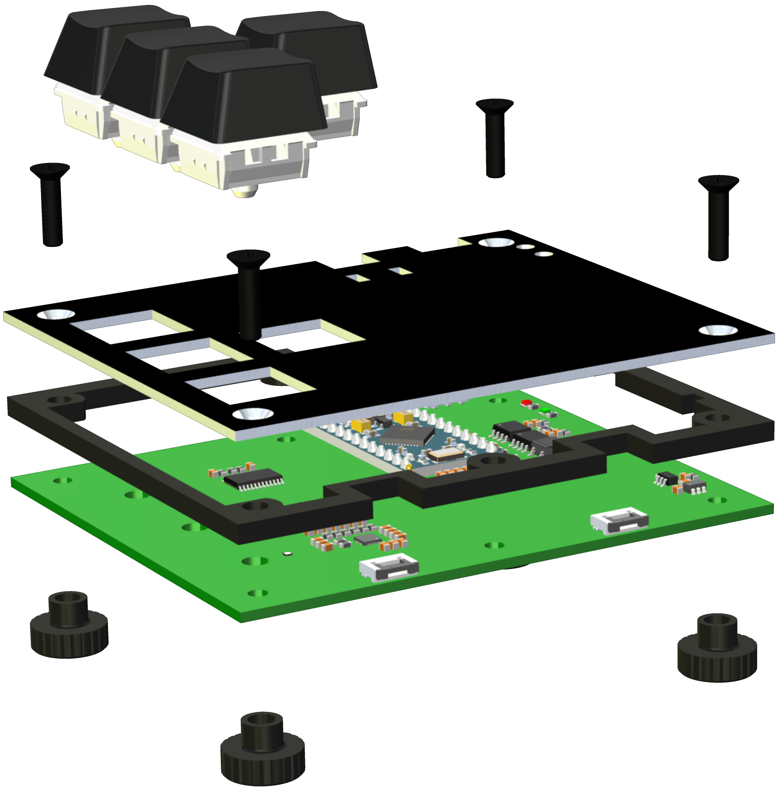


Figure B.1: Proximity Keyboard Exploded Assembly

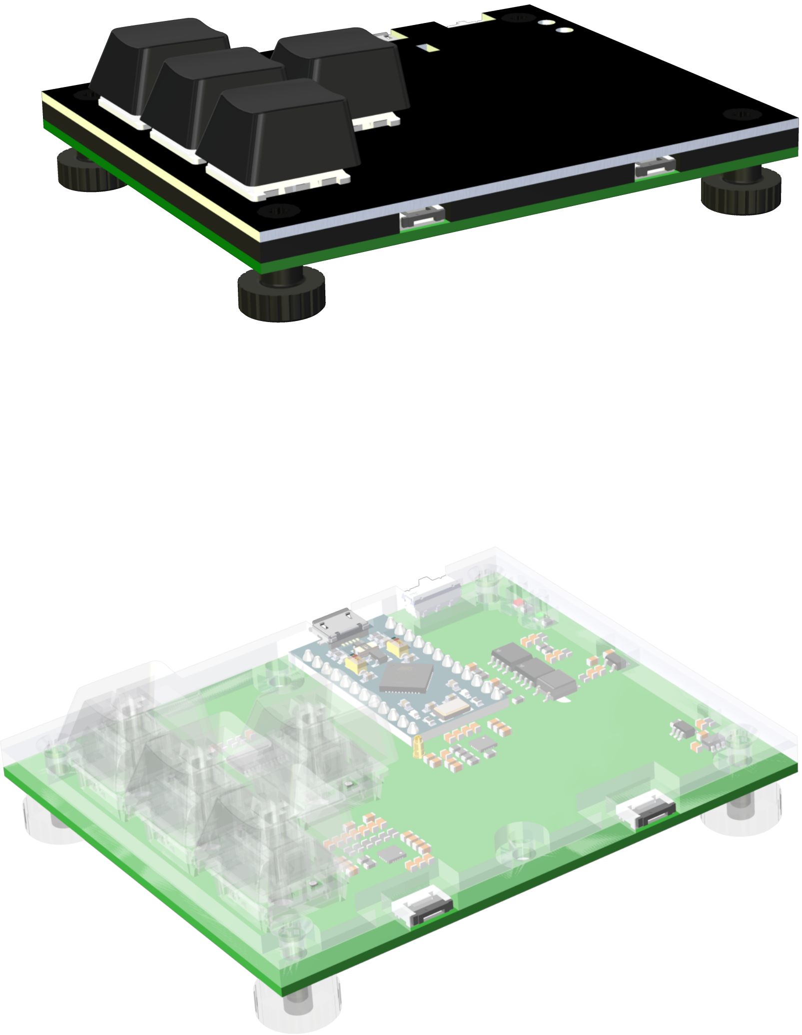


Figure B.2: Proximity Keyboard Final Assembly

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