AZD135 - Headphone Wear Detect Design Guide

Design Guide for On-Ear and Over-Ear Headphone Wear Detection

Contents

1 Introduction

This document aims to give a step-by-step guide on how to design capacitive sensors for on-ear and over-ear wear detection applications. The Azoteq technology used for this application provides an intuitive, low-power detection solution. A summary of the design process is shown in Figure 1.1.

Figure 1.1: Design Process Summary

This design guideline helps designers integrate ProxSense® technology into new and existing designs. The guideline will also give general recommendations for a quick-start design for detecting wear in both on-ear and over-ear configurations. Please note that this document should only *guide* the product designer towards a final solution, i.e. designs discussed in this document should not be scaled directly to suit your application, and all product-specific considerations should be kept in mind. The given guidelines are for designs that specifically employ self-capacitive sensing. For a more in-depth explanation of capacitive sensing, refer to AZD004.

The document is structured as follows: Chapter 2 outlines the design specifications for on-ear and over-ear wear detection. Chapter 3 describes the capacitive proximity solution offered by Azoteq. Chapter 4 provides various resources to aid in the design of wear detection solutions. Chapter 5 demonstrates an example design of an on-ear and over-ear wear detection solution utilizing the IQS323. Chapter 6 provides a process for validating the sensor design to ensure the requirements are met. Chapter 7 describes the interface between the microcontroller (MCU) and the sensor. Chapter 8 discusses important considerations for moving the wear detection solution into production.

2 Design Specification / Product Requirements

This chapter outlines the key specifications for the on-ear and over-ear wear detection sensors that need to be considered during the design process.

2.1 Mechanical Specification

In on-ear and over-ear headphone designs, the driver (also known as the speaker or transducer) is specifically engineered to align with the user's ear. It's only natural to leverage this existing mechanical design when incorporating a wear detection electrode. The driver is typically enclosed in a perforated plastic housing to allow sound transmission. This housing is often cushioned and enveloped with fabric for comfort and aesthetics. Consequently, this plastic enclosure emerges as the prime location for the electrode.

Considering the typical diameters of on-ear and over-ear drivers, which range from 30 mm – 40 mm, the wear-detection electrode should cover at least 30% of the driver's surface area.

2.2 Electrical Interface Specification

The electrical and interface design specifications for the wear detection sensor system are listed in Table 2.1 below.

Table 2.1: Electrical Specifications

Specification	Requirement
Supply Voltage (V_{DD})	1.8 V – 3.3 V
Internal Regulation (V_{REG})	Digital and analogue domains (requires external decoupling capacitors).
Communication Interface	I^2C (SCL & SDA) + interrupt or 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 3 outputs with custom configurable logic and output assignment.
ESD protection	HBM up to class 3 A and B, or IEC 61000-4-2 standard level 4 (contact and air) discharge. System-level qualification of the 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 or floods for safe discharge. For extreme measures, incorporate the use of TVS diodes to clamp nodes when and where necessary.
Radiated noise immunity	IEC 61000-4-3 standard test levels 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 that are sufficiently stitched and commonly connected in a system are crucial for improved radiated immunity.
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 wear detection applications is 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 Table 2.2 below.

Table 2.2: Operational Environment Specifications

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

2.4 Sensing Range

In wear detection systems for on-ear and over-ear headphones, where the electrode is aligned with the driver, user proximity and considerations regarding air gaps are essential to ensure accurate sensing. Factors such as electrode positioning, the thickness of the electrode overlay, and the choice and arrangement of foam or fabric can impact the system's efficacy. Typically, a sensing range of 15 mm – 25 mm is required from the electrode to the user.

2.5 Report Rate and Wake-up Response Time

Table 2.3 shows the typical requirements for the required report rates and timing settings during operation. In wear detection applications, the system is designed to accommodate prolonged periods of either activation or deactivation. Intuitive release algorithms manage the transition from activation back to deactivation.

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	0 ms (Never)

2.6 Communication Interface

For I^{2}C solutions, "Event Mode" may be used to prompt an interrupt (through the RDY line) to the master solely when an event, such as a wear state change, is detected. This approach conserves power and reduces MCU processing demands.

In a standalone configuration, a GPIO level can be used to indicate the activation or wear detection state.

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 sensor system.

[i] A higher report rate can be set to achieve better responsiveness at the cost of increased current consumption.

3 Proposed Solution

This chapter provides a high-level overview of Azoteq's on-ear and over-ear wear detection solutions, including a brief overview of different sensing methods, a system diagram, a mechanical stack-up, and a list of recommended Azoteq part numbers.

Wear detection products are inherently consistent across applications, as they all interface with the user's ear. While the detection distance might vary due to specific design nuances, the proposed solution is versatile and can be easily adapted for different scenarios. Figures 3.1a and 3.1b, respectively, show generic representations of the on-ear and over-ear headphone configurations.

(a) On-Ear Headphone Representation

(b) Over-Ear Headphone Representation

Figure 3.1: Typical Headphone Representations

3.1 Sensing Methods

A self-capacitive sensing electrode pattern paired with a self-capacitive reference pattern is advised. While projected capacitive designs are an alternative, they are best suited for designs where conductors are in close proximity to the electrode, such that excessive parasitic capacitance is formed. Additionally, mutual capacitance may only be considered where sufficient electrode area is available, which is rarely the case for headphones. Therefore, self-capacitance remains the preferred approach.

3.2 System Description

Typically, the system consists of three main entities:

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

Figure 3.2 provides a system block diagram of a generic I^2C on-ear and over-ear implementation with wear detection. It shows that the user can interact with multiple sensor elements, including a slider, an inductive force sensor, a wear detection sensor, and a touch button. These are part of the sensor solution controlled by the IQS IC. The IQS IC device can intelligently interrupt the Host MCU with relevant sensor events, thereby reducing communication frequency, host processing load, and, most importantly, system power consumption.

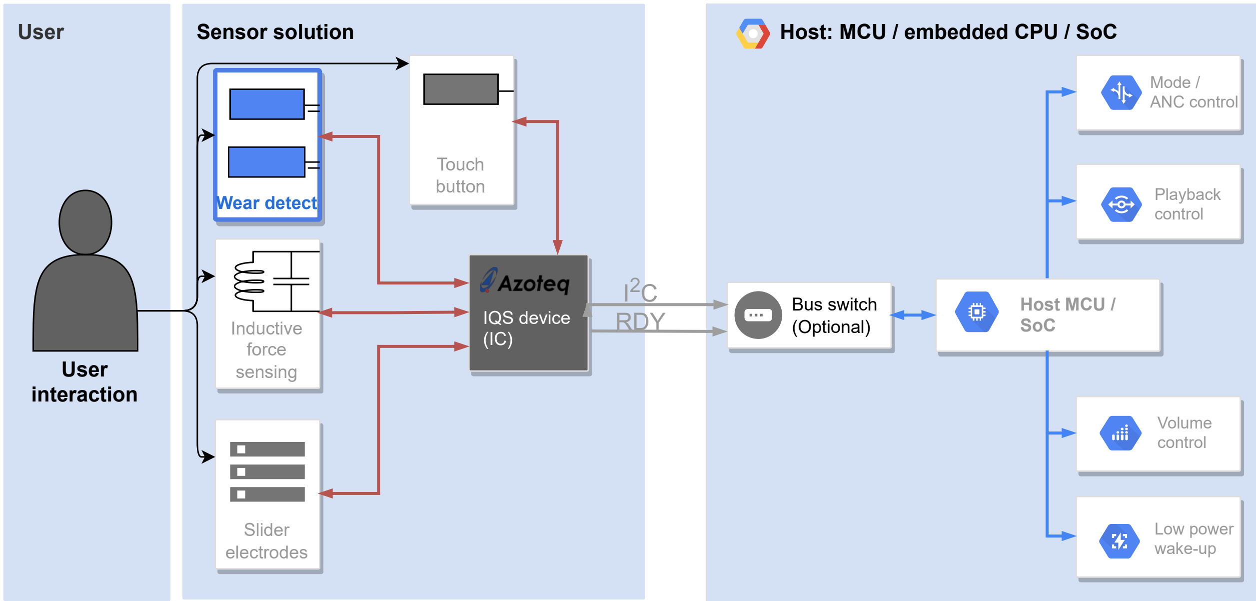

Figure 3.2: System Block Diagram of a Wear Detection Solution in Headphones

3.3 Mechanical Stackup

3.3.1 On-Ear Headphones

The inherent mechanical design of on-ear headphones, as shown in Figure 3.3 below, provides an optimal setup for incorporating wear detection. The driver, also known as the speaker, is nestled within an acoustically ventilated plastic enclosure, cushioned, and enveloped in fabric. For the best wear detection results, it's recommended to position the sensor directly on the speaker grille. This strategic placement efficiently senses ear presence and significantly reduces interference from users gripping the headphones.

To enhance audio quality, it's essential to incorporate a considerable amount of printed circuit board (PCB) or flexible printed circuit (FPC) cut-outs in the design, which can ideally mirror the speaker grille's outline. The IQS IC, which processes sensor data, should be situated close to the sensing pattern to optimise performance. If the IQS IC is on the main PCB and not the sensing board, it's vital to use a shielded cable or twisted pair for the sensor line connection, ensuring minimal interference.

3.3.2 Over-Ear Headphones

For over-ear headphones that have a reasonable amount of speaker grille cut-outs, the same procedure as stipulated in Section 3.3.1, can be applied. Typically, over-ear headphones do not have a grille that can accommodate an electrode. In this case, a ring-shape electrode is fitted around the speaker grille, as shown in Figure 3.4. It is still important to place the IQS IC on or near the electrode PCB to minimise interference and parasitic capacitance.

Figure 3.3: Typical On-Ear Assembly

Figure 3.4: Typical Over-Ear Assembly

3.4 Azoteq Device Selection Guide

The following listed devices are Azoteq's recommended on-ear and over-ear wear detection solutions. For more detail on these devices, please refer to its datasheet.

- IQS7222C (WLCSP18 / QFN20)
  - Up to 4 self-capacitive channels
  - Up to 4 mutual capacitive channels
  - Arduino Example code available
  - Recommended for applications requiring various sensors in addition to wear detection, for example sliders or force sensing.
- IQS323 (WLCSP11 / DFN12)
  - Multi-channel self-capacitive sensor ability
  - Built-in signal processing options:
    - Standalone proximity output
    - Movement user interface
    - Release user interface
  - Arduino Example code available
  - Recommended for applications that only requires wear detection, with a full suite of wear algorithms.
- IQS318 (WLCSP11 / DFN12)
  - Single channel self-capacitive sensor
  - Built-in signal processing options:
    - Standalone proximity output
    - Release user interface
  - Recommended for applications that require a budget friendly, basic wear detection solution.
- IQS7223C (WLCSP18 / QFN20)
  - Up to 4 self-capacitive channels
  - Up to 4 mutual capacitive channels
  - Can perform differential capacitance measurement
  - Arduino Example code available
  - Recommended for wear detection solutions requiring multiple electrodes and maximum flexibility on wear detection algorithms to accommodate challenging sensing scenarios.

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 IC Device Datasheets
- Application Notes:
  - AZD004 - Azoteq Sensing overview
  - AZD044 - Azoteq MSL and Reflow specifications
  - AZD125 - Capacitive sensing design guide
  - AZD102 - Series resistance limit of self capacitance charge transfers

4.2 Hardware Design Resources

- IQS7222CzzzQNR [QFN20] SCH symbol and PCB footprint
- IQS7222CzzzCSR [WLCSP18] SCH symbol and PCB footprint
- IQS323zzzDNR [DFN12] SCH symbol and PCB footprint
- IQS323zzzCSR [WLCSP11] SCH symbol and PCB footprint
- IQS318zzzCSR [WLCSP11] SCH symbol and PCB footprint
- IQS7223CzzzQNR [QFN20] SCH symbol and PCB footprint
- IQS7223CzzzCSR [WLCSP18] SCH symbol and PCB footprint

4.3 Software, Tools and Example Code

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

5 Design Implementation

This chapter describes the design implementation of wear detection in an on-ear and over-ear headphone configuration.

5.1 Sensor Design

5.1.1 On-Ear Electrodes

Given the inherent need for cut-outs in the sensor electrode to meet acoustical requirements, it's vital to ensure they maintain comprehensive sensor coverage and robust signal amplitude. Bearing this in mind, utilising a self-capacitance sensor with a copper pour can yield an optimal layout within the available real estate. While a thin FR4 substrate is recommended, FPC alternatives can also be effective.

Implementing a wear reference enhances the effectiveness of counteracting capacitance drift, which can arise from material variations and environmental factors such as temperature and humidity. For more detailed guidance on implementing a wear reference, refer to Section 7 of AZD125.

For the most effective signal-to-drift ratio, especially in long-term wear applications, the recommended placement of the IQS IC is directly on the sensor pad. Conversely, positioning the sensor IQS IC on the primary PCB can yield adequate results, provided the distance remains minimal and there's effective management of the GND shielding capacitance drift. For instance, when the sensor and reference traces run adjacent but in separate time slots, they can function as a GND shield for one another. In such configurations, the use of a twisted or shielded wire pair is advocated. It's imperative to mitigate any mechanical impacts on this wire to avert inadvertent capacitive shifts during regular usage.

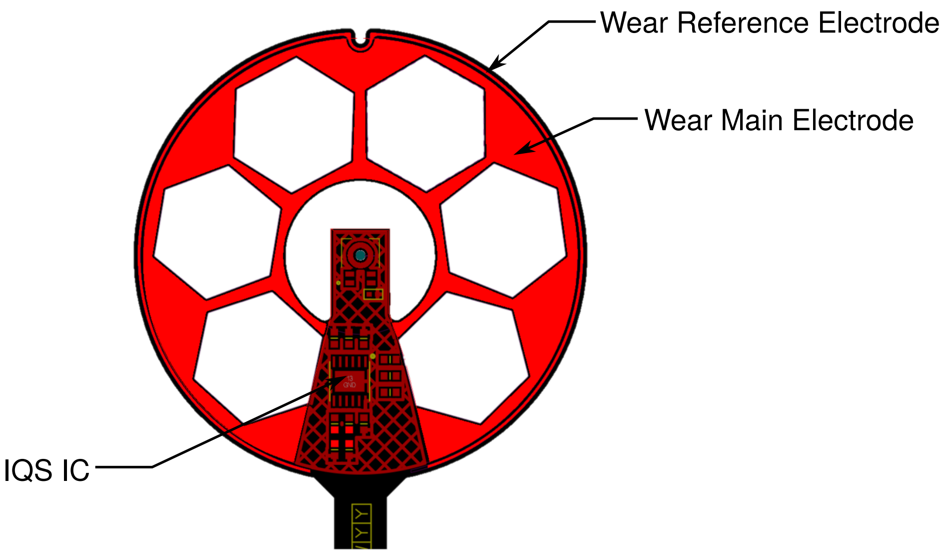

Figure 5.1: On-Ear Wear Detection Electrode Design

In the previous sections, it was established that the wear detection electrode for an on-ear headphone design typically aligns with the outline of the speaker grille. This principle is evident in the design depicted in Figure 5.1 above, where the FPC not only mirrors this outline but also houses the noise-cancelling microphone and speaker terminals. The main wear detection electrode is highlighted in the figure. Additionally, the thin reference channel encircling the outline is also emphasised.

5.1.2 Over-Ear Electrodes

If it is feasible to use the speaker grille as the base platform for an electrode PCB, then the principles of Section 5.1.1 can be followed. If not, a ring-shaped (wear detection) electrode is fitted around the speaker grille; see Figure 5.2 below. The electrode also has a solid section and a reference strip to track the environment.

Recommended electrode width (OD-ID = 6.5 mm minimum). FR4 substrate is preferred, as it is less susceptible to environmental changes. No GND pour must be placed on the bottom layer of the electrode PCB. Similar to on-ear, it is important to place IQS IC nearby.

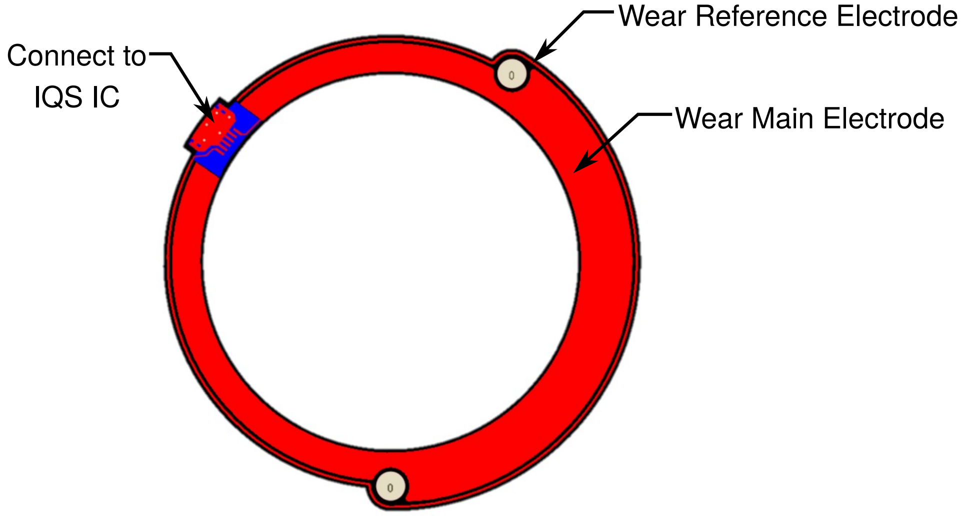

Figure 5.2: Over-Ear Wear Detection Electrode Design

5.2 Circuit Design

A circuit was designed with the IQS323 (DFN12 package), and a simplified schematic diagram is shown in Figure 5.3 below. Note that CRX0 is the sensor trace, and CRX1 is the reference trace.

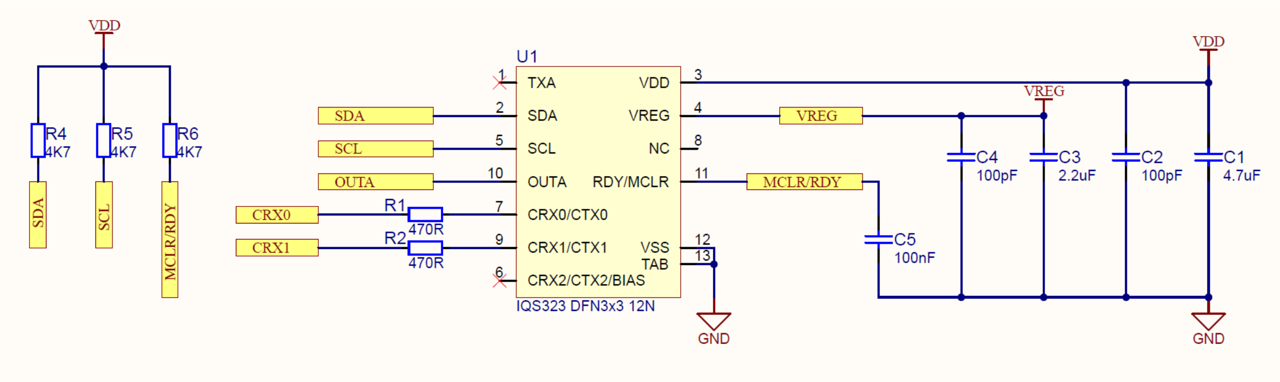

Figure 5.3: Simplified Schematic Design for Wear Detection Solution[i]

5.2.1 Power Supply Decoupling and Regulation

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

5.2.2 Capacitive Sensor Nodes

All the self-capacitive sensor inputs (CRX) must be used with external series resistors to increase radiated immunity (please refer to AZD125 for fundamental design discussions; AZD015 for considerations of radiated or RF immunity; and AZD102 on using resistive paths higher than the recommended). A TVS diode is recommended for applications where the electrode is prone to stray, induced voltage spikes.

5.2.3 Routing

Digital signals such as pulse width modulation (PWM) signals, I^2C signals, or serial peripheral interface (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

Test points are essential for efficient design development, debugging, and validation. They're recommended when they can be situated on an FPC tail or when the sensor PCB components occupy minimal space. When the sensor IQS IC is placed on the main board, adding test points nearby for power and communication simplifies troubleshooting during production.

[i] Although this design makes use of the IQS323, the IQS318 can also be used as they are pin compatible. The IQS7222C can additionally be used in a similar schematic configuration.

5.3 IQS IC Setup

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

An introduction on how to use Azoteq's debug and display tools 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. The settings below are shown on the GUI for the IQS323, however these concepts also apply to the IQS318, IQS7222C, and IQS7223C.

5.3.1 Channel Settings

Channel sensor settings can be seen in Figure 5.4 below.

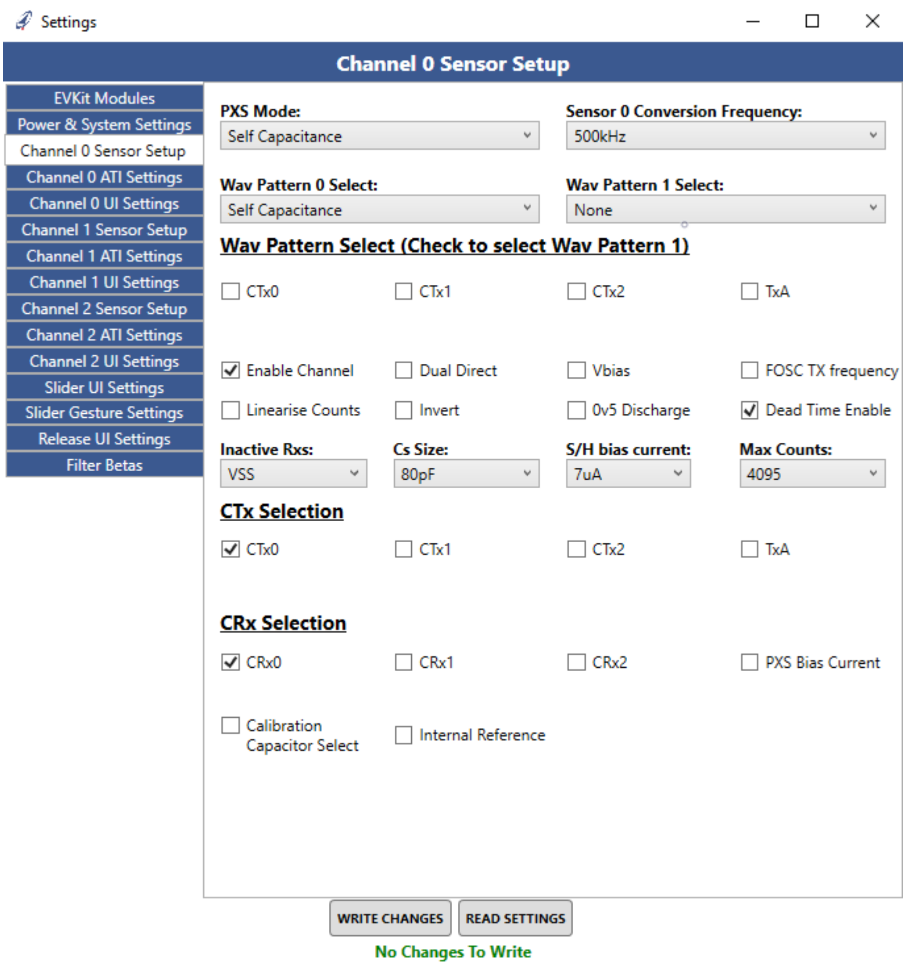

Figure 5.4: Channel Sensor Setup

The selection of CTx and CRx can be altered to designate the sensor Cx pin for the desired channel, providing more flexibility in the PCB layout by enabling the choice of alternative pins if necessary. It's important to note that for self-capacitance applications, like the one discussed in this design guide, it is imperative to select both the CTx and CRx pins.

Channel UI settings can be seen in Figure 5.5 below. Here, the channel activation thresholds can be adjusted.

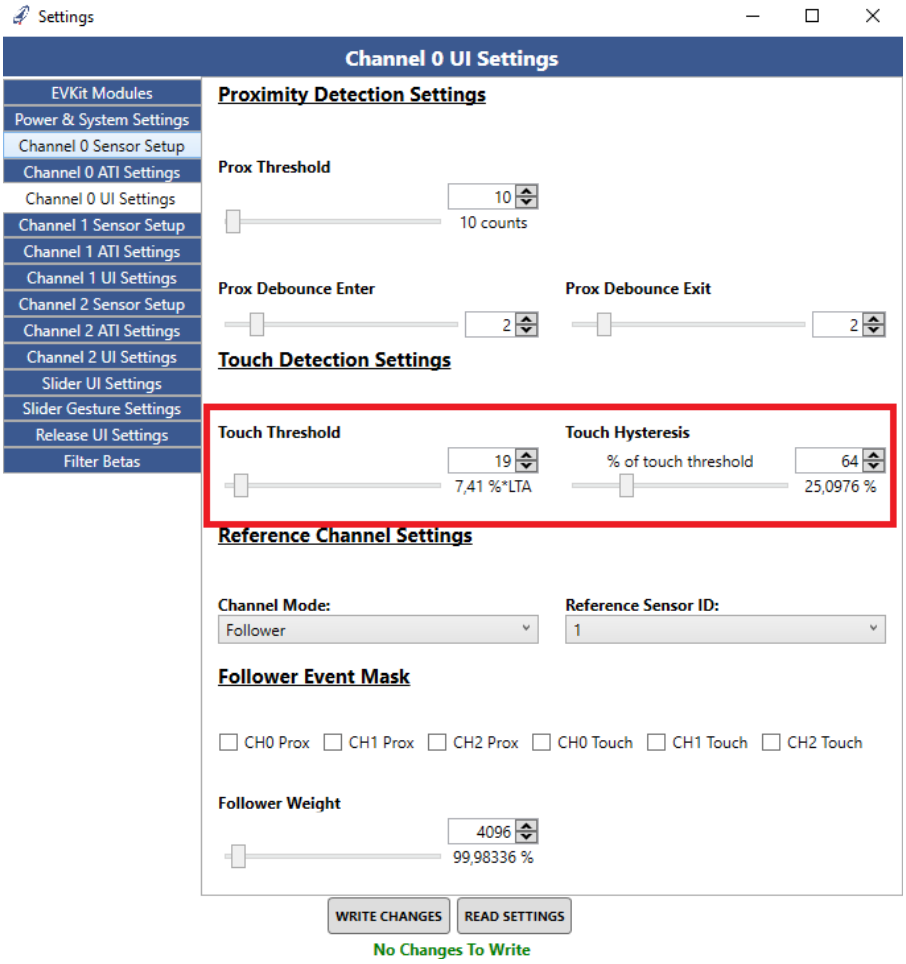

Figure 5.5: Channel UI Settings

5.3.2 System Settings

Power and system settings can be seen in Figure 5.6 below. Here, power mode timeouts, report rates, and event settings can be configured.

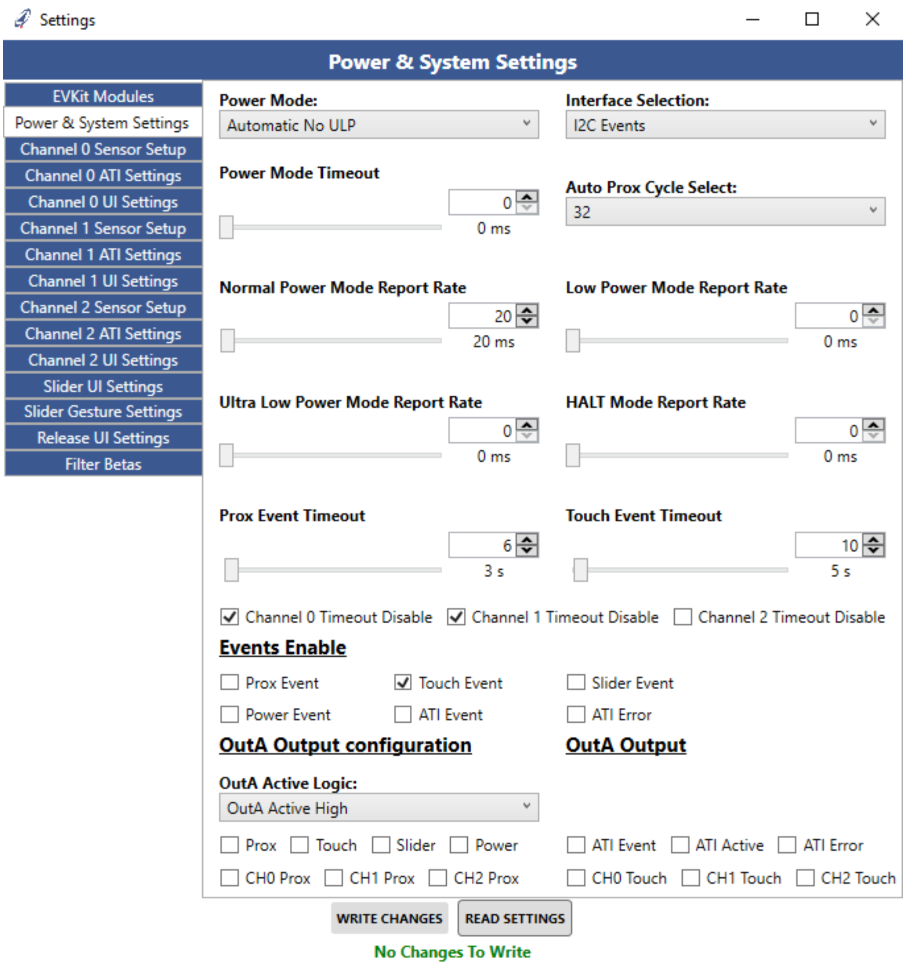

Figure 5.6: Power and System Settings

Event Mode should be enabled to prevent the master MCU from being interrupted unnecessarily. The Event Mode bit must only be set, after the MCU has finished the I^{2}C initialisation process.

Firstly, configure which events should be generated in event mode. In this case, an event will be registered when an IQS IC detects a touch. When an event occurs, the communications window will be opened for the MCU to retrieve the necessary data from the IQS IC.

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

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. Individual verification of each of these items may not be necessary in the mass production testing phase, but it is preferred by some to ensure that the wear function has in fact been correctly calibrated by the on-chip ATI routine.

6.1 Test Setup

Design verification is done using the product GUI. Connect the power, I^{2}C, and RDY lines of the relevant IQS IC to the CT210A USB dongle, as shown in the Table 6.1 and Figure 6.1 below. Then, connect the CT210A via a micro-USB cable to an available USB port on a Windows PC.

Table 6.1: CT210A Pinout

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

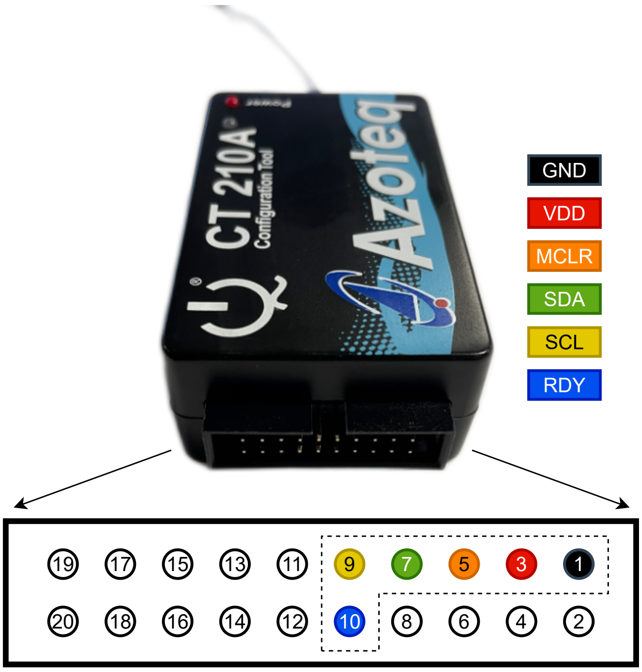

Figure 6.1: CT210A Power, I^{2}C and RDY Connections

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 sub-menus.
- 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^2C and RDY logic behaviour and event activities.

For further detailed information on the related device and/or GUI support, please consult the necessary documents 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.

For the IQS318, the wear and release signals are obtained through a single channel. On the IQS323, IQS7222C, and IQS7223C, separate channels may be used for wear detection and wear release. The example in this section is based on the latter.

Depicted in Figures 6.2 and 6.3 below is the response output of a typical wear detection configuration where CH0 acts as the wear activation channel, CH1 acts as the reference channel for CH0, and CH2 acts as the wear release channel.

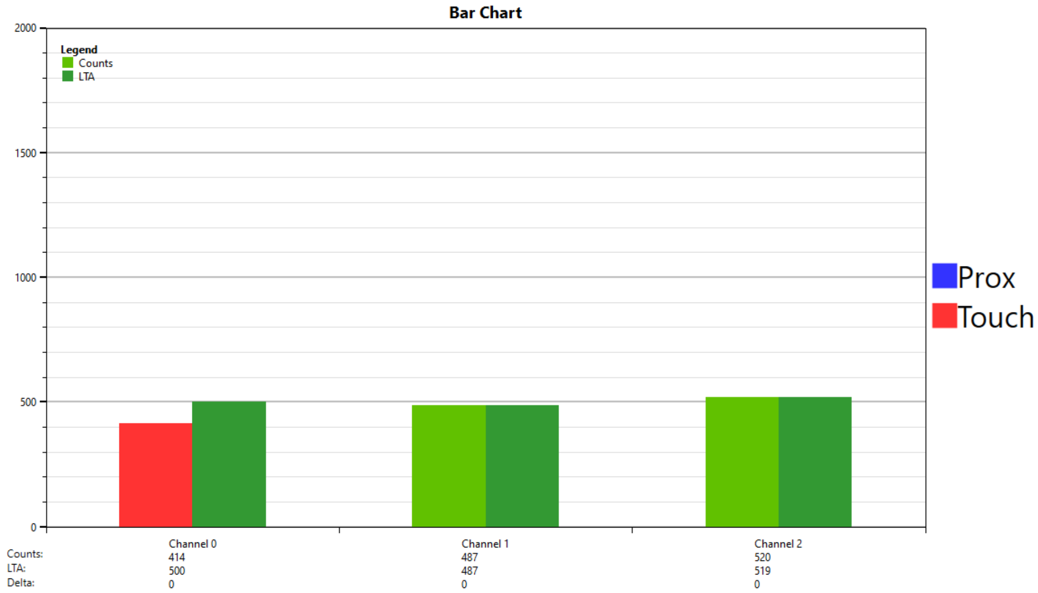

Figure 6.2: GUI Bar Output for Count and LTA Data While Activated in Wear

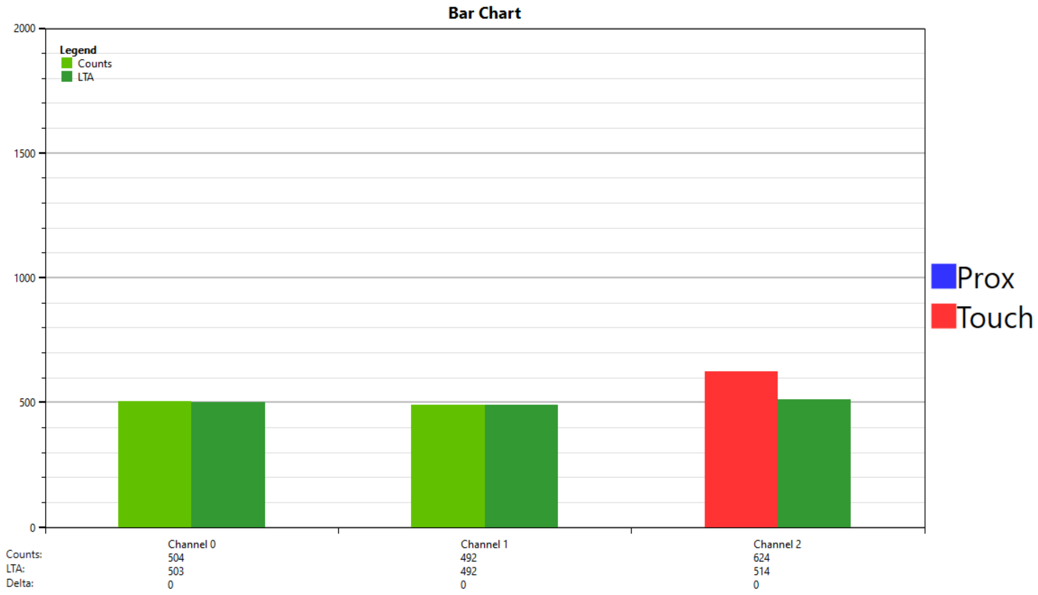

Figure 6.3: GUI Bar Output for Count and LTA Data When Indicating a Release Event

Figure 6.4 shows the scope view of the events illustrated in Figures 6.2 and 6.3. The wear state started at approximately sample 14950, and a release event occurred at sample 15350.

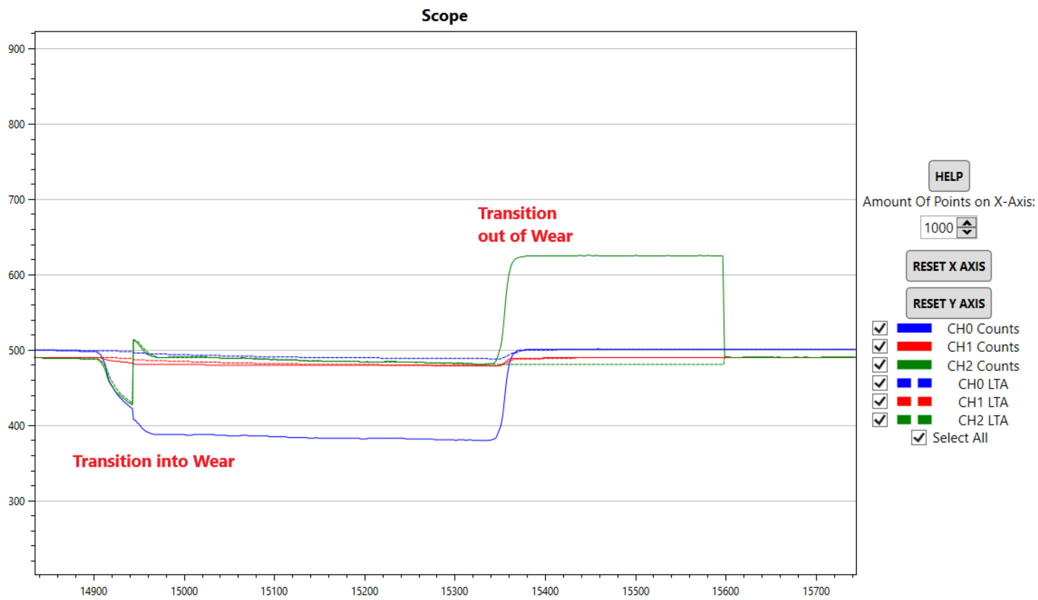

Figure 6.4: General GUI Scope Output for Count and LTA Data

In addition, the following scope view depicted in Figure 6.5 shows what happens if an electrode is powered up while in wear and then released. The value of CH2, specifically detecting a release, is shown here.

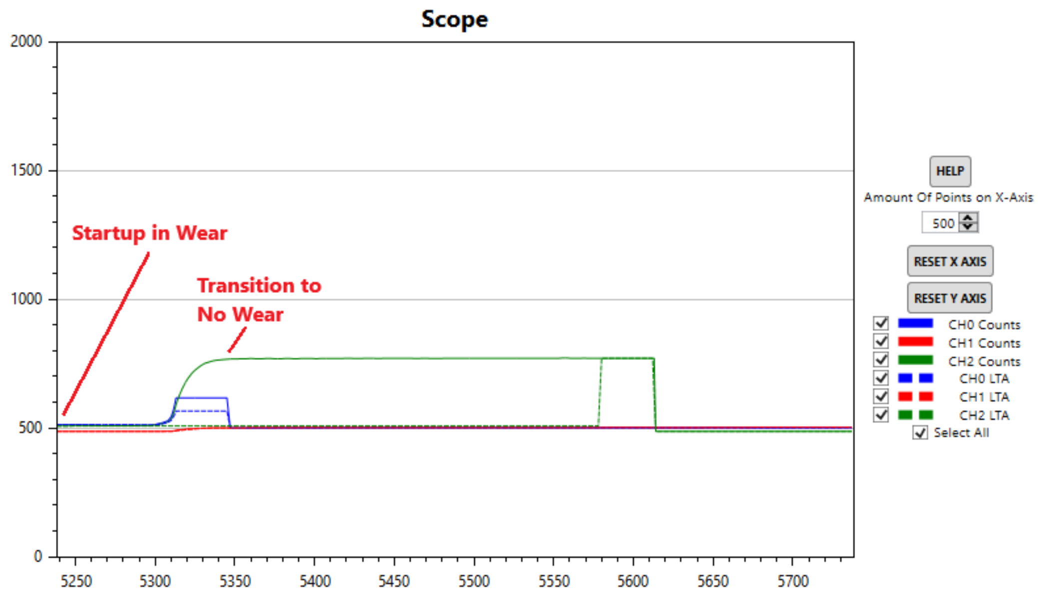

Figure 6.5: General GUI Scope Output for Count and LTA Data

This is a self-capacitive setup where the counts are not linearised and an increase in capacitance results in a decrease in counts. While still not linearised, the output of CH2 is inverted, which provides a wear release indication. This is especially useful if the device was powered on while being worn. To save power, CH2 can be disabled after the first release event after power-on.

The outputs shown in Figures 6.2, 6.3, and 6.4 are the results for a device that is connected via USB power, thus having a good ground reference. For battery-powered applications, the wear detection signal is expected to be weaker. This should be accounted for when configuration the IQS IC during the setup phase. The test setup can be seen in Figures 6.6 and 6.7 below. Figure 6.7 can also be used for the over-ear headphone test setup.

Figure 6.6: Proximity Range Test Setup

Figure 6.7: Proximity Range Test Setup

To evaluate and analyse the response of the sensors thoroughly, it is recommended to log sample data in various conditions. These conditions may involve extended activation periods, temperature or humidity variations, or other stimuli. These testing conditions depend on the specific use case or required qualification. To ensure a robust device, the headphones should be tested by multiple users with varying head sizes, ear sizes, and hair lengths.

6.3 Temperature and Humidity Tests

A temperature- and humidity-controlled environmental chamber can be used to validate sensor reliability and performance within product operating specifications. However, this may not emulate the true environment for typical real-life product use scenarios and dynamic combinations thereof. Some challenges typically experienced include inducing wear-versus-out-of-wear state changes, body heat influence, and other system operational influences. Practical use of the on-ear and over-ear headphone products in different environments should form part of the functional testing during design validation.

6.4 Noise Tests

Normal product noise variation should be evaluated over numerous pre-production units or 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 presumed 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 that the product needs to comply with.

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 IQS IC's in a wear detection application. The chapter should be read in conjunction with the relevant device's datasheet.

7.1 Software Implementation

Figure 7.1 below represents a flow diagram that describes the general operation of any given IQS IC.

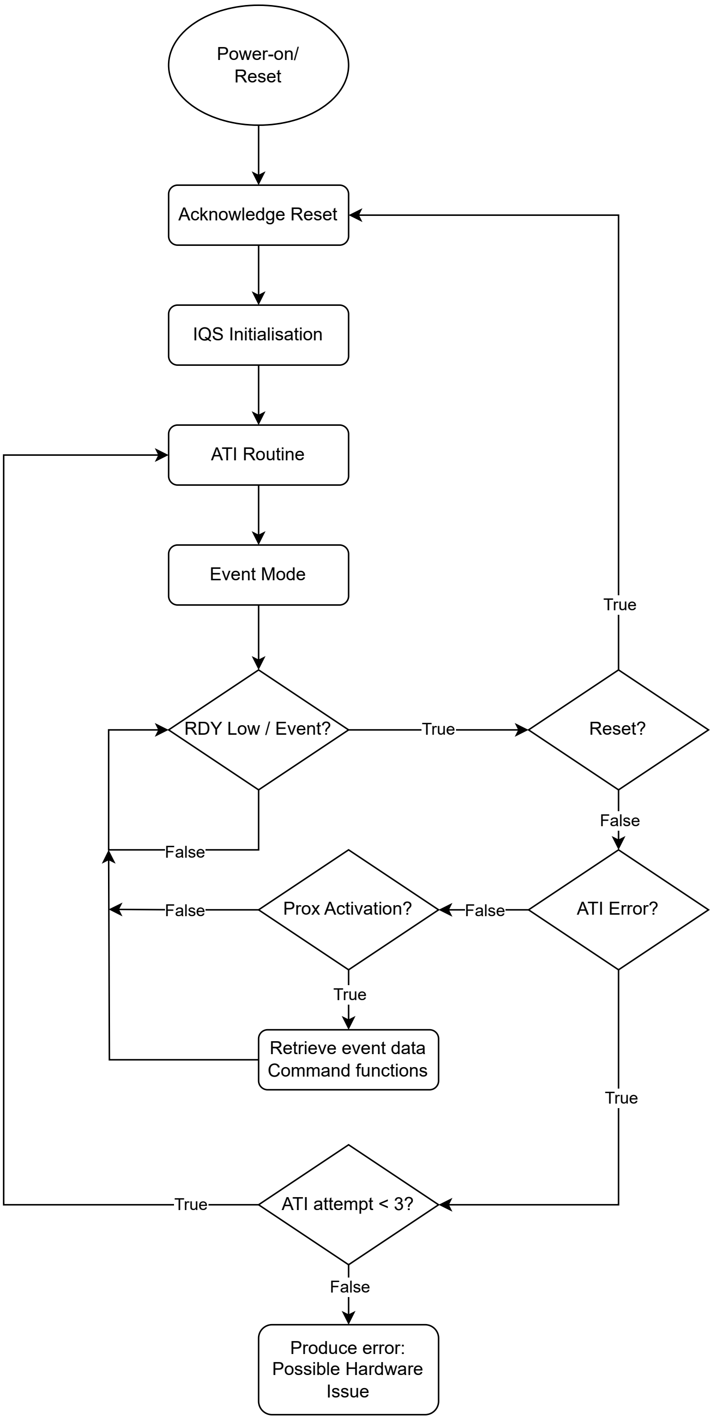

Figure 7.1: Software Flow Diagram

The following flow diagram, Figure 7.2, shows the typical back-and-forth communication between the MCU and the IQS IC.

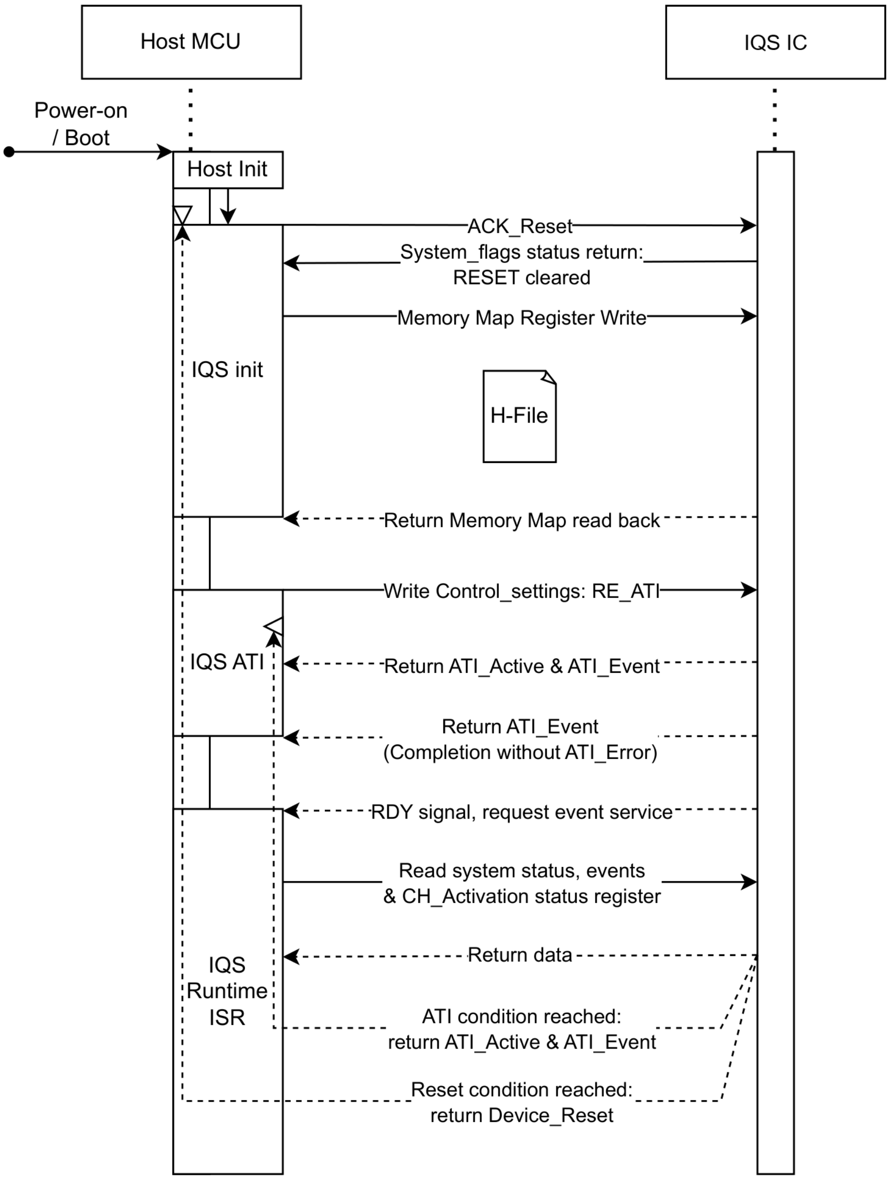

Figure 7.2: Host Software Sequence Diagram

Once the initialisation has been completed, the IQS IC 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

An example flow diagram of the headphone behaviour can be seen in Figure 7.3. Upon powering on the Bluetooth Low Energy (BLE), the system enters the active mode. If a wear event is detected, the music starts playing with Active Noise Cancellation (ANC) activated. After wearing the headphones, the system continues to play music for at least 5 seconds (due to debounce). If a release event is subsequently detected, the system transitions to a state where the music is paused and the ANC is deactivated. In the absence of any wear event for a duration of 5 minutes, the system shifts into standby mode and turns off the BLE.

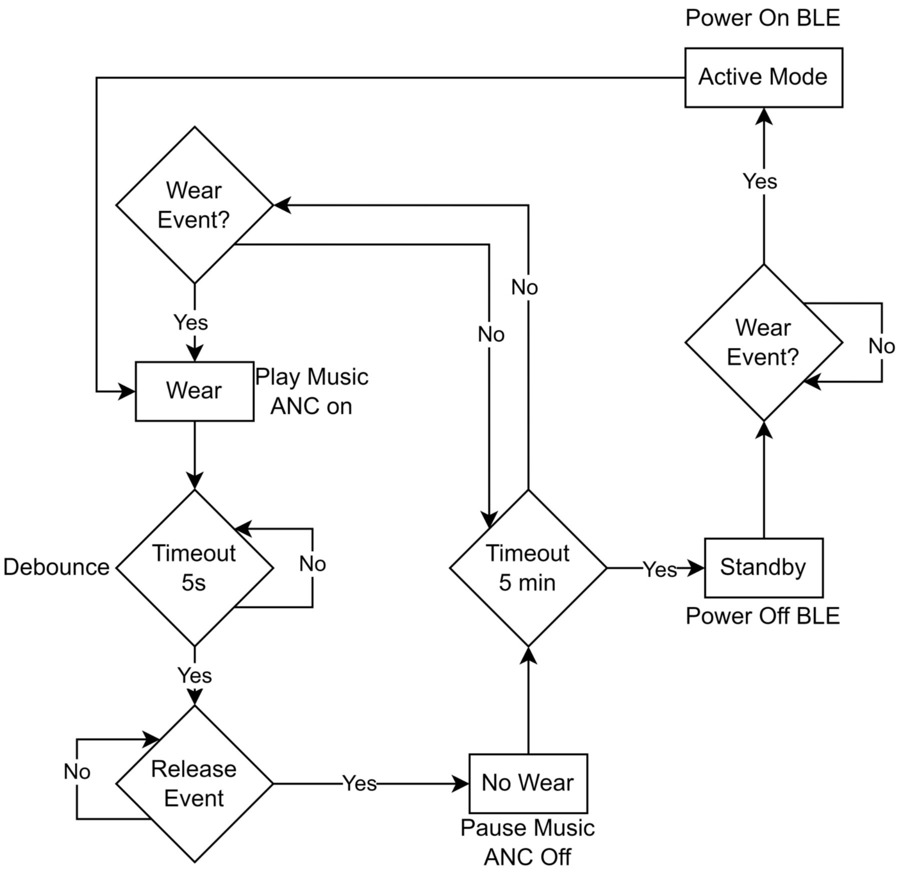

Figure 7.3: Example Host Software Flow

7.1.2 Communication Protocol

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

8 Mass Production Testing

This chapter provides information concerning testing during mass production.

8.1 In-circuit Testing (ICT)

Printed circuit board assembly (PCBA) testing should ideally be done with the product assembled to determine the effect of all auxiliary functions, such as Bluetooth, etc. Ideally, the test should be done in the typical operating environment of the headphones. 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 the device product number.
  - Check device major and minor firmware version information.
  - 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 a known or controlled benchmark for sensitivity and reactivity qualification).
  - Raw signal noise assessment.
- Current consumption
  - The 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 or conversion does not have a large effect on the measured average current.

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

Testing should also be done where a unit is only battery-powered and isolated from the earth, and in 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's 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 or erratic behaviour such as unexpected wake-ups from low-power modes or excessive high currents (short-circuit assembly issues).

Standard SMT production line practices and guidelines should always be followed with respect to IQS 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	2023/10/27	Initial document released
v2.0	2024/07/16	Over-ear headphone guidelines added

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