



AZD129 - Headphone Trackpad Design Guide

Design guide for headphone trackpads

Contents

1	Introduction	3
2	Design Specification / Product Requirements	4
2.1	Mechanical Specification	4
2.2	Electrical Specification	5
2.3	ESD Specification	5
2.4	Temperature Specification	5
2.5	Report Rate and Wake-up Response Time	5
2.6	Resolution and Pitch	5
2.7	Single Finger Performance	5
2.8	Gesture Recognition	6
2.9	Communications Interface	6
2.10	Test Points	6
3	Proposed Solution	7
3.1	System Description	7
3.2	Mechanical Stackup	7
3.3	Azoteq Device Selection Guide	8
3.4	Selected Azoteq Device	8
4	Design Resources	10
5	Design Implementation	11
5.1	Circuit Design	11
5.1.1	Power Supply Decoupling and Regulation	11
5.1.2	Rx and Tx Selection	11
5.1.3	Alternate Low Power Sensor Selection	12
5.1.4	Component Placement and Size	13
5.2	PCB Layout Design	14
5.2.1	General Guidelines	14
5.2.2	Diamond Pattern	15
5.2.3	ESD Ring	15
5.2.4	Test Points	15
5.2.5	Flying Probe Test Points	15
5.2.6	Hatched Ground Pour	15
5.3	Mechanical Design	15
5.4	Manufacturing	16
5.5	IC Setup	17
5.5.1	Product GUI	17
5.5.2	Cycle Allocation	17
5.5.3	ALP Channel	18
5.5.4	ATI Configuration	18
5.5.5	Trackpad Threshold Settings	19
5.5.6	ALP Threshold Settings	19



5.5.7	X and Y Resolution	20
5.5.8	X & Y Trim	20
5.5.9	Event Mode Communication Configuration	21
5.5.10	Gesture Configuration	21
6	Design Verification	22
6.1	Test Setup	22
6.2	Touch Delta and Threshold	23
6.3	ATI Compensation	24
6.4	Touch Test	25
6.5	Gesture Verification	25
7	Interface Description	26
8	Mass Production Testing	27
8.1	Flying Probe Test	27
8.2	In-circuit Testing (ICT)	27
9	Conclusion	28
10	Revision History	29
A	Bill of Materials	30
B	PCB Layout	31



1 Introduction

This document describes the design and integration of a low cost trackpad into headphones. Azoteq's solutions provide high performance sensing with on-chip gesture recognition at a low cost.

This design guide outlines the process of designing and integrating the IQS7211E into a headphone trackpad and then testing the trackpad in a production environment. The IQS7211E is a low cost alternative to the IQS572, offering simultaneous two finger tracking as well as one finger gesture recognition. It is capable of sensing up to 42 trackpad channels making it ideal for the size of trackpads typically found in headphones.

A summary of the design process is shown below:



Figure 1.1: Design Process Summary

2 Design Specification / Product Requirements

A trackpad module is required to be integrated into headphones. Trackpads designed for use in headphones must meet a number of typical specifications.

These include:

- > Low power operation
- > Response time
- > Gesture recognition
- > Resolution
- > Mechanical constraints

2.1 Mechanical Specification

Figure 2.1 shows the typical area (highlighted in green) in which a trackpad is placed in headphones.



Figure 2.1: Typical trackpad sensing area

Table 2.1 outlines common mechanical specifications and constraints.

Table 2.1: Mechanical specification

Specification	Design Requirement
Circuit substrate	Rigid FR4 PCB
Mechanical housing	Extruded (ABS or similar) plastic
PCB height	~ 60 mm
PCB width	~ 40 mm
Sensing area height	~ 50 mm
Sensing area width	~ 35 mm
PCB thickness	0.8 - 1.6 mm
PCB layers	2
Component height	≤ 1.2 mm
Passive component size	0402/0603 SMD
Overlay thickness	0.8 - 1.2 mm
Top adhesive	High quality double-sided tape (e.g. 3M 9448A)



2.2 Electrical Specification

Specification	Requirement
Supply Voltage(VDD)	1.8 V - 3.3 V
Internal Regulation(VREG)	Digital and analog domains (requires external decoupling capacitors)
Current Consumption	<ul style="list-style-type: none"> > Active: < 4 mA > Idle: < 1 mA > Low Power: < 1 mA > Suspend: < 10 µA

2.3 ESD Specification

ESD levels are stated for product level testing (i.e. fully assembled product).

- > ±13 kV AIR discharge on overlay above touchpad area
- > ±8 kV HCP (Horizontal Coupling Plane - indirect discharge)
- > ±8 kV CONTACT discharge on exposed metal

2.4 Temperature Specification

- > Operating Temperature: 0°C to 45°C
- > Storage Temperature: Adhesive’s recommended storage conditions

2.5 Report Rate and Wake-up Response Time

Table 2.3: Report Rate, Power Consumption and Wake-up Response Time

Specification	Design Requirement
Sensor configuration start up time	≤ 1000 ms
Active Mode Report Rate	100 Hz

2.6 Resolution and Pitch

Resolution is specified in both the *x* and the *y* directions and is specified in *pixels/mm*.

Pitch is specified in *mm* in both the *x* and the *y* directions. Pitch defines the minimum detectable finger size and how well the trackpad is able to differentiate between multiple simultaneous touches.

Table 2.4: Resolution and pitch specification

Specification	Design Requirement
Resolution x	30 - 40 pixels/mm
Resolution y	30 - 40 pixels/mm
Pitch x	~ 5 mm
Pitch y	~ 5 mm

2.7 Single Finger Performance

Single finger performance is quantified by the specifications outlined in Table 2.5, where the following definitions apply:



- > Linearity: Maximum deviation from straight line drawn at any angle
- > Static finger jitter: Maximum reported finger movement for a single stationary finger

Table 2.5: Single finger performance specification

Specification	Design Requirement
Linearity	≤ 1.0 mm
Static finger jitter	≤ 0.5 mm
Finger size	8 - 19 mm diameter (metal slug with flat tip)
Finger speed	up to 250 mm/s

2.8 Gesture Recognition

Headphones with trackpads require on-chip gesture recognition for volume control, media playback and other novel headphone features such as noise cancellation/transparency activation.

A typical gesture set includes:

- > Single Tap
- > Double Tap
- > Triple Tap
- > Press-and-Hold
- > Horizontal Swipes (Swipe x)
- > Vertical Swipes (Swipe y)
- > Palm Detection

2.9 Communications Interface

The master MCU should not be unnecessarily interrupted by the trackpad module. Therefore, an event based communication protocol is required.

Communication is done using the I²C protocol with the addition of a ready (RDY) line to indicate trackpad events. Typically, a pull-up resistor on RDY is needed on the module side. Pull-up resistors on SDA and SCL are usually placed on the MCU side, with a DNP option to place them on the module side.

The trackpad module typically connects to the main PCB via an FPC connector and FFC cable.

2.10 Test Points

Exposed copper test points are required for VDD, GND, SDA, SCL and RDY/MCLR. The test points are to be used during production testing to power and communicate with the module.

Exposed copper flying probe test points are required for every Rx and Tx. These must be located at the endpoints of each row and column, to test full continuity of that electrode.



3 Proposed Solution

A self-contained trackpad module PCB will be designed and integrated into a headphone casing. The module will connect to the master of the headphone via an FFC cable and on-board FPC connector. The module will report single tap, double tap, triple tap, hold, swipe and palm events using a two wire I²C plus RDY line interface.

The solution will demonstrate on-chip gesture recognition, low power modes, fast wake-up time, high performance and low cost trackpad sensing.

3.1 System Description

The user interacts with the trackpad by performing known gestures such as taps and swipes, or by simply touching the trackpad sensing area. Azoteq's IQS device handles the sensing and processing of the trackpad channels.

The IQS device performs on-chip gesture recognition and reports the detection of any enabled gestures, relative finger movement and absolute finger co-ordinates through I²C. The master device is notified of any trackpad events using the RDY line, allowing the master to focus on other processing tasks while the trackpad is inactive. The master can process the outputs of the IQS device and react appropriately.

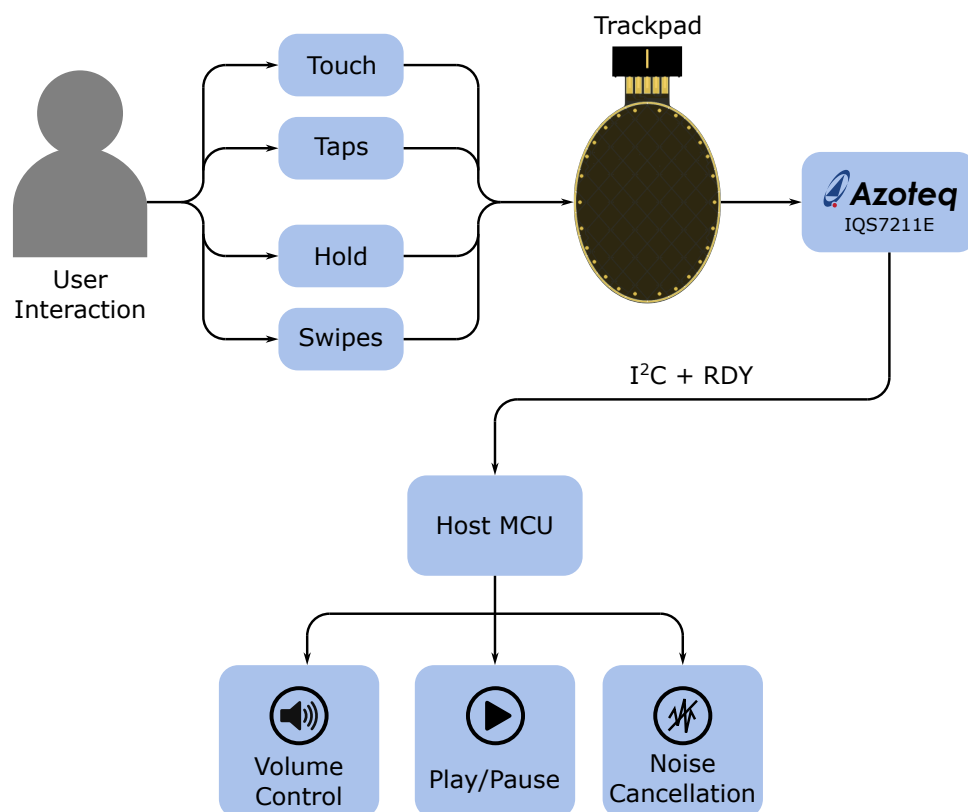


Figure 3.1: System Diagram

3.2 Mechanical Stackup

The PCBA is attached to the plastic overlay material using high quality double-sided adhesive. 3M 9448A double-sided tape has a total thickness of 0.15 mm.

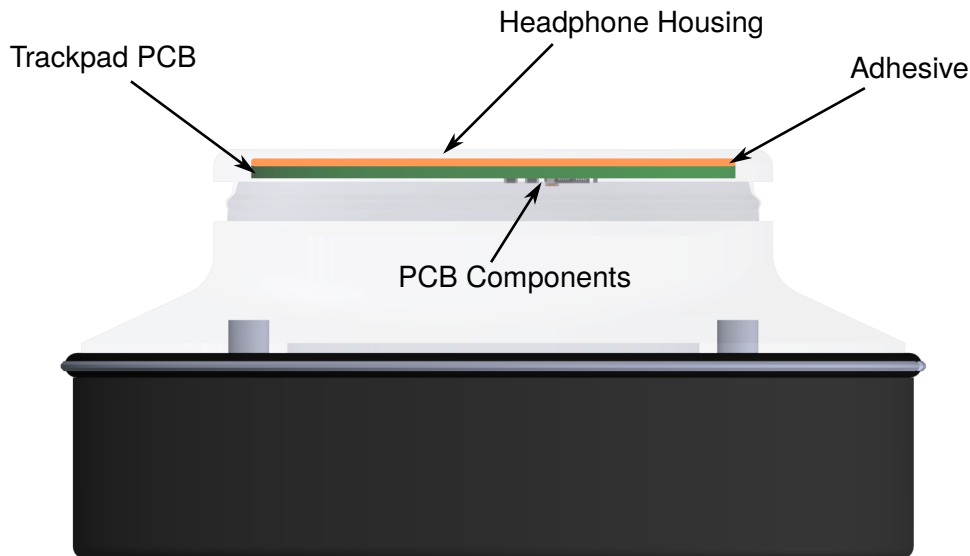


Figure 3.2: Stackup

3.3 Azoteq Device Selection Guide

Azoteq offers a number of products that are suitable for headphone trackpads.

These products are:

- > IQS572 - 72 channel trackpad sensor
- > IQS7211A - 32 channel trackpad sensor
- > IQS7211E - 42 channel trackpad sensor

The IQS572 is a high performance trackpad sensor IC with on-chip gesture recognition for both one and two finger gestures. It can sense up to 72 trackpad channels allowing for a fine pitch in both the x and y directions. As a result, the IQS572 is capable of differentiating between two simultaneous touches even on physically smaller trackpads.

The IQS7211E is a low-cost alternative to the IQS572 offering similar sensing performance but without support for two finger gestures. However, it supports an extended set of one finger gestures, offering multiple tap-gesture support and swipe-and-hold detection. Although the IQS7211E does not detect two finger gestures, it is capable of tracking and reporting data for two fingers simultaneously.

The IQS572 has flash memory which allows OTA (over-the-air) updates, while the IQS7211E has OTP (one-time-programmable) memory.

3.4 Selected Azoteq Device

This design guide focuses on the use of the IQS7211E. Trackpads in headphones are typically small making it relatively easy to meet minimum detectable finger size. It is also possible to meet finger separation requirements with fewer channels. With 42 sensing channels, a headphone trackpad with x and y pitch of ~5 mm is easily achievable. This is a typical pitch for a trackpad and will provide a minimum detectable finger size of approximately 7 mm in diameter.

The IQS7211E supports single, double and triple taps, palm detection, a press-and-hold gesture and single finger swipes in both the horizontal and vertical directions. This gesture set is ideal for headphone trackpads. Tap-and-hold and palm gestures can be used for play/pause functionality,



noise cancellation activation and other novel headphone features. Swipe gestures can be used for volume and media control.

Due to the size and placement of the trackpad, two-finger gestures are awkward to activate. For this reason the IQS7211E, with an extended set of on-chip single finger gestures, is a more than adequate choice.



4 Design Resources

All design resources can be found on the [Azoteq website](#).

Datasheets, Application Notes and User Guides

- > [IQS Device Datasheets](#)
- > [AZD004 - Azoteq Sensing Overview](#)
- > [AZD026 - Configuration Tools Overview](#)
- > [AZD044 - Azoteq MSL & Reflow specifications](#)
- > [AZD068 - Trackpad Design Guide](#)
- > [AZD087 - IQS5XX-B000 User Guide](#)
- > [AZD123 - IQS72XY Trackpad User Guide](#)
- > [AZD125 - Capacitive Sensing User Guide](#)

Graphical User Interfaces and Product Resources

- > [Product GUIs](#)
- > [IQS7211A Product Page \(Datasheet, GUI and Arduino Example Code\)](#)
- > [IQS7211E Product Page \(Datasheet, GUI and Arduino Example Code\)](#)
- > [IQS572 Product Page \(Datasheet, GUI and Arduino Example Code\)](#)

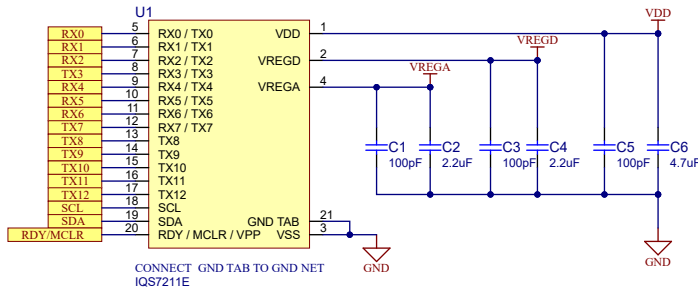


5 Design Implementation

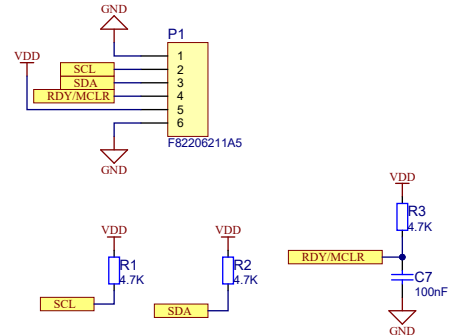
The design implementation described here adds a box header to the PCB assembly for evaluation and debugging purposes. A production version of this module would connect to the host MCU using the FPC connector located on the bottom side of the PCB.

5.1 Circuit Design

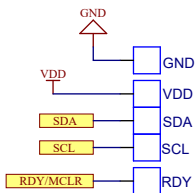
IQS7211E and Passives



I2C Connector and Pull-ups



Test Points



Pin Mapping

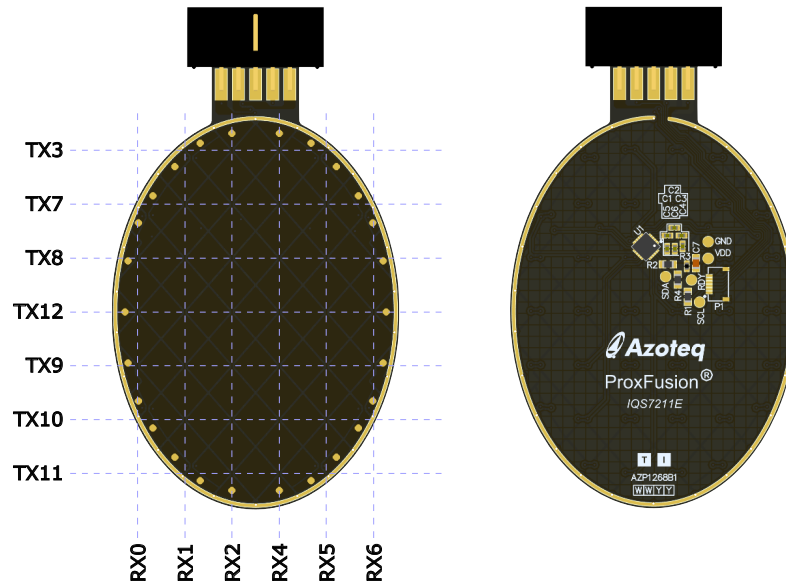


Figure 5.1: Reference Schematic

5.1.1 Power Supply Decoupling and Regulation

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

5.1.2 Rx and Tx Selection

The design is chosen to be a 6x7 trackpad. By having 6 columns and 7 rows, the pitch along the x and y directions can be designed to be similar. This ensures that performance is similar in both the x and the y directions and improves linearity. Figure 5.2 shows the Rx and Tx selection for this design.

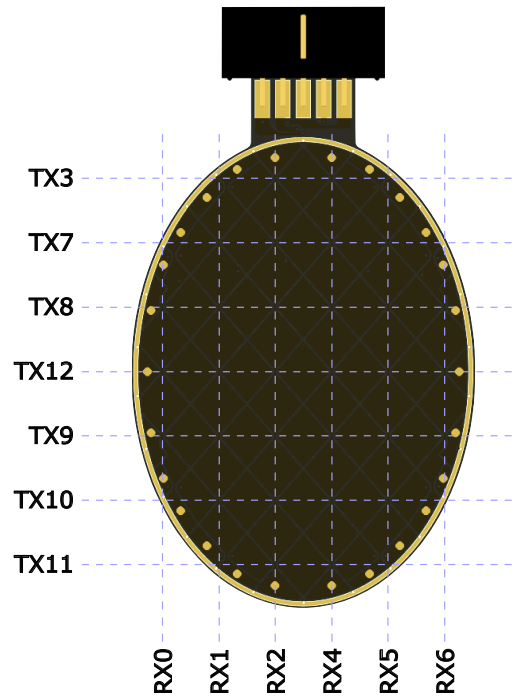


Figure 5.2: Rx and Tx Selection

Using more channels improves resolution as well as one- and two finger performance. However, in certain designs the PCB shape and size does not allow to use all channels. It is important to choose pins from the Rx0-Rx3 group AND from the Rx4-Rx7 group. This is because one Rx from the Rx0-Rx3 group is sensed together with one Rx from the Rx4-Rx7 in the same sensing cycle. Thus, it is optimal to distribute the Rx selection between the two groups.

5.1.3 Alternate Low Power Sensor Selection

The Alternate Low Power (ALP) channel is used to wake the trackpad from its low power modes when user proximity is detected. Figure 5.3 shows the sensors selected for the ALP channel.

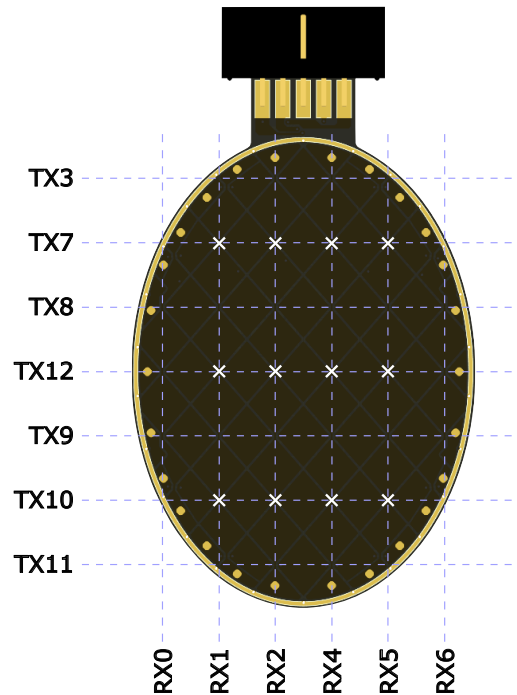


Figure 5.3: ALP Channel Sensor Selection

The ALP channel sensors are chosen to be evenly distributed across the trackpad to ensure consistent wake-up performance. It is important to note that it is still a requirement to have a balanced number of Rxs from the Rx0-Rx3 group, and from the Rx4-Rx7 group. They are configured as mutual-capacitive sensors because the PCB layout is designed for mutual-capacitive sensing.

5.1.4 Component Placement and Size

Components are placed underneath the sensing area on the bottom side of the PCB. This saves board space and does not affect trackpad performance if placed correctly.

Component sizes are chosen to be 0402 which helps with layout and routing. Care should be taken when selecting component sizes for power decoupling capacitors. Physically small capacitors with large capacitances can be expensive and may have undesirable characteristics. It is acceptable to use 0603 components. Remember to place passive components as close as possible to the IC, refer to [AZD068 - Trackpad Design Guide](#).



5.2 PCB Layout Design

For detailed information on trackpad PCB design see [AZD068 - Trackpad Design Guide](#).

Figure 5.4 highlights some important areas. These points are discussed in this section.

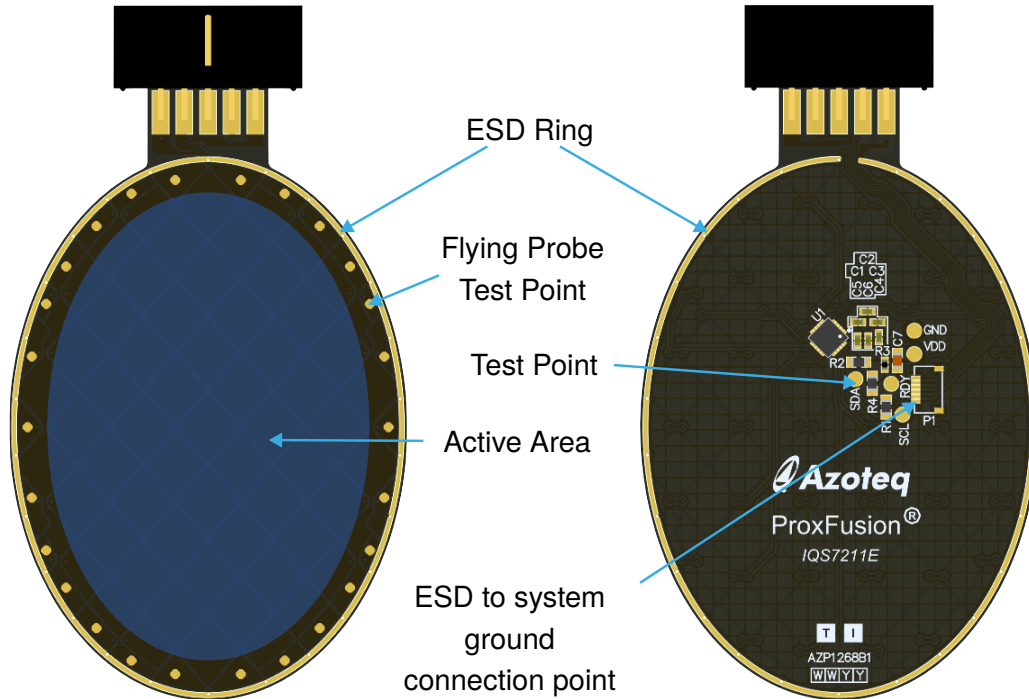


Figure 5.4: PCB Overview

5.2.1 General Guidelines

It is important to reduce overlap between Rx and Tx lines when routing the PCB. A common practice in trackpad layouts is to rotate the sensing IC so that Rx pins are below Rx diamonds and Tx pins are below Tx diamonds. Figure 5.5 illustrates this concept.

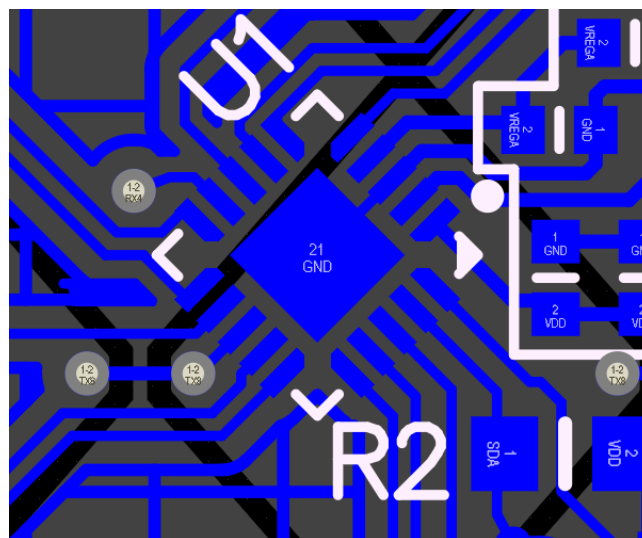


Figure 5.5: Rotated IC



Placing series resistors on both Tx and Rx lines can enhance ESD stability, boost noise immunity for Rx lines, and reduce noise emission from Tx lines. Series resistors should not be necessary in most cases and can be left off the board unless the PCBA is unable to pass noise and ESD tests. It is suggested to use a series resistor value ranging from 100 to 1 k Ω . However, it is essential to ensure that the signal integrity is not compromised while implementing the resistor.

5.2.2 Diamond Pattern

A classic diamond pattern is used with rows as Tx's and columns as Rx's. In this design the Tx's and Rx's were not arranged in order. The IQS7211E supports any arrangement of Rx's and Tx's through the use of its Rx/Tx mapping setting.

The gap between diamonds is 0.25 mm. For ABS-like materials, this gap is suitable for overlay thickness's between 0.8 mm and 2.0 mm.

Diamond pitch in the y direction is 7.25 mm. Diamond pitch in the x direction is 6.34 mm. This gives a minimum detectable finger size of approximately 10 mm and a finger separation distance of roughly 16 mm. Smaller finger sizes may still be detectable. The active sensing area is 35 mm by 50 mm. The active area extends from the midpoint of the first channel to the midpoint of the last channel.

Taken together, these design choices give excellent single finger performance across the whole active area and allow for two finger detection along the vertical direction (y-axis).

5.2.3 ESD Ring

An exposed Electrostatic Discharge (ESD) ring is included on both PCB layers for protection against ESD strikes. The ESD ring connects to system ground at the main (FPC) connector. Stitching vias are spread throughout the ESD ring to lower the impedance of the ring.

5.2.4 Test Points

Test points are included for VDD, GND, SDA, SCL and RDY/MCLR. The test points provide a testing and debug interface to be used when the PCBA undergoes production testing.

5.2.5 Flying Probe Test Points

Test points are included for every Rx and Tx. These points are placed on the outer diamonds and are used to conduct a flying probe test. The flying probe tests continuity for all Rx and Tx nets.

5.2.6 Hatched Ground Pour

The hatched ground pour on the bottom layer protects against interference from noise sources around the bottom layer of the PCBA. It also helps to couple the user to system ground which is important in battery powered applications.

The density of the ground pour depends on the PCB substrate and thickness. Thinner PCB's require a less dense ground pour. Ground pour density is a design consideration which must be evaluated and adjusted using physical hardware. Refer to [AZD068 - Trackpad Design Guide](#) for more detail.

5.3 Mechanical Design

Figure [5.6](#) shows the typical assembly process.

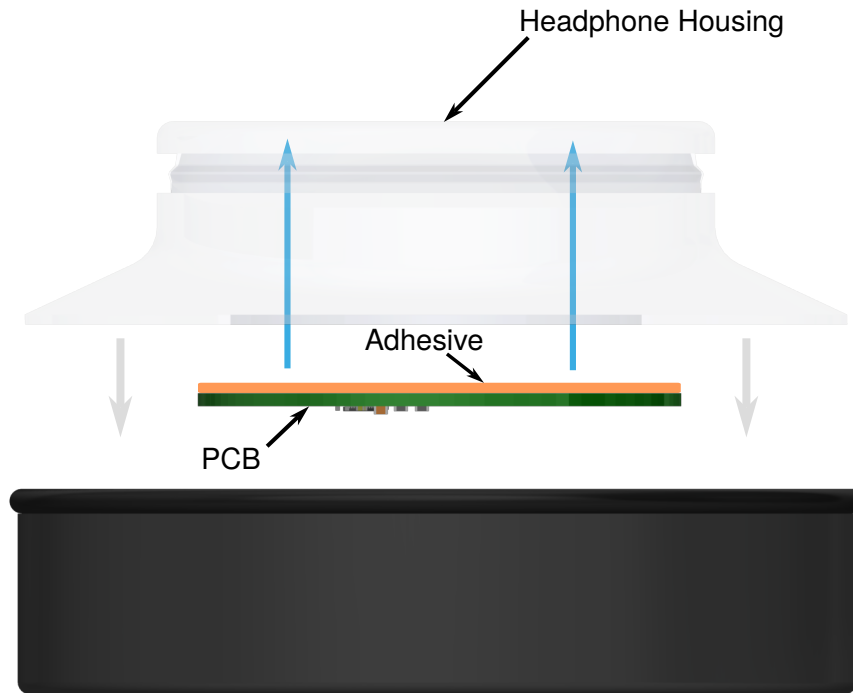


Figure 5.6: Mechanical Assembly

The PCB is attached to the separate headphone housing using double-sided adhesive. The headphone housing is then attached to the main body of the headphone. This allows for testing of the PCBA and headphone housing assembly before final product assembly.

The following considerations must be taken into account when designing the headphone housing and assembling the product:

- > The headphone housing should be fixed firmly in place and should not have any wobble when fixed to the main body
- > There should be no air gaps between the PCB, double-sided adhesive and headphone housing material
- > The headphone housing material should not flex when fixed to the main housing
- > It is preferable to keep conductive materials away from the underside of the trackpad module
- > The headphone material above the trackpad should not have any conductive material properties (such as those found in certain metallic paints/compounds)

5.4 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 5.1 is found in Appendix A.



5.5 IC Setup

For a more detailed description of configuring the settings and operation of the IQS7211E, see the [AZD123 - IQS721XY Trackpad User Guide](#).

5.5.1 Product GUI

The product graphical user interface (GUI) can be used to determine application specific settings. The product GUI can export an h-file containing the chosen settings which can then be used together with the Azoteq master I²C [example code](#) to create the setup code needed to configure the device.

The IQS7211E GUI is found on the [IQS7211E Product Page](#). All relevant design resources are listed in Section 4.

5.5.2 Cycle Allocation

The process of allocating channels into cycles is described in a graphical and more detailed manner in the [AZD123 - IQS721XY Trackpad User Guide](#). Below is a brief description of the process and its results for this design.

Trackpad channels are numbered from 0 to (Total Rxs * Total Tx) - 1. They are assigned from the top-left corner, first along the Rxs before stepping to the next Tx row. The channel number must be known for allocating channels into sensing cycles (timeslots). Table 5.1 shows the channel numbers for this design.

Table 5.1: Channel Number Assignment

		Rxs						
		0	1	2	4	5	6	
		Columns						
		0	1	2	3	4	5	
Tx	3	0	0	1	2	3	4	5
	7	1	6	7	8	9	10	11
	8	2	12	13	14	15	16	17
	12	3	18	19	20	21	22	23
	9	4	24	25	26	27	28	29
	10	5	30	31	32	33	34	35
	11	6	36	37	38	39	40	41

It is important to note that due to the oval shape of this design's trackpad, certain channels (shown in grey in Table 5.1) do not exist, and are simply not allocated to sensing cycles, effectively disabling them. This is graphically illustrated in Figure 5.7 found in Section 5.5.7.



Using the channel numbers from Table 5.1, the channels are packed into the cycles shown in Table 5.2.

Table 5.2: Channel Cycle Allocation

Cycle Number	Prox Block A (Rx0-3)	Prox Block B (Rx4-7)
	Channel Number	
0	1	3
1	2	4
2	6	9
3	7	10
4	8	11
5	12	15
6	13	16
7	14	17
8	18	21
9	19	22
10	20	23
11	24	27
12	25	28
13	26	29
14	30	33
15	31	34
16	32	35
17	37	39
18	38	40

5.5.3 ALP Channel

Wake-up response time from Low Power 1 (LP1) and Low Power 2 (LP2) modes is dependent on the ALP channel setup. The maximum wake-up time from each mode is equal to that mode's report rate (LP1 Report Rate or LP2 Report Rate).

For this design, the LP1 Report Rate is set to 10 ms and the LP2 Report Rate is set to 10 ms. This provides a fast wake-up response time that is typically required for gesture input detection in this type of application.

The master is able to put the IQS7211E into a deep sleep state known as Suspend by setting the suspend bit. The master must manually wake the IQS7211E from this state. The report rates for LP1 and LP2 can be set to achieve a faster wake-up time from low power modes, and Suspend mode can be utilised to enable deep sleep for lower power consumption.

5.5.4 ATI Configuration

The selection of the Coarse Divider, Fine Divider, and Coarse Multiplier is critical for proper trackpad operation. These settings, along with the Compensation Divider, must be manually chosen by the designer.



To set the Multipliers and Dividers for this design, the ATI Target is set to 0 and the mirrors are adjusted until the counts are around 80. For a typical trackpad this is a good operating point.

To set the Compensation Divider, the ATI Target is first set to its desired value. In this case, the ATI Target is set to 250 counts, it can be set lower, but should be kept above 200 counts. The target is kept low to be able to reach the required report rate. The ATI Target can be increased to increase sensitivity through thicker overlay materials. The Compensation Divider is adjusted until each channel's compensation value is around 512 and the count deltas are appropriate.

Touch sensitivity must be verified to be acceptable with the ATI parameters configured. Typically, acceptable touch deltas are near or greater than 128, if high resolution X and Y outputs are required. However, acceptable touch delta counts can be defined much lower in a system with low noise.

Determining the ATI parameters is done at room temperature.

For detailed information on how to determine trackpad ATI parameters, refer to the ATI Setup section of the [AZD123 - IQS721XY Trackpad User Guide](#).

5.5.5 Trackpad Threshold Settings

The ATI settings directly affect the channel sensitivity, so after these are modified, the thresholds usually need to be adjusted.

With a small finger, press lightly between 4 channels. Try to make the deltas of the 4 channels a similar delta value by being positioned evenly between the 4 channels. This therefore places the finger the furthest away from the four channel centres (their most sensitive areas), giving a good indication of a weak touch that should still be detected. The value you set in the GUI is the *multiplier* value. The touch threshold for a specific channel is calculated as follows:

$$\text{Threshold} = \text{Reference} \times \left(1 + \frac{\text{Multiplier}}{128}\right)$$

Assuming a reference count value of 250 and using a value of 20 for the multiplier as example, the threshold can then be calculated as follows:

$$\text{Touch Set Threshold} = 250 \times \left(1 + \frac{20}{128}\right) = 289 \text{ counts (39 counts delta)}$$

Now add a hysteresis to the touch thresholds by decreasing the touch clear value, so that jitter is not seen on touch outputs, because a touch release is now at a lower threshold value compared to the threshold where a touch becomes set. The four channels in the test above should now all detect constant touch outputs.

$$\text{Touch Clear Threshold} = 250 \times \left(1 + \frac{14}{128}\right) = 277 \text{ counts (27 counts delta)}$$

5.5.6 ALP Threshold Settings

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



5.5.7 X and Y Resolution

The output resolution for the X and Y coordinates are configurable in the 'Trackpad Settings' in the Azoteq GUI. The on-chip algorithms use 256 points between each row and column. For the AZP1268B1 hardware the theoretical maximum resolution can be configured as 1280x1536 (6x7 channels). It is possible to increase the resolution beyond the theoretical maximum, however, there are only 256 data points available between the midpoints of the channels.

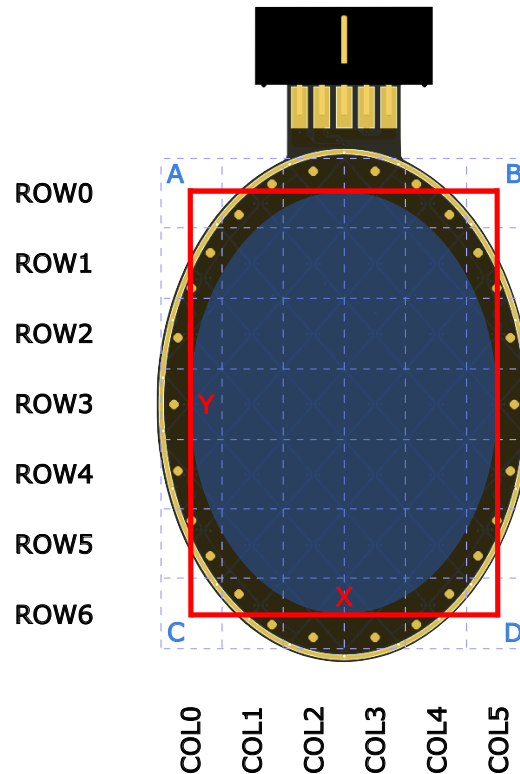


Figure 5.7: Trackpad Resolution and Active Area

The dimensions of the trackpad sensing area are 50 mm in height and 35 mm in width. The resolution has been set to ensure that the requirements of ~ 37 pixels/mm in the x-axis and ~ 31 pixels/mm in the y-axis are met. Because of the AZP1268B1's oval shape, it is important to remember that there will be areas of the specified resolution that will never be reported. These areas are shown in Figure 5.7 where the red square (representing resolution) is outside the active area (shown in blue). Channels marked A, B, C and D are completely outside the active area and can not be used for any form of detection.

5.5.8 X & Y Trim

Due to boundary conditions at the edges of the trackpad, it is unlikely that the X and Y extreme values will be achievable (0 and X/Y Resolution). To be able to achieve this, the edges can be trimmed with a configurable amount (*X Trim* / *Y Trim*) on-chip. For example, say *X Trim* is set to 0, and a finger on the left of the trackpad gives a minimum X output of 18, and a maximum of 1517 for a finger to the far right (for X resolution set to 1536). Then an *X Trim* = 20 could be used to trim away the 'dead' area, and the full 0 to 1535 range will be achievable.

For the AZP1268B1 hardware the X Trim value was set to 20 and the Y Trim value was set to 30.



5.5.9 Event Mode Communication Configuration

Event Mode should be enabled in order to meet the requirement that the master MCU should not be interrupted unnecessarily.

Firstly, configure which events should be generated in event mode. In this case, gesture events and trackpad events are activated, so that gestures and tracking information will trigger an I²C communication transaction to occur.

Enable the Event Mode bit when the MCU has finished the I²C initialisation process.

5.5.10 Gesture Configuration

No changes to the default on-chip settings was necessary to meet the gesture requirements. Please refer to the [IQS7211E Datasheet](#) for an in-depth explanation of the gesture settings.



6 Design Verification

The performance of this specific design must be verified that it meets the 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 requirements.

With the design verified, similar performance will be expected in mass production due to the on-chip calibration (ATI) technology. Individual module verification of performance requirements is not needed during mass production.

There are numerous metrics that can be used to measure the performance of a trackpad design. It is not important to test all the metrics during mass production as a number of them are fixed inherently by design during the prototype and pre-production/trial-run phases. The following are examples of such aspects of the trackpad performance that are essentially determined by design:

- > Sensitivity
- > Finger position accuracy
- > Tracking linearity
- > Sensor active area
- > Gesture output reliability

The metrics listed above will not change from one module to the next provided the module is fully operational within the touchpad controller IC's operating range. Mass production testing ensures that a module is free from defects, and is fully operational.

6.1 Test Setup

It is recommended to perform design verification using the MCU and the final working setup rather than relying solely on streaming it through the GUI. This approach will provide a more accurate representation of the system's performance and behavior, ensuring that any issues are identified and addressed before deployment.

Initial design evaluation and verification is done using the product GUI. The IQS7211E GUI is found on the [IQS7211E product page](#).

Connect the application hardware power, I²C & RDY lines to the CT210A USB dongle as shown in the table and figure below. Now connect the CT210A via a USB-micro cable to an available USB-A port on a PC.

Table 6.1: CT210A Pin-out

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

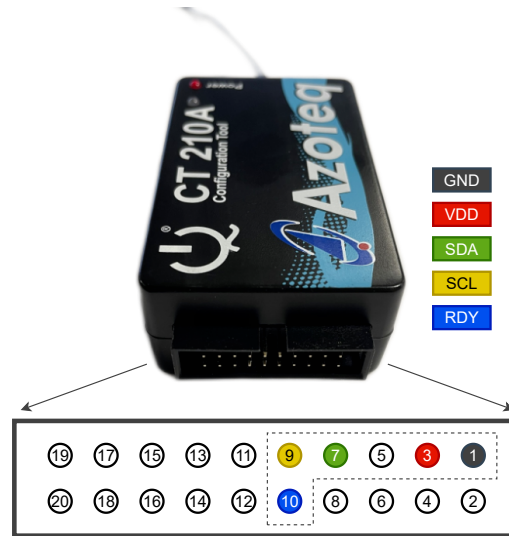


Figure 6.1: CT210A Power, I²C & RDY Connections

Device evaluation setup procedure will typically be as follows:

- > Open the device specific GUI software
- > Initiate the streaming communication of device data (Start Streaming)
- > Setup or load the specific product or application configuration settings (Import H-file)
- > Ensure that the latest H-file settings are imported and that the ATI algorithm executes without setting the ATI Error bit
- > View the system response using the graphical trackpad interface
- > Specific operating modes (such as low power sampling or event mode operation) can also be induced to measure current or monitor I²C & RDY logic behaviour and event activities.

The following sections describe the design verification checks that were done for this module.

6.2 Touch Delta and Threshold

A single finger touch is applied at the center of the trackpad. Figure 6.2 shows the resulting channel deltas. Multiple channels are activated with the central channel having the largest delta. At the center of the touch the delta is more than 500 counts. This is sufficient for this application.

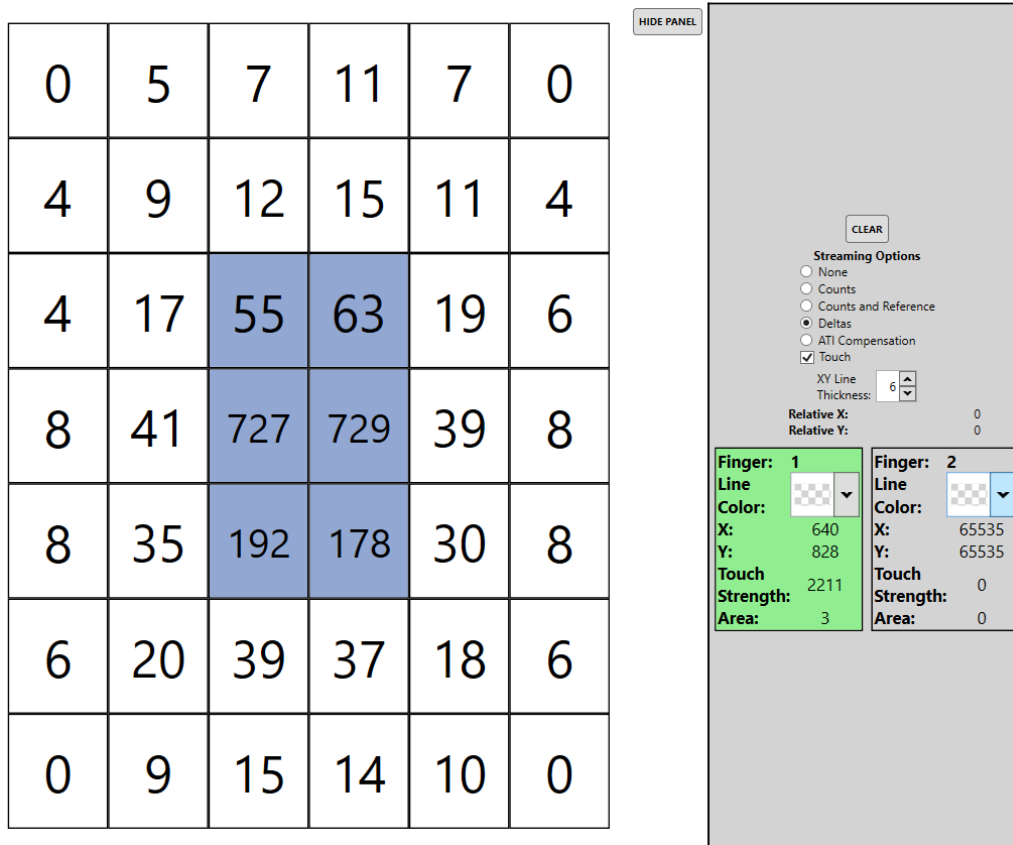


Figure 6.2: Touch Delta

As shown in Section 5.5.5, the touch threshold is set to 39 counts delta. This means a small touch can still be detected reliably, but a large touch doesn't detect in the air. The threshold setting is a trade-off between detecting a small touch and not detecting a finger in the air.

6.3 ATI Compensation

With no touch present the trackpad is re-ATI'd at room temperature. ATI for each channel is seen to be centered around 512. This is ideal for handling environmental drift. Note that this check should be done at the expected operating temperature of the PCBA.

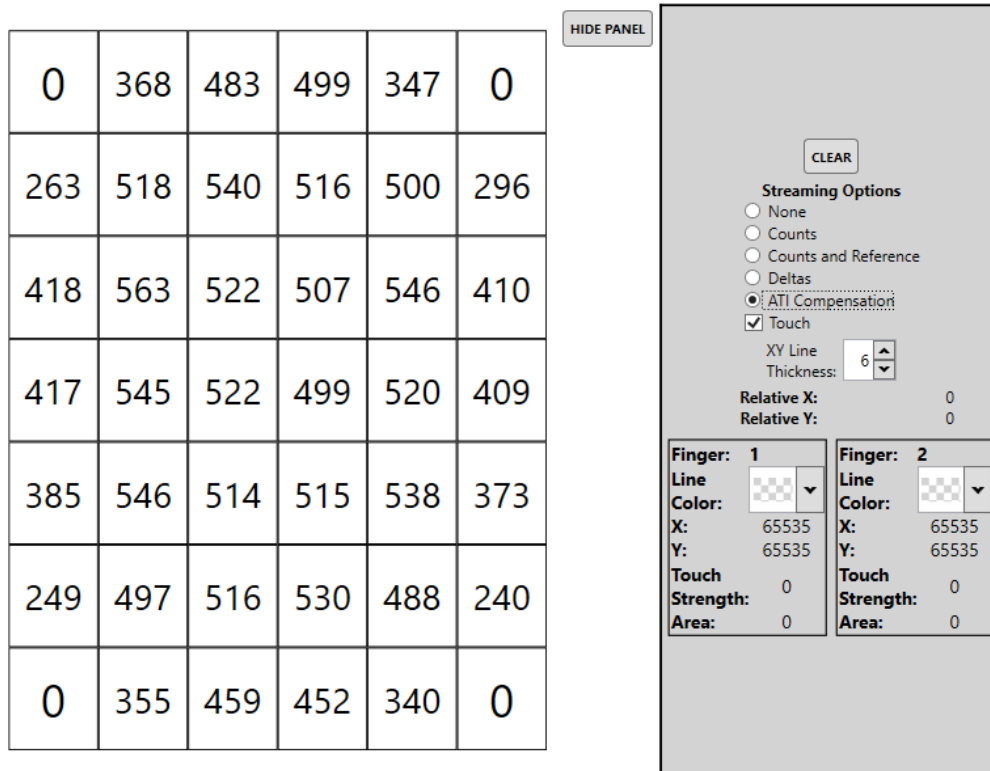


Figure 6.3: ATI Compensation Values

6.4 Touch Test

Basic tracking over the trackpad is monitored to make sure that reliable, accurate XY positions are reported. The XY coordinates do not appear noisy, and are smooth and of good quality. During single finger tracking, the finger is not lost, and another 'false' finger is not detected either.

Single finger touches are individually induced on the corners of the trackpad. A single finger touch is induced in the centre of the trackpad. The output coordinates of each touch are verified using the product GUI.

The X and Y Trim values are verified as set correctly if coordinates 0 and max resolution can be reached in both x- and y-axis. Test edges of the trackpad, including the four corners.

6.5 Gesture Verification

Gestures are verified by performing the selected gestures and using the product GUI to evaluate their detection. It is also verified that the gestures are rejected correctly by performing "non-gesture" movements.

It was ensured that both horizontal and vertical swipes are recognized correctly and reliably, while swipes that fall outside the selected swipe angle are rejected.



7 Interface Description

Azoteq IC's make use of a standard two wire I²C interface with the addition of a ready (RDY) line. The RDY line serves as indication of a trackpad event and can be configured to activate upon gesture recognition and/or while a user is touching the trackpad.

Arduino example code can be found on the [IQS7211E product page](#).

A detailed description of the IQS7211E's I²C interface can be found in the [IQS7211E datasheet](#).

Figure 7.1 shows the initialisation sequence followed by the Arduino example code. A sequence such as this must be done each time the IQS7211E is power cycled.

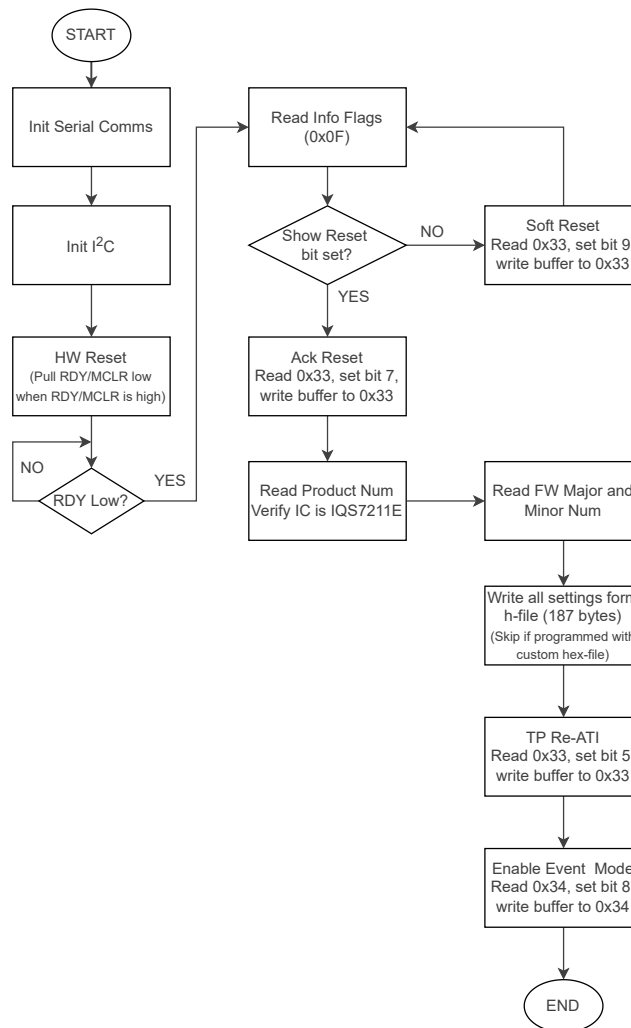


Figure 7.1: Software Flow Diagram

Note that the IQS7211E uses MCLR as its RDY line. Thus, the device can only be reset by pulling RDY/MCLR LOW when outside of the communications window (i.e., when RDY/MCLR is HIGH).

Once the initialisation has been completed, the IQS7211E will notify the master of events by pulling the RDY line LOW. The master can then read the event flags and act accordingly.



8 Mass Production Testing

8.1 Flying Probe Test

Flying probe tests are typically performed on PCBs during the PCB manufacturing process and prior to the assembly.

Flying probe testing is a type of automated electrical testing that is used to verify the connectivity of the PCB's electrical circuits. This testing is typically done after the PCB has been fabricated, but before any electronic components have been added to the board during the assembly process. The purpose of the flying probe test is to ensure that the PCB has been fabricated correctly and is functioning properly before any components are added to it.

Best practice for ensuring the success of the flying probe test involves incorporating soldermask openings into the sensor pads to serve as test points. These openings should be strategically placed at the ends of the Rx and Tx rows and columns, allowing for the flying probe test to check the continuity of each Rx and Tx

Once the flying probe test is completed, the board can then move on to the assembly process. During assembly, the electronic components are added to the PCB, and the board is then subjected to additional testing, such as functional testing and in-circuit testing, to ensure that the final product meets the required specifications.

8.2 In-circuit Testing (ICT)

The PCBA should be tested with the final adhesive and overlay attached. In certain cases, this test scenario is not viable. At a minimum the PCBA testing should be done with the final doubled-sided adhesive with liner applied.

Typically, module PCBA's are tested by placing the PCBA face down in a test jig. The test cavity should touch only the outer edges of the PCB *outside* of the trackpad sensor area. This setup ensures that the test jig does not interfere with the ATI Compensation results and stops users and objects coming into proximity with the sensors during testing. Spring loaded pogo pins are used to interface with the module using PCB test points.

Typically, ATI Compensation and threshold limits are determined using a sample set of the PCBA modules. Touch threshold and release settings should be determined from the noise from the sample set. ATI Compensation limits are determined from the operating temperature range of the module and the ATI Compensation Divider selection. The ATI Compensation limits are dependent on the overlay. If the sample set does not have the overlay attached, the compensation limits must be adjusted accordingly.

It is important to note that there is variation in ATI Compensation values between ICs. Furthermore, it should be noted that the ATI Compensation for a single unit can also vary as the temperature changes. Therefore, in order to determine appropriate limits, a handful of units should be tested at the maximum and minimum operating temperatures, with ATI Compensation variation being monitored over temperature.

To verify current consumption in all power modes, the average current for each mode is measured. To ensure accurate measurements, it is recommended to take measurements over a period of at least 15 cycles of the current power mode's report rate. For instance, if the report rate for the Idle mode is set to 50 ms, the measurement should be taken over a minimum of 750 ms (i.e. 50 ms x 15 cycles).



9 Conclusion

After analysing the different aspects involved in designing a trackpad for a headphone, it is evident that the process requires careful consideration of multiple factors. A clear and detailed design specification is necessary to ensure that the product meets the desired requirements. A proposed solution that is well thought out and feasible should be developed, using the design resources provided to achieve it. Design implementation should be done following the necessary interface description, and design verification should be carried out with a focus on identifying any potential issues. Finally, mass production testing should be conducted to ensure that the trackpad functions as intended. By following these steps, a functional and high-quality trackpad for a headphone can be designed and mass produced.



10 Revision History

Release	Date	Comments
v1.00	2023/04/14	Initial document released



A Bill of Materials

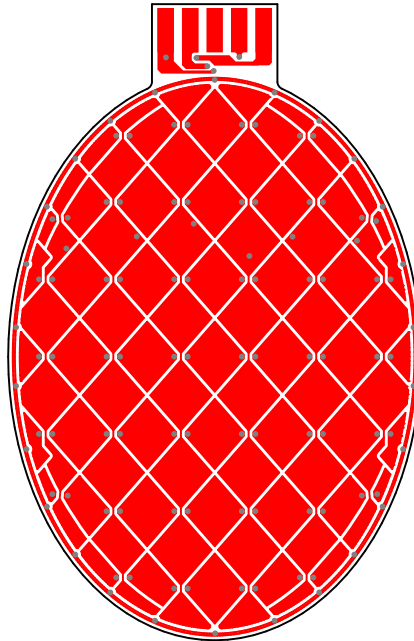
Table A.1 provides the bill of material detail for the schematic layout of Figure 5.1.

Table A.1: Bill of materials

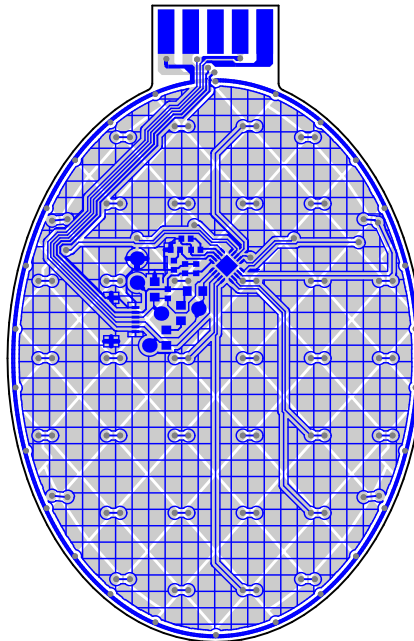
Comment	Description	Designator	Footprint	Manufacturer (P/N)
IQS7211E	IQS7211E-QFN-20N	U1	QFN-20N	Azoteq (IQS7211E)
F82206211A5	FPC Connector, 6 way	P1	Special	VIGORCONN (F82206211A5-6W)
Box Header	Box Header, edge, 10 way	P2	Standard	
100 pF	Capacitor, ceramic, X7R	C1, C3, C5	0402	AVX (04025A101JAT2)
100 nF	Capacitor, ceramic, X7R	C7	0402	AVX (04023C104KAT2)
4.7 μF	Capacitor, ceramic, X5R	C6	0402	Samsung (CL05A475MQ5N)
2.2 μF	Capacitor, ceramic, X5R	C2, C4	0402	Panasonic (ECJ-0EB0J225M)
4.7 k	Resistor, 4.7 kΩ, 5%, 0.1W	R1, R2, R3	0402	Yageo (RC0603JR-074K7L)
AZP1268B1	FR4-PCB, ENIG finish, 1.6 mm thick, 2-layer	AZP1268B1		PCB manufacturer of choice



B PCB Layout



TOP VIEW



BOTTOM VIEW

Figure B.1: PCB Layout



Contact Information

	USA	Asia	South Africa
Physical Address	11940 Jollyville Suite 120-S Austin TX 78759 USA	Room 501A, Block A T-Share International Centre Taoyuan Road, Nanshan District Shenzhen, Guangdong, PRC	1 Bergsig Avenue Paarl 7646 South Africa
Postal Address	11940 Jollyville Suite 120-S Austin TX 78759 USA	Room 501A, Block A T-Share International Centre Taoyuan Road, Nanshan District Shenzhen, Guangdong, PRC	PO Box 3534 Paarl 7620 South Africa
Tel	+1 512 538 1995	+86 755 8303 5294 ext 808	+27 21 863 0033
Email	info@azoteq.com	info@azoteq.com	info@azoteq.com

*Visit www.azoteq.com
for a list of distributors and worldwide representation.*

Patents as listed on www.azoteq.com/patents-trademarks/ may relate to the device or usage of the device.

Azoteq®, Crystal Driver®, IQ Switch®, ProxSense®, ProxFusion®, LightSense™, SwipeSwitch™, and the  logo are trademarks of Azoteq.

The information in this Datasheet is believed to be accurate at the time of publication. Azoteq uses reasonable effort to maintain the information up-to-date and accurate, but does not warrant the accuracy, completeness or reliability of the information contained herein. All content and information are provided on an “as is” basis only, without any representations or warranties, express or implied, of any kind, including representations about the suitability of these products or information for any purpose. Azoteq disclaims all warranties and conditions with regard to these products and information, including but not limited to all implied warranties and conditions of merchantability, fitness for a particular purpose, title and non-infringement of any third party intellectual property rights. Azoteq assumes no liability for any damages or injury arising from any use of the information or the product or caused by, without limitation, failure of performance, error, omission, interruption, defect, delay in operation or transmission, even if Azoteq has been advised of the possibility of such damages. The applications mentioned herein are used solely for the purpose of illustration and Azoteq makes no warranty or representation that such applications will be suitable without further modification, nor recommends the use of its products for application that may present a risk to human life due to malfunction or otherwise. Azoteq products are not authorized for use as critical components in life support devices or systems. No licenses to patents are granted, implicitly, express or implied, by estoppel or otherwise, under any intellectual property rights. In the event that any of the abovementioned limitations or exclusions does not apply, it is agreed that Azoteq’s total liability for all losses, damages and causes of action (in contract, tort (including without limitation, negligence) or otherwise) will not exceed the amount already paid by the customer for the products. Azoteq reserves the right to alter its products, to make corrections, deletions, modifications, enhancements, improvements and other changes to the content and information, its products, programs and services at any time or to move or discontinue any contents, products, programs or services without prior notification. For the most up-to-date information and binding Terms and Conditions please refer to www.azoteq.com.