# AZD128 - Gamepad Trackpad Design Guide

Guidelines for gamepad trackpad design, verification and testing

## Contents

## 1 Introduction

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

This design guide outlines the process of designing and integrating the IQS7211E into a gamepad 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 gamepad controllers.

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 a gamepad controller. Trackpads designed for use in gamepads must meet several 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 on a gamepad controller.

*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 width | ∼25mm |
| PCB length | ∼45mm |
| Touch area width | ∼20mm |
| Touch area length | ∼40mm |
| PCB thickness | 0.6 - 1.6mm |
| PCB layers | 2 or 4 |
| Component height | ≤1.2mm |
| Passive component size | 0402/0603 SMD |
| Overlay thickness | 0.8-2.0mm |
| Top adhesive | High-quality double-sided tape (eg. 3M 9448A) |

## 2.2 Electrical Specification

| Specification | Requirement |
|---|---|
| Supply Voltage(VDD) | 1.8V-3.3V |
| Internal Regulation(VREG) | Digital and analog domains<br>(requires external decoupling capacitors) |
| Current Consumption | › Active: < 4mA<br>› Idle: < 1mA<br>› Low Power: < 1mA<br>› Suspend: < 10uA |

## 2.3 ESD Specification

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

- ±13kV AIR discharge on overlay above touchpad area
- ±8kV HCP (Horizontal Coupling Plane - indirect discharge)
- ±8kV 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 Timing

*Table 2.3: Report Rate and Wakeup Response Time*

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

## 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 | 40 pixels/mm |
| Resolution y | 50 pixels/mm |
| Pitch x | ∼5mm |
| Pitch y | ∼5mm |

## 2.7 Single Finger Performance

Single finger performance is quantified by the specifications outlined in Table 2.5.

The following definitions apply to the specifications in Table 2.5.

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

## 2.8 Gesture Recognition

Gamepads with trackpads require gesture recognition for menu navigation, in-game map controls and other novel game features.

A typical gesture set includes:

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

## 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 $I^2C$ 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 gamepad controller casing. The module will connect to the master of the gamepad via an FFC cable and on-board FPC connector. The module will report single tap, double tap, hold and swipe events using a two wire $I^2C$ 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 $I^2C$. 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.

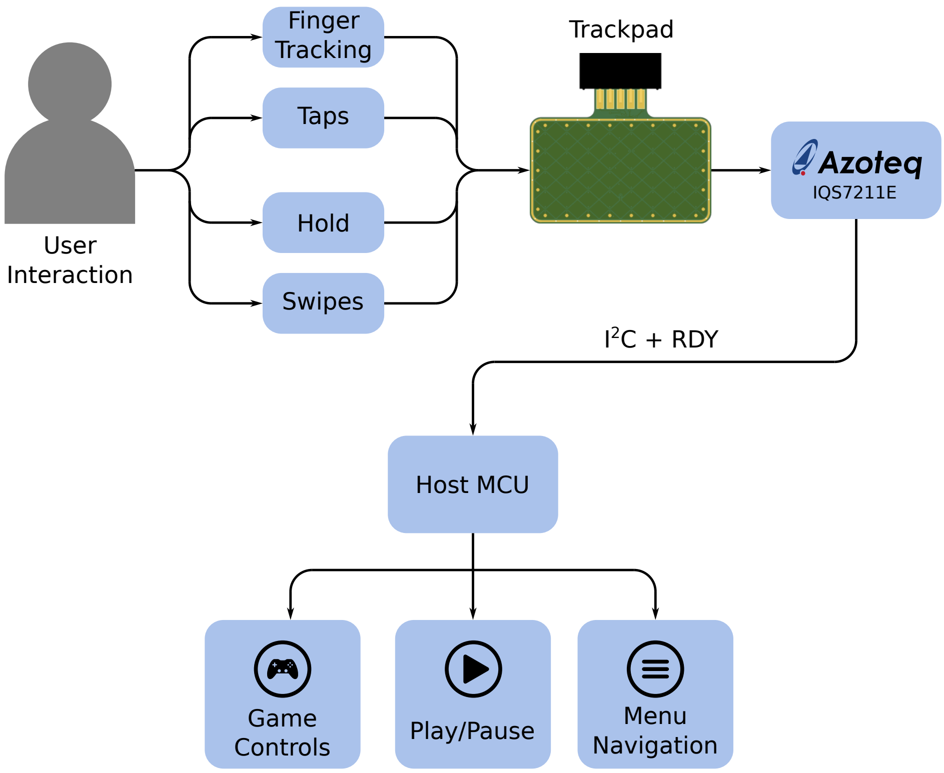



*Figure 3.1: System Diagram*

## 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 0.15mm.

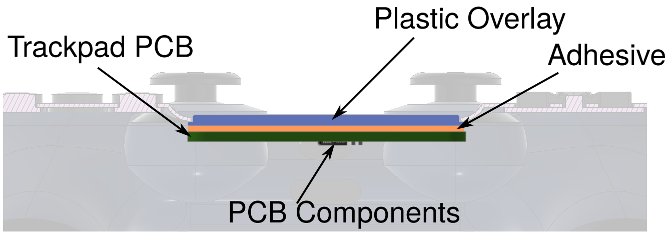



*Figure 3.2: Stackup*

## 3.3 Azoteq Device Selection Guide

Azoteq offers a number of products that are suitable for gamepad 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 gamepads 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 gamepad trackpad with x and y pitch of ~5mm is easily achievable. This is a typical pitch for a trackpad and will provide a minimum detectable finger size of approximately 7mm in diameter.

The IQS7211E supports single, double and triple taps, a press-and-hold gesture and single finger swipes in both the horizontal and vertical directions. This gesture set is ideal for gamepad trackpads. Tap and hold gestures can be used for menu navigation, play/pause functionality and additional game actions. Swipe gestures can be used for menu navigation, in game object manipulation and other novel game features.

Due to the size and placement of the trackpad, two-finger gestures are more awkward to activate, except for a zoom gesture. For this reason, the lack of on-chip scroll gesture recognition is not a problem, but zoom gesture recognition may be.

## 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 - IQS721XY 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

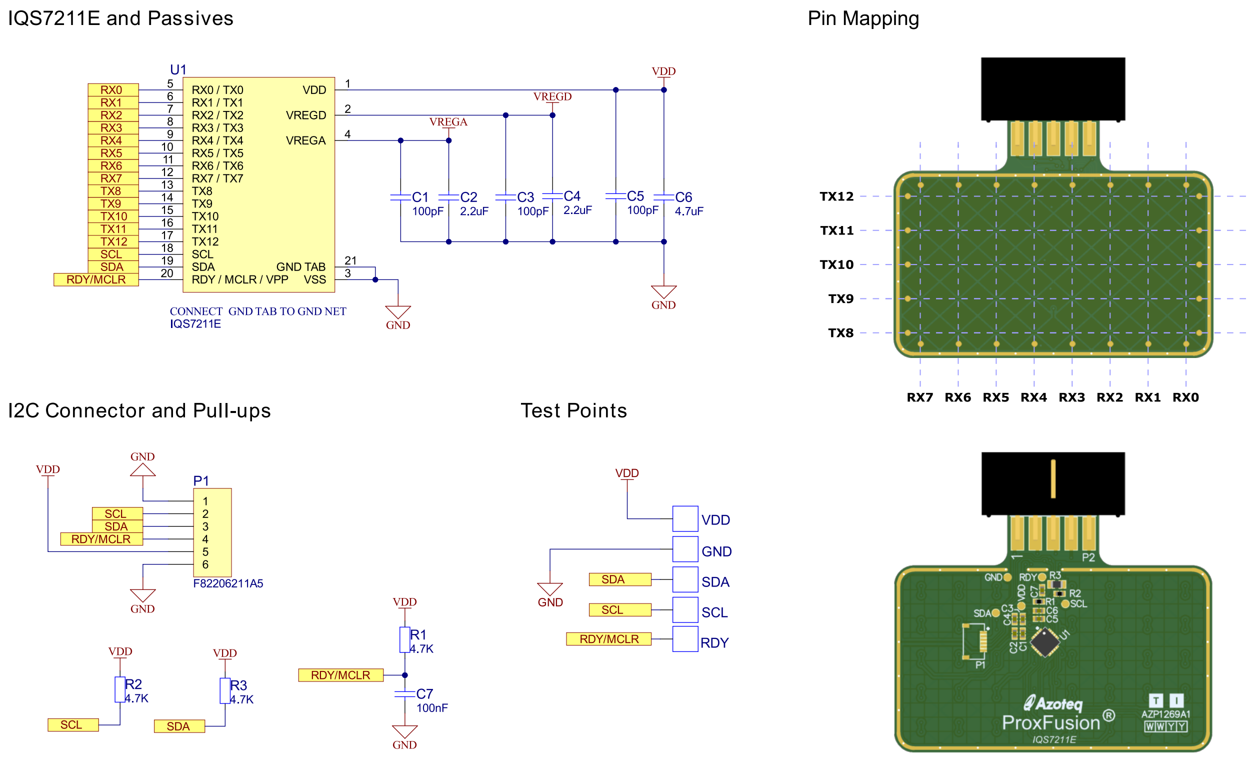



*Figure 5.1: Reference Schematic*

### 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 an 8x5 trackpad. This is done because the trackpad is wider than it is high. By having 8 columns and 5 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.

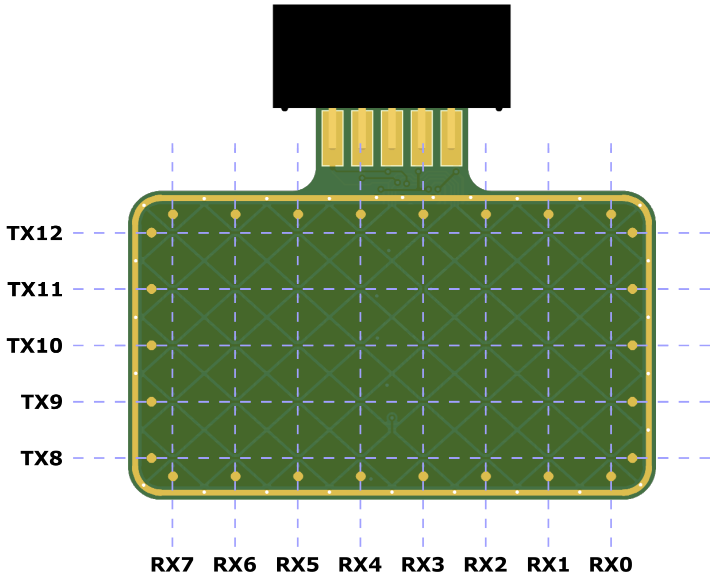



*Figure 5.2: Rx and Tx Selection*

All Rx pins are used to maximise the number of channels. More channels improve resolution as well as one and two finger performance. Should a design not use all Rx pins, it is important to choose alternate pins from Rx0 to Rx3 and from Rx4 to Rx7. This is because one electrode from the Rx0 to Rx3 group is sensed together with one from the Rx4 to Rx7 group 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.

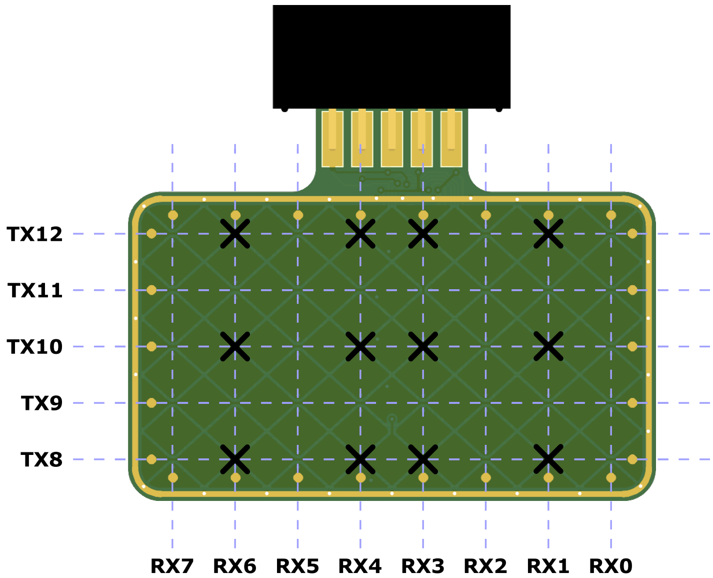



*Figure 5.3: ALP Channel Sensor Selection*

The ALP channel sensors are chosen to be evenly distributed across the trackpad to ensure consistent wakeup performance. Again it is required to have a balanced number of Rxs from the Rx0-Rx3 group, and from the Rx4-Rx7 group. In this case 2 from each group was selected. 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.

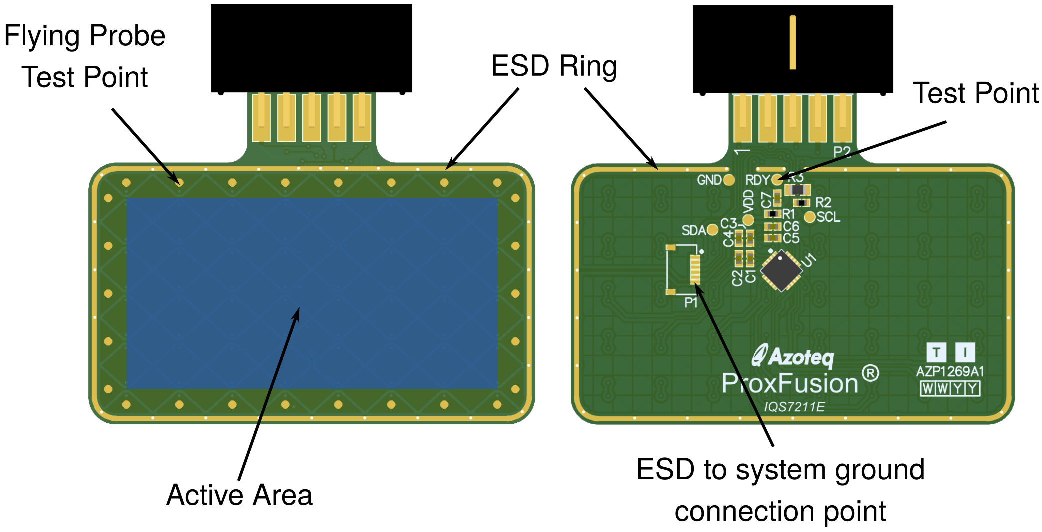



*Figure 5.4: PCB Overview*

### 5.2.1 General Guidelines

It is important to reduce overlap between Rx an 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.

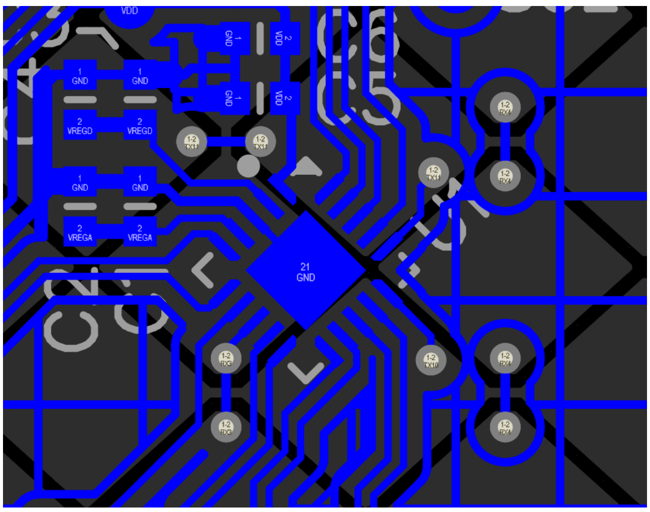


*Figure 5.5: Rotated IC*

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 1k Ohm. 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 or visa versa. In this design the Tx's and Rx's are arranged in order. This is not a requirement as the IQS7211E supports any arrangement of Rx's and Tx's through the use of it's Rx/Tx mapping setting.

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

Diamond pitch in the y direction is 4.82mm. Diamond pitch in the x direction is 5.35mm. This gives a minimum detectable finger size of approximately 7.20mm and a finger separation distance of roughly 12mm. Smaller finger sizes may still be detectable. The active sensing area is 37.45mm by 19.28mm. 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 horizontal direction (x-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.

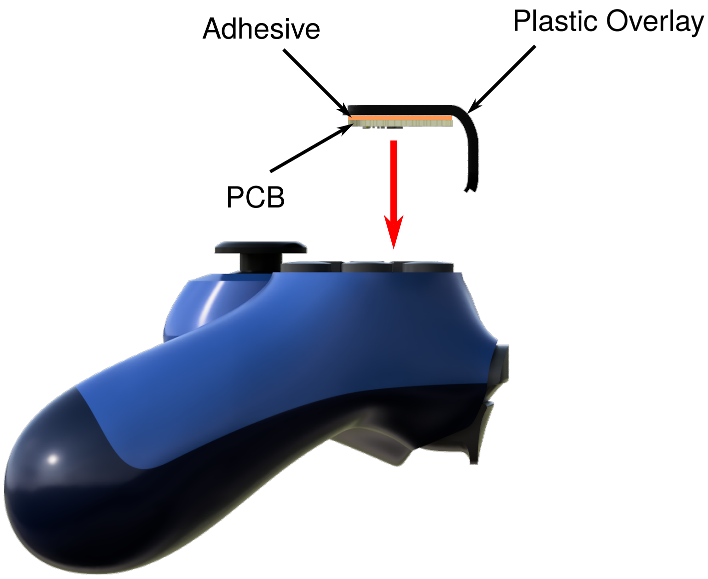



*Figure 5.6: Mechanical Assembly*

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

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

- The overlay should be fixed firmly in place and should not have any wobble when fixed to the main housing
- There should be no air gaps between the PCB, double-sided adhesive and overlay material
- The overlay material should not flex when fixed to the main housing
- It is preferable to keep conductive materials away from the bottom side of the trackpad module

## 5.4 Manufacturing

The following is typically included 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 IQS7211E, see 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 I$^2$C example code to create the setup code needed to configure the device.

The IQS7211E GUI is found on the IQS7211E product page. All design resources are listed in Section 4.

### 5.5.2 Cycle Allocation

The process of allocating channels into cycles is described in detail in 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 Txs) - 1. They are assigned from the top-left corner, first along the Rxs before stepping to the next Tx. The channel number must be known for allocating channels into sensing cycles (timeslots). Table 5.1 shows the channel numbers for this design.

*Table 5.1: Channel Number Assignment*

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

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*

| | Prox Block A (Rx0-3) | Prox Block B (Rx4-7) |
|---|---|---|
| **Cycle Number** | **Channel Number** | |
| **0** | 4 | 0 |
| **1** | 5 | 1 |
| **2** | 6 | 2 |
| **3** | 7 | 3 |
| **4** | 12 | 8 |
| **5** | 13 | 9 |
| **6** | 14 | 10 |
| **7** | 15 | 11 |
| **8** | 20 | 16 |
| **9** | 21 | 17 |
| **10** | 22 | 18 |
| **11** | 23 | 19 |
| **12** | 28 | 24 |
| **13** | 29 | 25 |
| **14** | 30 | 26 |
| **15** | 31 | 27 |
| **16** | 36 | 32 |
| **17** | 37 | 33 |
| **18** | 38 | 34 |
| **19** | 39 | 35 |
| **20** | 255 | 255 |

### 5.5.3 ALP Channel

Wakeup response time from Low Power 1 (LP1) and Low Power 2 (LP2) modes is dependent on the ALP channel setup.

For this design, the LP1 Report Rate is set to 10ms and the LP2 Report Rate is set to 10ms. This provides a fast wakeup response time that is typically required from 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 and reinitialise the settings via $I^2C$. 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 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 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:

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

Assuming a reference count value of 250, the threshold can then be calculated as follows:

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

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.

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

#### 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

AZP1269A1 hardware the theoretical maximum resolution can be configured as 1792x1024 (8x5 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.

The dimensions of the trackpad sensing area are 20mm in height and 40mm in width. The resolution has been set to ensure that the requirements of ∼44 pixels/mm in the x-axis and ∼51 pixels/mm in the y-axis are met.

#### 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 1773 for a finger to the far right (for X resolution set to 1792). Then an X Trim = 20 could be used to trim away the 'dead' area, and the full 0 to 1792 range will be achievable.

For the AZP1269A1 hardware the X Trim value was set to 40 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 $I^2C$ communication transaction to occur.

Enable the Event Mode bit when the MCU has finished the $I^2C$ 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 of 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, I$^2$C & 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 |

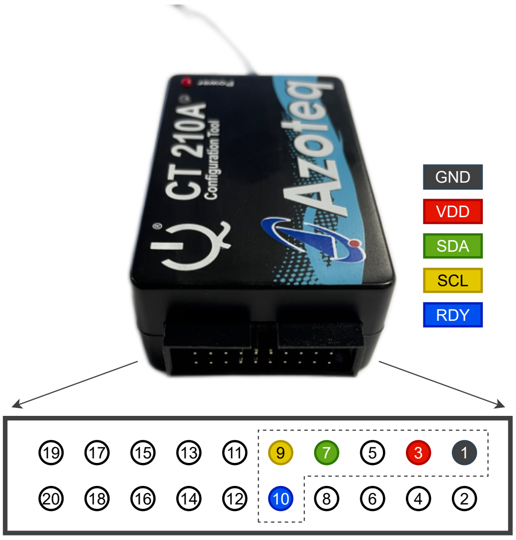



*Figure 6.1: CT210A Power, I²C & RDY Connections*

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 $I^2C$ & 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 centre 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 centre of the touch the delta is 137 counts. This is sufficient for this application.

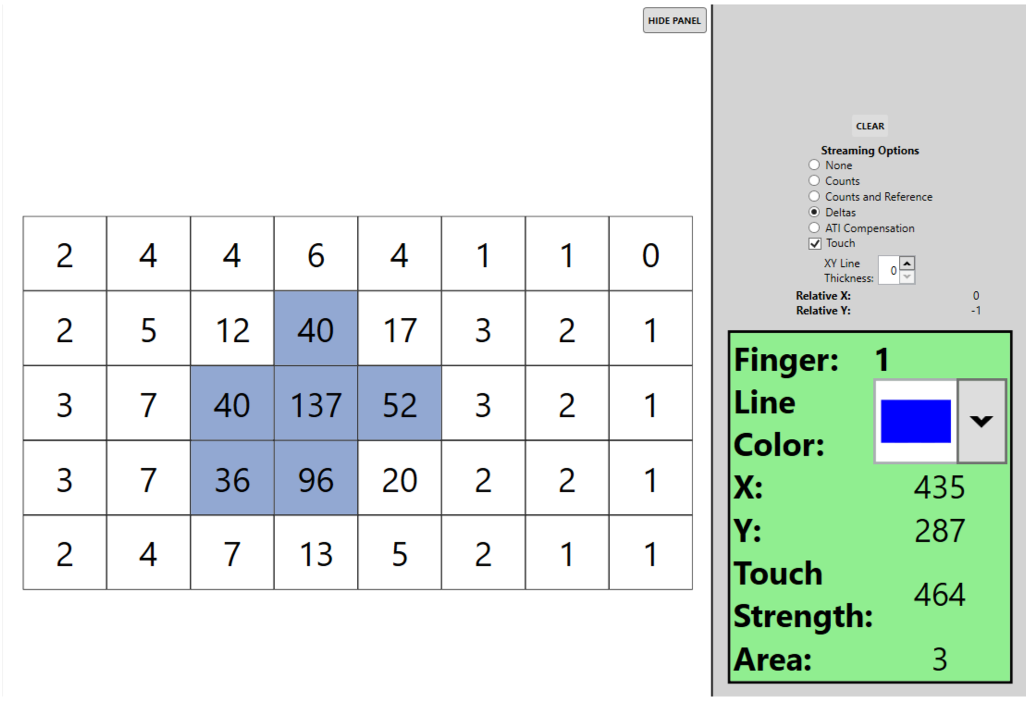



*Figure 6.2: Touch Delta*

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 centred around 512. This is ideal for handling environmental drift. Note that this check should be done at the expected operating temperature of the PCBA.

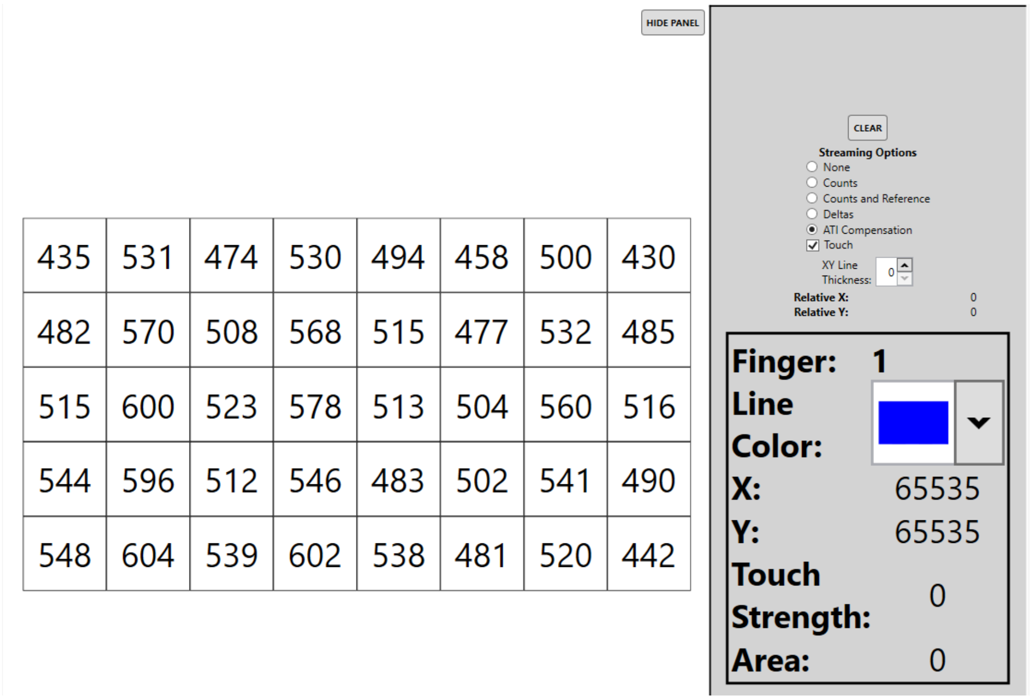



*Figure 6.3: ATI Compensation Values*

## 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 co-ordinates of each touch are verified using the product GUI.

The X and Y Trim values are verified as set correctly if co-ordinates 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.

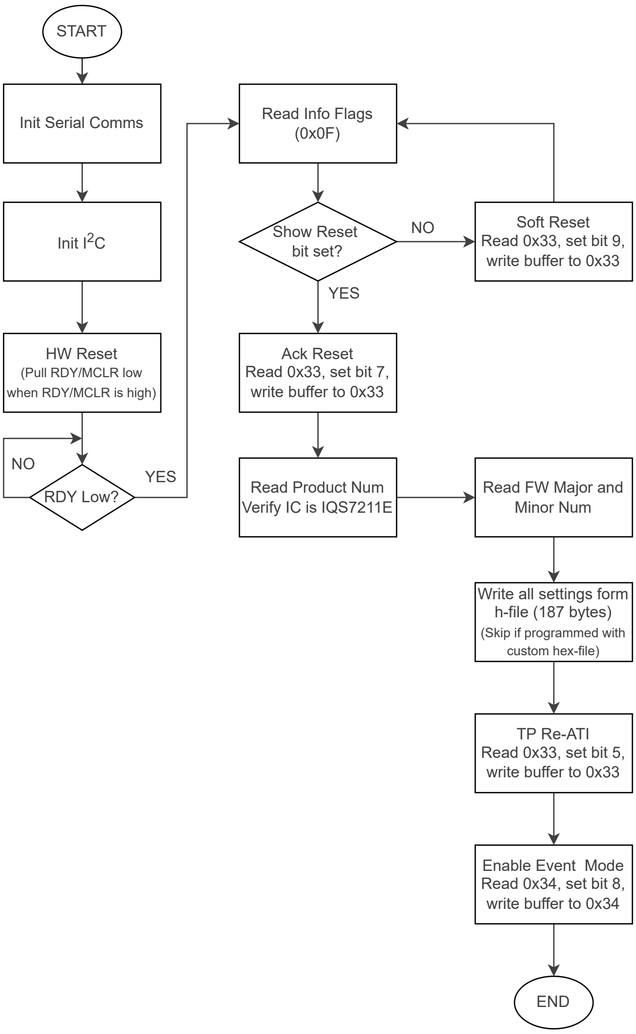



*Figure 7.1: Software Flow Diagram*

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 50ms, the measurement should be taken over a minimum of 750ms (i.e., 50ms x 15).

## 9 Conclusion

After analysing the different aspects involved in designing a trackpad for a gamepad, 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 gamepad can be designed and mass produced.

# 10 Revision History

| Release | Date | Comments |
|---|---|---|
| v1.00 | 2023/03/30 | Initial document released |

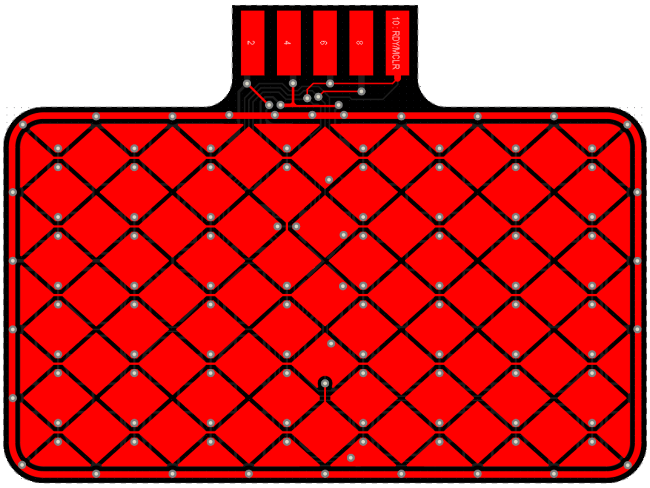
# A Bill of Materials

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

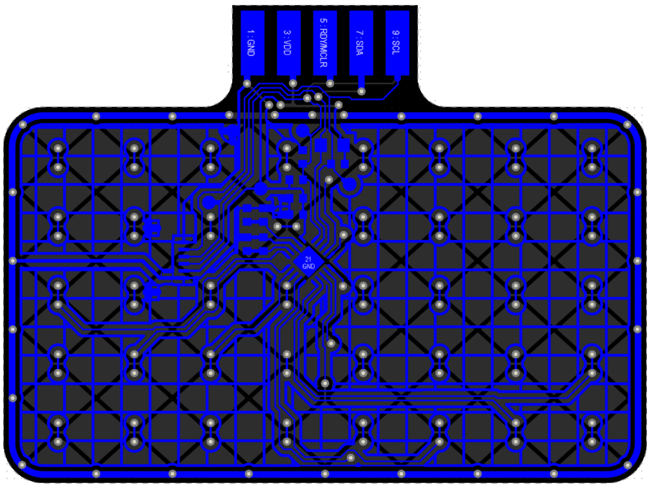
*Table A.1: Bill of materials*

| 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 | |
| 100pF | Capacitor, ceramic, X7R | C1, C3, C5 | 0402 | AVX (04025A101JAT2) |
| 100nF | 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) |
| 4.7k | Resistor, 4.7 kΩ, 5%, 0.1W | R1, R2, R3 | 0402 | Yageo (RC0603JR-074K7L) |
| AZP1269A1 | FR4-PCB, ENIG finish, 1.6mm thick, 2-layer | AZP1269A1 | | PCB manufacturer of choice |

# B PCB Layout




TOP VIEW




BOTTOM VIEW

*Figure B.1: PCB Layout*

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