AZD068 - TRACKPAD APPLICATION NOTE

A guide on trackpad design and layout

Contents

1 Introduction

This document offers an overview of important factors for designing a trackpad, including sensor design, the typical pattern for creating sensor rows and columns, the crucial overlay structure, and expected performance. It also discusses how design parameters can impact performance, as well as common design challenges like irregular shapes, mechanical cut-outs, and PCB routing guidelines. While not comprehensive, this resource aims to assist engineers in making critical decisions that lead to optimal performance.

2 Mutual Capacitive Sensing

2.1 Mutual Capacitive Sensor/Electrodes

A mutual capacitive sensor consists of a transmitter (Tx), and a receiver (Rx) electrode. Where these two come together in the design, they form the mutual capacitive sensor. The mutual capacitance between these two (C_M) is what the Azoteq controller measures and it reacts to changes in this measurement to determine proximity or touch events. Figure 2.1 shows a top view of a single channel. The two Tx diamonds are connected on a different layer with a via that is not shown for simplicity.

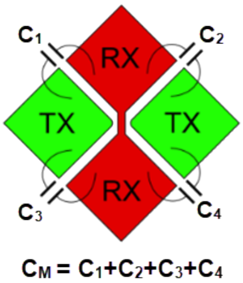


Figure 2.1: Top view of a channel

A simplified equivalent circuit is shown in Figure 2.2, with the transmitter (Tx) driving and a receiver (Rx) sensing the mutual capacitance. A parallel plate capacitor exists between the finger and the Tx electrode. The capacitance sensed on the Rx is the component of the reflected signal and the mutual capacitance between Tx and Rx.

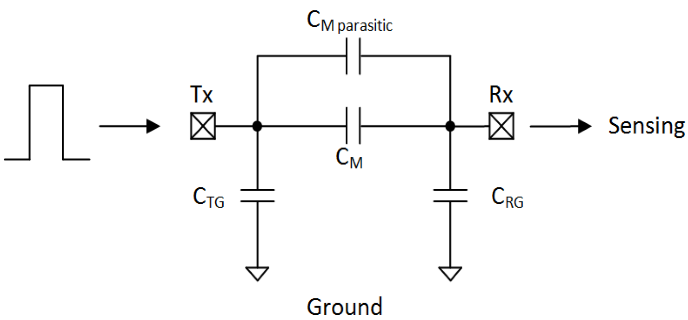


Figure 2.2: Simplified equivalent circuit of a single channel

Where, C_M: Mutual capacitance
C_{TG}: Capacitance Tx to Ground
C_{RG}: Capacitance Rx to Ground

2.2 Trackpad Sensor

The design of a trackpad involves the placement of multiple mutual capacitive sensors in close proximity to each other. This arrangement enables the simultaneous evaluation of data from all the sensors, thereby allowing for the precise determination of a finger's location.

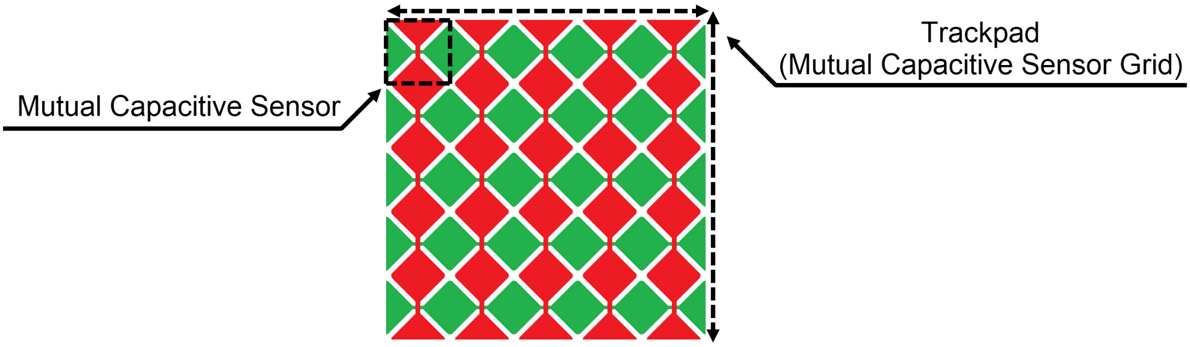


Figure 2.3: Trackpad sensor definition

2.2.1 Half Channels on the Edges

Care should be taken with the diamond pattern design when connecting the rows and columns so that full/complete sensors are achieved up till the edges. If connected incorrectly, you effectively create 'half' channels as shown below in Figure *2.4*.

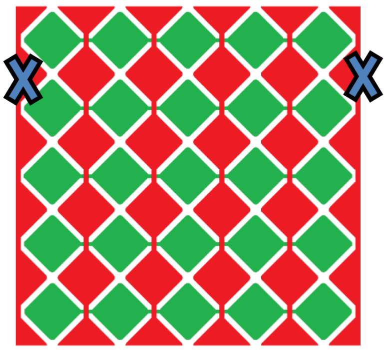
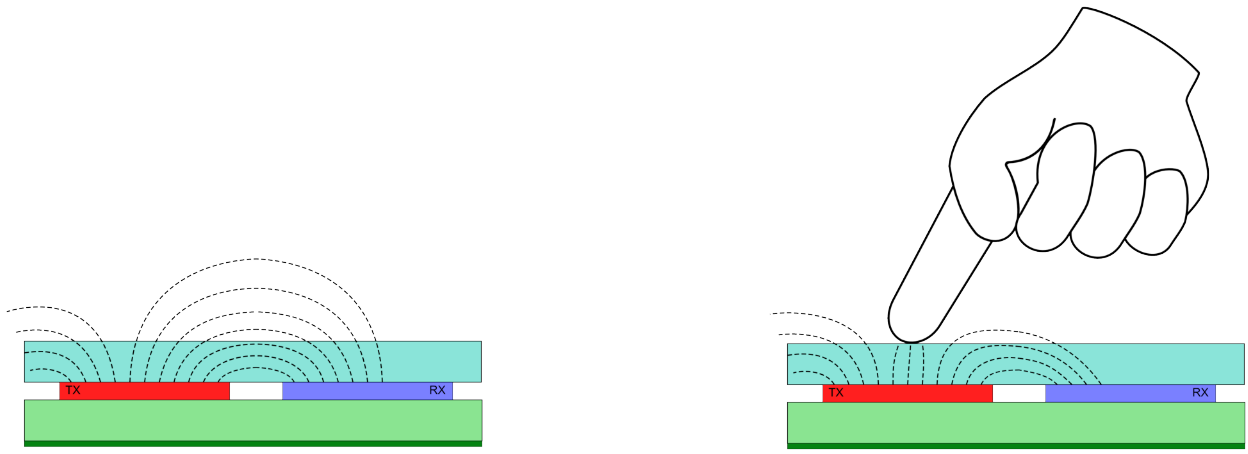


Figure 2.4: Incorrect sensor design

2.3 Interaction with Mutual Capacitive Sensor

A hand or finger when moved towards a receiver (Rx) transmitter (Tx) mutual pair affects the capacitance of the circuit. This normally results in capacitance decreasing on the Rx/Tx electrode. This decrease is measured by the ProxSense® engine by the increase of count[1] values. The count values measured increase above the non-touch state since more charge transfer cycles are required to charge the internal capacitor in the charge transfer phase. This concept of mutual capacitance is critical in the understanding on how a trackpad works so that it can be designed optimally and provide the best user experience possible.

[1] The term 'Count' is just a unit value of how many charge transfer cycles the engine requires to reach the trip voltage.



(a) Idle or no touch state

(b) Touch state

Figure 2.5: Illustration of mutual capacitive sensor and reflection of e-fields for an incoming touch

During touch the finger reduces the mutual capacitance (C_M) between the Tx and Rx from the no touch capacitance and the change is measured on the touch IC.

As a result there will then need to be more charge transfers to reach the required trip voltage, thus higher counts. In other words if the C_M decreases, the count values will increase. This is shown in Figure 2.6.

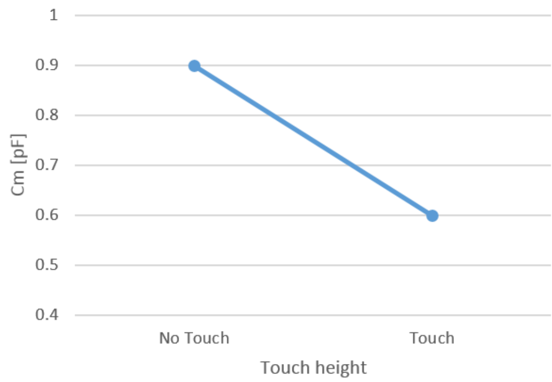


Figure 2.6: Touch vs no-touch comparison for mutual capacitive sensor

2.4 Channel Sensitivity

With a diamond pattern the touch sensitivity is not uniform over the entire sensor. The sensitivity is concentrated at the channel centre (ie Tx & Rx intersection) with decreasing sensitivity towards the edges. The single channel in Figure 2.1 is now expanded to consist of 9 channels in a 3x3 configuration, Figure 2.7.

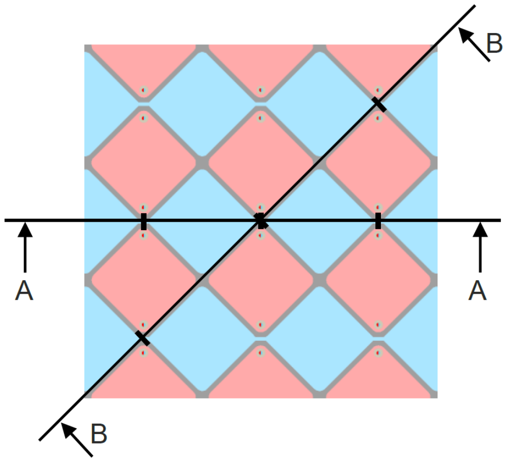


Figure 2.7: 3x3 trackpad indication sections A-A and B-B

The sensitivity of the trackpad is now looked into a bit further, from two different perspectives, A-A, and B-B. In, Figure 2.8, along the A-A segment, the sensitivity can be seen to vary as your touch moves over the channel centres.

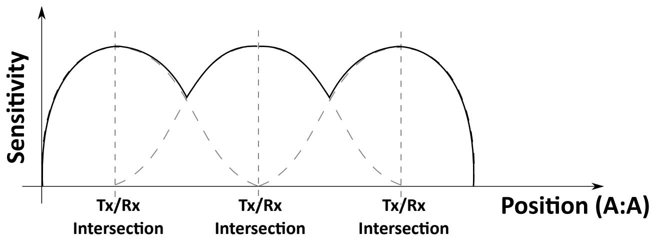


Figure 2.8: Section A-A sensitivity plot (not exact, only illustrative)

Along the B-B axis there is less overlapping as compared to the A-A axis and this leads to 'dead spot' between the channels, Figure 2.9. In other words, a small finger touching in this low sensitivity area will not be detected and gives rise to the specification of the minimum finger size, described in Section 4.8.

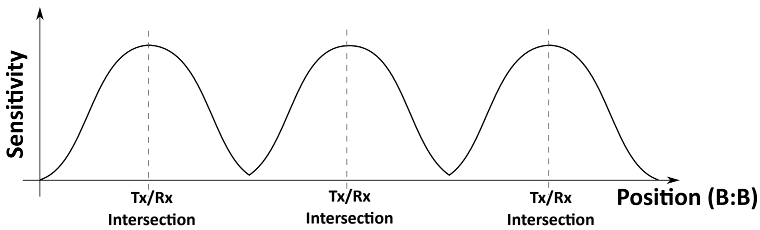


Figure 2.9: Section B-B sensitivity plot (not exact, only illustrative)

The visualization of the high and low sensitivity area concept is important in the trackpad design, especially when choosing a pitch, described later in Section 4.5.

1. **Design tip:** The designer must ensure that a small finger will still be detected as a touch when located in the least sensitive area.
2. **Design tip:** If holes are necessary in the design such as alignment holes, etc., place them in the low sensitivity areas.

2.5 Ground

The amount of ground in a trackpad is a very important factor in determining the sensitivity of the channels. This is also influenced by the thickness of the PCB and the distance between diamonds. Too much ground too close to the Tx and Rx electrodes lowers sensitivity. This effect on the Tx electrode can be seen in Figure 2.10. It is evident that the majority of the field lines will be directed towards the ground plane instead of the Rx electrode. The aforementioned effect can be prevented by implementing hatched ground planes or by creating cut-outs in the ground plane under the gaps between Rx and Tx electrodes. See Section 5.7 for detail, as well as AZD125 - Capacitive Sensing Design Guide.

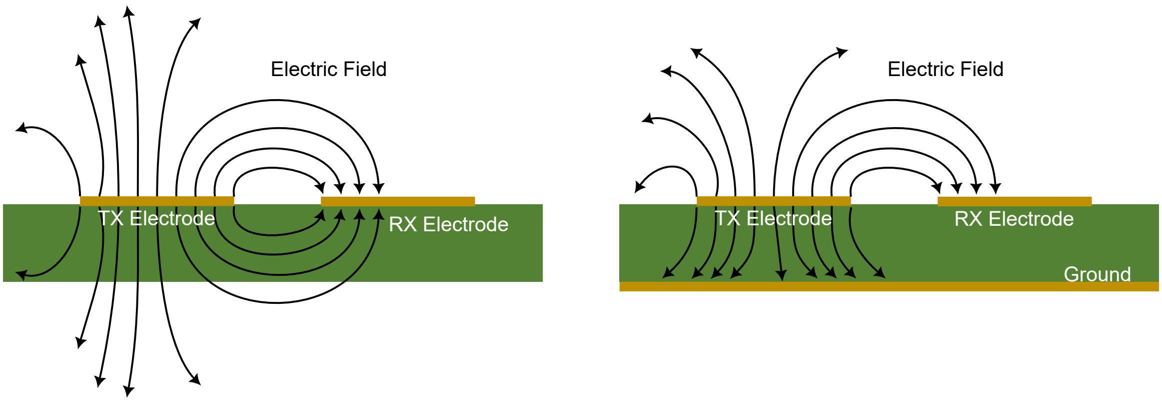


Figure 2.10: Ground effect on E-field

More parasitic capacitance is added when the ground pour is on a layer below the sensing electrodes. Although new-generation ICs (IQS721xy) can compensate for larger parasitic capacitance in the system, the ground around the sensing area will still attract the field lines which can cause a perceived reduction in sensitivity.

If the ground plane is too small, an interaction with ground influences the measurements on the Rx electrode. It is usually not a concern with a trackpad design due to the nature of trackpads and how the channels are scanned. For trackpad ICs rows and columns are scanned sequentially with only one row and column active at any given time, all the remaining channels will become inactive. The increased ground area from the inactive channels further improves the coupling for the user to ground. An example of an active row and column is shown in Figure 2.11.

3 **Design tip:** To allow for production variations the amount of compensation added to a channel should be around the centre[2] of the compensation resolution[3].

4 **Design tip:** When choosing the settings to achieve the average compensation, temperature limits should also be considered since it varies across the temperature range.

[2]The onus remains on the designer to evaluate the variation during design verification testing.
[3]Compensation resolution: IQS5xx = 255; IQS721xy = 1023

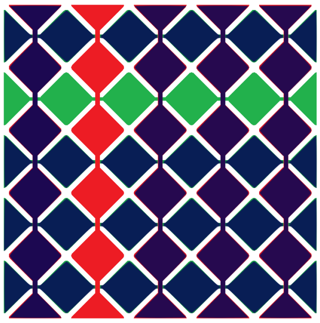


Figure 2.11: Illustration of active row and column with inactive rows and columns grounded

From Figure 2.11 above it can be seen that the ground is much larger than the C_M of the active channel.

2.6 Battery-powered Devices

When the trackpad is incorporated into a battery-powered device there is inherently a low ground reference compared to a grounded application. This low ground reference can be modelled as a capacitor between the system ground and earth, Figure 2.12.

To determine the effect of the capacitance between the system and ground (C_{SG}) on the mutual capacitance a Y to Δ transformation can be done. It can be seen that this C_{SG} capacitance is coupled into C_M that is being measured. Since the mutual capacitance has a C_{SG} component, lowering C_{SG} will improve C_M so that is can approach the value of a grounded system.

This can be shown in a PCB cross sectional view to better understand the capacitance, Figure 2.13.

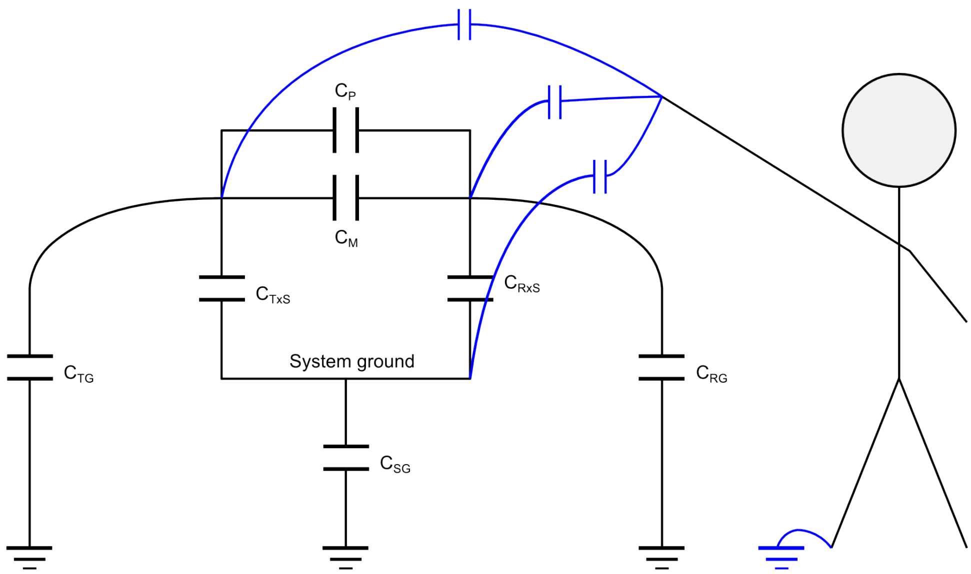


Figure 2.12: Trackpad model of a battery-powered device

A few key points to remember on a battery system are as follows:

- The change in C_M induced by a user is lower compared to grounded system.

- There is lower noise on a floating/battery system.
- There is a fine balance between the reflected capacitance and the parallel plate capacitance.
- As the distance of the finger from the electrodes approaches zero the parallel plate factor becomes more dominant and it can be said that the sensor becomes saturated, see 2.7.

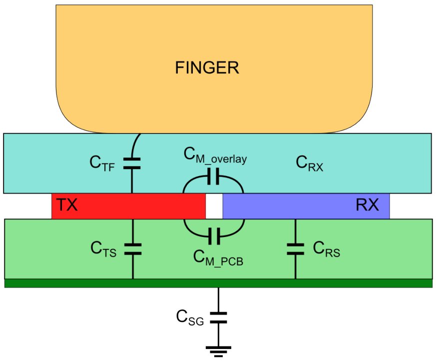


Figure 2.13: Trackpad cross sectional view

To summarise, weak or poor ground coupling can reduce the touch signal. This needs to be remembered when tuning the touch IC for a battery-powered device. The amount of C_{SG} will have a different sensitivity to that of a grounded system. It is advised to tune the touch IC via an isolation PCB or via the host processor. To stream the touch IC via the Azoteq development tools an I^2C isolation PCB can be used, Figure 2.14.

5 **Design tip:** If your application is battery-powered, makes sure the user can somehow couple to the system ground. See Section 2.7.

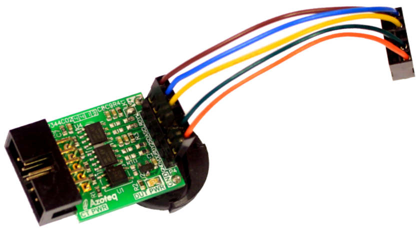


Figure 2.14: Isolation PCB

More information can be found in AZD084 - A Guide for isolated digital communications.

2.7 Sensor Saturation

Sensor saturation is a phenomenon that occurs when the trackpad becomes saturated with a touch. This happens when a finger moves too close to the electrodes and the mutual capacitance increases instead of decreases, see Figure 2.15. The result shown in this figure is derived from a MoM simulation, which illustrates the change in capacitance at different heights above the trackpad electrode. The turn-around point is dependent on how much ground coupling there is to the users' finger and the entire graph can moved to the right depending on the finger size, which is unknown. The change in capacitance is quite interesting since in the working range capacitance is reflected.

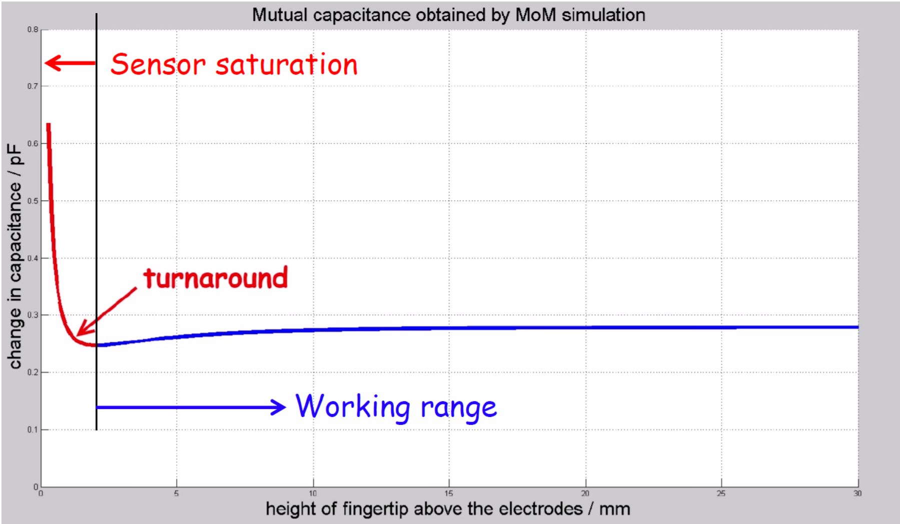


Figure 2.15: Simulated mutual capacitance at different finger heights

While in the saturation region the sensor and finger form a parallel plate capacitance like a self-capacitance sensor and the measured capacitance increases. This area of operation is used in capacitive snap theory, as discussed in Section 11. To avoid entering the saturation region the overlay thickness would need to be chosen so that the turnaround point is not obtained during normal use, say with a finger or thumb. However, in battery operation with a low ground reference the saturation curve moves to the right with increasing finger or palm size, so extra care will need to be taken in this setup.

Methods to reduce sensor saturation include:

1. Increase overlay thickness
2. Improve the coupling of the user to system ground
3. Increase the ground plane
4. Modify the sensor pattern to increase C_M

6 **Design tip:** 2 and 3 above can be achieved with conductive tape, such a copper foil. This tape can be lined in the device enclosure. A larger battery could also be used. Adding ground areas in the diamonds is also a possibility.

2.8 Noise

In capacitive sensing systems, placing series resistors on the Rx lines can help provide noise immunity by reducing the impact of noise on the sensing signals. This can help improve the accuracy and reliability of the sensing system. Additionally, placing series resistors on the Tx lines can help limit the emitted noise when all Tx lines switch together in Alternate Low Power (ALP) mode. By limiting the emitted noise, interference with other components in the system can be reduced. Overall, the use of series resistors is a useful technique for improving the noise immunity and EMI performance of capacitive sensing systems.

Typically, 100R series resistors are used as a starting value for selecting Rx or Tx series resistors. However, 470R and 1k resistors are also good options to consider.

Refer to AZD015, AZD015b, AZD051 and AZD051b for detailed information on noise.

3 Overlay

The overlay is one of the most important aspects for a correctly functioning trackpad. It is also the area where the user interacts. The overlay allows the user to use the trackpad in the working range and avoid sensor saturation affects.

There are some general principles in addition to general aesthetics such as feel, colour and surface friction that should be adhered to when considering the type of overlay for the specific application:

- Overlay material must be non-conductive.
- Mechanical properties of the overlay and its suitability.
- Adhesive must also be compatible with the overlay and PCB materials[4].
- If multiple materials are used, they must be firmly connected together. (Try to avoid different materials.)
- Air gaps should be removed completely.
- If minor air gaps are present, mechanical stresses should not cause these spaces to vary in size.

3.1 Overlay Thickness

The overlay thickness has an impact on the sensitivity of the trackpad. As the overlay thickness is increased, sensitivity is decreased, and vice versa. See Figure *3.1*.

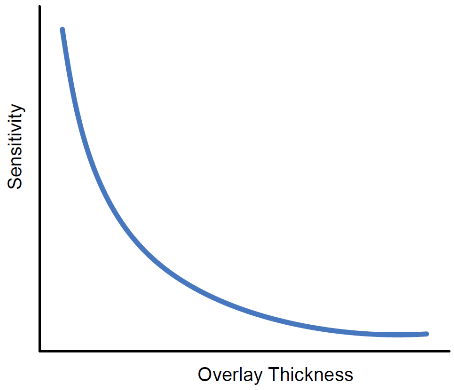


Figure 3.1: Overlay thickness vs sensitivity

The overlay must be thick enough so that sensor saturation region is not observed during normal use, see Section *2.7*. The overlay should also be thick enough so that there is no break though from ESD events. In some applications very thin overlays are used (such as PET with 0.2mm thickness), heating caused by a prolonged touch in a fixed position must be evaluated so that it does not become a problem in the field. The dielectric constant of some materials like PET changes significantly with temperature.

7 **Design tip:** An isolation PCB should be used when testing and tuning the trackpad using the Azoteq development GUI via a USB dongle such as the CT210. This is required since sensor saturation is more prevalent in battery-powered devices due to the low ground coupling.

[4] A high surface energy (HSE) plastic like ABS would require a HSE tape

3.2 Overlay Material

The overlay must be non-conductive and non-metallic, with a dielectric constant that is higher than 2.5 to achieve good sensitivity. If the overlay is conductive/metallic the E-fields cannot pass through it and the trackpad will not sense the user's interaction. The paint used in the overlay must also be non-conductive and non-metallic.

8 **Design tip:** In some products the same trackpad is used for different model colour variations. For example, one model is black while the other model is white and has different dielectric properties. The designer needs to evaluate all the colour variations to ensure the difference between the different colour overlays is not too great. If the difference is too great for production limits, then each model will need its own settings.

3.2.1 Mechanical Properties

The mechanical properties of the overlay must be noted when choosing the material composition and thickness. The three most important material properties are list below;

1. Dielectric constant (ε_r) - mutual capacitance
2. Break down voltage - ESD immunity
3. Thermal conductivity - finger heating (especially for thinner overlays)

It is important to remember the parallel plate capacitance equation when choosing an overlay material as it directly impacts on sensitivity.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{D} \tag{1}$$

Decreasing the overlay thickness (D) or increasing the touch size area (A) will increase the capacitance. However the touch size which is the size of users' finger in contact with the overlay is unknown. To improve sensitivity the overlay thickness can be reduced. A few common overlays and PCB substrates are shown below, in Table 3.1.

Table 3.1: Material properties estimated for reference only - Actual values to be confirmed by designer

Material	Dielectric Constant (ε_r)	Breakdown voltage (V/mm) (approx.)	Minimum thickness at 13kV (mm)
Air	1	1,180	11.02
Glass (standard)	7.6 - 8.0	7,800	1.67
PMMA (Plexiglas®)	~2.8	17,700	0.73
Rubber (Neoprene)	6.6	15700	0.83
ABS (plastic)	2.0 - 3.5	16,000	0.81
FR4	4.30 - 4.7	27,500	0.47
Polyimide (PI)	3.5	200,000	0.07
Polyester	~3.4	17,000	0.76
PET film (Mylar®)	3.3	275000	0.05

3.2.2 Overlay Temperature Dependency

When an overlay is very thin, such as less than 0.5mm, finger heating must be taken into consideration, since thermal conductivity and dielectric constant (ε_r) are related. A change in temperature induced by finger heating could change the ε_r of the overlay. In some materials, such as PET, the ε_r dependency on temperature is greater.

For long touch activations the user's finger and the location around the finger will heat up (in some materials this happens faster). If the dielectric constant of the overlay material is very dependent on temperature then the mutual capacitance will change as the overlay heats up.

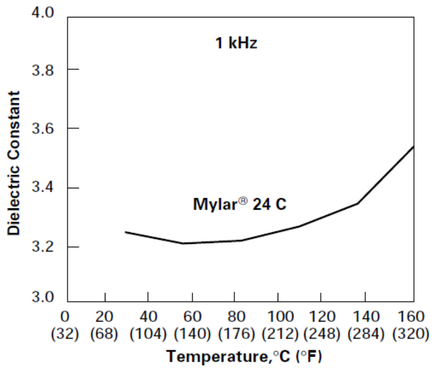


Figure 3.2: Dielectric constant vs temperature for Mylar®

When a warm finger touches a cool overlay, as used in Figure 3.2, the counts increase by the same amount as the zero temperature differential. However, the counts begin to drop as the heat from the finger is transferred into the overlay. The increase in temperature in the overlay changes the dielectric constant resulting in a lower ε_r than before the touch. In extreme cases the touch could be lost if the touch threshold was not chosen correctly.

When the finger is removed and the touch released the counts drop by the same amount as they increased for the initial touch before the overlay heated up. The overlay would then cool down causing the counts to increase again to the steady state condition.

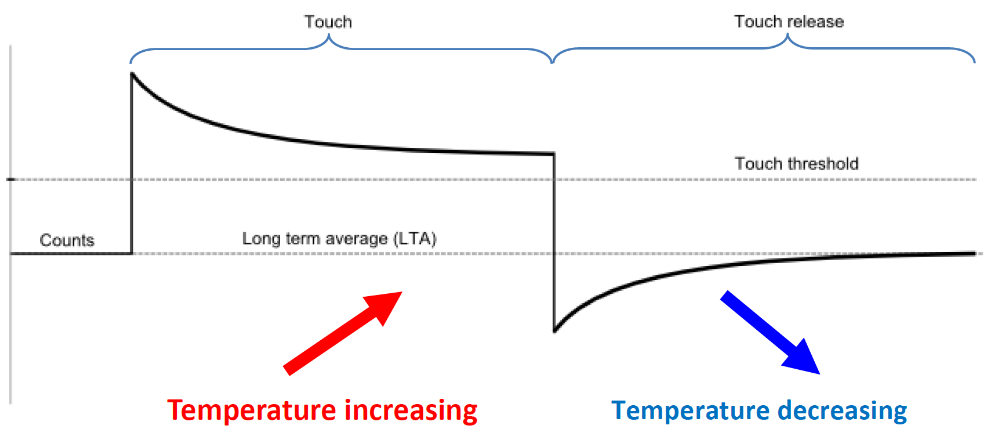


Figure 3.3: Example of count change for an overlay that is very temperature dependent

3.3 Overlay Adhesive

Adhesive tape is used to securely stick the overlay to the PCB so that it does not move during normal use. The adhesive also removes the thin air layer between the two parts so that sensitivity can be increased even further.

Types of adhesive must be compatible with the overlay material so that there is no delamination during the life of the product.

For example,

High surface energy materials: 3M 468MP
Low surface energy materials: 3M 300LSE

3M 9448A is good for both HSE and LSE materials

3.4 Finger Guides

By adding texture, grooves, bumps or similar modifications to the overlay material, you can force certain movements or interactions in certain areas of the trackpad.

For example, by sinking circular finger guides into an overlay, finger movement can be restricted and controlled inside an area over the trackpad. This information can in turn be used to create a wheel-type control, as displayed in Figure 3.4.

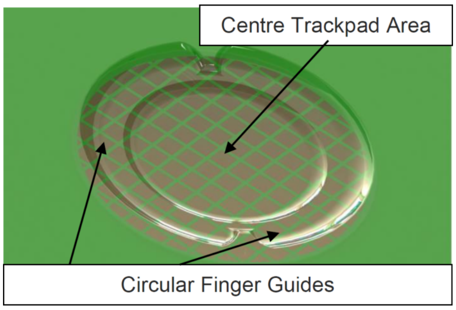


Figure 3.4: Circular wheel-type trackpad (angle view)

In another configuration, a diamond trackpad can be arranged to form a slider-type control, with the overlay restricting movement to a linear sliding motion. This arrangement is illustrated in Figure 3.5.

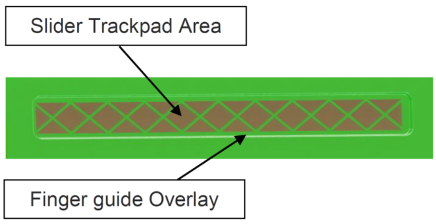


Figure 3.5: Slider-type trackpad

3.5 Curved and Non-Uniform Overlay Surfaces

The trackpad overlay can consist of gradual variations in thickness, the details of which are beyond the scope of this document, please refer to AZD076 - How to design a non-uniform/curved touchpad.

Depending on the amount of curve needed and spacing constraints, the PCB substrate can either be rigid (i.e. FR4) or flexible (i.e. FPC). The key concept is to ensure that the trackpad PCB/FPCB can be securely glued to the overlay surface without any risk of air gaps or delamination over time. The second key concept is to keep the sensitivity across the trackpad as similar as possible so that the resulting touch delta (change in counts) would be uniform over the entire surface.

If a curved overlay surface is required, it is advantageous to use a surface that is only curved in one axis, as shown in Figure 3.6 *(b)* below. When the surface is curved in two axes, Figure 3.6 *(c)*, the design becomes significantly more complex and may require strain-relief cuts to prevent cracking, tearing and air gaps. Refer to Section 5.8.3.

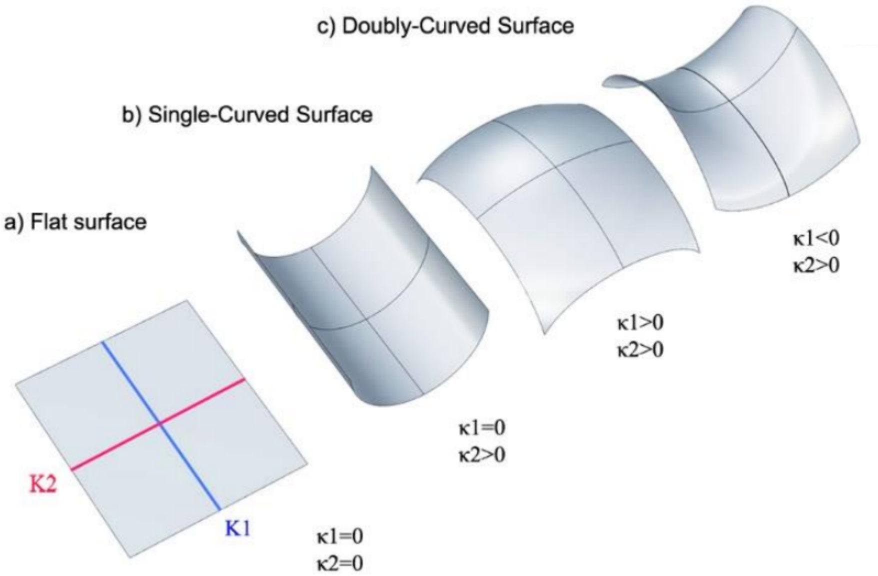


Figure 3.6: ***(a)*** *No curve* ***(b)*** *Line K2 curved* ***(c)*** *Both lines K1 and K2 curved*

4 Trackpad Design

This section deals with the design and specifications that are typically applicable to trackpads. The key trackpad physical parameters discussed are:

- Diamond pitch and gap
- Resolution
- Minimum finger size
- Active touch area
- Multi-touch parameters

4.1 Trackpad Parameter Definitions

A trackpad is a collection of individual touch buttons arranged in rows and columns, called channels, as shown in Figure *4.1*.

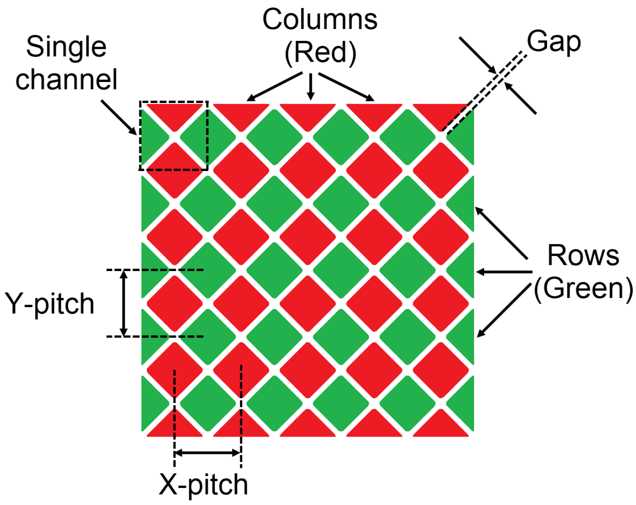


Figure 4.1: Trackpad parameter definitions

4.2 Number of Channels

The number of channels in the trackpad design plays an important role in the resolution and performance. Every column or row of the trackpad intersects at a particular point to create a channel.

The columns of a trackpad are all connected to a group of electrodes (Txs/Rxs), and the rows to the other group (Rxs/Txs).

For example:

Rows → Connected to Rx electrodes
Columns → Connected to Tx electrodes

OR

Rows → Connected to Tx electrodes
Columns → Connected to Rx electrodes

On a trackpad layout (typically a diamond shape pattern), each intersection of an Rx and Tx row/-column forms a unique mutual-capacitive sensing element which is referred to as a *channel*. Each channel has an associated count value, reference value and touch status.

Trackpad channels are numbered from 0 to *(TotalRxs $*$ TotalTxs)* - 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 some IQS721xy IC settings such as allocating channels into sensing cycles (timeslots). Refer to AZD123 - IQS721xy Trackpad User Guide for more information on timeslot allocations.

Here is an example of a 4x3 trackpads' channel numbers:

Table 4.1: Channel number assignment

	Rx0 (Column 0)	Rx4 (Column 1)	Rx1 (Column 2)	Rx5 (Column 3)
Tx8 (Row 0)	0	1	2	3
Tx10 (Row 1)	4	5	6	7
Tx2 (Row 2)	8	9	10	11

4.3 Trackpad Resolution

The on-chip native resolution for the trackpad algorithms is 256 pixels between rows or columns. This means there are 256 steps between channel centres. The trackpad resolution is configurable, but the maximum resolution is:

X range: 0 to 256 * (Trackpad Rxs - 1)
Y range: 0 to 256 * (Trackpad Txs - 1)

Selecting an X or Y resolution larger than this maximum would thus be artificial, and is not recommended. For example a trackpad with 5 columns would have a maximum X-resolution of 256*(5-1) = 1024.

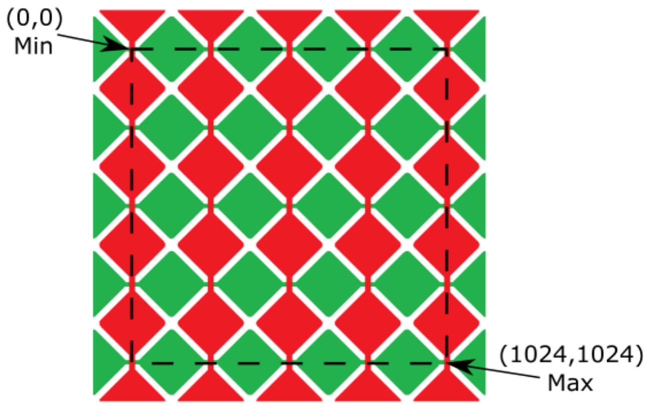
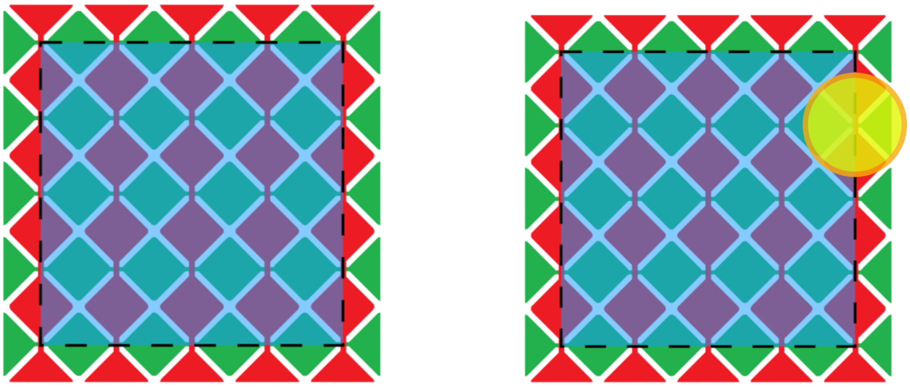


Figure 4.2: Resolution of 256 pixel / channel for a 5x5 trackpad

4.4 Trackpad Active Area

The XY co-ordinate range, or active touch area is displayed in Figure 4.2. It is clear that the active touch area, is smaller than the trackpad size. This is because the (0, 0) point is in the channel centre. To increase the active touch area and decrease the border, the pitch will need to be decreased, thus more channels will be needed and possibly a larger more expensive IC used.



(a) Active touch area

(b) Active touch area with 8mm touch

Figure 4.3: Indication of active touch area

Smaller pitch = less border = better edge performance

4.5 Trackpad Pitch

The pitch of a trackpad is defined as the distance between consecutive sensors in a row or a column, as illustrated in Figure 4.1. The pitch is chosen based on the performance required from the sensor and the required trackpad size. Minimum, typical and maximum pitch is given in Table 4.2.

Table 4.2: Pitch

Dimension	Min.	Typical	Max.
Pitch	1.56 mm	3 - 6mm	8mm

4.6 Trackpad Gap

Trackpad patterns with a low C_M have higher finger noise during a touch. For this reason it is important that the base mutual capacitance is high enough for the design. To increase the base mutual capacitance the gap between diamonds need to be small, with a typical gap in the range of 0.3mm.

Table 4.3: Gap between diamonds

Dimension	Min.	Typical	Max.
Gap	0.1mm	0.3mm	0.5 mm

4.7 Hover

Hover is defined as the distance a finger is above the trackpad when a touch coordinate is first detected. The touch threshold should be selected so that minimal hover is obtained, while still being able to detect small touches in the least sensitive part of the sensor (see Section 5.3).

It is thus evident that a trackpad sensor with a large pitch will have a larger variation in sensitivity between the most and least sensitive regions. This then makes it difficult to find touch thresholds that don't either miss small finger touches (not sensitive enough), or alternatively cause hover (too sensitive). However, with an appropriate pitch, these concerns can be circumvented.

Please refer to the 'Thresholds' sections in the AZD087 or AZD123 User Guide for selecting an optimal touch threshold.

4.8 Minimum Finger Size

The minimum finger size is defined as the smallest finger that can result in 100% tracking over the trackpad.

$$Minimum\ finger\ size = \sqrt{xPitch^2 + yPitch^2} \tag{2}$$

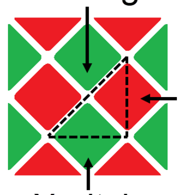


Figure 4.4: Minimum finger size

This measurement is the distance between channel centres, and is derived from the sensitivity plots in Figure 2.7 and Figure 2.8. Typically it is desirable to allow some hover as this would relax the minimum finger size specification. A typical allowable hover distance is 0.4mm. It is also advisable to enable hysteresis on the touch threshold where different thresholds are used to set and release touch conditions. The use of hysteresis ensure that a touch does not flicker in state (switch between touch and no-touch repeatedly) when a user hovers above the trackpad at the touch threshold height.

4.9 Minimum Touch Separation

Minimum touch separation is a parameter that is used in multi-touch trackpads to determine the shortest distance two fingers can come before they merge into one point. Multi-touch is used for functions such as two finger scroll, pinch and zoom. The estimated minimum touch separation distance is shown below, and assumes that two 8mm diameter fingers (common standard) are used.

$$Minimum\ Touch\ Separation \approx 2.5 * pitch \tag{3}$$

The factor of 2.5 is an estimated value, and individual touch points can be distinguished closer than the factor. However accuracy is no longer guaranteed due to the two touch areas overlapping and distorting the actual output.

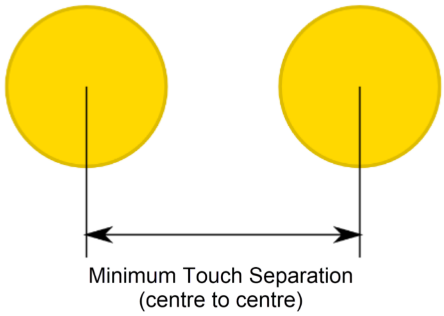
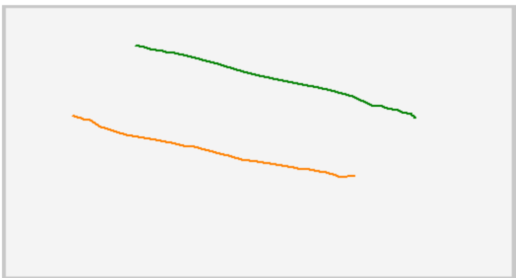
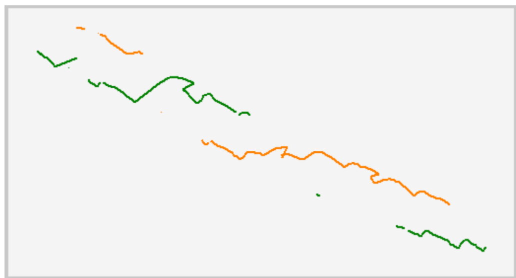


Figure 4.5: Minimum touch separation

The effect on tracking above and below the minimum touch separation is shown in Figure *4.6*. Proper tracking is illustrated in Figure *4.6a*, where two fingers directly adjacent to one another are dragged across the trackpad. The trackpad algorithm is able to adequately distinguish between the two touches, and provide accurate XY data for each of the two fingers.



(a) Proper tracking (separation > minimum)



(b) Improper tracking (separation < minimum)

Figure 4.6: Proper and improper tracking

In contrast, Figure *4.6b* illustrates improper tracking, where the trackpad algorithm is unable to distinguish between the two unique touches, and often merges the data of both fingers into a single XY data point.

9 **Design tip: How to determine the minimum touch separation:** The 2.5 times pitch can be verified by placing two test fingers a specified minimum distance apart, say 10mm with 8mm[5] test fingers. Then a test can be performed by tracing the two lines on the screen. If at any time the number or touch points drop to only 1, without lifting the finger, the fingers merged. Repeat the test increasing the separation until no merging is detected, this is the minimum touch separation distance.

4.10 Linearity

For a linearity test the best fitting line is compared to the line that is constructed by connecting all the recorded touch points together to form a continuous line (which is filtered). The maximum deviation of the recorded points from the best fitting line can then be found, Figure *4.7*.

In an automated linearity test a test finger is moved in a straight line across the trackpad. This is repeated multiple times with horizontal, vertical, and diagonal swipes. Each trajectory will subsequently

[5] The test fingers used first need to be verified that they are large enough and bigger than the minimum finger size before this test is started.

have a linearity error value derived and this value is used to determine how linear the trackpad pattern is.

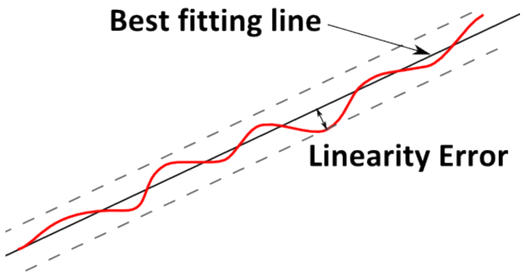


Figure 4.7: Linearity error illustration

The edge channels of a trackpad are all the channels on the border of the trackpad. Trackpads with a uniform pattern such as the traditional diamond pattern inherently have lower linearity on the edge channels as compared to the central area.

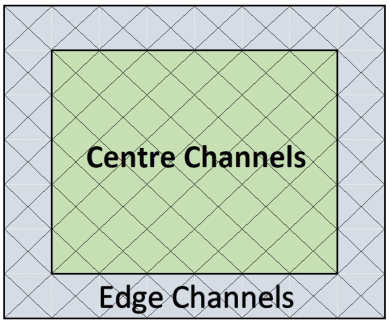


Figure 4.8: Edge channels of a trackpad - single channel border

The touch point distortion on the edge channels is due to the physical layout of the pattern, centroid detection of the touch algorithm and how the finger moves onto the trackpad area. The degraded linearity can be seen as tails or distortion between the start point and zero point, as shown in Figure 4.9. Effectively the lower linearity also depends on the shape and orientation of the approaching finger. With a well-designed and balanced trackpad the touch strength is close to uniform over the entire area of the trackpad, provided the touch size does not change, the point is confined to the centre channel region and there is no sensor saturation.

The edge channel performance is further clarified in Figure 4.9. A test finger is moved from point A to point B horizontally in a straight line. In this explanation the tail size has been exaggerated to clarify the effect. In practise the x coordinate would move backward and forward and would not be easily noticeable.

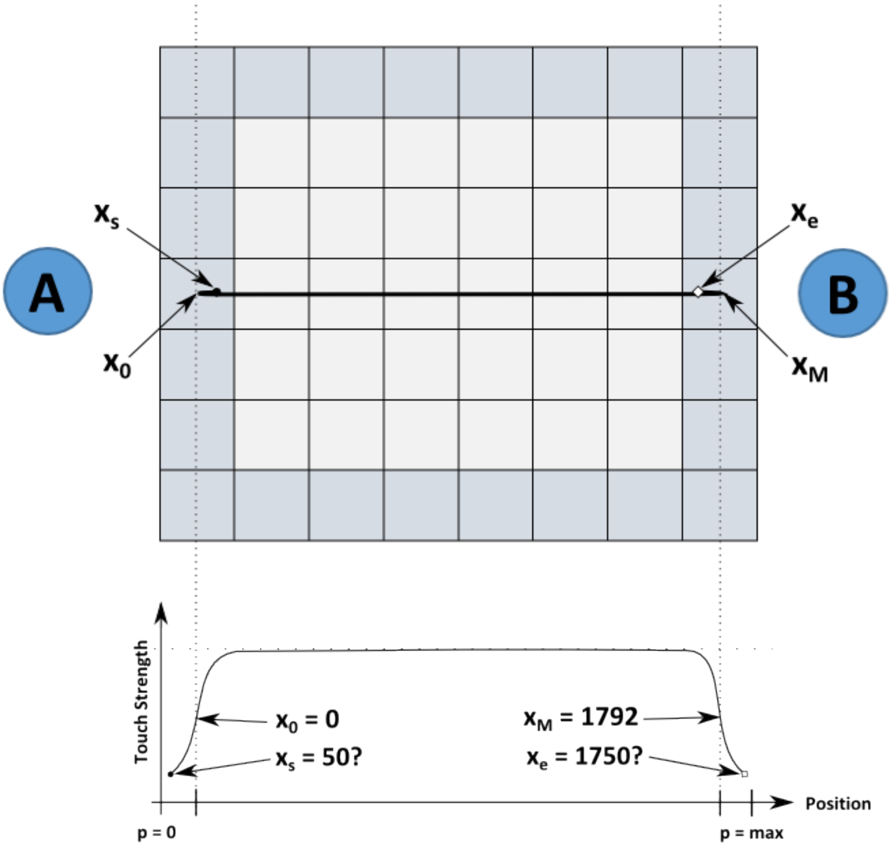


Figure 4.9: Touch point moved from A to B. The size and length of the tails have been exaggerated to highlight the effect.

x_0: x axis 0 coordinate
x_M: x axis maximum coordinate
x_S: first coordinate report on x axis coordinate on a touch
x_E: last coordinate report on x axis coordinate just before the touch was lost

As the finger moves from A onto the trackpad the touch delta increases. When the delta is large enough and the touch threshold reached, a touch event is reported, x_S. This reported x coordinate in the top image does not reflect the true x coordinate of the finger, since the finger is outside of the active touch area. The finger continues to move and at x_0 the fingers x coordinate is reported correctly. From x_0 up until point x_M the touch coordinate is undistorted. As the finger moves off the trackpad and outside the active touch area the x coordinate is distorted again up until point x_E when the touch delta is below the touch threshold and touch is subsequently lost. Similar distortion can be seen when the finger approaches at an angle that is not tangent to the trackpad diamond edge. A few examples are shown below and differences are discussed.

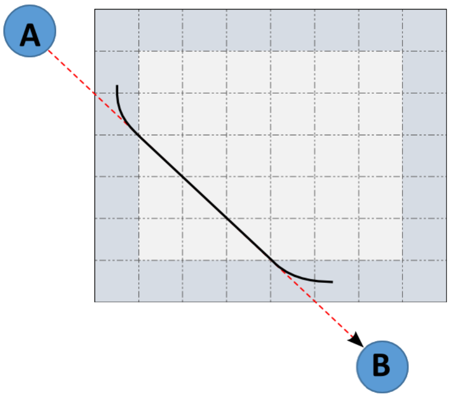


Figure 4.10: Fingertip / Stylus

Fingertip / Stylus
The distortion is limited to the edge channels.

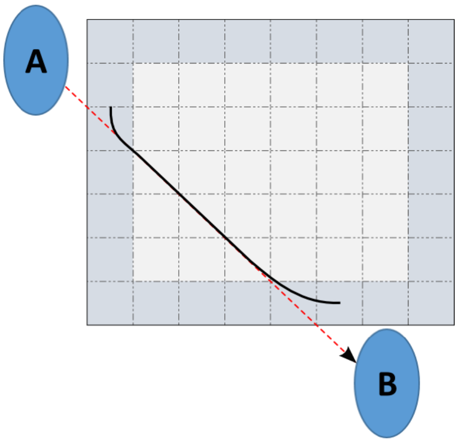


Figure 4.11: Thumb / Flat finger (parallel to edge)

Thumb / Flat finger (parallel to edge)
Notice the highlighted channels at the beginning and end of the trajectory. These are the channels which obtain a touch delta first and last, and cause the distortion. This distortion is normal since the trackpad has to have edges and is not infinite in size.

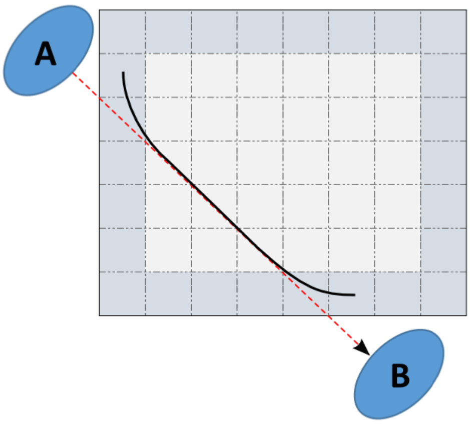


Figure 4.12: Thumb / Flat finger (45 degree angle)

Thumb / flat finger (45 degree angle)
This orientation would result in the most amount of distortion, however it is still mostly confined to the edge channels. This type of distortion is seen on circular trackpads, since any approaching finger which does not aligned to the centre of the trackpad will be distorted.

10 **Design tip:** There are methods to reduce the effects of these tails; the touch strength can be limited before an XY coordinate can be accepted, this could also make the trackpad more robust to noise from external sources such as NFC etc., however legitimate small sized touches, such as a child's finger might be missed.

4.11 Switching Circuitry Interference

The change in capacitance measured by Azoteq devices is typically very small and is measured using an oscillator circuit that generates an AC signal. However, LED driving circuitry can also generate electromagnetic interference (EMI) that can interfere with the capacitive sensing signals. This interference can cause inaccurate or unstable readings, making it difficult to reliably detect the proximity of objects.

To reduce the interference caused by LED driving circuitry, there are several techniques that can be used, such as using shielded cables, adding filtering capacitors, and optimising the layout of the circuit board.

11 **Design tip:** Keep changing potential traces such as PWMs etc. away from the Rx diamonds and traces, shield with ground if necessary. See Section *5.3.1*.

It is very important to ensure that the LED driving circuitry is properly grounded and isolated from the capacitive sensing circuitry to prevent coupling between the two circuits.

If the PCB includes LEDs that are controlled by switching circuitry, it is important to reference the switched side to ground using a capacitor. Otherwise, the floating net, which occurs when the FET/BJT is not active, can cause interference with the capacitive sensing. Figure *4.13* provides an example of this issue. Without a C_{float} capacitor between the LED and the FET/BJT, the net between the LED and the FET/BJT would be left floating when the switch is open, causing problems with capacitive sensing. This is why the C_{float} capacitor is added to prevent interference.

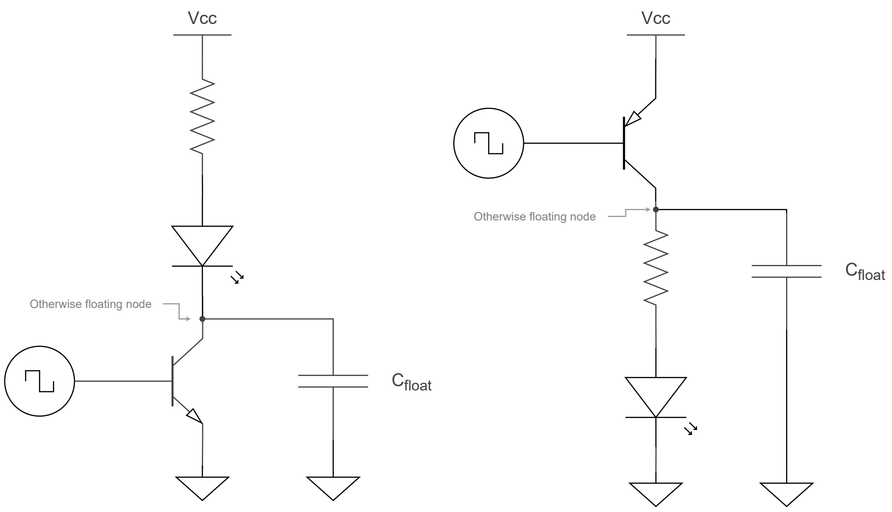


Figure 4.13: Example circuit diagrams with an LED driven by a switching transistor and a C_{float} capacitor to prevent interference with capacitive sensing

12 **Design tip:** The recommended capacitance value for the C_{float} capacitor depends on the specific design of the PCB and the capacitive sensing system. However, typical capacitance values for C_{float} are in the range of 100pF to 10nF, and typically 1nF.

13 **Design tip:** The C_{float} capacitor does not need to be physically close to the LED itself. Even if the capacitor is several centimetres away from the LED, it will still serve its purpose. This may aid layouts that are tight for space around the sensors.

5 PCB Layout

5.1 General Guidelines

Trace routing is another critical part of trackpad design. This important aspect is commonly overlooked and results in poor trackpad performance. Care and time must be taken by the designer to ensure that the trackpad layout and component orientation is optimal in such a way that it allows for the minimal parasitic capacitance and shortest sensor trace lengths.

The placement of the traces has an impact on both the desired mutual capacitance and the undesired parasitic capacitance of the trackpad. It is desirable to have a balanced trackpad, i.e. a trackpad where all of the channels have the same mutual capacitances and the same parasitic capacitances. It is important to note that circuits with thin substrates, such as FPC, are more susceptible to the negative effects of non-optimal routing.

5.2 Layout Guidelines

- Generally the Rx tracks should be routed as far away as possible from the Tx tracks.
- Rx and Tx tracks should not be routed in close proximity and parallel to each other.
- Rx tracks can be routed in close proximity and parallel to other Rx tracks.
- Tx tracks can be routed in close proximity and parallel to other Tx tracks.
- Where design limitations require the Rx and Tx tracks to run in close to each other, or in parallel, a ground track should be routed between them for shielding purposes as shown in Figure 5.1.

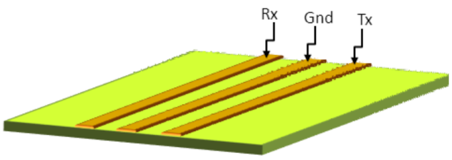


Figure 5.1: Shielding using ground

- If a Rx and Tx track has to cross on a multilayer PCB, the crossing should always be done at a 90° angle (right angles). This is demonstrated in Figure 5.2. Care should be taken for thinner PCBs, such as FPC, to reduce the area where the Tx and Rx cross each other and be kept to a absolute minimum.

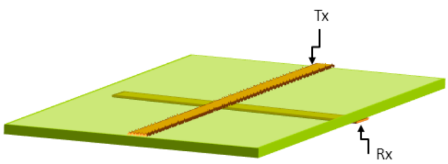


Figure 5.2: Right angle crossing

- No floating tracks or conductive materials should be placed in close proximity to either the trackpad sensors or the Tx and Rx tracks.
- Keep traces as short as possible.
- Place decoupling capacitors close to the IC.
- Trackpad design is all about uniformity so that the touch delta can be uniform, thus aim to have all electrodes designed as similar to each other as possible.

- Rotate the touch IC so that routing of the Rx and Tx traces run directly to their respective diamonds.
- Keep switching traces such as PWMs etc. away from the Rx diamonds and traces, shield with ground if necessary
- Generally used thicknesses:
  - Trace thickness 0.15mm
  - Trace to ground spacing 0.3mm

Great care should be taken when designing trackpads on flexible PCBs. Like all trackpads the goal is to minimise parasitic capacitance and maximise the touch delta. For rigid two-layer FR4 PCBs the routing guidelines can be followed less strictly, this is because the two copper layers are far enough apart so that the parasitic capacitance is small in relation, in relation to the mutual capacitance, to ensure proper operation. A theoretical comparison of the parallel plate capacitance, Figure *5.3*, of two 4mm long tracks of 0.1mm and 0.2mm thicknesses at different base material thicknesses is shown in Figure *5.4*.

It can be seen that any routing mistake on a PCB with a thinner substrate would result in a larger addition of parasitic capacitance than the same routing mistake on a PCB with a thicker substrate. Each channel a track runs under adds additional unwanted parasitic capacitance (C_P).

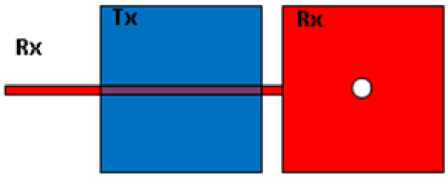


Figure 5.3: Example of Rx trace being routed under a Tx

The RC time constant should also be considered when driving an electrode. The constant is especially important for ITO s as the resistance on the traces is large, see Section *8* for detailed information.

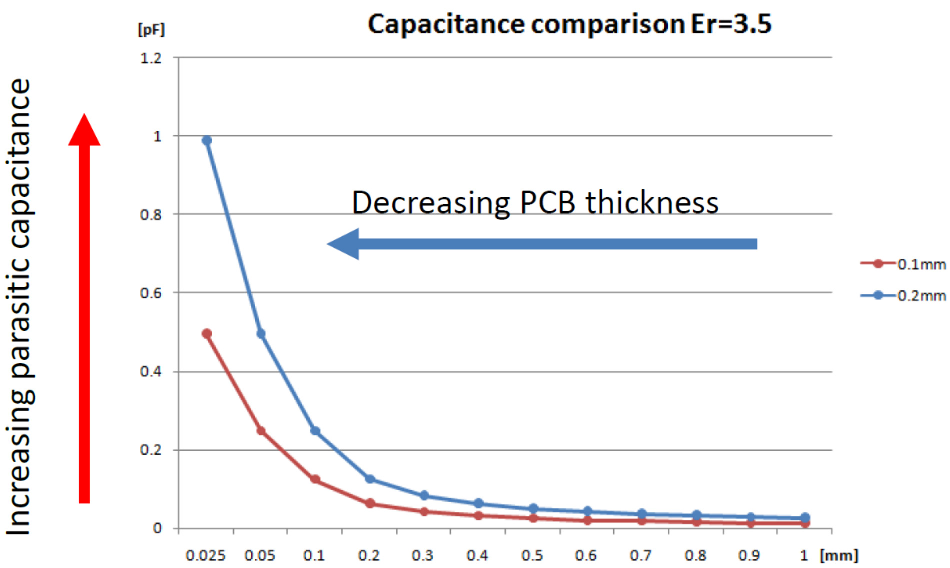


Figure 5.4: How the capacitance increase when the base material thickness decreases.

5.3 Mechanical Cutouts

Any mechanical cutouts in the PCB need to be carefully planned to be located in areas that will have the smallest effect on the capacitive sensing.

Mechanical cutouts may be needed to orientate the trackpad PCB correctly in a housing during manufacturing and testing. However, in order to avoid degrading the touch performance in the area where the cutout is placed, the cutout should be placed in the areas that would have the least impact on the sensor performance. The sensitivity distribution of a channel using a diamond pattern can be imagined as a Gaussian distribution with the peak at the channel centre and the valleys on the channel edges as described in Section 2.4. The ideal locations of these cutouts can be seen by looking at the sensitivity distribution illustrated in Figure 5.5. The green areas are the ideal locations since this is the area of reduced sensitivity, while the red areas are the channel centres. Cutouts must be avoided in the channel centres.

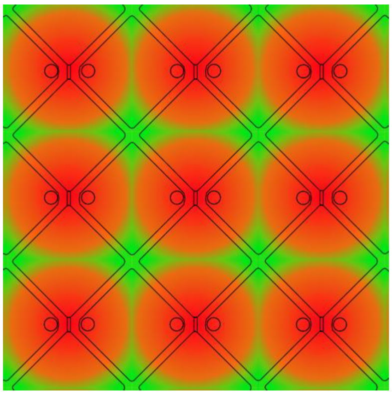


Figure 5.5: Alignment hole or LED through-hole backlighting areas indicated by green areas (image not to scale)

5.3.1 LED Backlighting

The LED backlighting holes can be placed in the same locations as described in Figure 5.5. If the LED is driven with PWM this could interfere with the capacitive charging. It is advised that the LED level is either constant during this time, or, the driving lines be shielded from the Rx signals. Shielding can be either achieved with a ground layer or the traces can be routed behind a Tx diamond since this is also a driving line. Refer to Figure 4.13 to make sure the capacitive sensing is not affected by switching the LEDs.

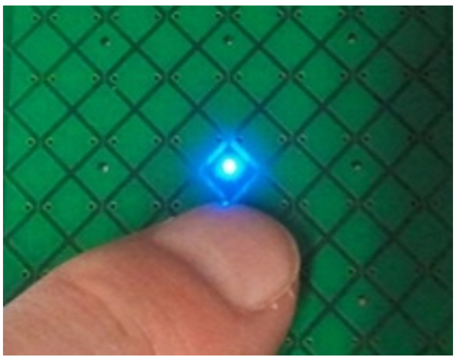


Figure 5.6: LED in the centre of a diamond

5.4 Ground / ESD ring

Some ESD immunity can be achieved by placing a suitable ESD ring around the trackpad. To protect the IC from ESD effects, the ESD ground should be separated from the circuit ground and only connected to the circuit ground at the connector to the main PCB.

To be effective, the ESD ring should not be covered with solder mask. Figure 5.7 provides a general guideline for the ESD ring. Remember to connect the ESD ring to the ground on the bottom layer of the PCB using vias.

The ESD ring also improves edge performance since the edge E-fields are shunted to ground. It also plays a second role as a shield when the device is held in a user's hand. The ESD/Ground ring helps to reduce the effect of a hand on the outside of the trackpad when the fingers wrap around the unit, i.e. the chance of an unwanted proximity or touch event would be reduced.

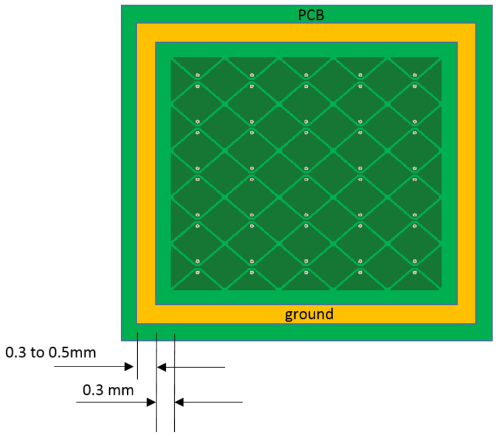


Figure 5.7: ESD ring guideline

5.5 Signal Lines

Signal tracks that are routed directly beneath a trackpad can increase the noise on the capacitive measurements. Examples of possible noise sources include PWMs for LEDs, voltage tracks from noisy switch mode power supplies, data communication tracks, and even control tracks for buzzers and motors. These tracks should be routed away from the Rx electrodes on the trackpad and should preferably be routed on the edge of the PCB. For situations where it is possible to control the timing of the noise source, it is beneficial to sync the IQS device and to then only do charge transfers when there is no noise. For more information refer to the specific device's datasheet.

5.6 Two-layer PCBs

The touch IC should be placed away from the trackpad area. Practically, this is not always possible with the tight and limited space available in consumer electronics. With the high sensitivity of the Azoteq range of ICs, and the power of the ProxSense® engine, an IC can be placed directly behind the trackpad without causing any issues. However, some design rules still need to be followed so that the average ATI Compensation for each channel is in the centre of the sensitivity range. This allows for a wider range of limits during production and in turn reduces the fallout percentage.

Components should also be placed behind the areas of lower sensitivity as explained in Sections 2.4 and 5.3.

Ground is also important and keeps the trackpad balanced. Therefore, avoid areas with large gaps in the ground pattern. This would lower the C_{TG} or C_{RG} and thus affect their ratios to C_M, which in turn would affect the sensitivity of that channel.

Prioritise IC placement and routing of Rx and Tx signals before routing the rest of the circuit:

- IC can be placed behind or outside the trackpad area.
- For thin PCB thicknesses (<0.6mm) or on FPC, the IC should not be placed directly behind the TP.
- Place and rotate the IC so that the Rx pads on the IC lie behind a Rx diamond and the Tx pads on the IC directly behind a Tx diamond, or as close as possible.
- Place and rotate the IC so that the distances from the electrodes to the Rx and Tx pins are at a minimum.
- Route in same methodology as for ITO and FPC
- Route Rx traces first directly to the electrodes
- Followed by Tx traces (ensure separated by ground)

In the following subsections we discuss different routing methodologies:

Type 1: Space not critical

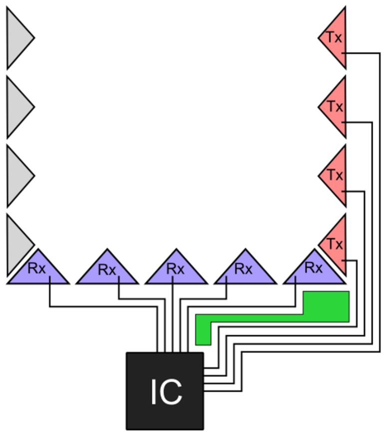


Figure 5.8: Illustration of Type 1

- This routing methodology is employed for any PCB with a thin substrate. This includes ITO and FPC.
- Route is same methodology as for ITO
- Route Rx traces first directly to the electrodes
- Followed by Tx traces (ensure separated by ground)

Type 2: Narrow PCB or FPC trackpad

The touch IC is placed outside of the trackpad area. The Rx traces are routed directly to their respective diamonds to minimise the trace lengths. The Tx trace are evenly routed around the outside of the pattern. Notice that ground separates the Rx and Tx traces to minimise parasitic capacitance.

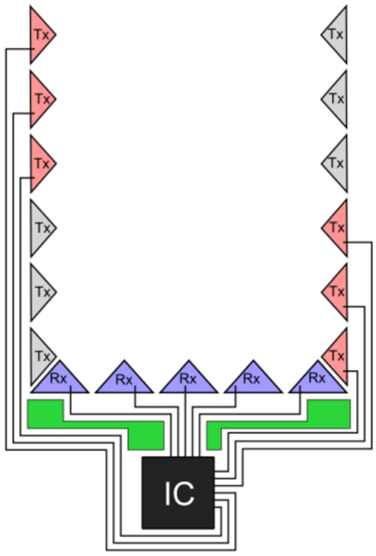


Figure 5.9: Illustration of Type 2

- Suitable for narrow PCBs.
- Half of the Txs are routed on the left side of the PCB.
- The other half of the Txs are routed on the right side of the PCB.
- This routing methodology is employed for any PCB with a thin substrate. This includes ITO and FPC.

Type 3: Minimal PCB width

This method is suitable when it is required to use the minimum PCB width while also allowing for the maximum trackpad width. This method will have a higher parasitic capacitance than the type 1 and type 2 methods. The Rx traces are routed directly to the respective diamonds to minimise trace length. The Tx traces are routed between Rx diamonds to minimise parasitic capacitance, however only a few Txs can be grouped together to fit between the Rxs. Ground is used to separate and shield the Rxs from the Txs.

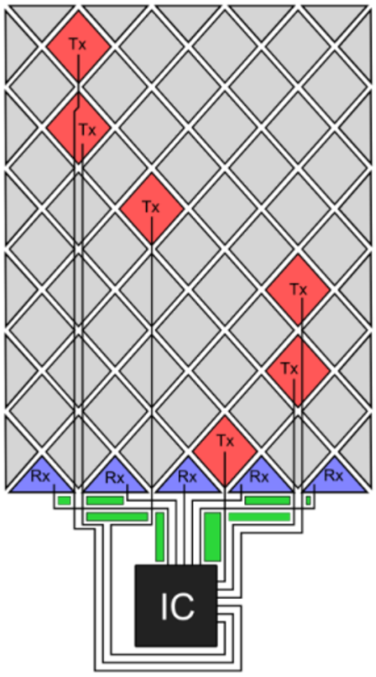


Figure 5.10: Illustration of Type 3

- Suitable for narrow PCBs.
- Large diamond pattern area with minimal border.
- Txs are routed in groups between Rxs.
- The number of Txs per group should be kept as low as possible.
- This routing methodology is employed for any PCB with a thin substrate. This includes ITO and FPC.

Type 4: Minimal PCB area

The touch IC is placed directly behind the trackpad's diamond pattern. This method has a high parasitic capacitance. The method is not advised for two-layer PCBs with a total thickness of less than 0.6mm. The IC should be positioned in such a way that the Rx pads on the IC fall behind an Rx diamond, and vice versa for the Tx IC pads. The Rx traces are routed directly to the Rx diamonds to minimise trace length. Again the Tx traces are routed between the Rx diamonds to minimise the parasitic capacitance.

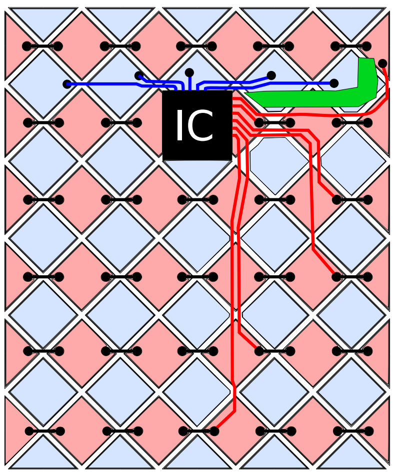


Figure 5.11: Illustration of Type 4

- The method results in the maximum trackpad area for a given PCB size.
- The method has high parasitic capacitance coupling on crossing channels.
- Suitable if the PCB thickness > 0.6mm
- Place Rx pad on IC opposite Rx electrode, and vice versa for Tx pads.

5.7 Multi-layer PCBs

A multi-layer PCB offers more freedom with IC placement and routing, since a ground pour can be placed on one of the internal layers. This ground pour shields the routing on the component layer from the trackpad layer.

However, there are drawbacks with multi-layer PCBs. The copper density needs to be mirrored around the middle layer to prevent PCB warping during reflow. With the addition of a ground shield in the layer second from the bottom, this would imply another ground directly behind the trackpad! This ground in close proximity to the trackpad would increase the C_M - C_{TG} and C_M - C_{RG} ratio significantly. In this case the diamond gap needs to be as small as possible, between 0.1 and 0.2mm depending on the ground separation. Additionally the ground density needs to be reduced.

If the ground density percentage does not need to be mirrored due to extra strength being on other places on the PCB, no ground should be placed directly behind the trackpad.

Most of the E-fields are concentrated on the diamond edges toward the channel centre. In PCBs <0.8mm a ground pattern can be used rather than the 100% ground pour used in the majority of other designs (if diamond gap is small). Refer to Figure *5.12* for an illustration of a ground pattern.

The gap between ground diamonds is more than 5 times the diamond gap (depending on the layer separation). I.e. a 0.3mm diamond gap would result in a 1.5mm gap with a 0.4mm gap between layers.

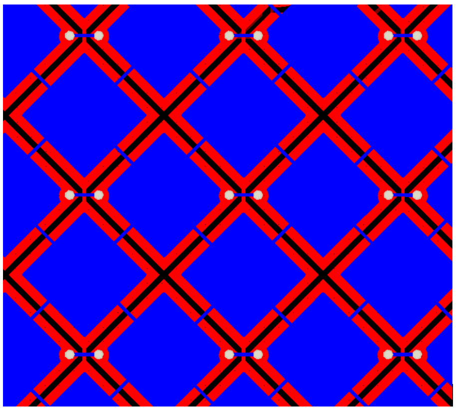


Figure 5.12: Ground pattern example

Capacitive loading must be employed in extreme cases where it is not possible to achieve the required C_M ratio. Loading is a specialised area and a client should contact Azoteq for assistance.

5.8 FPC

Traditionally, trackpads are flat with a uniform overlay thickness. One of the main reasons for this is that with a uniform pattern and a uniform thickness, the touch strength when the user's finger touches the surface will be uniform over the entire touchpad. If, however, the overlay is not of uniform thickness, the mutual capacitance and therefore the touch deltas will no longer be uniform.

As a solution to this flexible PCBs can be used so that the overlay can remain uniform.

5.8.1 IC Placement

FPC is used so that the PCB can flex and conform to a 3D shape. It is also not advised to place the IC in an area that will flex and bend as solder connections could break. The routing method can be type 1, 2 or 3. Type 4 is not advised as described in Section 5.6.

5.8.2 High Coupling

In flexible PCBs the capacitive coupling between the layers is very high due to the very small distance between the conductor layers, typically in the order of 30um. For this reason it is not advised to place the IC directly behind the trackpad. The high capacitance between layers is shown in Figure 5.4.

Contact Azoteq for guidelines on diamond and ground pattern for the specific application using FPC.

With the high coupling between layers on the flex-PCB it is not advised to place the IC directly behind the flexible trackpad. Rather place the IC on a dedicated component area away from the trackpad. Figure 5.13 is an example of the IC being placed.

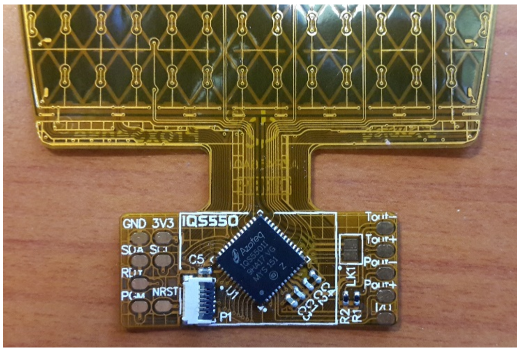


Figure 5.13: FPC with component area with bottom stiffener, flexible tail and routing area (Type 3)

If needed the IC could also be glued to the FPC to prevent solder pads cracking.

5.8.3 Strain-Relief Cuts in FPC Trackpads

Flex PCBs can be used to conform to almost any shape. They can also be used to conform to 3D shapes, although where possible this should be avoided, since it adds considerable complexity. Refer to Section 3.5 for more information.

In 3D overlays strain relieve cuts need to be placed in strategic locations on the FPC so that air gaps are removed. The relief cuts should be placed in areas with the lowest sensitivity and where the impact on the trackpad linearity is minimal. This would be between channels as this is already the area of lower sensitivity while maintaining the sensitive channel centre. The tracks that need to be routed around the cut need to be shielded to prevent unwanted user coupling. The shield can be a ground track placed on the top layer of the FPC. Cuts can also be place in the channel intersections but this would result in the peak being flattened creating an area of lower sensitivity.

The cuts should also be as narrow as possible since the more trackpad channel that is removed the lower the mutual capacitance would be, thus reducing sensitivity. Cut channels will also have a lower compensation value as compared to a full channel and must also be taken into consideration.

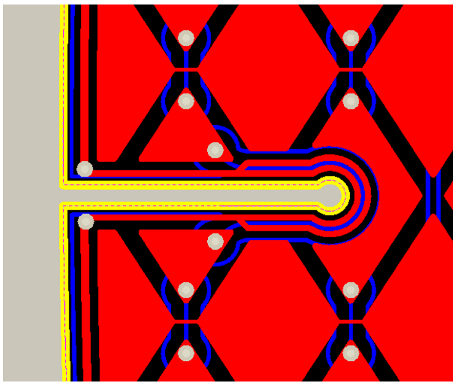


Figure 5.14: Example of relief cut

5.9 Methods to Optimise Routing

Trace routing on a trackpad must be optimised to allow for the widest production limits possible. The delta between the lowest channel's compensation to the highest channel's compensation must be as small as possible.

During the design of the trackpad the designer will need to evaluate a large enough sample so that the IC and PCB variation can be evaluated. From this sample set the minimum and maximum compensation can be determined and settings adjusted to lower the differential. If required the PCB pattern and or trace routing will need to be modified.

6 Circular Trackpads

Trackpads can have any shape, but where possible, it is advised to use square or rectangular shapes, since the row/column sensor arrangement is suited to this. Cutting a channel when forming a circular shape lowers the amount of mutual capacitance available for that channel. If too large an area of a channel is removed, that channel will need to be disabled so that it is no longer used for capacitive measurements, since there will not be enough signal/count delta when touched.

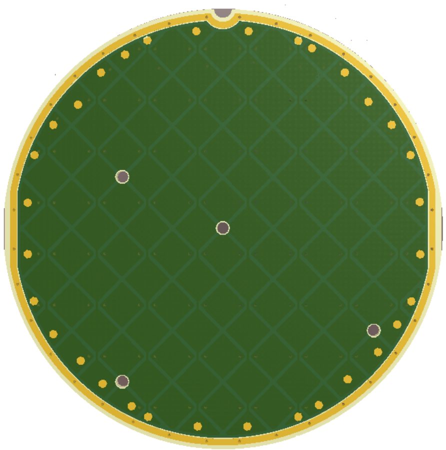


Figure 6.1: Example of a circular trackpad

Channels with a small amount of electrode area removed can still be enabled but the touch delta resulting from user interaction will be lower than that of a full channel.

Rule-of-thumb: channels with more than 50% area removed will probably need to be disabled.

The trackpad pitch can be adapted to take this rule into account and allow for the optimal pitch. When choosing the pitch the designer also needs to keep in mind the other single and multi-touch parameters as described in section *4*.

In some cases, it is recommended to modify the diamond pattern in an attempt to restore partial channels. The concept behind altering the diamond pattern is to create space for the cut diamond pads to complete a partial sensor by reducing the neighbouring diamond pad areas. Refer to Figure *6.2* as an example.

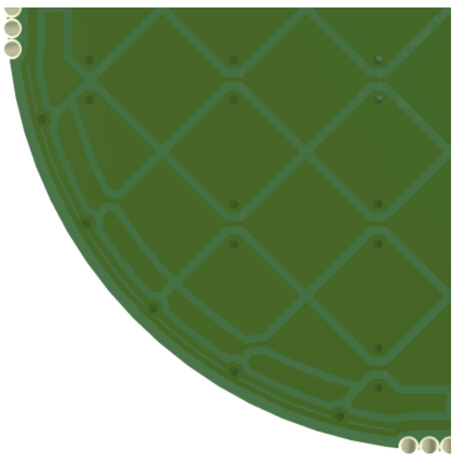


Figure 6.2: Example of restored Rx/Tx pairs

Another reason why channels with a reduced area need to be disabled is for production limits. During production, cut channels will also have wider compensation variations and increase the range that would have to be allowed. Care must be taken when choosing the trackpad settings.

It can be seen in Figure 6.3 that channel 1 lies completely outside of the trackpad area while channels 2 and 5 have less than 50% area remaining. Thus these three will need to be disabled in firmware. Channels 3, 6 and 7 still have the majority of their copper available and will not need to be disabled. However, these channels will have a lower compensation value as compared to a full channel and a wider compensation variation during production.

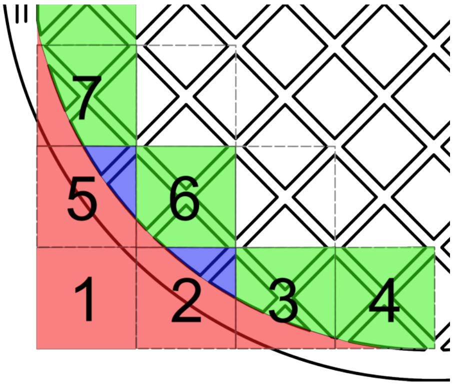


Figure 6.3: Diamonds cut to conform to circular shape. Channels 1, 2 and 5 will need to be disabled.

6.1 Effect of Removed and Cut Channels

Channels with reduced area that are still enabled will now be looked into a little further.

As mentioned previously, a channel with reduced area has a smaller C_M-C_P ratio compared to a full channel. This would result in the widening of the testing limits so that the yield can be improved. The difference between a full and half channel can be seen when comparing the change in mutual capacitance between steady state (no touch) and the touch conditions. This is shown in Figure 6.4.

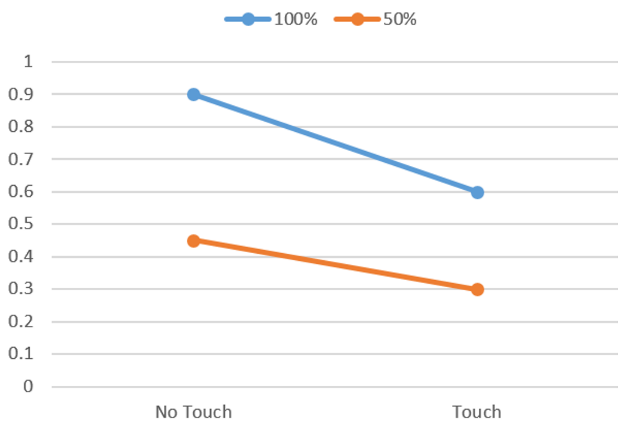


Figure 6.4: Comparison of mutual capacitance between touch and no touch of a 100% and 50% area channel

The internal ProxSense® engine would calibrate the entire trackpad so that all the channels are at the same ATI target. To do this the ATI Compensation will be added in different amounts to each channel.

The ProxSense® engine also measures the change in the capacitance (delta) after compensating for the different levels of mutual capacitance in the trackpad. If the touch delta is too small a definite touch decision cannot be made since this small touch delta is too close to the proximity delta and noise.

The effect of removing and cutting away area in channels can be seen when reading the compensation values form the IC during the tuning and debugging phase of development. It can be seen in Figure 6.5 that the compensation values for the channel 3, 6 and 7 in Figure 6.3 are lower when compared to the full channels in the same column.

0	0	80	96	85	64	0	0
0	92	107	101	91	88	80	0
84	85	101	100	90	92	92	74
107	85	101	96	84	86	92	98
106	88	105	96	85	86	105	104
82	86	105	98	90	89	100	69
0	76	100	98	89	96	84	0
0	0	68	91	84	73	0	0

Figure 6.5: Compensation value example (channels 1 to 7 highlighted)

For example, channel 3 in Figure 6.3 has a compensation value of 68, while the full channels have a compensation value of between 100 and 107. This is 35% lower than the 100% channels and closely matches the area lost! Of course there is always a tolerance in the internal circuitry of the IC and there is difference in parasitic and mutual capacitance, which results in the channel similar to channel 3 being between 64 and 84 in this example.

6.2 XY Output for a Circular Trackpad

Due to the physics of the actual layout of the pattern. When a finger swipes across the centre of the trackpad the output line capture from the XY coordinates is straight. However, if the finger is swiped close to the edge of the tracking area there is an apparent distortion of the XY coordinates. This is due to how the finger comes into contact with the trackpad. This distortion increases when the angle of the finger approaches 45° to the tangent of the circle. This was explained in detail in section 3.1.4 on linearity, an example of XY coordinates reported for horizontal swipes is shown in, Figure 6.6.

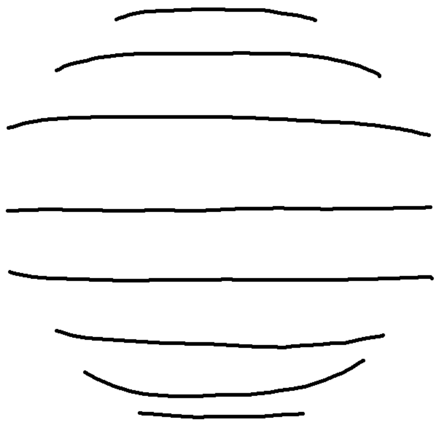


Figure 6.6: Horizontal swipes with an 8mm test finger illustrating distortion towards the top and bottom of the trackpad

7 Azoteq Trackpad Products

Sense channel properties of the IQS5xx and IQS721xy family of trackpad controllers are briefly summarised in Table 7.1. In conjunction with the information summarised in this table, please also refer to the respective datasheet of each device for additional information[6].

Table 7.1: Azoteq trackpad products

Controller	Total Tx	Total Rx	Condition	Max Number of Sense Channels
IQS7210A	Up to 9	Up to 6	Max 16 Timeslots	25
IQS7211A	Up to 10	Up to 7	Max 18 Timeslots	32
IQS7211E	Up to 11	Up to 7	Max 21 Timeslots	42
IQS525	Up to 9	Up to 8	TotalRx + TotalTx $\leq$ 10	25
IQS572	9	8	N/A	72
IQS550	15	10	N/A	150

Table 7.2 below provides a summary of the recognised on-chip gestures by each respective trackpad controller. Please contact Azoteq for custom gestures recognition.

Table 7.2: Trackpad controller on-chip gesture recognition capability

Controller	**Single Finger Tap**			**Press and Hold**	**Swipe**			**Palm**	**Two Finger Tap**	**Scroll**	**Zoom**
	Single Tap	Double Tap	Triple Tap		Swipe X/Y	Swipe and Hold	Cont. Swipe				
IQS7210A	✓	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗
IQS7211A	✓	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗
IQS7211E	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗
IQS525	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✓
IQS572	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✓
IQS550	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✓

7.1 Device Selection

This guide discussed the techniques and ideas used when designing a trackpad. To conclude a worked example is provided on how to choose the best touch IC given the user requirement. The key ideas are summarized below:

- Size of the trackpad and active touch area required
- Performance: Resolution, Minimum touch separation, Minimum finger size
- Overlay Structure and Composition
- PCB Layout
- Mechanical Housing
- Cost

[6] Some device I/O pins can be configured to be either a Tx channel or an Rx channel, but not both simultaneously, please refer to the datasheet of each device for additional information.

7.2 Worked example

Choosing the number of channels for a specific trackpad generally depends on touch separation (if a multi-touch trackpad) and the minimum finger size. However, ultimately it comes down to a question of cost. This section shows some of the design choices involved in deciding on an IC and a trackpad configuration. Firstly, for a multi-touch application and secondly for a single touch application.

PCB size: 50 x 24.5mm
PCB thickness: 1.2mm
Overlay thickness: 2mm (ABS plastic)

Below is a table comparing the pitch, touch separation and minimum finger size estimations for the dimensions of the required trackpad. The trackpad is 0.9mm smaller on each side of the PCB to allow for 0.3mm (see Figure *5.7* and PCB edge recommendations) clearance board edge to copper, 0.3mm ground traces and a 0.3mm ground-to-diamond edge gap. The higher channel count would be in the horizontal direction will the low count would be in the vertical direction.

Table 7.3: Configuration examples with supported Azoteq ICs

Config	Chs	Pitch [mm]		Touch separation [mm]		Min finger size [mm]	Supported touch IC			
		Tx	Rx	Tx	Rx		IQS550 (150ch)	IQS572 (72ch)	IQS525 (25 ch)	IQS721xy (42 ch)
13 x 6	78	3.71	3.78	9.27	9.46	5.29	✓	✗	✗	✗
11 x 5	55	4.38	4.54	10.95	11.35	6.31	✓	✗	✗	✗
9 x 6	54	5.36	3.78	13.39	9.46	6.56	✓	✓	✗	✗
9 x 5	45	5.36	4.54	13.39	11.35	7.02	✓	✓	✗	✗
3 x 7	21	7.57	6.89	18.92	17.21	10.23	✓	✓	✓	✓
4 x 6	24	5.68	8.03	14.19	20.08	9.84	✓	✓	✓	✓

To achieve a touch separation of 10mm due to a multi-touch specification, a 13x6 channel configuration is needed and to achieve this an IQS550 would be required.

For a single touch application the IQS572 would be sufficient with a 9x6 channel configuration. More hover can also be added to allow for a smaller finger size.

The IQS721xy family ICs are a cheaper alternative for smaller tracking area and single touch requirement applications.

8 Signal Analysis

8.1 Purpose

This chapter provides background information to assist designers in identifying and rectifying issues with the sensor electrodes of a trackpad. In any electrical system, the input impedance of a load influences the system to which it connects. Therefore, a system has a range of acceptable loads with which it can operate. The same principle applies to trackpad ICs. This chapter describes the expected voltage signals that a designer can measure at the sensor electrodes using high input impedance probes. It offers guidance on how to utilise these voltage signals to confirm whether a load is acceptable and how to rectify the situation if the load is not acceptable.

8.2 Theory

The trackpad IC measures the mutual capacitance at a sensor by transferring charge from the sensor to an internal capacitor. Charge is transferred until the voltage over an internal capacitor reaches a trip value. The number of discrete transfers that are performed before the voltage reaches the trip point is referred to as the count value. The count value is proportional to the mutual capacitance of the sensor. An increase in the mutual capacitance of the sensor will result in a decrease in the count value of the measurement, and vice versa.

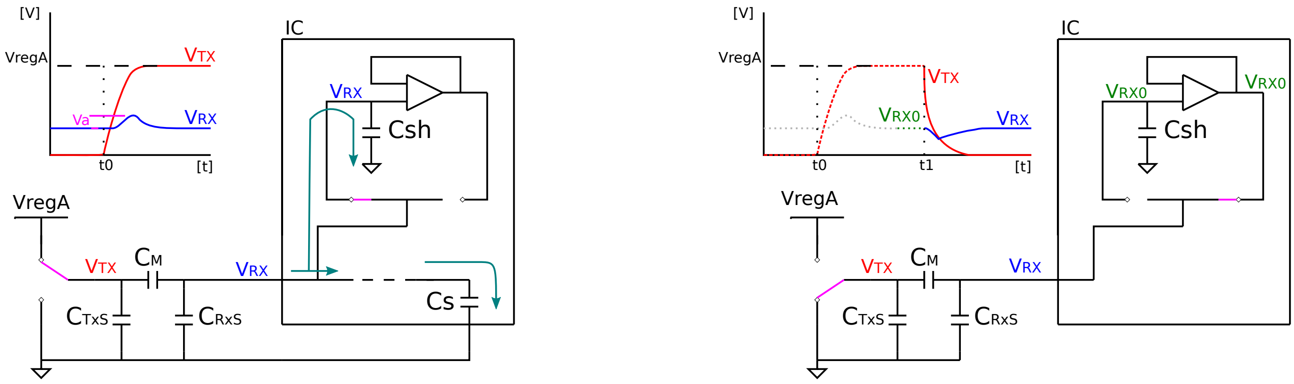


*Figure 8.1: Illustration of the two phases of a charge transfer. **Left:** The Tx pin is pulled to VregA and charge flows into the internal measurement capacitor (C_S). **Right:** The Tx pin is pulled to ground, and the Rx pin is pulled to its nominal value by the sample-and-hold circuit to prepare the system for the next transfer.*

A discrete charge transfer consists of two phases, as illustrated in Figure 8.1.

During the first phase the Tx pin is connected to VregA, the analogue regulator output. Charge is transferred during this phase to the internal sample capacitor (C_S). While this is happening, an internal sample-and-hold circuit is connected to the Rx pin, and the voltage at the Rx pin is stored in the sample-and-hold capacitor (C_{sh}). During this phase the voltage at the Rx pin will show a slight initial increase, and then a gradual decay to its nominal value. The increase in amplitude (V_a) is due to the charge being transferred. The second phase of the charge transfer then commences.

The second phase essentially resets the system for the next charge transfer. During the second phase the Tx pin is connected to ground and the sample-and-hold circuit is switched from its sampling mode to its holding mode. The sample-and-hold circuit now attempts to keep the voltage at the Rx pin at the value that it had at the end of the first charge transfer phase. The Rx pin is connected to the Tx pin via the mutual capacitance of the sensor, and as the Tx pin is being pulled low, the Rx pin will also be pulled low. There is therefore a slight decrease in the Rx voltage at the start of the second charge transfer phase, followed by a gradual settling of the Rx voltage at its nominal value (the value it had before the previous charge transfer started). The two phases of the charge transfer are repeated until the voltage over the internal sampling capacitor reaches its trip value. The charge transfer frequency (for phases 1 and 2 together) can be configured from the tens of kilohertz to the single-digit megahertz range.

The next section contains measurement examples to illustrate the signals that can be observed under ideal and non-ideal circumstances.

8.3 Measurement Examples

8.3.1 Tx Voltage Signal

Figure 8.2 shows a comparison of the Tx voltage signals of an ideal system and of a system with a large time constant. The time constant of a system becomes too large if the series resistance is too high and/or if the capacitance between the electrodes and the system ground is too high. Device datasheets indicate appropriate ranges for these parameters.

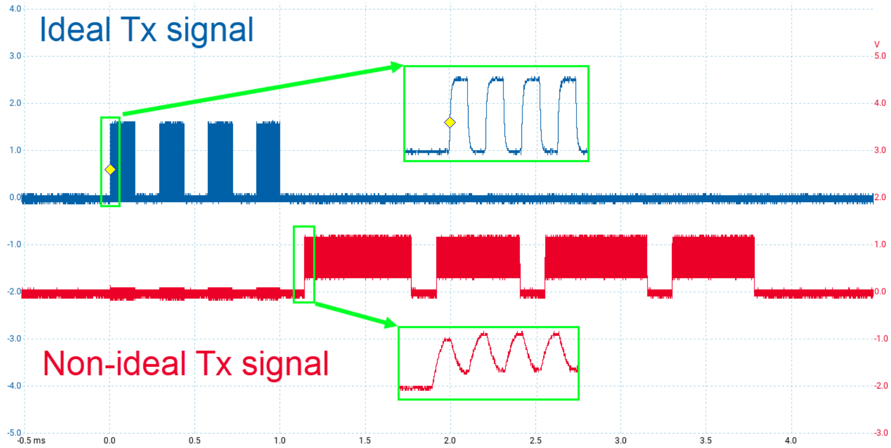


Figure 8.2: A comparison of the Tx voltage signals between an ideal sensor configuration and a sensor configuration with a large RC time constant. In the non-ideal case, the Tx voltage signal does not have sufficient time to reach the VregA voltage during the first phase, nor to discharge to ground during the second phase.

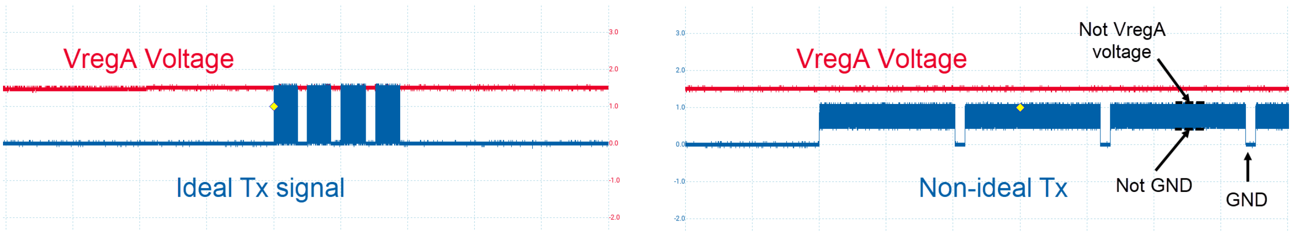


Figure 8.3: Left-hand side shows an ideal Tx voltage signal. Right-hand side shows a non-ideal Tx voltage signal.

To address a problem like this, there are three possible solutions:

1. Reduce the series resistance of the Tx line.
2. Decrease the capacitance of the Tx line to GND (C_{TxS}, see Figure 8.1).
3. Lower the charge transfer frequency in the firmware settings to allow the Tx signal sufficient time to switch between VregA and system ground.

14 **Design tip:** In certain applications, such as an ITO touchscreen, it may not be feasible to decrease the resistance of the electrodes. In such instances, the optimal solution is to lower the charge transfer frequency.

The non-ideal signal in Figure 8.2 was corrected by lowering the charge transfer frequency. The resulting signal is shown in Figure 8.4.

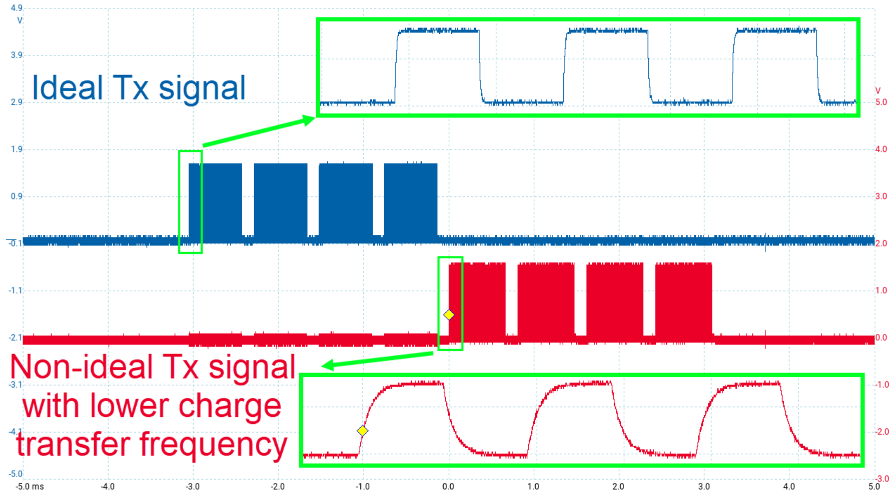


Figure 8.4: By lowering the charge transfer frequency, it becomes evident that the VregA and ground voltage levels can be reached as expected

Note that a correct Tx voltage signal on its own is not indicative of a functioning system. The Tx and Rx voltage signals must be investigated together to determine whether a system is behaving correctly.

8.3.2 Rx Voltage Signal

Figures 8.5, 8.6 and 8.7 show the Rx and Tx voltage signals measured at a specific sensor on a trackpad. The Rx and Tx pins are connected in a grid and form part of multiple sensors, so the part applicable to the measurement of the specific sensor is between 0 and 0.6ms.

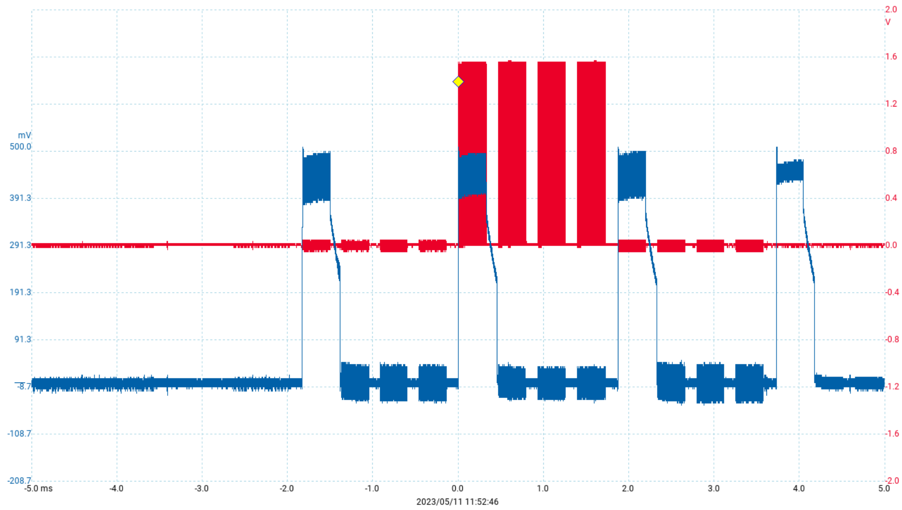


Figure 8.5: Tx and Rx voltage signals measured at a specific sensor on a trackpad. The measurement for this particular sensor is taken between 0 and 0.6ms. The Rx and Tx pins are connected in a grid, so the remaining portion of the graph indicates where the pins are active during the measurement of other sensors.

At the start of the measurement of a sensor there is a period where the Rx voltage fluctuates before settling at an average value. The initial period is referred to as the pre-charge. The pre-charge is followed by a period where charge transfers are performed until the end of the measurement. The pre-charge is visible in Figure 8.6 and the individual charge transfers are shown in Figure 8.7.

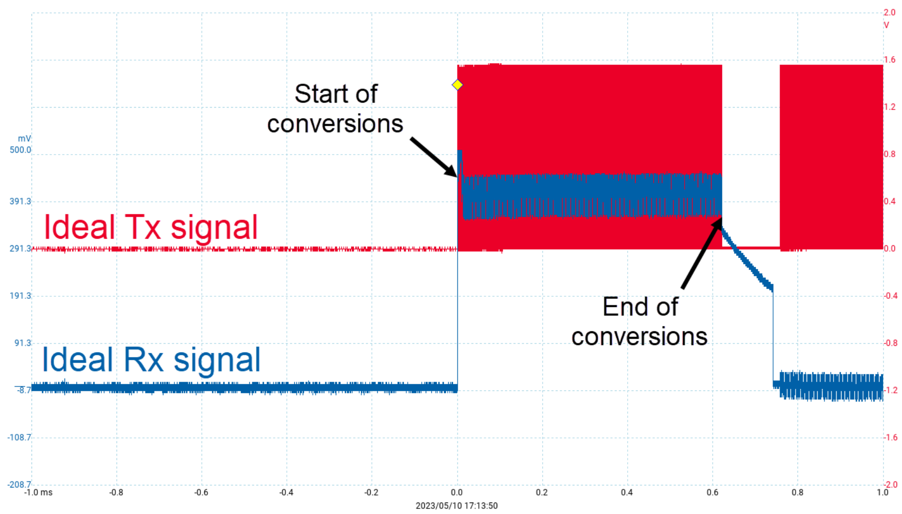


Figure 8.6: Zoomed-in version of Figure 8.5. Plot of the Tx and Rx voltage signals during a measurement of a sensor. The pre-charge period is visible after the start of conversions.

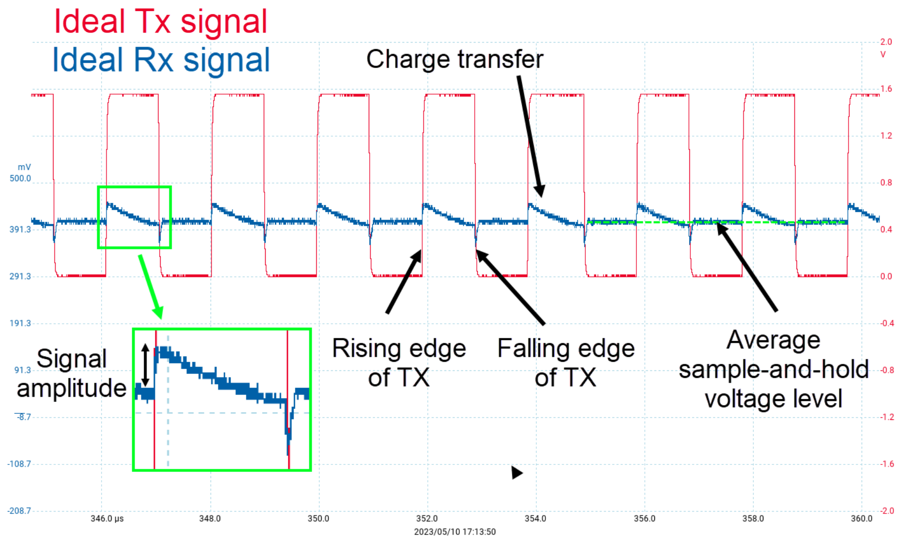


Figure 8.7: Zoomed-in version of Figure 8.6. Ideal Tx and Rx voltage signals during charge transfer cycles.

When looking at the Rx and Tx voltage signals during charge transfers, the following is important:

1. The increase in amplitude of the Rx voltage just after the rising edge of the Tx signal should be visible. The typical amplitude is in the order of tens of millivolts. If the increase in amplitude is not visible, it means that only a small amount of charge is flowing into the IC. The result is that the measurement will either take very long, or not be possible at all. This issue can be corrected by increasing the C_M/C_{RxS} ratio.
2. The DC level of the Rx voltage signal, just before each rising edge of the Tx voltage signal, should remain constant. This aspect is important to ensure the accuracy of the measurement. If there is a drift in this voltage level, it means that the sample-and-hold circuit did not have

enough time to pull the voltage at the Rx pin to the required level, and that the charge transfer frequency should be reduced.

Figure 8.8 shows an example of a case where the C_{RxS} capacitance on a trackpad is very large compared to the C_{TxS} and C_M capacitances. The effect here is that the Rx voltage takes a long time to settle at the required level before charge transfers can commence. Inside the individual charge transfers it takes longer for the Rx voltage to settle at the correct level before each rising edge of the Tx voltage signal. The time constant is clearly higher on the Rx pin when comparing to Figure 8.7 which implies that the system associated with Figure 8.8 has a lower maximum charge transfer frequency.

Figure 8.9 shows the voltages associated with a system where both the Tx and Rx lines have large time constants. The system appears to be operational due to the clearly visible increase in amplitude for the Rx voltage signal following each rising edge of the Tx voltage signal. Additionally, the Rx voltage signal stabilises at the same DC level before each rising edge. However, it seems that the system is operating at its maximum frequency because the sample-and-hold circuit only barely manages to restore the Rx voltage to its nominal point, while the Tx voltage is not fully pulled up to VregA or down to ground during the measurement.

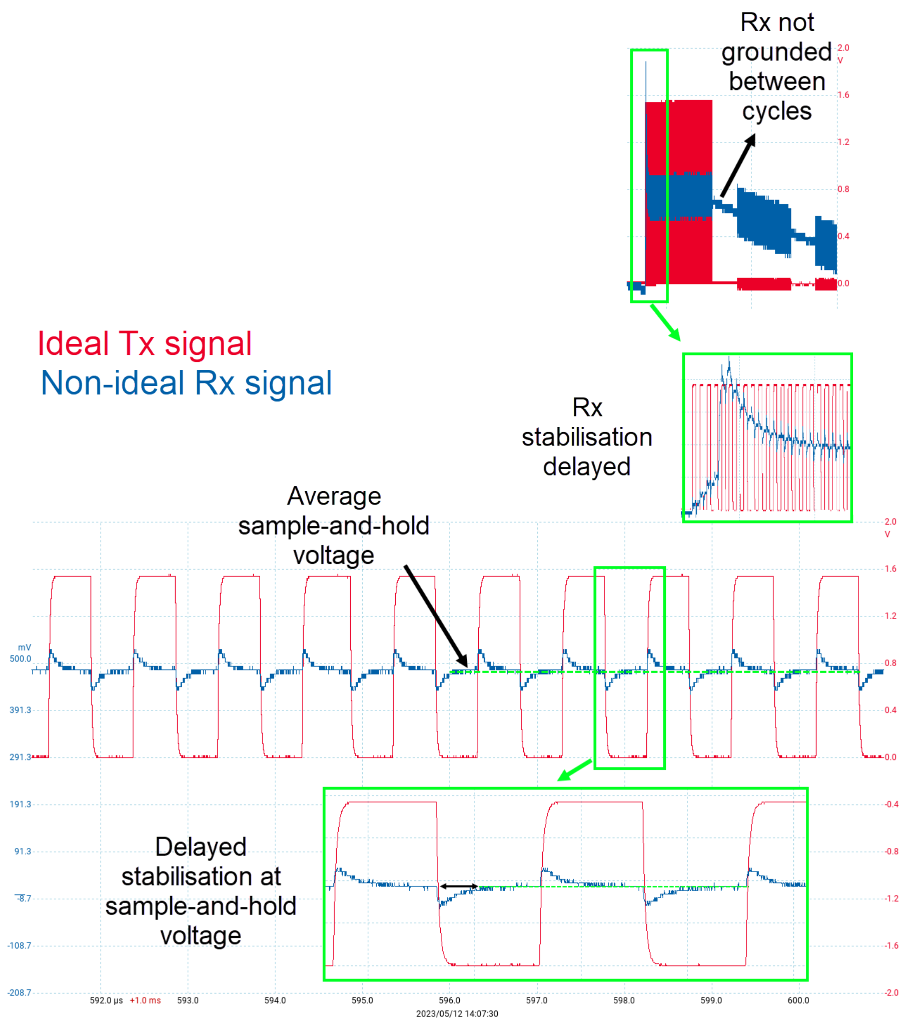


Figure 8.8: Tx and Rx voltage signals measured at a specific sensor on a trackpad where the C_{RxS} capacitance is very large

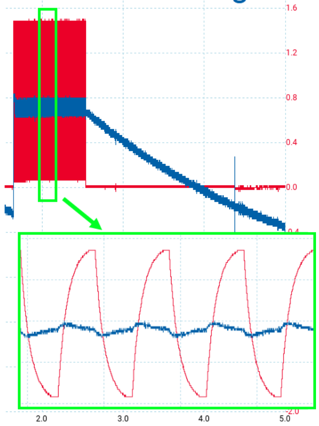


Figure 8.9: Tx and Rx voltage signals measured at a specific sensor on a trackpad where both the C_{RxS} and C_{TxS} capacitances are very large

The problems highlighted in Figures 8.8 and 8.9 can be addressed through a combination of the following:

1. Reduce the series resistance of the Rx and Tx lines.
2. Decrease the capacitance of the Rx and Tx lines to ground (C_{RxS} and C_{TxS}).
3. Lower the charge transfer frequency in the firmware settings to allow sufficient time for the Rx voltage to settle at the sample-and-hold voltage, and for the Tx pin to be pulled to VregA and ground.
4. Increase the opamp bias current in the firmware settings so that the sample-and-hold voltage is reached in a shorter amount of time.
5. Increase the mutual capacitance (C_M) of the sensor by modifying the trackpad sensor pattern. This can be achieved by decreasing the gap between diamond sensor pads.

9 Azoteq Design Resources

Azoteq offers a wide range of Application Notes to serve as design resources to customers on our website.

We also recognize the importance of providing technical design support to our customers to facilitate the development of their capacitive sensing systems. In line with this, we offer DXF trackpad sensor patterns as part of our design support service to support and accelerate the customers' design and PCB layout process. To take advantage of this service, customers need to provide us with an outline DXF of the required sensor pattern, overlay thickness, touch performance and ESD requirements for the trackpad. With this information, we can create a custom-designed trackpad sensor pattern that meets the customers' specific needs. Our design support service ensures that our customers have access to the necessary resources and technical expertise to create high-performance and reliable capacitive sensing systems.

Azoteq also offers turn-key, custom designed modules along with a manufacturing service.

10 Diamond Pattern Warping

Sometimes the overlay design is fixed before a trackpad is designed, this is not ideal but it happens. However if the overlay is suitable for tracking and snap functionality a trackpad can still be designed to achieve linear results. If the chosen overlay with snap dome buttons are not aligned in rows and columns it is possible to modify the diamond pattern layout (sometimes called 'warping') in such a way that good tracking is still achieved.

In short the diamonds are stretched or squashed to align with snap dome button locations.

A key point to note is that when the diamond pattern is modified to the desired layout all the diamonds must be uniform (in at least one axis) as this will yield linear results with high line accuracy.

10.1 Linear Warping

The most simple diamond warp is a linear warp in only one direction that is aligned to a row or column, as shown in Figure 10.1. The top row has been stretched to compensate for function keys that are separate from the QWERTY keyboard keys. Tracking between the two areas (A and B) will have a slight acceleration in the vertical direction. In some cases the small change in the acceleration will go unnoticed by the user, but in other cases where linearity is critical, acceleration can be compensated for in post-processing. In this example no post processing was needed as the acceleration was deemed small enough. A user also tends to quickly adjust their finger speed accordingly.

Figure 10.1: Single row stretched warp - the top row has been stretched

10.2 Curved Warping

Some keypads have an ergonomic design where the keys are laid out in a curve. The diamond pattern can be warped to this curve while still achieving very good tracking and high linearity.

Figure 10.2 is an example of a diamond pattern that has a curved warp. The curve has been shown in black. If a user moves their finger along this black line the XY output will be a horizontal line. Conversely if a user moves their finger horizontally the tracking will have the same amount of curve as there is curve in the pattern. This concept is clarified using, Figure 10.3. The curve can easily be removed in post-processing as the amount of curve is known. If the XY data is only used to produce a swipe output, no post-processing is needed. When a linearity test is done the amount of curve must be taken into account.

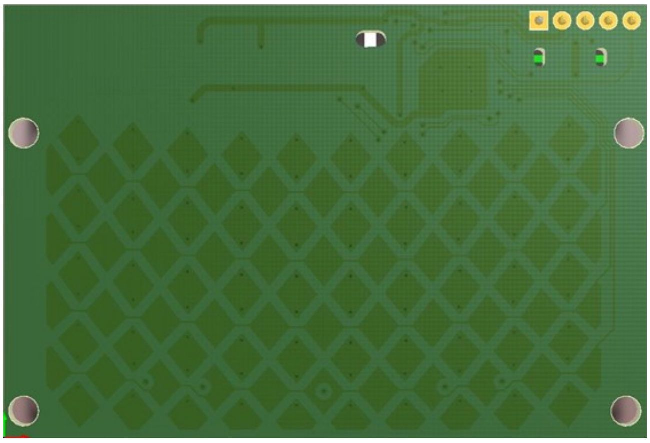
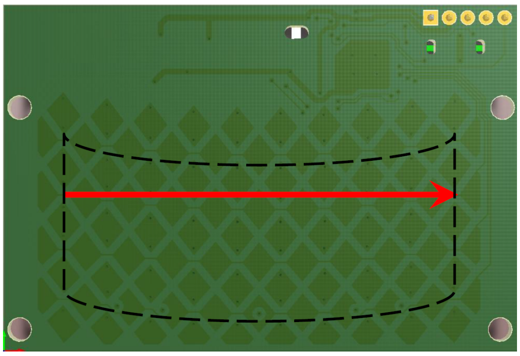
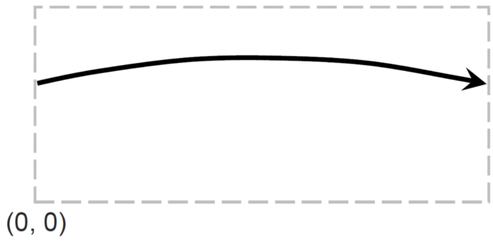


Figure 10.2: Curved warp - the entire diamond pattern has been curved



(a) Horizontal finger movement (red)



(b) Actual output shown with a black line. The output can be easily corrected to form a straight line in post-processing as the amount of curve is known.

Figure 10.3: Illustration of finger movement on a warped trackpad versus the actual output

11 Snap

11.1 Snap Sensing

Multiple patents apply to the Snap[7] functionality. Snap is only available on applicable products. Please contact info@azoteq.com for details.

A trackpad can be added behind a traditional keypad or directional pad on a remote control, allowing for both cursor and snap functionality in the same area. Trackpad design with snap domes is not a trivial task and there are always compromises that need to be made to find the best design. This section is dedicated to showing the designer what to keep in mind and what to look out for when designing the trackpad and mechanical overlay.

Key factors and concepts to note:

- Mechanical design is very important
- Detect capacitive change of snap dome when depressed
- Snap dome electrically isolated from the trackpad
- Distinguish between touch and a snap

11.2 Capacitive Snap Theory

When adding a metal snap-dome button on to the trackpad, an additional 'Snap' function is available. The Azoteq touch ICs are able to distinguish between a normal 'touch' on the overlay and an actual button 'snap', which depresses the metal dome onto the Rx/Tx pattern. This output is referred to as a snap. The design must be configured so that a snap on the metal dome will result in a channels' sample value falling well below the Reference value for that channel. The different stages of the snap are shown in, Figure 11.1, where the snap is triggered in region 'C'.

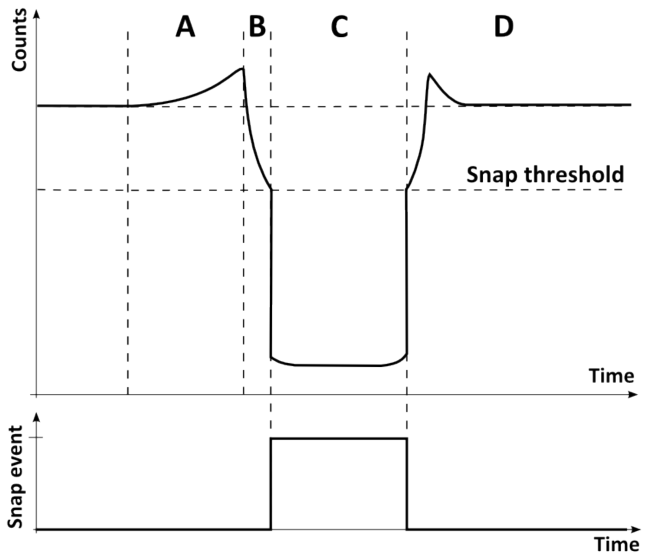


Figure 11.1: Signal associated to a snap event. Count values (top). Snap output (bottom).

A: **Touch -** The button is being touched lightly

B: **Press -** The button and snap dome is now being depressed

C: **Snap -** The snap dome now snaps and a snap event is generated*. Note snap de-bounce value can change the output offset

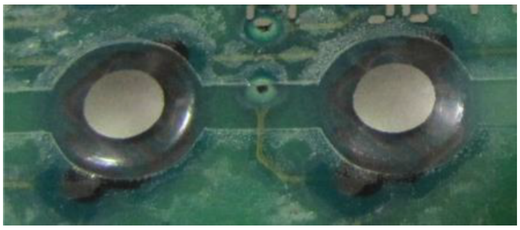
D: **Release -** The button is now released and the counts return to their original state.

Note: duration of B can be reduced by pre tensioning the snap dome in steady state. Or, by pressing the snap dome in quicker * If the threshold is chosen correctly.

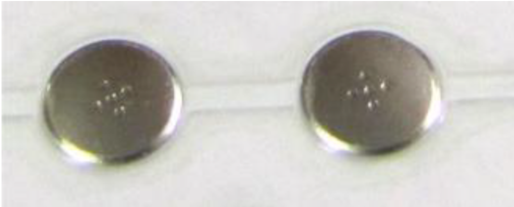
[7] Patented

11.3 Snap Dome Types

There are two common types of snap domes used. PET, with a conductive coating as shown in Figure 11.2a and metal snap domes, as shown in Figure 11.2b. The metal snap dome type is preferred since there is a clear snap sound as well as a sharp count drop when the snap dome is snapped.



(a) PET with conductive coating

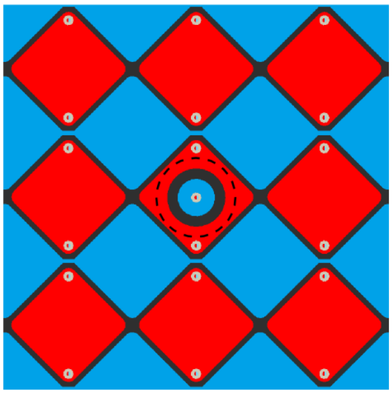


(b) Metal snap dome

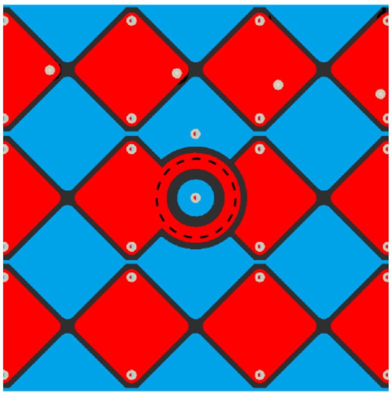
Figure 11.2: Snap dome types

11.4 Snap Dome Location

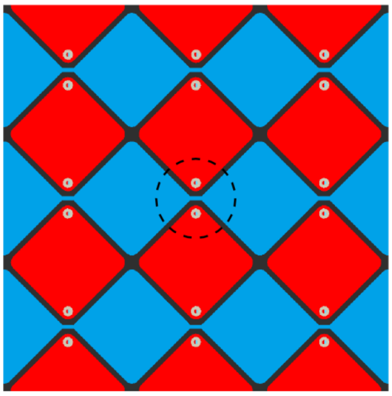
The snap dome should be placed in the centre of a diamond shape so that the channel centres are not obstructed with a piece of metal. The channel centres are also closer to the snap dome so a touch can be detected before the dome is depressed. Below are a few examples of snap dome locations. Placing the snap dome in position as shown in Figure 11.3a will have the least impact on tracking linearity and have the best range of finger sizes.



(a) Best location (Type A)



(b) Good location (Type B)



(c) Bad (Type C)

Figure 11.3: Snap dome location comparisons (Snap dome location is indicated with a dotted line)

Type A Small fingers detected over snap dome | Minimal impact on tracking linearity | Trackpad diamond modification required.

Type B Minimum finger size detected over snap dome | Slight non-linearity with a small touch in the area over the modified diamond | trackpad channel modification required. This is also a good location for a remote control with one centre button and four directional buttons around it.

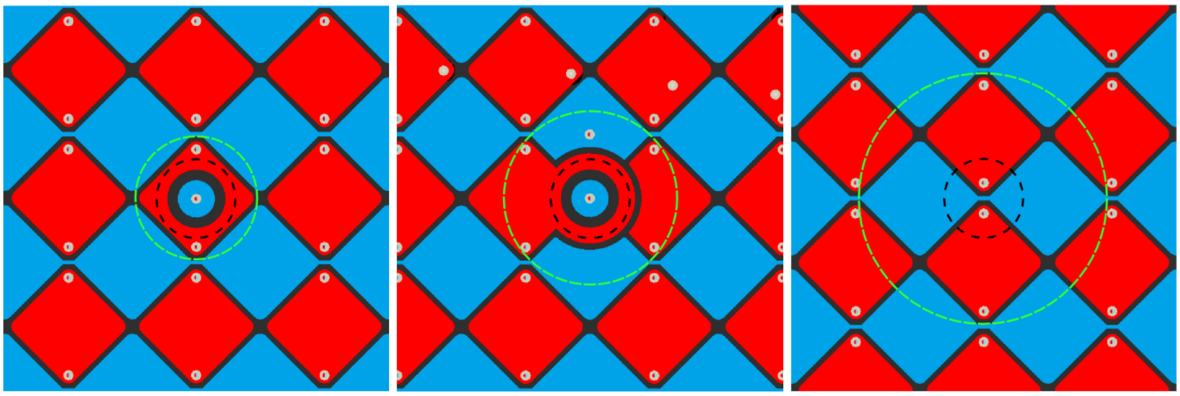
Type C Small finger not detected over snap dome | degraded linearity on and around the snap dome.

When placing a snap dome the designer must ensure a user's finger will be able to activate a touch, so that the device wakes up and enters Normal mode, before the snap is detected. The touch will allow the reference value to first halt before the counts drop and a snap event is detected. On the snap release the reference values would be unchanged due to the halt.

In the event of a non-conductive object snapping the snap dome, such as a finger nail or plastic pen for example the counts would drop and the reference values would slowly follow. After the snap has been detected and the touch has been released a false/stuck touch/prox could be detected.

There are methods available to handle snap dome depression with non-conductive objects, i.e. a plastic pen or long finger nail, please contact Azoteq for support.

15 **Design tip:** When designing the trackpad the designer should avoid large air gaps above the channel centres and rather move these air gaps to areas of lower sensitivity.



(a) Smallest touch < Minimum finger size (b) Smallest touch = Minimum finger size (c) Smallest touch > Minimum finger size

Figure 11.4: Comparisons of the smallest touch area if a finger is touched directly on the centre of the snap dome, indicated in the green outer dotted circle in each of the images above

11.5 Snap Dome Size

The size of the snap dome is very important, in terms of a user's feel when pressing in the button, as well as, the tracking linearity of the pattern. The larger the snap dome relative to pitch would result in linearity distortion.

Snap domes should also not be larger than the trackpad can accommodate. Large snap domes that cover both the Rx and Tx electrodes would influence the compensation values of the channel and lower the sensitivity in the area around the snap dome.

Figure 11.5 shows a correct snap dome size in relation to the designed trackpad. However, in Figure 11.6 it can be seen that the snap domes are too big for the given trackpad design.

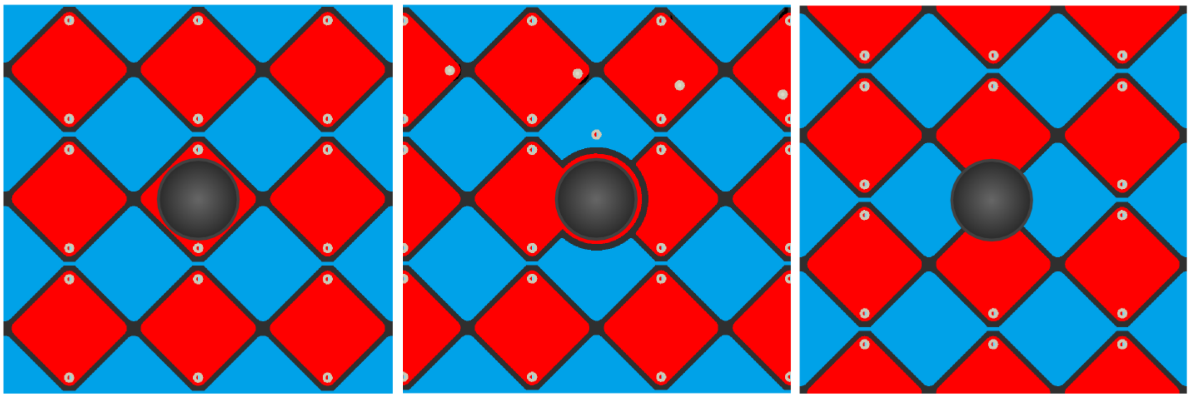


Figure 11.5: Correct snap dome size for trackpad design

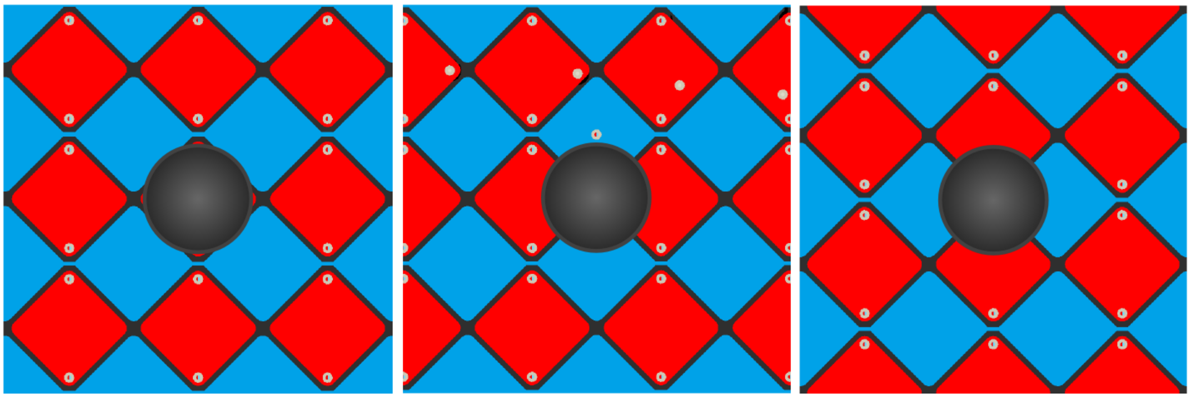


Figure 11.6: Oversized snap dome size for the trackpad design (incorrect)

11.5.1 Oversized and Non-Round Snap Domes

If the snap dome size cannot be reduced due to some reason the diamond pattern can be further modified. Bulge's can be added as shown in Figure 11.8, so that the snap dome does not touch or come close to the neighbouring diamonds.

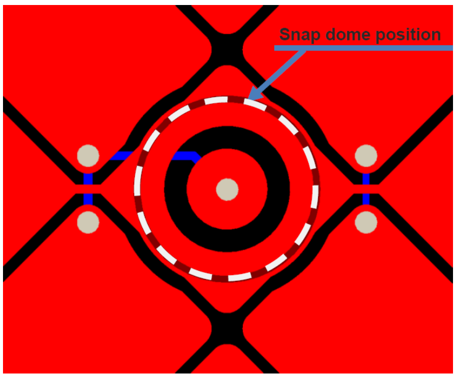


Figure 11.7: Slightly modified diamond with large snap domes

Snap domes are also not necessarily round. For oval snap domes the pattern could be modified as shown in Figure 11.8. Note that the more the channel is modified, the higher the impact on linearity.

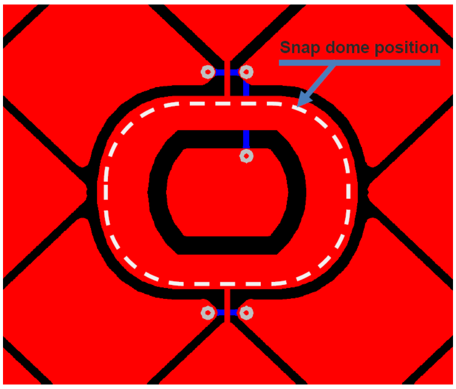
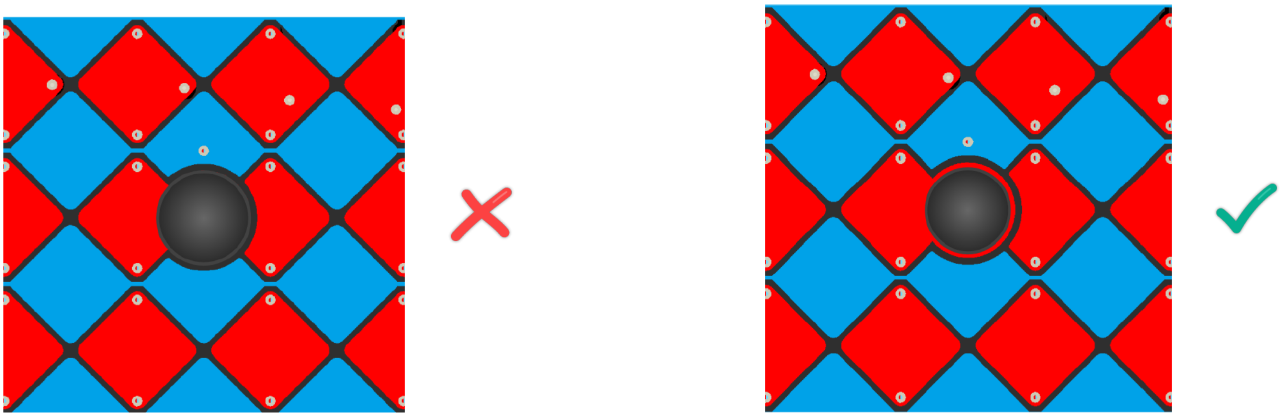


Figure 11.8: Oval snap dome example.

11.5.2 Alignment of Snap Domes to Trackpad

It is important to align the snap domes correctly and to use snap domes that fit the snap dome pattern on the PCB.



(a) Incorrect snap dome size

(b) Correct snap dome size

Figure 11.9: Incorrect and correct snap dome sizes

To allow for more lenient manufacturing limits it is strongly advised to make the snap dome pad slightly larger than the actual snap dome. This would prevent unaligned snap domes from capacitive 'shorting out' the Tx and Rx pads, as mentioned earlier.

11.6 Putting it All Together (Example)

The snap domes do not necessary need to be of the same type, as described in Figure 11.3, and can be a combination. An example of this is shown below with both type A and type B snap dome locations.

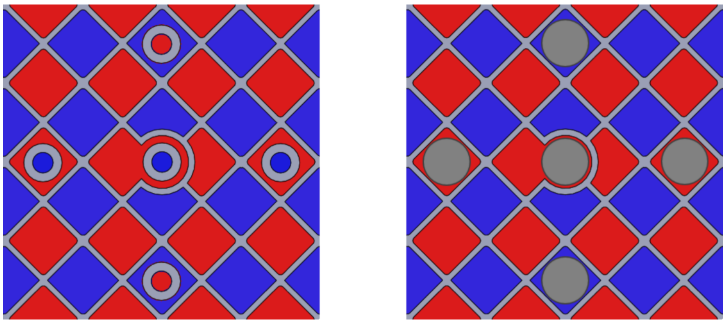


Figure 11.10: Snap dome example

11.6.1 How to Connect to the Touch IC and Net Assignments

When the trackpad diamond pattern is modified to allow for a type A or a type B snap dome, the central pad will need to be connected to either a Tx or Rx electrode. If the outer part of the diamond is a Tx then the inner pad must be an Rx, and vice versa. The electrode assignment depends on where the snap dome is place on the trackpad pattern.

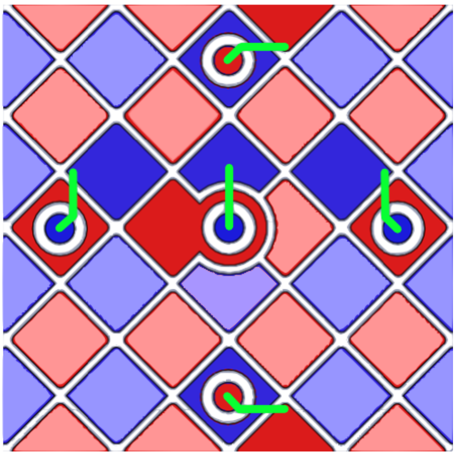


Figure 11.11: Example connections shown in green that would be traces on the bottom layer if the diamond pattern is on the top PCB layer, and connected with a via

The inner pads in Figure 11.12 above are connected directly to the neighbouring diamonds. These snap channel allocations can been seen below.

	Rx0	Rx1	Rx2	Rx3
Tx0			Up	
Tx1	Left	OK		Right
Tx2				
Tx3			Down	

Figure 11.12: Snap channel allocation

16 **Design tip:** Connect the pad under the snap dome to an Rx/Tx pair further away, so that a decreasing count value doesn't affect the XY location.

11.6.2 PCB Layout

The snap dome size depends on the size of the diamonds used for the trackpad. Recommended dimensions for a 4 mm snap dome:

Inner pad: small via with 2 mm copper area
Gap: 0.5 mm
Outer Diameter: 3 mm

The minimum pitch for this snap dome without any further modification, as shown in Figure *11.13*, is ∼5.2mm (with 0.3mm gap).

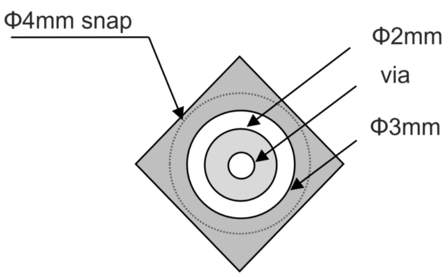


Figure 11.13: Example snap dome dimensions

11.7 Overlay Design Rules using Snap Domes

In order to design a snap dome trackpad that works well and as anticipated the designer needs to understand the following key concepts with regard to the overlay.

- The buttons must fit well and must not wobble during normal use, such as normal tracking.
  - A wobbly button would cause the counts to drop and cause the Reference value to follow the drop, or would cause the overlay to change its resting position, thus changing the overall sensitivity of the trackpad. All of this would eventually lead to a stuck touch being detected on the release of the touch.
- No excessive tilting of the buttons during normal sliding of a finger.
- The overlay must not lift during or after pressing a button; expect for the actual moving key. Minimise all changing air gaps.
- A flat tracking area is desired (buttons can be slightly raised) since the touch threshold can be easily chosen.
- The bottom of the overlay is as important, if not more important as the top of the overlay.
- Air has a relative permittivity of 1, compared to plastics which are ∼3. This implies that, the sensitivity is lower in the areas where there are air gaps, resulting in an unbalanced trackpad.

11.8 Mechanical Stack-up

Snap dome trackpads typically have overlays which consist of numerous different components. These include and is not limited to; a textured top cover, a rubber/silicone compressible sheet, and a snap dome sticker. The different layers are important as they influence the tactile feedback the users experiences as well as the capacitive properties of the trackpad. The capacitive properties include the snap signal as well as linearity of the XY coordinate data.

11.8.1 Types of Snap Dome Applications

Common applications for trackpads which incorporate the snap functionality are:

1. Single button / distributed buttons
2. Multiple button : QWERTY key board
3. D-pad navigation area on a remote control

We shall now briefly discuss different snap dome design examples.

Figure 11.14: D-pad navigation area for a remote control

11.8.2 Simple Snap Button

This example is a simple snap button in a trackpad, which has an overlay fixed to the PCB.

The snap dome sticker with adhesive must cover all the diamonds in the trackpad. This removes all the unwanted air that would lower the mutual capacitance for the trackpad, allowing the E-fields to project towards the user interaction area. A simple stack-up of a snap button is shown in, Figure *11.15*.

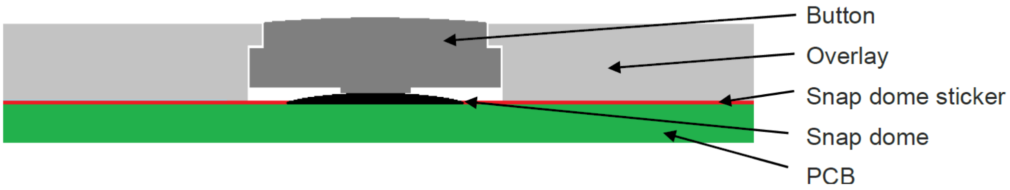


Figure 11.15: Snap dome button stack-up example

It is important to ensure that the button does not extend too far above the fixed part of the overlay. If the button is significantly higher than the surrounding overlay, the large height difference would result in a proximity or touch detection in the air over the fixed part of the overlay. This is not ideal, since the touch threshold is usually chosen so that a light touch on a button would trigger a touch event. Using individual touch thresholds is possible, but places more emphasis on tuning during development adding time to the project, so the designer will need to evaluate this.

17 **Design tip:** For buttons with a diameter much larger than the snap dome (>1.5 pitch), ensure that when the button is fully depressed it is aligned to, or slightly higher than, the surrounding overlay. If not, the count values of the other channels that have not been classified as snap channels will also drop resulting in a re-ATI.

11.8.3 Snap Dome D-pad

The snap dome D-pad as shown in Figure *11.14* usually consists of 5 snap domes, 4 for the directional keys and 1 for the central OK button.

Due to the construction of the D-pad navigation area on a remote control there is a large moving area gap between the underside of the overlap and the PCB.

18 **Design tip:** The latest IQS5xx_B000 firmware can better accommodate mechanically unstable buttons. This is because the reference values for the channels are only updated in the Low Power modes. The count values for the channels should however not decrease to such a degree that they become less than the re-ATI boundary, as this would result in a recalibration of the trackpad (re-ATI).

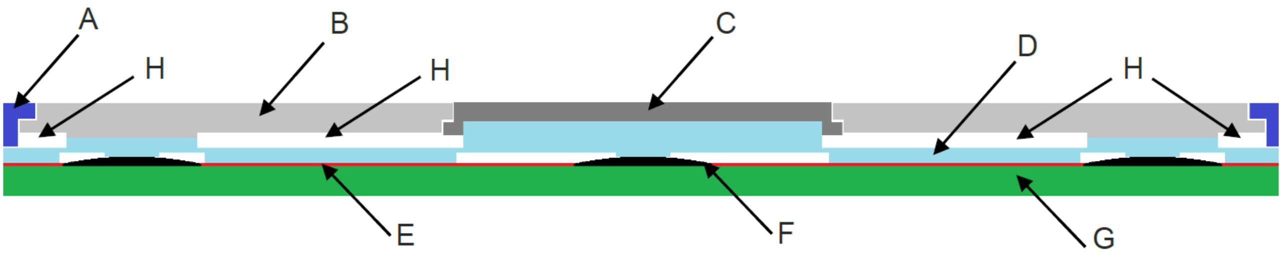


Figure 11.16: Snap dome navigation area for remote control example

A - Main housing
B - Navigation key overlay
C - OK button overlay
D - Rubber/Silicone key mat
E - Snap dome sticker
F - Snap dome
G - PCB
H - Unavoidable air gap

The air gap H must be kept as small as possible BUT must not be squashed out when the user presses the key in. Basically if there is an air gap the air gap MUST remain there in normal use.

If the air gap is squashed out the mutual capacitance will quickly increase in that area resulting in the touch being lost since the delta would decrease and possibly go negative.

In the navigation area of a remote control the OK button moves independently from the directional keys, with a uniform air gap. The two materials used in the OK button area are also very close together (glued or fused), preventing performance degradation.

Avoid adding multiple air gaps on top of each other, as shown in Figure 11.17. This will lower the sensitivity in the region significantly and degrade performance.

Figure 11.17: OK button with a large and moving air gap in the navigation area

11.8.4 Gap Between Diamonds

Depending on the amount of air ($\varepsilon_r = 1$) above the trackpad the gap between diamonds would need to be decreased from the recommend gap for normal trackpads. This is definitely the case for D-pad trackpads. The decrease in the diamond gap will increase the mutual capacitance allowing for a larger base C_M since capacitance through the air gap and subsequent overlay would be naturally lower. This improves sensor performance in these situations.

11.8.5 Non-conductive / Non-metallic Buttons and Paint

All parts in the overlay must be non-conductive and non-metallic, including the buttons and paint. If metallic buttons and/or paint are included in the overlay, the user would couple directly to the metal during a touch resulting in an enlarged and distorted touch area. This becomes more evident when the user performs a swipe gesture occasionally touching the metal area causing the trajectory to be distorted in one or other direction, Figure 11.18.

Figure 11.18: Two horizontal swipes illustrating poor performance due to metals keys (Top line: undistorted swipe; Bottom line: distorted swipe.)

The distortion also causes acceleration in the XY coordinate data which would affect the instantaneous velocity used in gestures, also causing havoc on functions such as relative coordinate movement, inertial scrolling and even a simple tap. Figure 11.19 provides an illustration of acceleration, as seen with wider spaced dots.

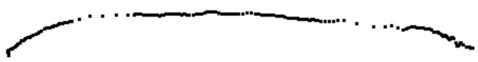


Figure 11.19: Freehand horizontal trajectory with metal buttons on the overlay

Any metal or conductive paint must be removed from the overlay and replaced with a non-conductive alternative.

12 Revision History

Release	Date	Comments
v4.00	2023/05/31	Major update. Revised with the latest product information and relevant new details.

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

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