Application Note: AZD068
Trackpad Design Guide

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1 Introduction

This document discusses general trackpad design guidelines and best practices for designing efficient trackpad implementations. When these simple principles are understood and applied, a versatile trackpad can be designed. Figure 1.2 illustrates the design flow for designing trackpads.

Azoteq recommends the evaluation of the IQS550EV03 EV-Kit prior to starting the design. It serves as reference design, showcase for the technology and familiarises the designer with the GUI. Figure 1.1 illustrates a trackpad as used in the IQS550EV03 evaluation kit.

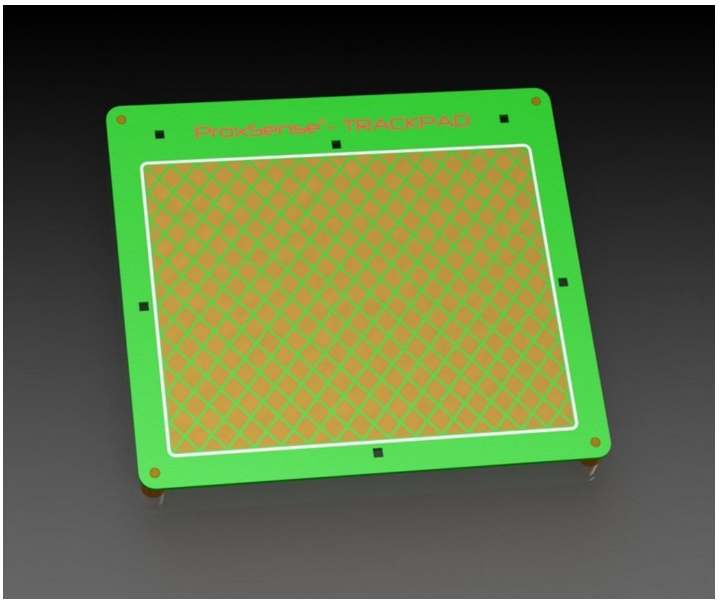


Figure 1.1 IQS550EV03 Trackpad

Note: This guide applies to the present family of trackpad controllers, i.e. IQS550, IQS525 and IQS512**.**

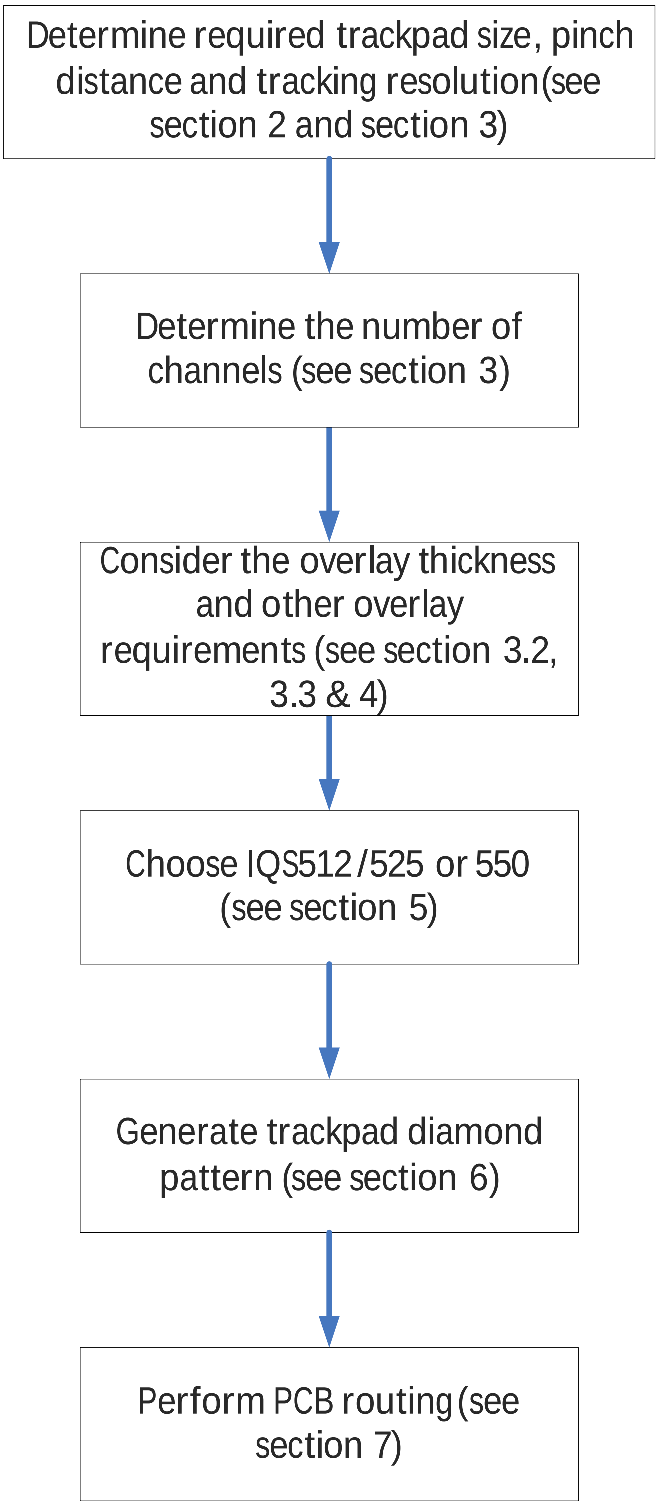


Figure 1.2 Design Flow Summary

2 Key design choices

Key design choices that must be considered when designing a trackpad:

- Size
- Performance: Resolution + Minimum pinch distance
- Overlay Structure and Composition (see section 4.)
- PCB Layout (see section 5.)
- Mechanical Housing (see section 6.)

3 Design Parameter Definitions

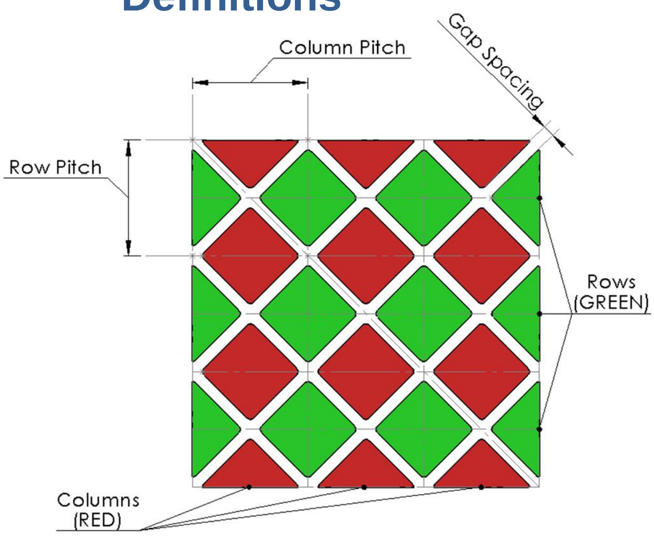


Figure 3.1 Parameter Definitions

3.2 Diamond Pitch

The pitch of a trackpad is defined as the distance between consecutive diamonds in a row or a column, as illustrated in Figure 3.1.

If the number of channels in the design is set and the size of the trackpad is a limiting factor, the pitch will be the adjusted variable to find a suitable fit to the desired trackpad dimensions.

The pitch size is also limited by the overlay thickness, and should be smaller than the total overlay thickness. In Figure 3.2, the E-fields are concentrated and couple strongly to the finger. As a result the touch peak is on the largest channel, which increases linearity.

Figure 3.3 illustrates how the E-fields couple weakly and are blended with the finger. As a result the touch peak can switch between the two channels which reduce linearity considerably.

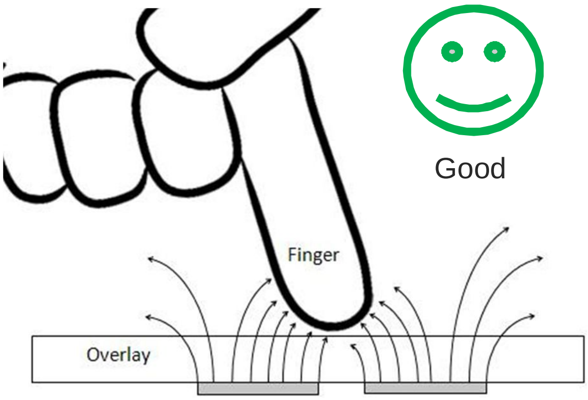


Figure 3.2 Low overlay thickness to pitch ratio

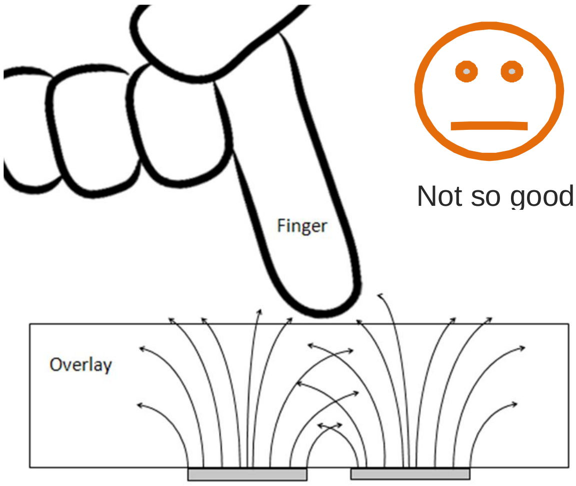


Figure 3.3 Large overlay thickness to pitch ratio

3.3 Diamond Gap Spacing

The diamond gap spacing is defined as the diagonal spacing formed between diamonds as depicted in Figure 3.1.

The gap spacing is strongly correlated to overlay thickness, and as a general rule should always be smaller than the overlay thickness.

- For overlays up to 2 mm thick, the gap spacing should be approximately $\frac{2}{3}$ of the overlay thickness.

3.4 Pinch Distance

The Pinch distance is defined as the minimum distance that enables the correct detection of multiple touches in close proximity to one another.

It is desired in most cases that this distance is smaller than that of two fingers directly adjacent with each other (touching each other), placed on the trackpad.

- If the desired pinch distance is not adequate, the number of channels i.e. diamonds need to be increased with respect to this pinch distance (decreasing the channel pitch).
- The minimum pinch distance is 2.5 times the pitch (worst case).

Figure 3.4 Proper Tracking

Proper tracking is illustrated in Figure 3.4, where two fingers directly adjacent to one another are dragged across the trackpad. The trackpad is able to adequately distinguish between the two touches.

Figure 3.5 Improper Tracking

In contrast, Figure 3.5 illustrates improper tracking, where the trackpad is unable to distinguish between the two unique touches.

- The trackpad pitch needs to be reduced to avoid this problem (this enables more channels to be covered by the fingers, increasing multi-point detection ability)

3.5 Number of Channels

The number of channels in the trackpad design plays an important role in the resolution and performance of the trackpad.

Each individual column or row is connected to a separate RX or TX channel.

For example:

Rows **-> Connected to RX channels**

Columns **-> Connected to TX channels**

OR

Rows **-> Connected to TX channels**

Columns **-> Connected to RX channels**

3.5.1 Channel Locations

The trackpad RX and TX channels must be connected sequentially as laid out in Figure 3.6.

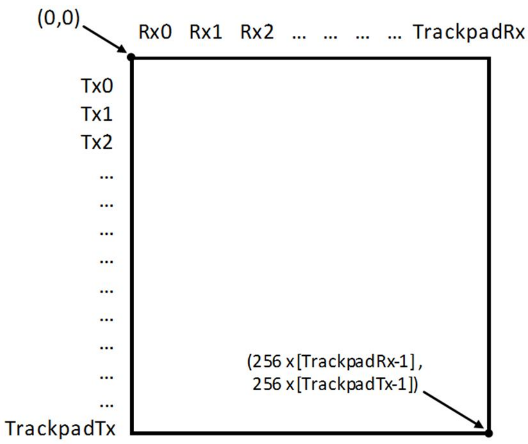


Figure 3.6 Hardware TX/RX setup

- Channel resolution, 256 points

256 steps are implemented between the relative RX's and also between the relative TX's, giving X coordinates that range from 0 to (256 x (TrackpadRXs-1)). The Y coordinates will have an output range from 0 to (256 x (TrackpadTxs-1)). Thus in a 10x15 system:

$(0 < x < 2304)$ and $(0 < y < 3584)$.

For more detail on the Trackpad XY data please refer to the 2D Trackpad Firmware description.

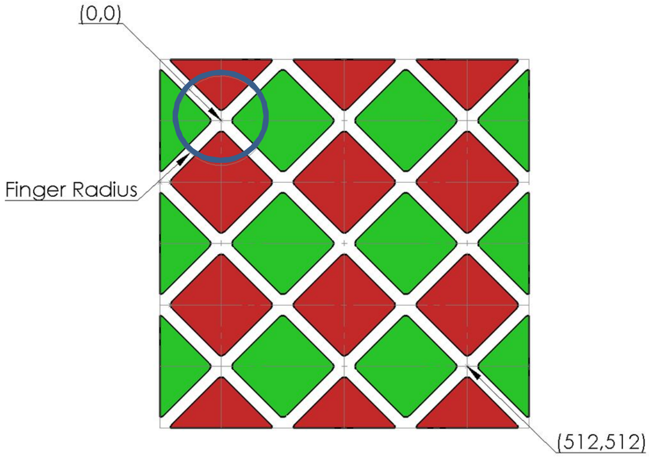


Figure 3.7 XY Co-ordinates relative to the diamond pattern

The relative XY co-ordinates are displayed in Figure 3.7. It is apparent that the active touch area is somewhat dependent on the finger radius size. This concept is illustrated in Figure 3.8 for a large finger radius and in Figure 3.9 for a small finger radius.

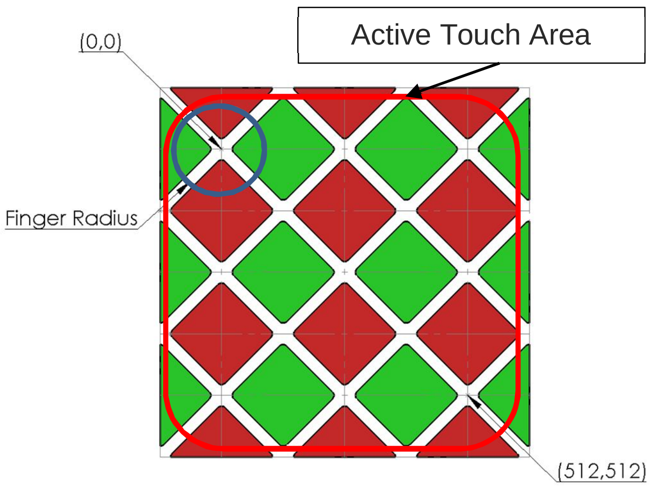
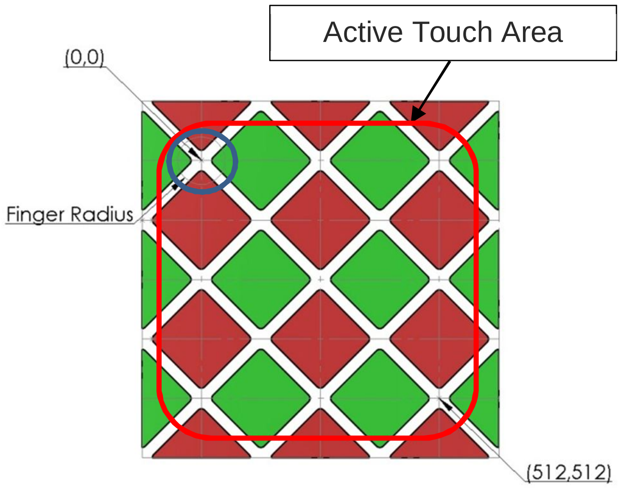


Figure 3.8 Active Touch Area (large finger size)



4 Overlay structure and composition

The overlay is one of the most important components for a correctly working trackpad design.

There are some general principles that should be adhered to when considering the type of overlay that is to be used in the specific application:

- Air gaps should be removed completely if possible
- If minor air gaps are present, mechanical stresses should not cause these spaces to vary in size
- Overlay material must be non-conductive
- If multiple materials are used, they must be firmly connected

4.1 Finger Guides

Finger guides present one of the ways that can add flexibility to a 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 4.1.

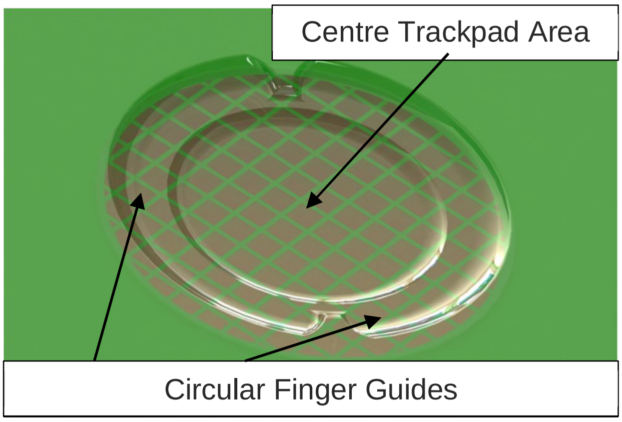


Figure 4.1 Circular Wheel-Type Trackpad (angle view)

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 4.2.

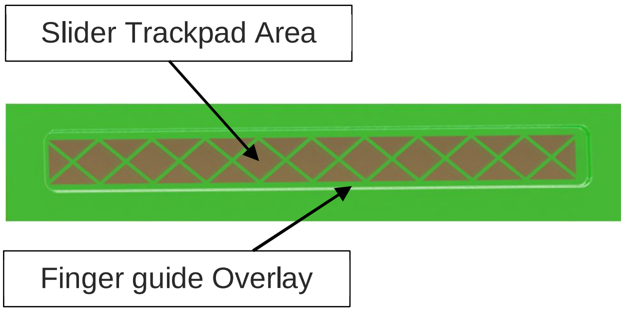


Figure 4.2 Slider-Type Trackpad

4.2 Snap dome Overlays

When adding a metal snap-dome type button to the overlay of the trackpad pattern, an additional 'Snap' function is available. The IQS5xx 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 channel's sample value falling well below the Long-Term Average value for that channel.

General snap dome guidelines:

- Place the snap-dome directly above a channel (thus exactly on the Rx-Tx junction, Figure 4.5)
- Alternatively place the snap-dome in the centre of the diamond pattern, and add a round pad of the second sensor inside the diamond, Figure 4.7
- The snap-dome must consist of the standard metal dome or carbon circle pattern (or similar conductive material) on the inside of the dome.
- This conductive dome must be of adequate size to provide good count value deviation below the Long-Term Average of the channel on a snap.

The conductive dome must however not be too large relative to the pitch of the Rx/Tx sensors, so as to block the field lines for the trackpad sensing, refer to section 4.2.4.

No electrical connection between the snap-dome and the Rx-Tx must be made. Usually PCB solder-mask is adequate. Optimally the sensors are covered by solder-mask, with the snap-dome directly above.

The snap-dome overlay must not be able to vary the air-gap between itself and the sensors, except when a user actually presses down the metal dome. Thus having the overlay stuck securely to the PCB is ideal. A variable air-gap causes sporadic sensing.

If required, the function can be enabled, and the Snap bits are then available to the user, similar to the Prox and Touch status bits. The Long-Term Average filter halt is also implemented on snap outputs.

With the high level of sensitivity found on the IQS5xx devices, a touchpad/Trackpad can now be projected through keys, providing full XY functionality behind these conventional keys, without requiring additional real-estate or sense ICs.

4.2.1 Snap dome keypad example

For design simplicity, the snap domes should be aligned in straight rows and columns; this will ensure the tracking is uniform. Any warping of the diamond pattern to accommodate the snap dome will add acceleration when moving over a warped part of the pattern, (acceleration can be compensated in post processing in master software).

Figure 4.3 is an example of a non-ideal keypad layout with an ideal layout shown in Figure 4.4.

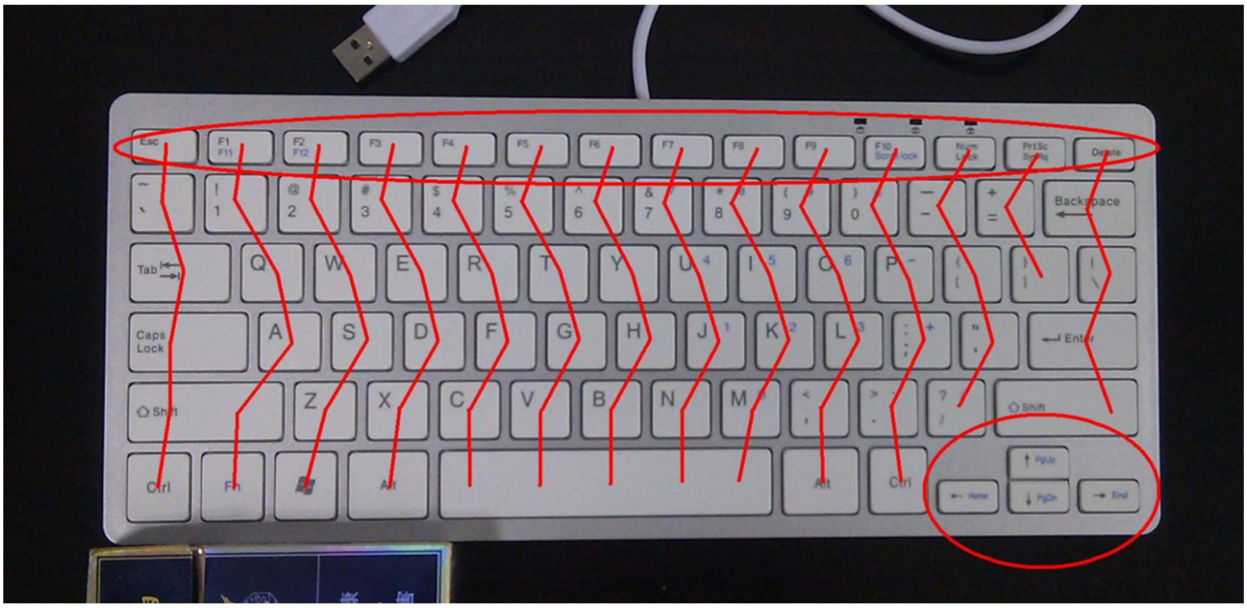


Figure 4.3 Unaligned rows and column – not good for uniform tracking

Figure 4.4 Aligned rows and columns – good for uniform tracking

4.2.2 Snap dome location

The snap domes must be placed on a Tx/Rx intersection, (see ■ in Figure 4.5). If the snap domes are placed in the middle of a diamond, (see + in Figure 4.5), the click response will not be predictable when the snap dome is pressed (A modification to the diamond will allow accurate click detection and is discussed in **section 4.2.3)**.

Ideally snap domes must be placed on Tx/Rx intersection, which is where the 'channel' is located (Blue circles). This will give the best coupling between the Rx and Tx when the snap dome is pressed, which will increase the ease of detection. In an unmodified diamond, placing the metal dome anywhere except on this intersection will yield unpredictable results, see Figure 4.5.

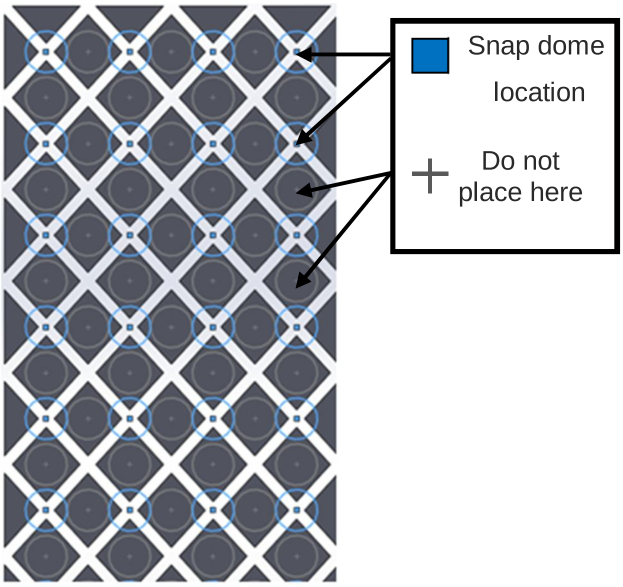


Figure 4.5 Correct and incorrect snap dome locations

Figure 4.6 illustrates GUI feedback that indicates a correct snap dome trigger, displayed in green.

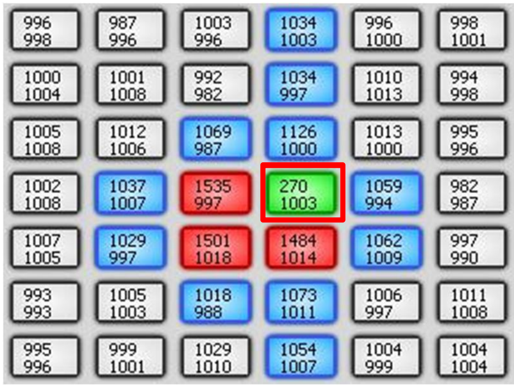


Figure 4.6 GUI sample counts (snap dome at correct location)

4.2.3 Snap domes inside diamonds

If a suitable pitch cannot be found that have all the required snap domes in the ideal locations a modification can be made to the diamond pattern layout. This modification has a hole in the middle of a Tx diamond, and a Rx from the adjacent column is connected to the round pad inside the hole. This gives predictable Snap outputs, which will be read from the channel consisting of the Tx and Rx channels used in the modification, see Figure 4.7.

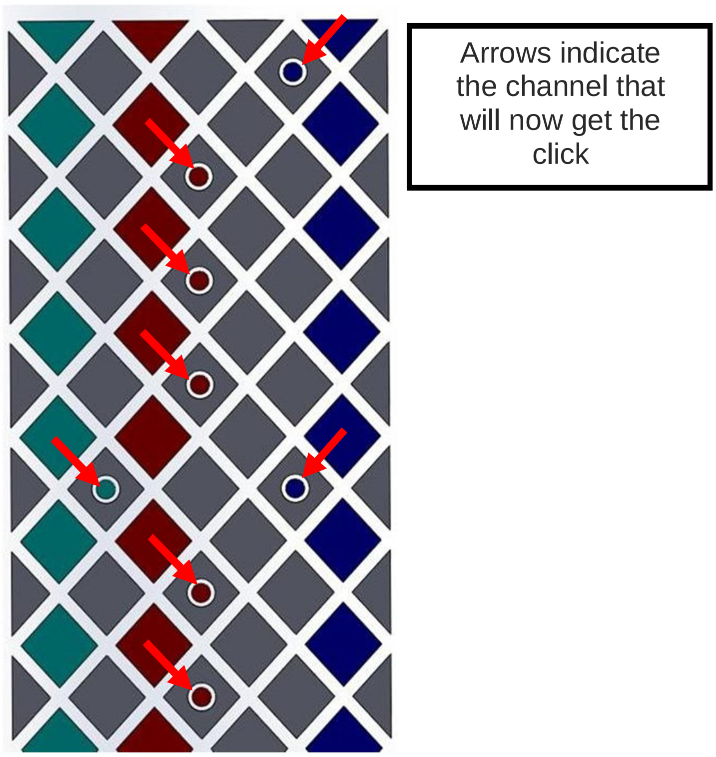


Figure 4.7 Snap domes inside diamonds

4.2.4 Snap dome sizes

Snap dome size depends on the size of the diamonds. A general rule for a diamond pitch of 6 mm is to use a 4 mm snap dome as depicted in Figure 4.8.

Recommended dimensions for a 4 mm snap dome:

Inner pad: small via with 1.5 mm to 2 mm copper area

Gap: 0.5 mm

Outer Diameter: 3 mm

The dimensions above are illustrated in Figure 4.8.

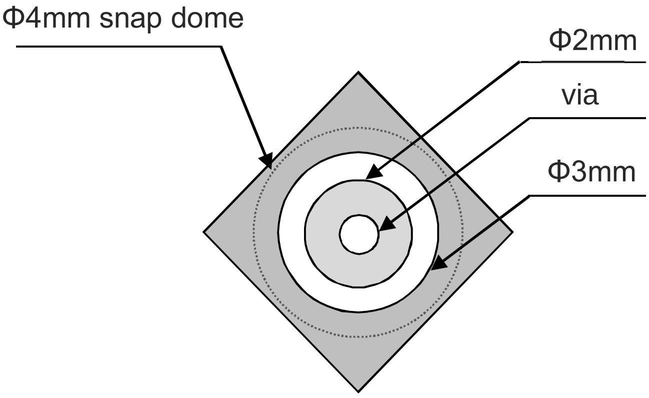


Figure 4.8 Recommended dimensions for a diamond centered snap dome

If the snap dome size relative to the diamond size is too large the tracking sensitivity and thus linearity will decrease. This is because more of the area is covered by the snap dome metal and in turn lowers the sensitivity in this area.

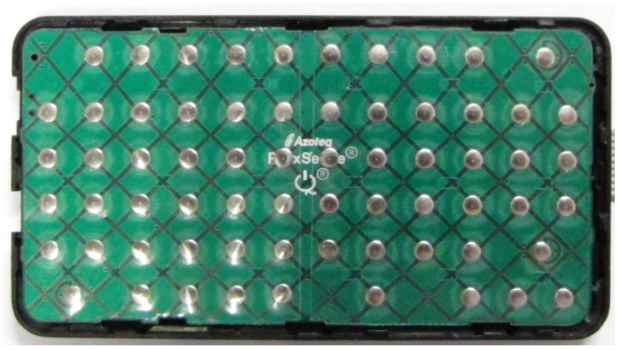


Figure 4.9 4mm snap domes correctly aligned

Figure 4.9 illustrates an example of 4 mm snap domes that are correctly aligned in a keyboard example.

5 IQS5xx Family Channel Resources

Sense channel properties of the IQS5xx family of trackpad controllers are briefly summarised in Table 5.1. In conjunction with the information summarised in Table 5.1, please also refer to the respective datasheet of each device for additional information.

Table 5.1 IQS5xx Controller Resources

Controller	Total Tx	Total Rx	Condition	Max number of Sense Channels
IQS512	Up to 6*	Up to 5*	TotalRx + TotalTx ≤ 7	12
IQS525	Up to 9*	Up to 8*	TotalRx + TotalTx ≤ 10	25
IQS550	15	10	N/A	150

* 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.

6 Diamond pattern warping

Sometimes the overlay design is fixed before a Trackpad is designed, this is not ideal but 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.

6.1 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 6.1. 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. This acceleration can be seen with a diagonal linearity test as there will be a larger tracking offset at the points where the pattern is warped. In some cases the small change the acceleration will be 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 and a user quickly adjust their finger speed accordingly.

Figure 6.1 Single row stretched warp : the top row has been stretched

6.2 Curved warping

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

Figure 6.2 is an example of 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, Figure 6.3. The curve can easily be removed in post processing as the amount of curve is known. If the XY data is used only 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.

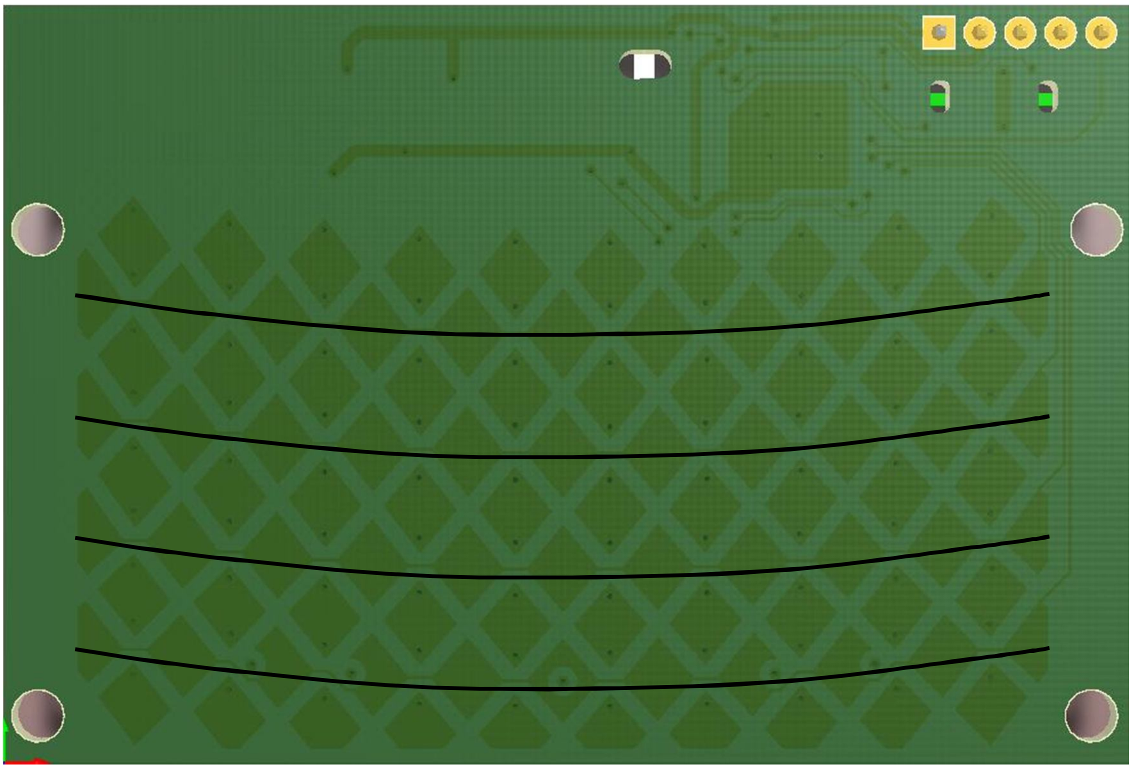


Figure 6.2 Curved warp : the entire diamond pattern has been curved

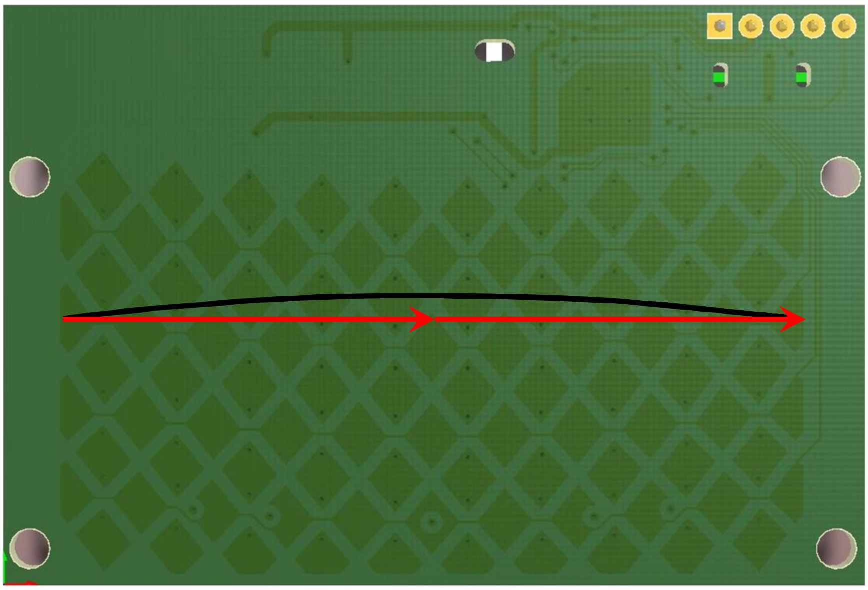


Figure 6.3 Horizontal finger movement (red) will have an output as shown by the black line. The output can be easily corrected to form a straight line in post processing as the amount of curve is known.

7 PCB Layout

7.1 General Guidelines:

- **A 2 layer 1.6 mm thick FR4 PCB is recommended**

- **Implement a 40%, 45 degree grounded hatched pour on the PCB rear – this will prevent a user's hand on the back of the trackpad from being sensed by the sensor.**

  NOTE: For FR4 or FPC up to 0.2mm thickness, a 5% hatched ground pour is recommended

- **Solder mask – The sensors MUST have a solder mask coating as it improves coupling between the diamond pattern copper and the overlay**

- **For low power applications a proximity channel can be added around the trackpad. This channel can be used to wake up the device on a proximity event (for information on how to accomplish this, please refer to the datasheet of the corresponding IQS device)**

- **Minimize any crossing between TX and RX tracks, if this must occur, keep them at 90 degrees and keep RX's and TX's far apart**

- **Avoid having a solid ground pour behind the diamond pattern, as this will significantly reduce sensitivity**

- **Do not allow TX and RX tracks to be routed parallel to each other unless a ground track separates the two groups, otherwise the coupling between the TX and RX channels will increase the parasitic capacitance on the electrodes and decrease sensitivity**

Good noise rejection is illustrated in Figure 7.1, where a hatched ground pour is utilised on the flip side of the diamond pattern.

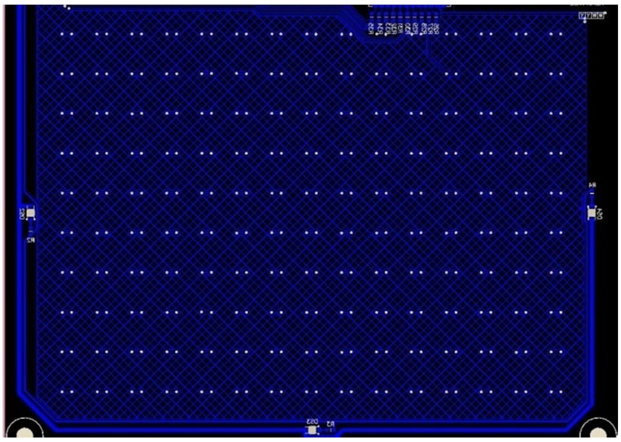


Figure 7.1 Hatched Ground Pour

Good routing is critical to realise good tracking. Figure 7.3 illustrates an example of good routing. RX and TX tracks should be separated with a ground. To maintain a high sensitivity, RX and TX tracks should not cross; if this is not possible they must cross at 90 degrees with respect to one another, and for as short a length as possible, as illustrated in Figure 7.2.

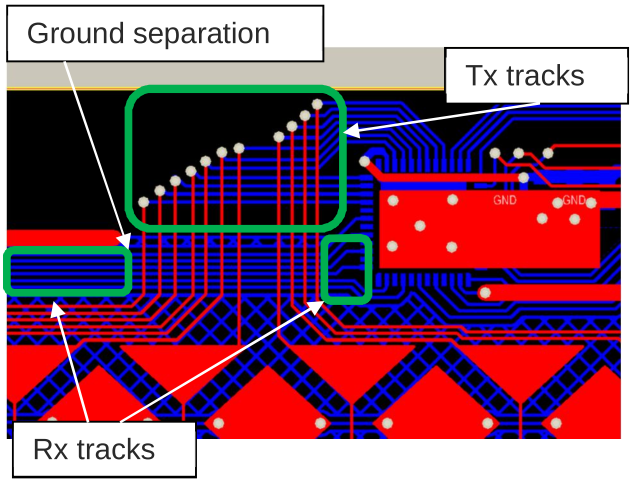


Figure 7.2 Good design practice

A better solution to crossing RX and TX tracks is to position the IC so that crosses will not happen.

A proximity channel can be added around the trackpad. This can be used to wake up the device from sleep mode on a proximity event. When in normal mode, the proximity channel is grounded and the antenna will act as a shield around the trackpad, preventing unwanted interference on the outside.

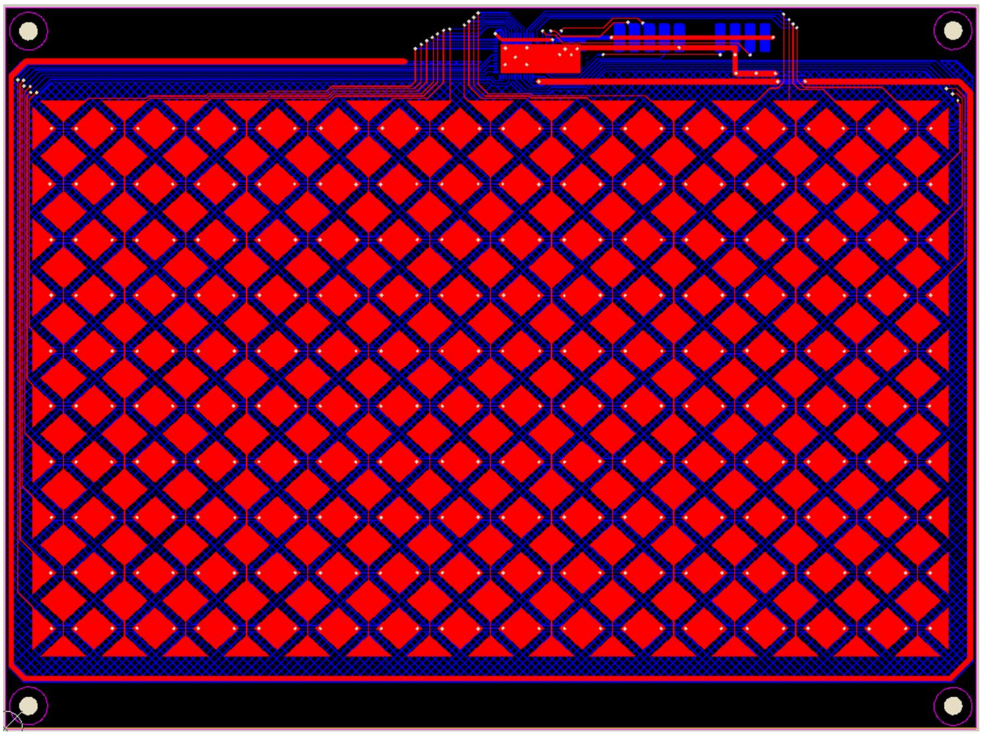


Figure 7.3 Example of good trackpad routing & proximity channel on the perimeter

7.2 LED Backlighting

If backlighting is needed LEDs can be placed in the centre of a diamond as illustrated in Figure 7.4. If the cut-out is kept at a minimum, the tracking will not be negatively affected.

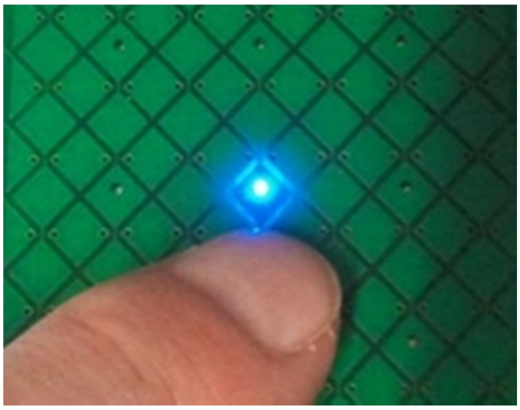


Figure 7.4 LED in the centre of a diamond

8 Mechanical Housing

8.1 General guidelines

The mechanical structure of the housing in which the trackpad is contained depends strongly on the application itself, but general guidelines include:

- The design of the mechanical housing must ensure that the overlay is as uniform as possible with no air gaps
- The design must be rigid enough to ensure that no bending and/or twisting occurs during operation.
- Mechanical stiffeners or ribs can be employed in keyboard-type designs to add increased rigidity

8.2 Keyboard housing guidelines

The mechanical structure for a keyboard Trackpad needs to be rigid with cross beams in strategic locations to prevent twisting and bending. Adding a stiffening grip as in (Figure 8.1) is not recommended as the frame will affect the tracking. The change between the rubber keys and the plastic frame will change the amount of coupling to the sensor below and tracking will be affected with the linearization error increasing.

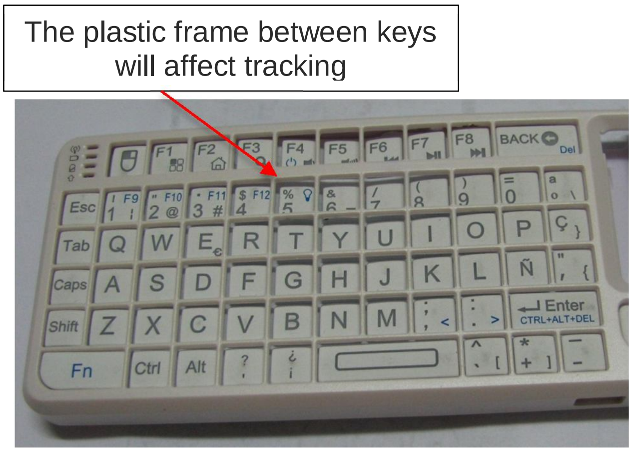


Figure 8.1 Bad keyboard design for tracking over keys

The mechanical stiffeners must be designed in such a way that any misuse, compression or twisting by a user must not lift up or make the key pad bulge up. The bulging up will result in a changing air gap and different overlay thickness, all of this is unpredictable resulting in unstable tracking, Figure 8.2.

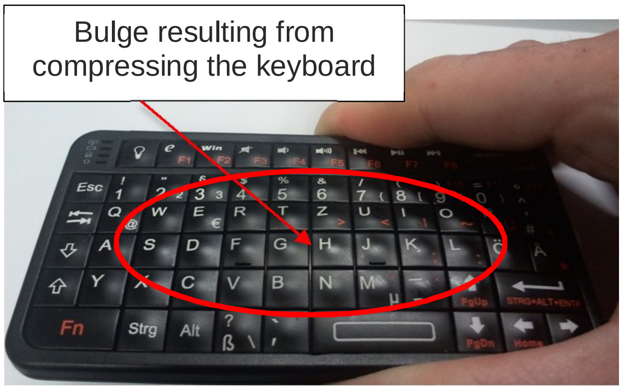


Figure 8.2 Weak mechanical structure

The most effective form of mechanical stiffness that can be added to the housing is to add ribs or solid pieces of plastic directly below the trackpad area. This will also guard against a user pushing the trackpad with too much force that would otherwise dent the trackpad. The PCB itself can also be used to stiffen the structure by screwing it to the housing.

The ribs behind the trackpad also contain an air gap; this air gap is an insulator and further shields the track pad from behind.

8.2.2 Keyboard friction

The amount of keyboard friction is another design choice that needs to be considered, and will be a tradeoff between a low or high static friction surface (stiction).

With a low stiction surface, the user finger glides smoothly and effortlessly over the keys, allowing for a better tracking experience.

With a high stiction surface the user's finger will grip the keys and stay in place; sliding the finger from side to side will result in jumps when the finger gains and loses grip on the keys.

For trackpad devices a low stiction surface is recommended.

9 Remote control overlay examples

Listed below are a few examples for navigation key trackpads with snaps.

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<td>Ideal for tracking
Flat / Smooth / Single material
Low profile
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<tr>
<td></td>
<td>Acceptable
Air gaps in the rubber – not ideal / air gap can vary when pushing button
Plastic is relatively flat
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Not ideal

- **Big distance between PCB and top of remote - BAD**
- **Plastic has large air gaps / Plastic walls will decrease linearity for tracking**


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Unusable

- **Plastic has multiple pieces and levels**
- **Plastic has multiple moving part**
- **Large uncontrolled air gaps**
- **Large distance between PCB and top sof OK button**


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The following patents relate to the device or usage of the device: US 6,249,089 B1, US 6,621,225 B2, US 6,650,066 B2, US 6,952,084 B2, US 6,984,900 B1, US 7,084,526 B2, US 7,084,531 B2, US 7,119,459 B2, US 7,265,494 B2, US 7,291,940 B2, US 7,329,970 B2, US 7,336,037 B2, US 7,443,101 B2, US 7,466,040 B2, US 7,498,749 B2, US 7,528,508 B2, US 7,755,219 B2, US 7,772,781, US 7,781,980 B2, US 7,915,765 B2, EP 1 120 018 B1, EP 1 206 168 B1, EP 1 308 913 B1, EP 1 530 178 B1, ZL 99 8 14357.X, AUS 761094

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