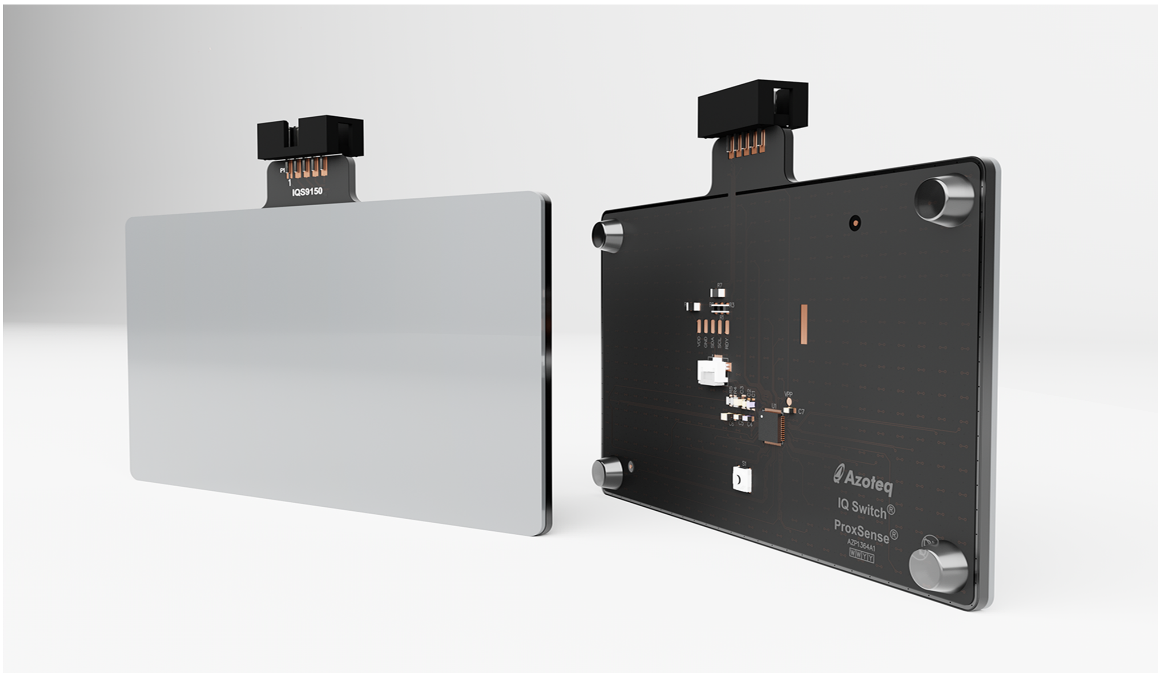
IQS9150/IQS9151 User Guide

The user guide assists in getting started with the IQS9150EV02 and IQS9151EV02 kits, and also provides step-by-step guidance to configure the IQS9150/IQS9151 product using the IQS9150EV02 hardware.



Contents

1 IQS9150 and IQS9151 EV-Kit

1.1 Introduction

This section describes the operation of the IQS9150EV02 and IQS9151EV02 evaluation kits.

The IQS9150 EV-Kit consists of three parts:

- IQS9150 trackpad module with glass overlay x 1
- 3D printed virtual sensor finger guides x 3
- CT210A/DS200 x 1

The IQS9151 EV-Kit consists of two parts:

- IQS9151 trackpad with acrylic overlay x 1
- CT210A/DS200 x 1

To visualise all sensor data from an EV-Kit, the module board can be interfaced to any Windows PC with USB support, along with the CT210A/DS200 and the IQS9150_IQS9151 Graphical User Interface (GUI) software available to download from the Azoteq website. The purpose of the EV-Kits are to help application and development engineers in evaluating the IC's capabilities. A picture of the trackpad modules from the evaluation kits are shown below in Figure 1.1.

(a) IQS9150EV02 EV-Kit *(b) IQS9151EV02 EV-Kit*

Figure 1.1: IQS9150EV02 and IQS9151EV02

Download the GUI from the IQS9150 or IQS9151 product page on Azoteq's website.

The GUI can be found in the following section:

- Design Support → Software
- Click on the *IQS9150 Debug and Display Tool* hyperlink to download the GUI.
- Install GUI on PC.
- Connect the CT210A/DS200 to the PC with a USB Type-C data cable.

1.2 Evaluating with PC GUI

To interface the IQS9150/IQS9151 trackpad module to a PC we advise using the CT210A/DS200. This module is set up in mutual capacitive mode. This EV-Kit can be set up with the following steps:

- Plug the module into the CT210A/DS200 via ribbon cable.
- Run the IQS9150_IQS9151 GUI.
- Select IQS9150 or IQS9151.
- Click *START STREAMING* button.
- Data should now stream to the GUI.
- Click *ACK RESET* button.
- Click the *USER SETTINGS* button.
- Click the relevant EV-kit picture button to write the latest settings.
- GUI should look as follow when streaming the IQS9150.

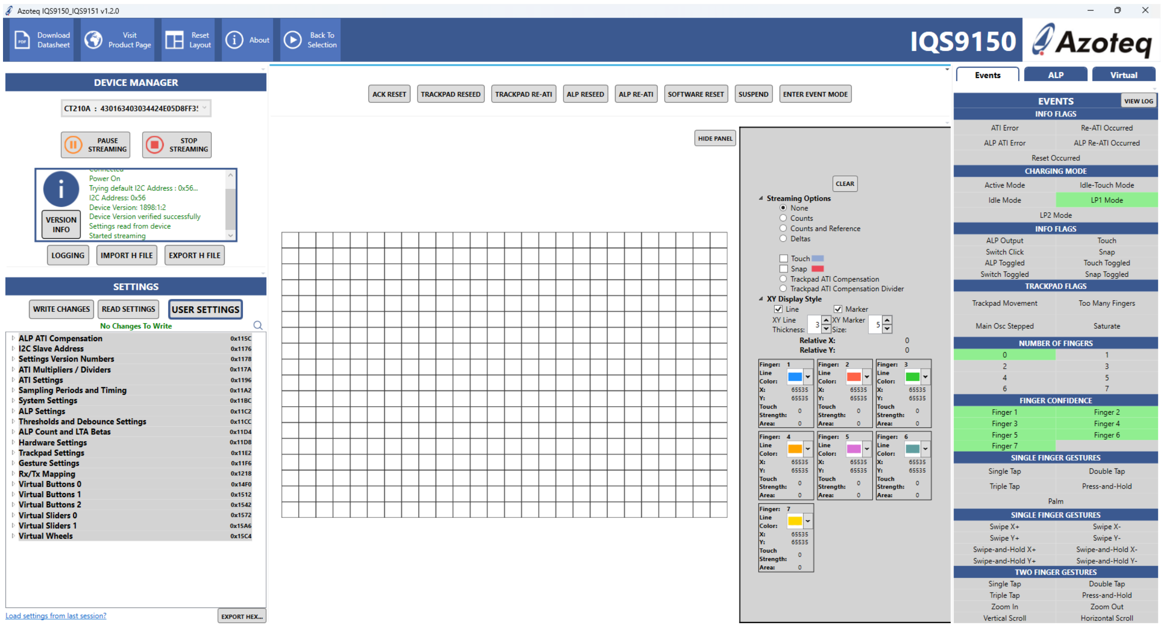


Figure 1.2: IQS9150 Streaming

Please note the following items while evaluating the IQS9150/IQS9151 trackpad module:

- Streaming channel data reduces the report rate of the trackpad, after evaluating the channel information (such as counts), it is recommended setting the Streaming Options to None.
- The trackpad XY output will be plotted onto the central channel canvas area.
- Numerous trackpad output and information, such as 1 and 2 finger gestures, can be seen on the 'Events' tab on the right side of the window.
- When the system transitions to LP1 and LP2, the low-power channel is active. To visualise its' data, switch to the 'ALP' tab on the right panel.
- To start adjusting/experimenting with the on-chip settings, press the *USER SETTINGS* button on the left side to open the pop-up settings window.
- Note: To reset the module back to the predefined settings, simply press *STOP STREAMING* and then *START STREAMING*.
- The IQS9150EV02 also has a push button on the bottom side of the PCB, and its output can be seen in the *Switch Click* status in the *Info Flags* section.

After evaluating click *STOP STREAMING* button.

1.3 Virtual Sensor Finger Guides (only for IQS9150EV02)

Three finger guides are added to the IQS9150 EV-Kit named:

- Numpad
- Mixer
- Joypad

These can be slid over the trackpad module to superimpose virtual keys onto the trackpad area. The three different options are shown in this section. When switching between overlays, slide very slowly and carefully to not break the overlay.

1.3.1 Numpad

Figure 1.3: IQS9150 virtual numpad with finger guide

Click *START STREAMING* button to start data stream to PC.
Click *ACK RESET* button.
Click *USER SETTINGS* button to open Settings window.
Click on the Numpad picture button to load the predefined settings for this overlay.
Minimise 'Settings' pop-up window.
Towards the right, below Azoteq logo, is the *Virtual* button, click to switch to this tab.

It should look like the following picture:

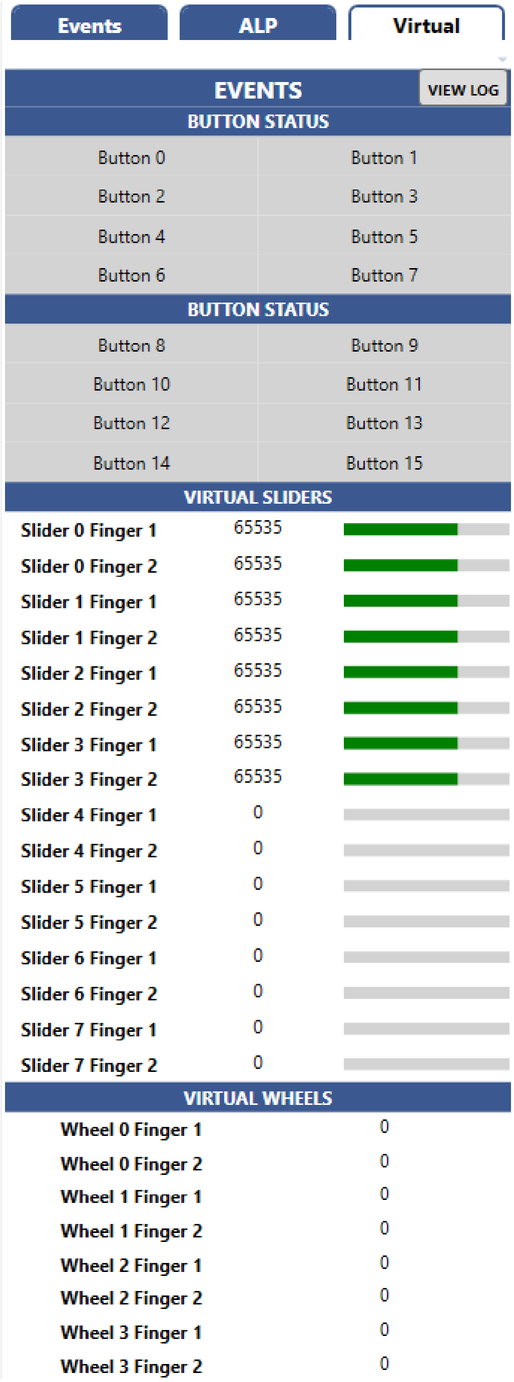


Figure 1.4: IQS9150 virtual sensor output tab

This tab shows the output status of the virtual buttons on the numpad, as well as the slider outputs for certain numpad keys that were implemented as sliders.

After evaluating click *STOP STREAMING* button.

1.3.2 Mixer

Figure 1.5: IQS9150 Virtual mixer with finger guide

Click *START STREAMING* button to start data stream to PC.
Click *ACK RESET* button.
Click *USER SETTINGS* button to open Settings window.
Click on the Mixer picture button to load the predefined settings for this overlay.
Minimise 'Settings' pop-up window.
Towards the right, below Azoteq logo, is the *Virtual* button, click to switch to this tab.

The virtual buttons, sliders and wheel outputs are displayed on this tab. Note that the sliders and wheels allow for up to 2 finger inputs simultaneously.

After evaluating click *STOP STREAMING* button.

1.3.3 Joypad

Figure 1.6: IQS9150 Virtual joypad with finger guide

Click *START STREAMING* button to start data stream to PC.
Click *ACK RESET* button.
Click *USER SETTINGS* button to open Settings window.
Click on the Joypad picture button to load the predefined settings for this overlay.
Minimise 'Settings' pop-up window.
Towards the right, below Azoteq logo, is the *Virtual* button, click to switch to this tab.

The virtual buttons, sliders and wheel outputs are displayed on this tab. Note that the sliders and wheels allow for up to 2 finger inputs simultaneously.

After evaluating click *STOP STREAMING* button.

1.4 EV-Kit Circuit Diagram

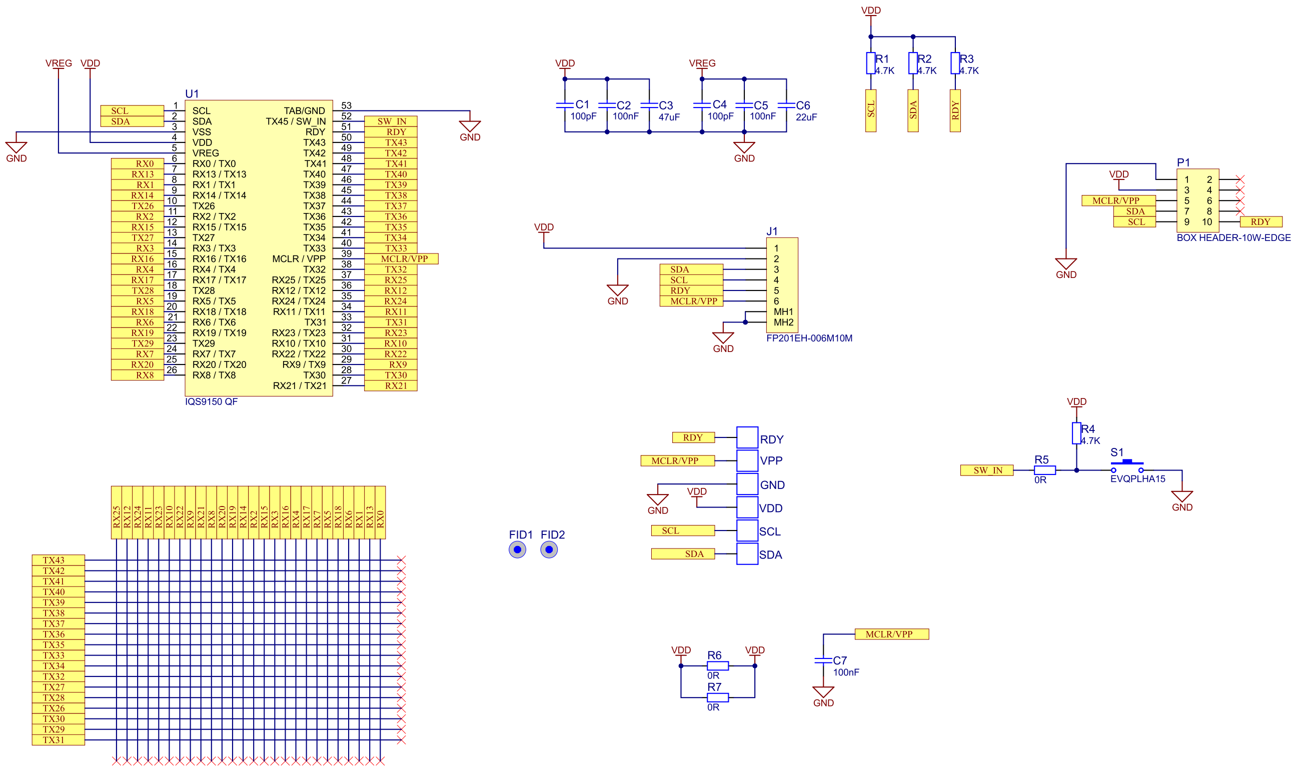


Figure 1.7: IQS9150EV02 Trackpad Schematic

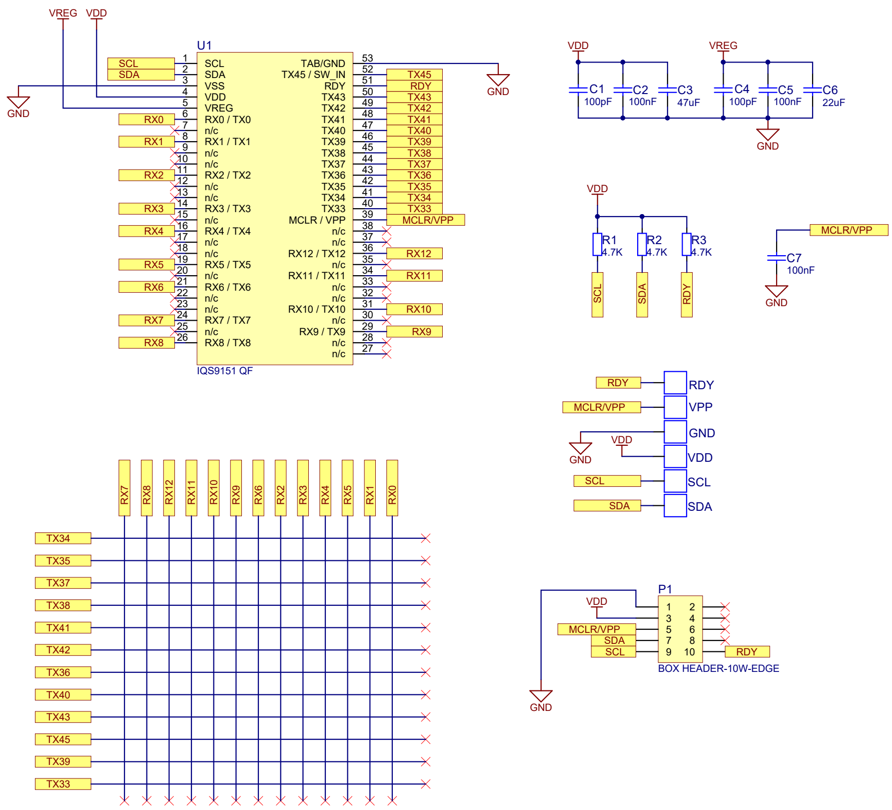


Figure 1.8: IQS9151EV02 Trackpad Schematic

2 IQS9150/IQS9151 Product Setup

2.1 Introduction

Section 1 described specifically how to get up and running with evaluation of the product using the IQS9150EV02 and/or IQS9151EV02 EV-Kits. The rest of the document dives deeper into the process of configuring any trackpad design using the available parameters in the product memory map by means of the Azoteq GUI. The recommended systematic setup process is stepped through using the IQS9150EV02 hardware as an example. By following this approach a custom trackpad module can be configured correctly and effectively. This guide is applicable to the IQS9151 as well, as the configuration process is identical.

A summary of the process is shown below:

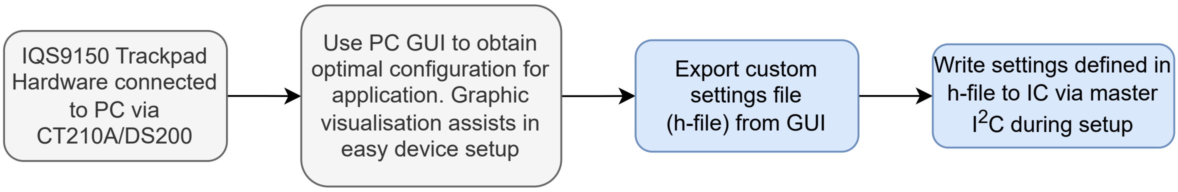


Figure 2.1: Process summary

The result of this process is to obtain a settings header file which includes the parameters specific for the current application.

Refer to the IQS9150/IQS9151 datasheet for specific product details.

Please see the sections listed below for a **summary** of the setup steps.

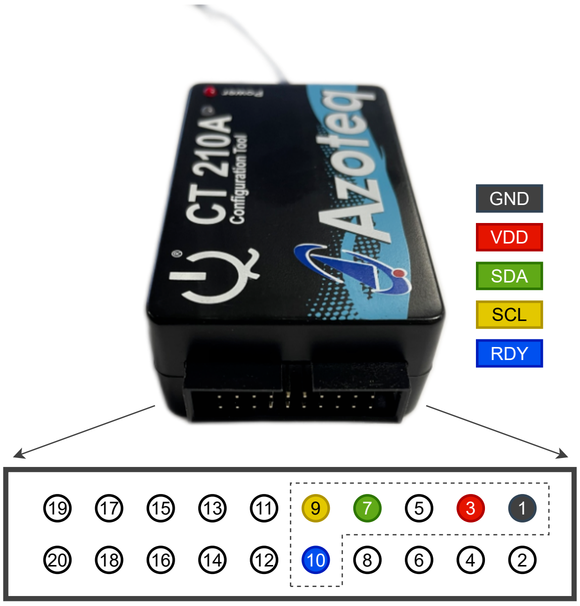
- Basic Setup Summary -> Section 3.5
- Intermediate Setup Summary -> Section 4.7
- Advanced Setup Summary -> Section 5.11

2.2 Hardware Connections

Connect the application hardware power and I^{2}C lines to the CT210A/DS200 USB dongle as shown in the table and figure below. Now connect the USB of the CT210A/DS200 to the PC.

Table 2.1: CT210A/DS200 Pin-out

IQS9150/IQS9151 Pins	CT210A/DS200 Pins
GND	Pin 1
VDD	Pin 3
SDA	Pin 7
SCL	Pin 9
RDY	Pin 10



(a) CT210A Connections

(b) DS200 Connections

Figure 2.2: Streaming I^{2}C Connections

2.3 IQS9150_IQS9151 GUI Software

The graphical user interface (GUI) is a powerful support/design tool to simplify the process of configuring the IQS9150/IQS9151 device with the parameters required for optimal performance for specific hardware.

An introduction on how to use Azoteq's debug and display tool can be seen in this video.

The latest GUI can be obtained from the relevant product page on the Azoteq website.

3 Basic Device Setup

The on-chip parameters need to be configured for the application to operate optimally. Setting up a capacitive sensing device for optimal performance requires several parameters to be tuned correctly. However, to get started, a basic setup is easy to achieve after which the settings can be optimised, and more advanced features can be configured.

3.1 Getting Started

The number of sensors implemented, and their connections, are configured together with an initial configuration from which to start optimising.

The IQS9150EV02 EV-kit with PCB number AZP1364A1 is the hardware used as example to be configured in this document.

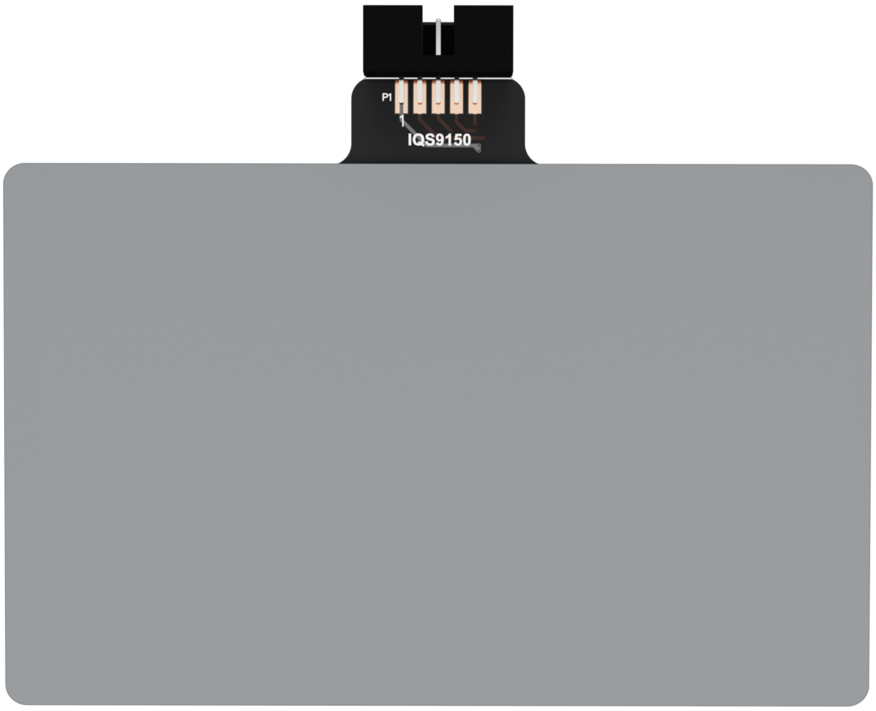


Figure 3.1: AZP1364A1 Trackpad Hardware

Start the device by pressing the *'Start Streaming'* button on the main window. Look out for any errors in the top left window, if all is in order, the configuration section should display as follows:

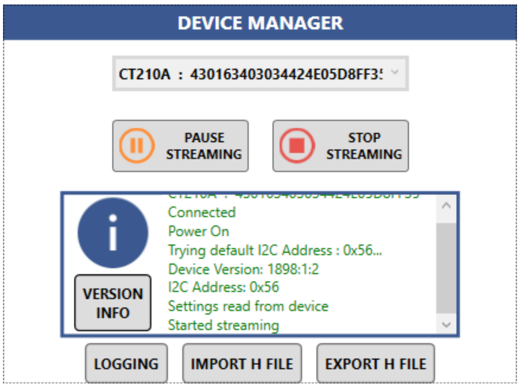


Figure 3.2: Successful Device Connection and Start

If this is not successful, make sure the I^{2}C connections to the device are connected correctly. Also make sure that the CT210A/DS200 is connected via USB to the PC. If successful, pressing the *'Ack Reset'* button will change it from red to black, showing the reset flag was cleared. If it ever becomes red again, the reset flag is set, indicating that an unexpected reset occurred.

The settings are configured from the separate settings window which can be opened from the main window by pressing the *'User Settings'* button. Once any setting is modified, it needs to be sent to the device by pressing the *'Write Changes'* button. To revert to the settings before the adjustment (if it has not yet been written), the *'Read Settings'* button can be pressed.

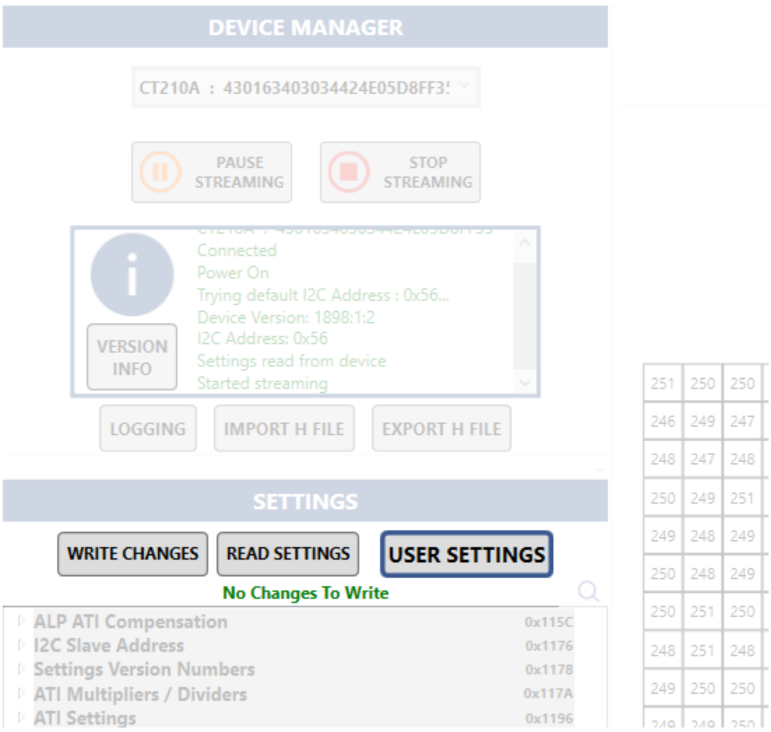


Figure 3.3: Buttons Preview

3.2 Rx and Tx Setup

3.2.1 Total Rxs and Txs

The first step is to select the total number of Rx and Tx sensors implemented in the design. The AZP1364A1 trackpad layout is shown in the figure below, and it can be seen that there are 26 Rxs configured as columns, and 18 Txs configured as rows.

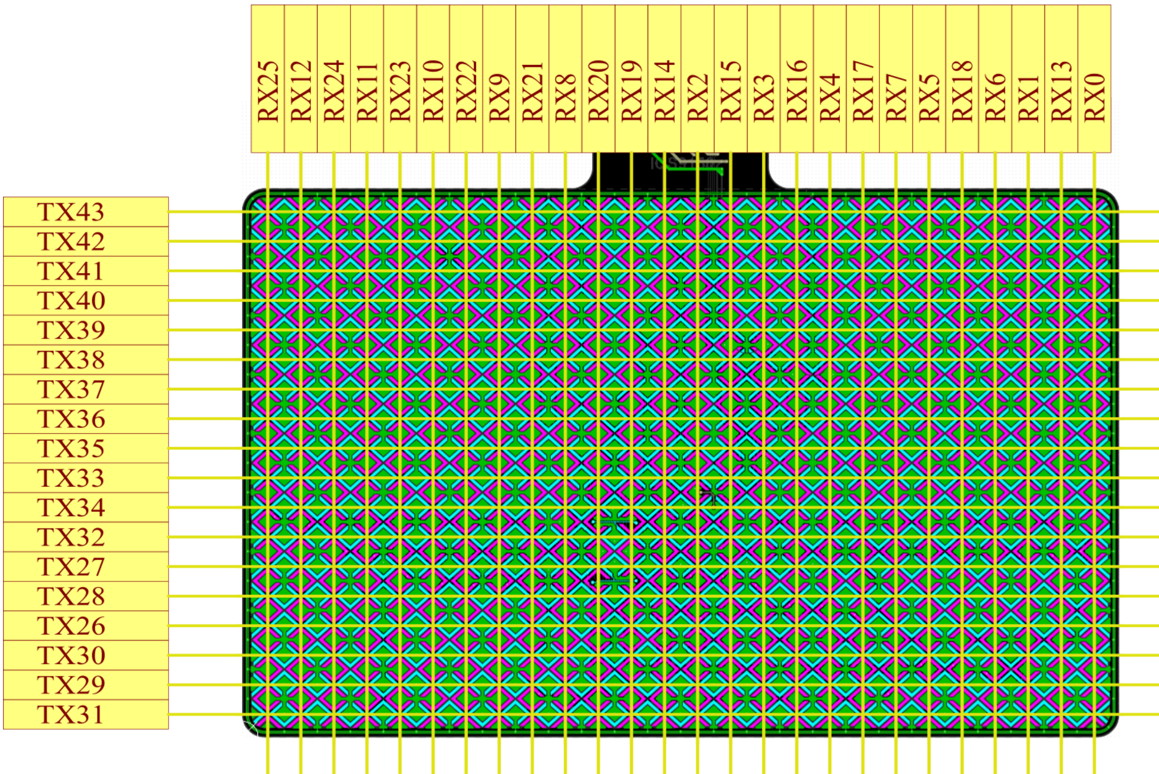


Figure 3.4: AZP1364A1 Trackpad Layout

To set up the Total Rxs and Total Txs parameters, open the *'User Settings'* window and click on the *'Trackpad Settings'* tab. Here the value for Total Rxs and Txs can be set to 26 and 18 respectively.

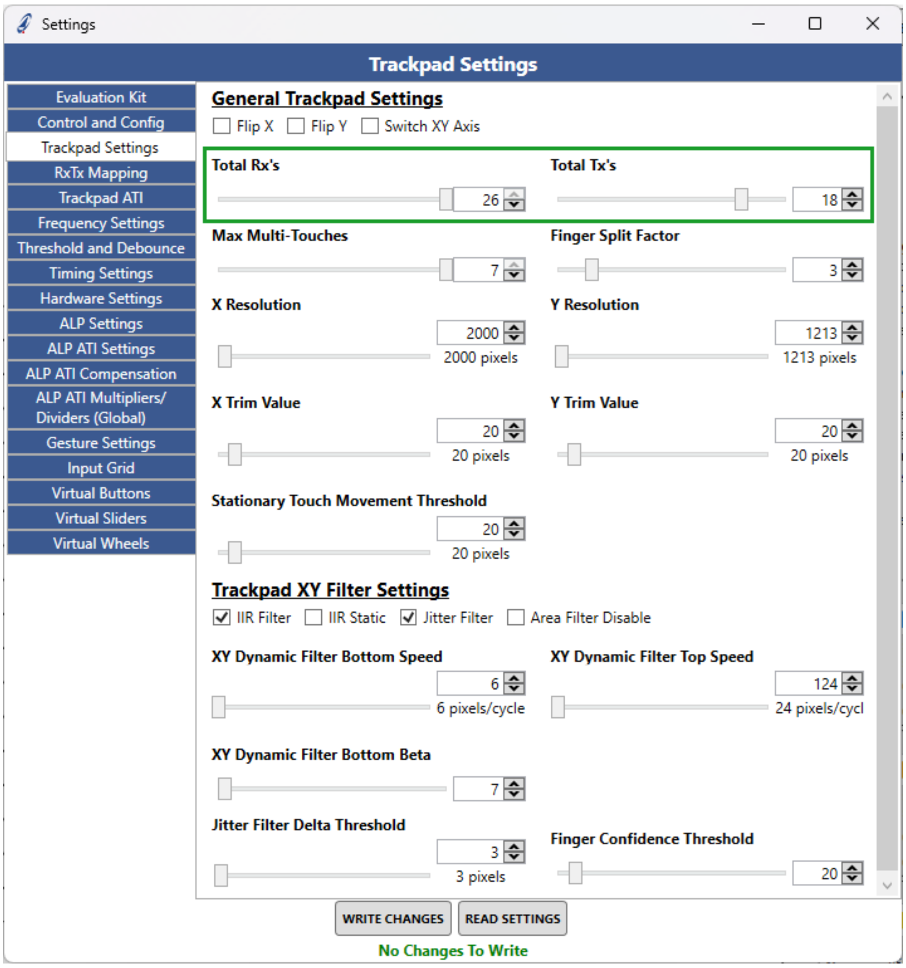


Figure 3.5: Total Rxs and Txs

3.2.2 Rx and Tx Mapping

The Rx and Tx numbers on the AZP1364A1 layout are shown in figure 3.4 (Rxs being columns, and Txs rows).

The mapping is now configured in the *'RxTx Mapping'* tab by modifying the selections. The Rx and Tx mapping is taken from the top-left corner of the trackpad, with the Rxs mapped firstly, followed by the Txs.

The mapping for the AZP1364A1 hardware is configured as shown in the figure below. Rxs are marked in blue and Txs are marked in green. When the Rxs and Txs are correctly set, press *'Write Settings'* to send the settings to the IQS9150. For the remainder of this document, it is assumed that *'Write Settings'* is pressed after any parameter is changed.

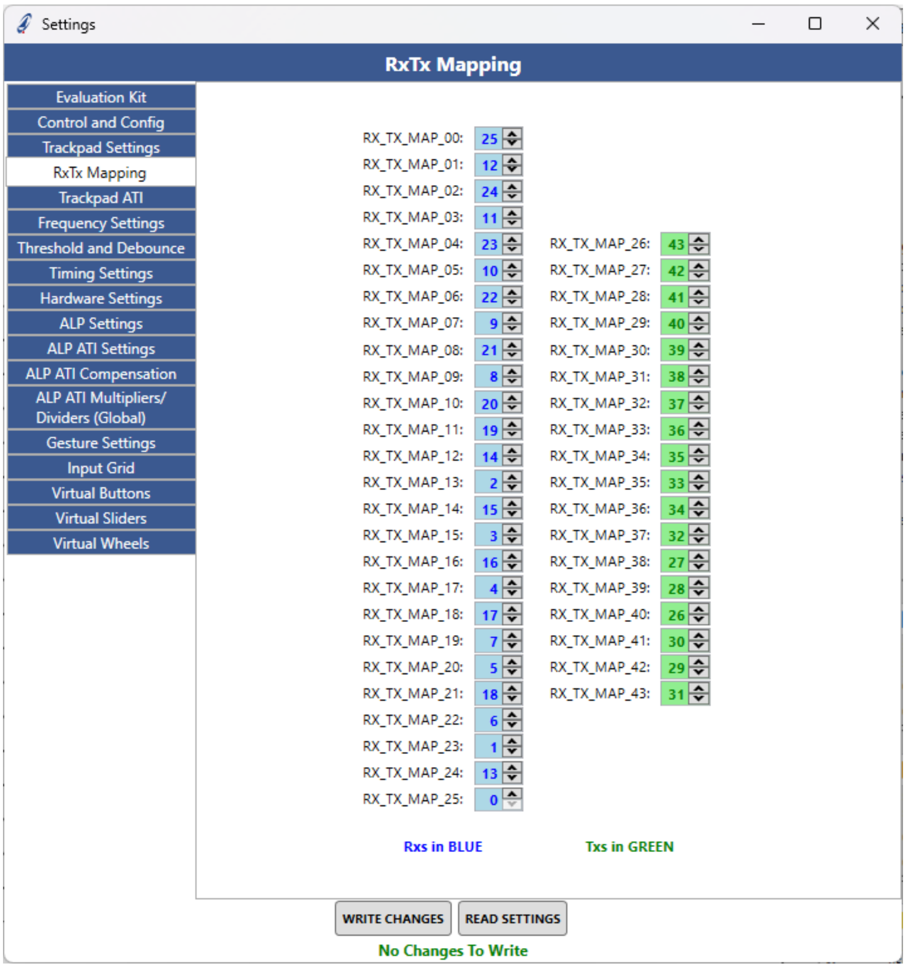


Figure 3.6: Rx/Tx Mapping

3.3 Trackpad Channel Numbers

Trackpad channels are numbered from 0 to (Total Rxs ∗ Total Txs) - 1. They are assigned from the top-left corner, first along the Rxs before stepping to the next Tx. The channel number is important for setting individual thresholds, disabling channels, or enabling snap channels, and the GUI can help with this. Hover over one of the channel blocks in the main window to see the channel number and Rx/Tx pair:

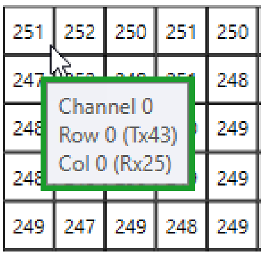


Figure 3.7: Channel Number and Rx/Tx pair

3.4 Alternate Low-Power Channel (ALP) Rx and Tx Selections

To provide lower power consumption, the trackpad can be configured as a single sensor in Low Power 1 (LP1) and Low Power 2 (LP2), instead of sensing the individual trackpad channels. This channel needs to detect user interaction to wake the device from LP1/LP2 and to make a transition to the trackpad sensing state (Idle mode).

Mutual- or self-capacitive charging can be configured. In most applications the trackpad sensors are used, and therefore, mutual- or self-capacitive can be used.

Select some of the Rx and Tx electrodes to form the ALP channel under the *'ALP Settings'* tab. In a mutual-capacitive ALP channel configuration, every second Rx and Tx of the trackpad is typically enabled. In a self-capacitive configuration, the 'Active Tx Shield' is activated to make Txs mimic Rx behavior; otherwise, Txs will be grounded, significantly reducing the sensitivity of the ALP sensor. All Rxs and Txs are usually selected for self-capacitive mode, as this does not greatly impact current consumption while providing good detection range and sensitivity.

Fewer or more electrodes may be selected than in the example below, based on the required wake-up capability and current consumption needs. For this application, self-capacitive mode was chosen for sensing due to its detection range and good sensitivity across the entire trackpad area. The active electrodes in low power mode are highlighted in pink below; these are the receiver electrodes used in the self-capacitive ALP sensor.

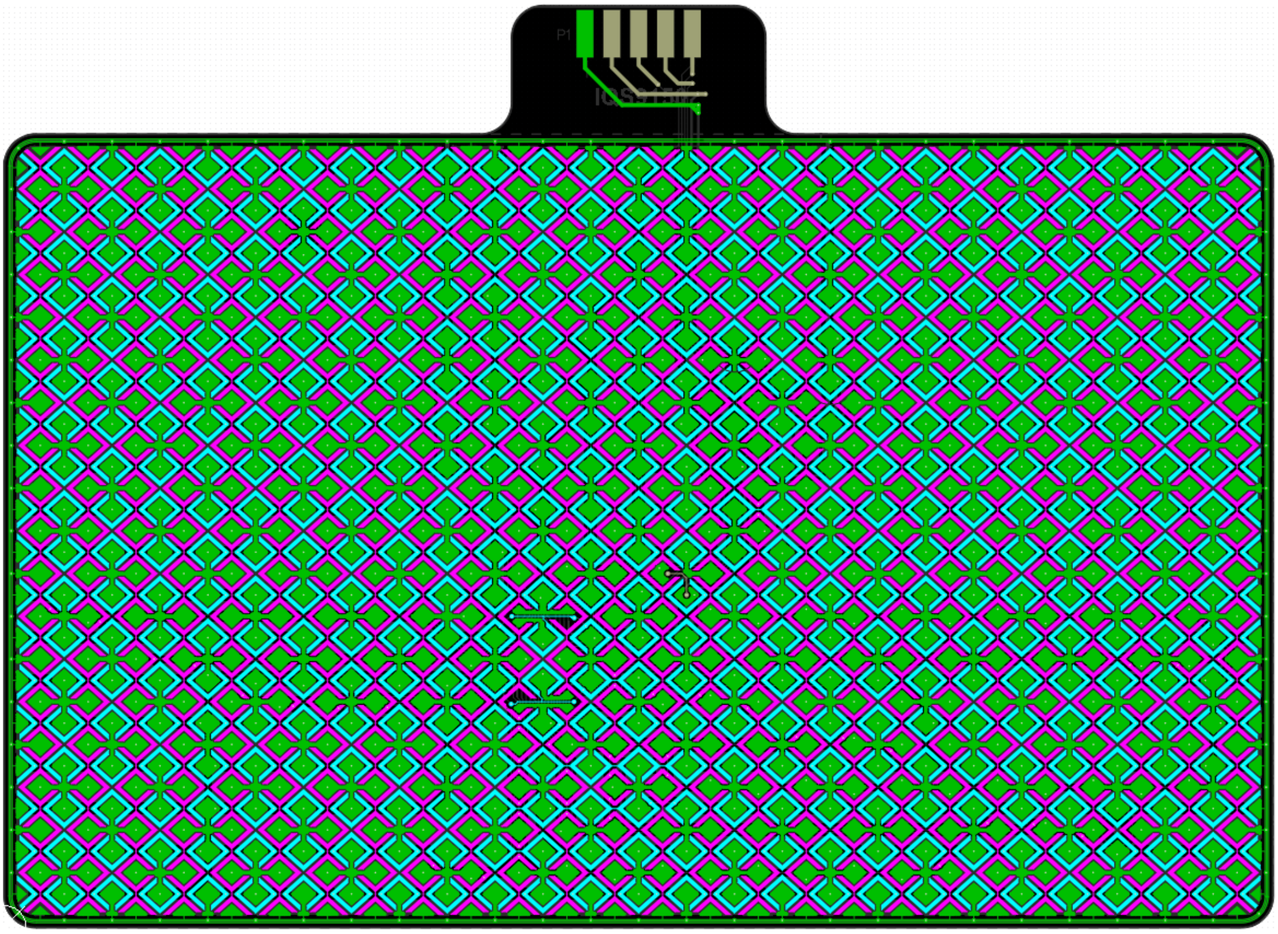


Figure 3.8: IQS9150 Electrodes (Rxs - pink; Txs - cyan; Ground - green)

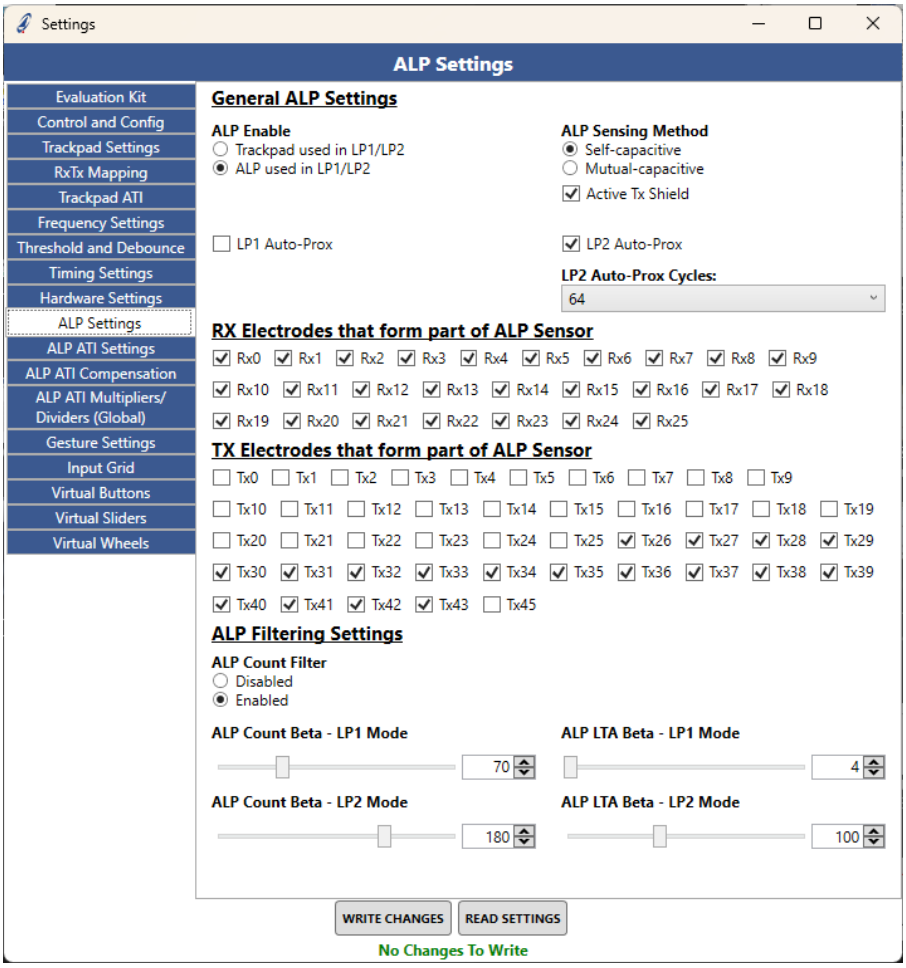


Figure 3.9: ALP Rx and Tx Selections

3.5 Basic Setup Summary

At this point the device is operational. The hardware (layout and sensor design) has been configured on the device. It is advised that settings changed up to this point are now saved to a header file (h-file) so that you don't lose these changes. Click the *'Export H File'* button and click *Save* to save the file. When you stop streaming and disconnect the device you can easily get back to the same save point. To import your settings, click the *'Import H File'* button and select the h-file. See Section 6.1 for more details.

Overview of the basic setup covered in this section:

1. Connect trackpad hardware to CT210A/DS200
2. Connect CT210A/DS200 to the PC via USB
3. Open Azoteq GUI software
4. Press *'Start Streaming'*
5. Press *'Ack Reset'*
6. Press *'User Settings'*
7. Configure Total Rxs and Total Txs
8. Configure the RxTx Mapping
9. Press *'Trackpad Re-ATI'*
10. Make the Rx and Tx selections for the ALP channel
11. Proceed to Section 4 if you experience any issues or require further assistance

4 Intermediate Device Setup

4.1 Rx/Tx Mapping Check

Confirm that the Rx/Tx mapping aligns with the channel display on the main window by touching left, right, top and bottom, and confirming whether the channels mirror the hardware locations (check only touch location, for now ignore the XY position output). If these do not match the finger location on the hardware, then you can reverse the order of the Rx and Tx mapping to correct this. This is mostly a GUI display setup, but it is beneficial that the GUI display and actual hardware location are aligned.

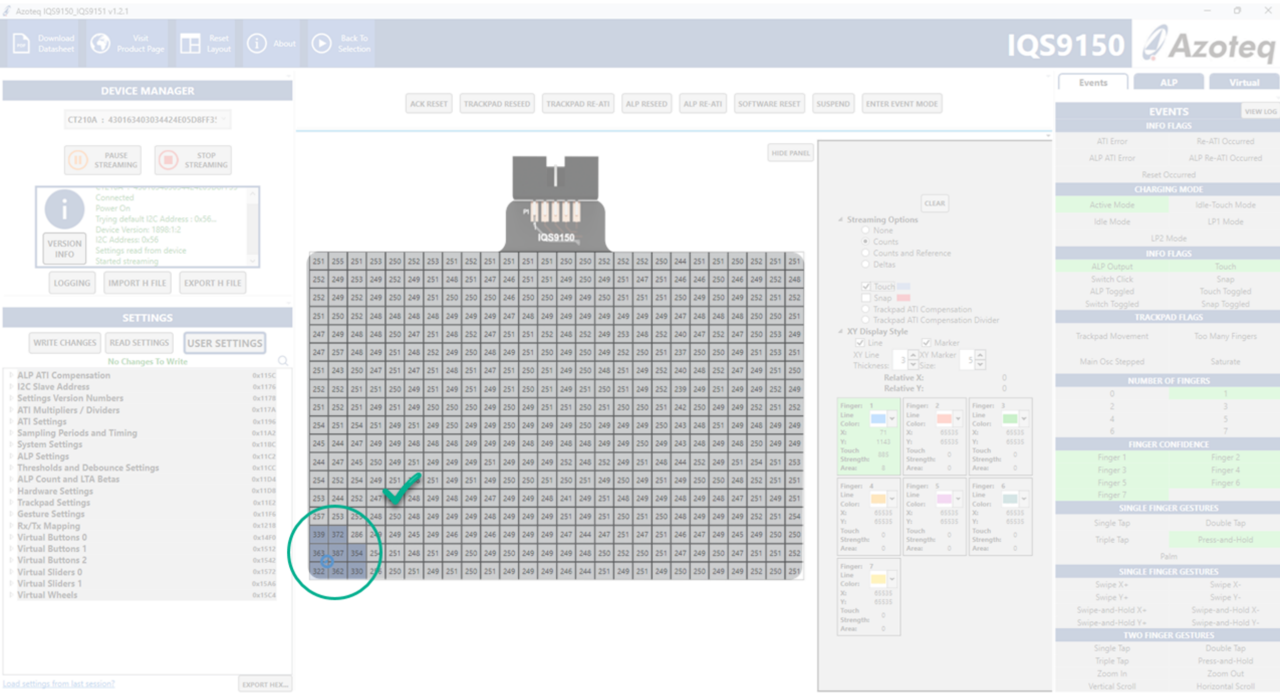


Figure 4.1: Rx/Tx Mapping Check - Example of touching the bottom left corner and verifying that it corresponds with the displayed location in the GUI.

4.2 ATI Setup

4.2.1 Trackpad ATI Setup

The ATI parameters are a very important step in the configuration of the IQS9150/IQS9151 device. The channels are configured to give acceptable sensitivity and performance. The setup will be kept basic here, but refer to Azoteq literature for further details regarding ATI technology. While changing trackpad ATI settings it is beneficial to enable *Manual Control* under the *'Control and Config'* tab and force the device to stay in *Active* mode. Remember to disable *Manual Control* again afterwards.

These parameters can be set in the *'Trackpad ATI'* tab to give acceptable sensitivity and performance. The channel sensitivity can be estimated by:

$$\text{Sensitivity} \propto \frac{\text{ATI Target}}{\text{ATI Base Counts}}$$

The *ATI Base Counts* can be read from the device and viewed in the channel grid as illustrated below. Click on the *'Counts'* radio button under *'Streaming Options'* in the main window. Set the *ATI Target* to 0. Remember to press the *'Trackpad Re-ATI'* button after changing ATI settings. The *ATI Error and*

Re-ATI Occurred flags can be seen under *Info Flags* in the *Events* tab to the right. The count values you see now are the *ATI Base Counts*.

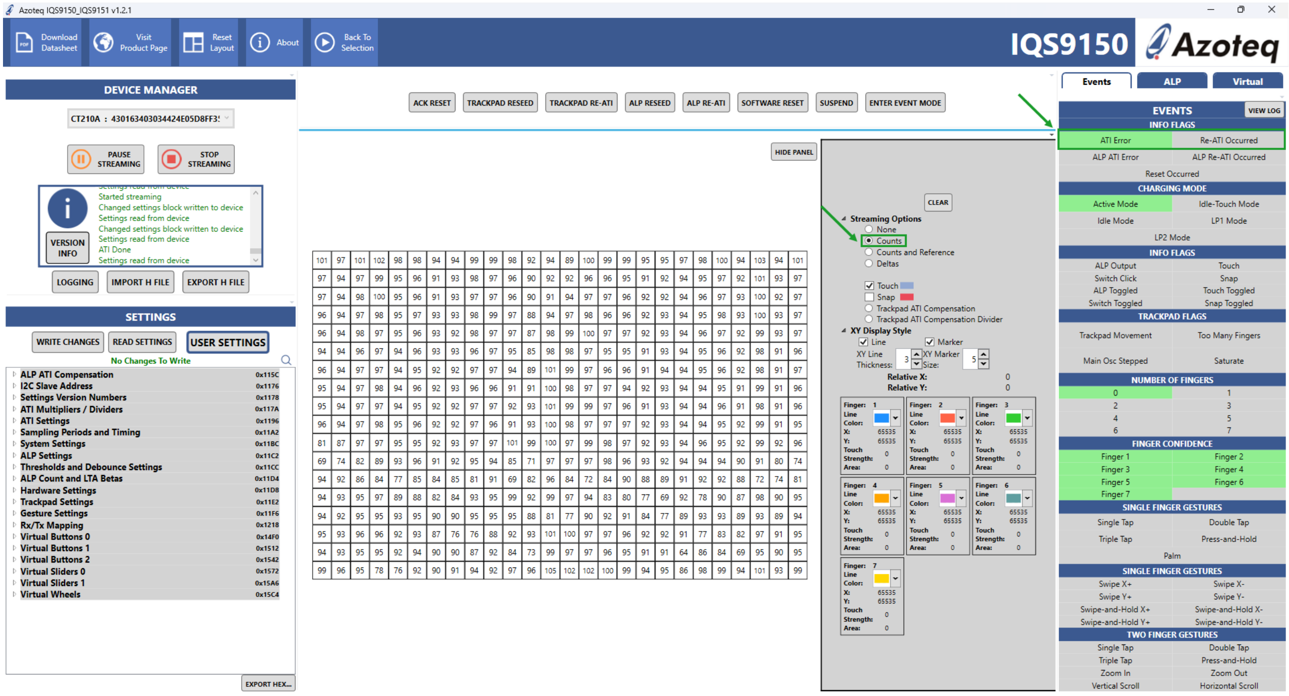


Figure 4.2: Read ATI Base Counts Values

The ATI Compensation can be read from the device and viewed in the channel grid as illustrated below. Change the ATI target back to 250, re-ATI and click on the *'Trackpad ATI Compensation'* radio button under *'Streaming Options'* in the main window.

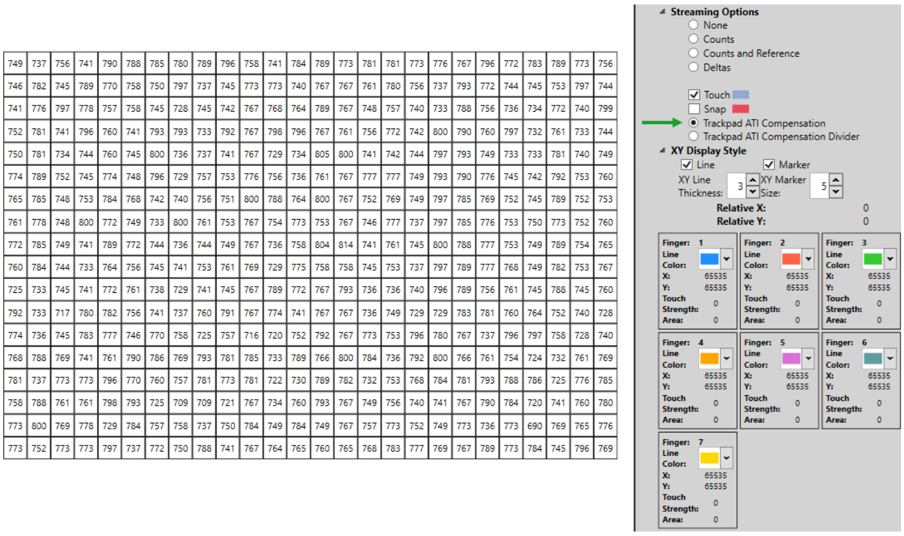


Figure 4.3: Read ATI Compensation Values

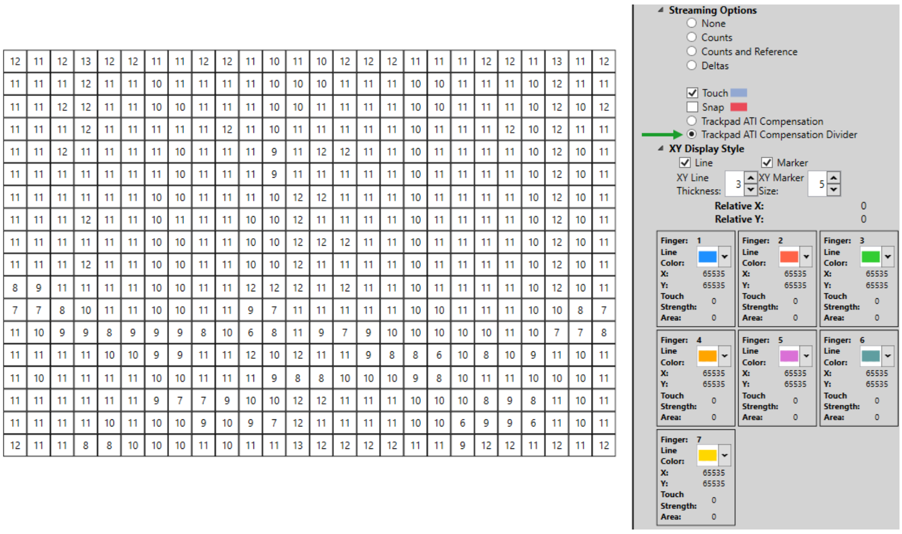


Figure 4.4: Read ATI Compensation Divider Values

- Increasing the *ATI Target* will increase sensitivity, resulting in larger touch deltas. Please keep in mind that significantly increasing the target can increase the sampling period, which may have negative implications depending on the report rate requirements. Rather adjust the base if more sensitivity is needed.

- The ATI Compensation is scaled by means of the *Trackpad Compensation Divider*. Since the 'size' of compensation is scaled, a small divider value will relate to large compensation, meaning the step size of each compensation unit increase will be larger. For smaller more accurate compensation steps, a larger divider is selected, but the 'range' of compensation is then reduced. The *Compensation Divider* is automatically set by the ATI algorithm. Ideally, the *Compensation Divider* values should not be near the lower or upper limits.

- The *Coarse Divider/Multiplier* can be used to configure the *base counts* value for the trackpad and ALP channels. The trackpad *Coarse Divider/Multiplier* can be set by selecting the predefined *Div/Mult* sets available in the GUI dropdown menu.
  - Increasing the set number of the *Coarse Divider/Multiplier* will raise the base counts, resulting in a decrease in ATI Compensation, an increase in ATI Compensation Dividers, and a reduction in touch deltas.

- The *Fine Divider* allows for further fine-tuning of the trackpad base counts. However, it is strongly recommended NOT to set this value below 6.
- Increasing the *Fine Divider* will decrease ATI Compensation, increase Compensation Dividers and decrease touch deltas when redoing the ATI process.

The table below outlines the parameters of the *Coarse Divider/Multiplier* sets. These settings are predefined in a dropdown menu within the GUI for ease of use.

Table 4.1: ATI Parameter Lookup Table

Set Index	Coarse Divider	Coarse Multiplier	Fine Divider	Fine Multiplier
0	1	9	20	1
1	1	6	20	1
2	2	8	20	1
3	4	8	20	1
4	4	4	20	1
5	7	4	20	1
6	14	4	20	1
7	27	4	20	1
8	27	2	20	1
9	27	1	20	1

Follow these steps to determine values for the ATI parameters:

1. Enable *Manual Control* under the *'Control and Config'* tab and force the device to stay in *Active* mode by selecting it.
2. Start with the values at *Coarse Divider/Multiplier Set 0* as indicated in Table 4.1.
3. Set the *Fine Divider* to 20
4. Set the *ATI Target* to 0 and press the *'Trackpad Re-ATI'* button.
5. Read the ATI Base Counts values as illustrated in Figure 4.2.
6. Choose a suitable ATI Base Count target. Choose 100 for this example.
7. If the count values you read are **below** the desired ATI Base Counts, step to the values at the next index. Continue to step to the next index until the count values are above the desired ATI Base Counts.
8. If the count values you read are **above** the desired ATI Base Counts, decrease the *Fine Divider* starting from 20. Continue to decrease the *Fine Divider* by one until the count values are below the desired ATI Base Counts. Do NOT decrease the *Fine Divider* below 6.
9. Set the *ATI Target* to 250 and press the *'Trackpad Re-ATI'* button.
10. Read the ATI Compensation values as illustrated in Figure 4.3.
11. The Compensation values should be close to 780. If they are too low, it indicates that the *Compensation Dividers* have reached their upper limit. On the other hand, if they are too high, the *Compensation Dividers* have reached their lower limit. Ideally, you want the *Compensation Dividers* to be centered within the range of 1 to 31.
12. The ATI setup is complete when all the *Compensation Divider* values read from the channels are near the centre of the range and the touch sensitivity of the channels are acceptable. Typically, adequate touch delta counts on a channel is about 128 counts or more. If the sensitivity is not acceptable, go back to step 5 and choose a lower ATI Base Target or increase the ATI Target.
13. Disable *Manual Control*.

Note: For most trackpad applications, it will not be necessary to step past the predefined set at index 0. This means that the *Coarse Divider* will typically be set to 1, the *Coarse Multiplier* to 9, the *Fine Multiplier* to 1, and the *Fine Divider* will be adjusted to achieve the ATI Base Target. Do not reduce the *Fine Divider* below 6.

4.2.2 ALP ATI Setup

The ALP ATI setup is similar to the trackpad ATI setup; however, you can configure the ALP ATI Mode to either *Full* or *Compensation Only*. It is recommended to always use the *Full* option.

When the ATI mode is set to *Full*, you can specify both an ATI Base Target and an ATI Target. The algorithm will automatically select ATI parameters to achieve the Base Target counts.

Alternatively, setting the mode to *Compensation Only* functions similarly to the trackpad ATI mode. This option allows you to select ATI parameters from a predefined set in a dropdown menu within the *User Settings* pop-up window under the *ALP ATI Multipliers/Dividers (Global)* tab. In this case, the Base Target must be configured manually, as outlined in section 4.2.

If *Compensation Only* mode is selected, the ATI algorithm will only adjust the compensation values and compensation divider values.

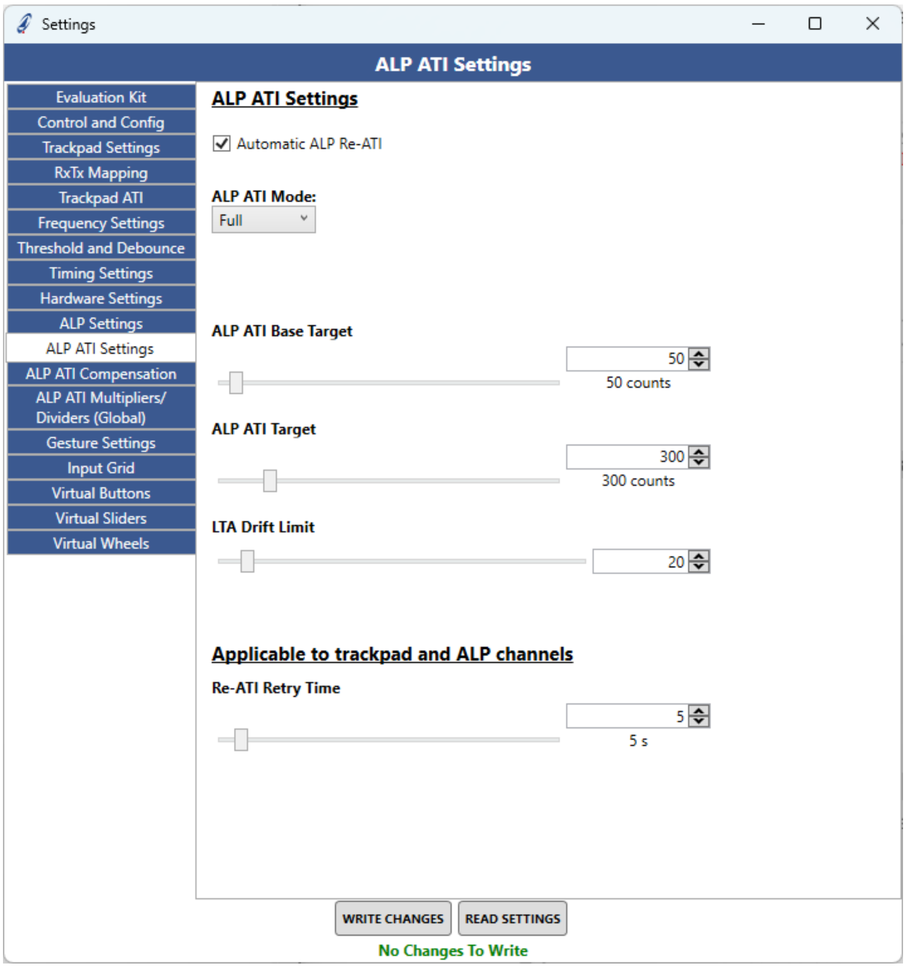


Figure 4.5: ALP ATI Settings

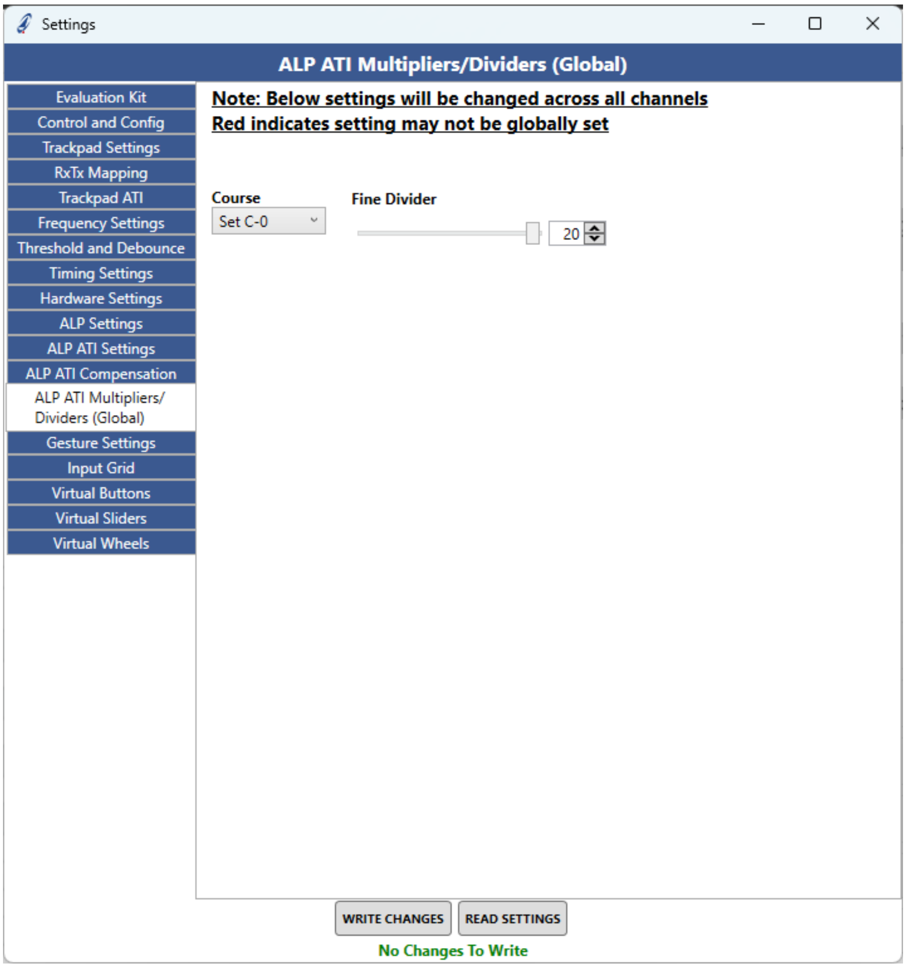


Figure 4.6: ALP ATI Multipliers/Dividers (Global) tab

It is recommended to enable *Manual Control* under the *'Control and Config'* tab and force the device to stay in *LP1* mode while changing ALP ATI settings. It is also recommended to disable *LP1 Auto-Prox Cycles* under the *'ALP Settings'* tab, so that all conversions are visible. Remember to disable *Manual Control* again afterwards and restore the *LP1 Auto-Prox Cycles* setting if changed.

The power mode is displayed in the right panel under Charging Mode - LP1 Mode. The ALP channel counts and LTA are visible in the top right corner of the main GUI window after selecting the ALP tab. ALP individual count values for each Rx engine can be found in the bottom right of the ALP panel. Additionally, the compensation values are accessible in the *User Settings* pop-up window under the *ALP ATI Compensation* tab.

Press the *'ALP Re-ATI'* button after changing ALP ATI settings.

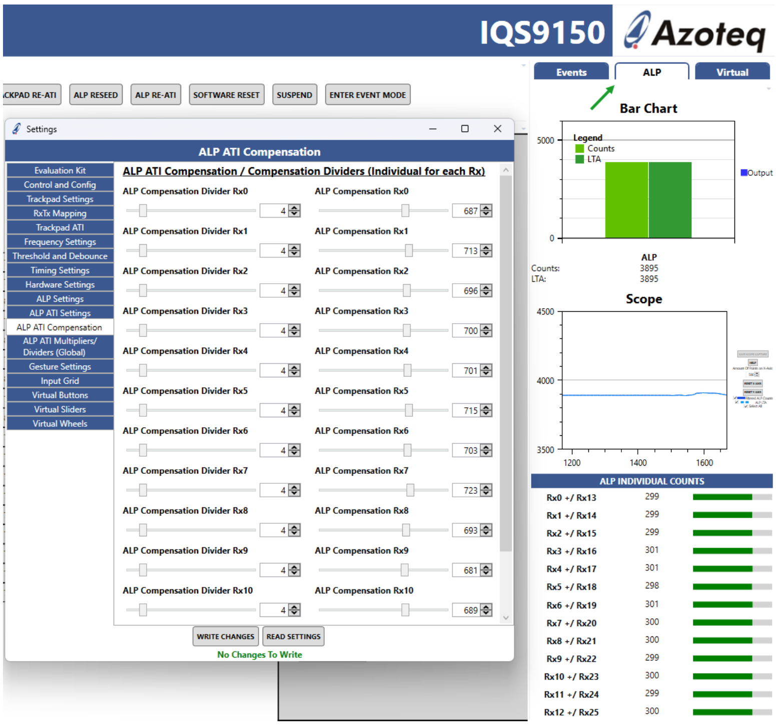


Figure 4.7: ALP ATI Compensation and ALP tab

4.3 Thresholds

4.3.1 Trackpad Threshold Settings

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

First configure the *Trackpad Touch Set Threshold* in the *'Threshold and Debounce'* tab. Change the main window display to *Deltas* under *Streaming Options*. Now, using a small finger, press lightly between the four channels. Aim to make the deltas of the four channels similar by positioning your finger evenly among them, as illustrated in the figure below.

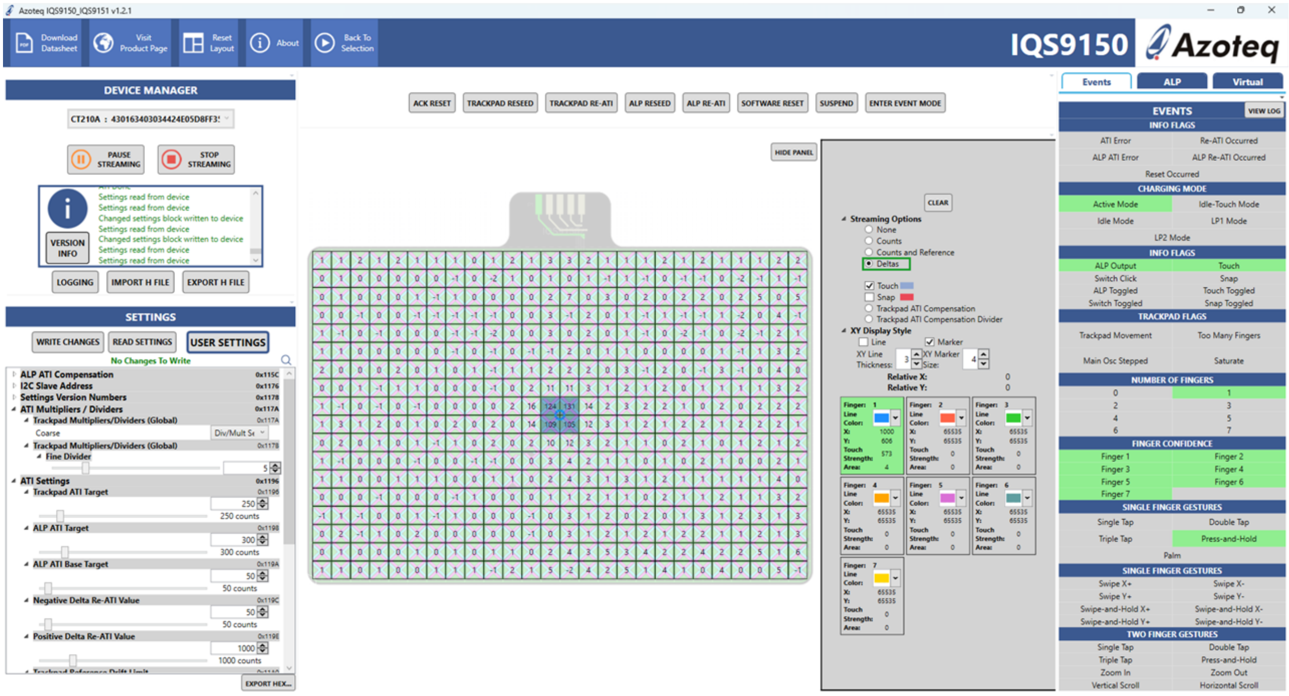


Figure 4.8: GUI Delta View - 4 Channels in Touch with small finger to determin threshold setting

This configuration positions the finger furthest from the four channel centres, which are their most sensitive areas. This setup provides a clear indication of a weak touch (or small finger) that should still be detected.

Set both the touch set and clear thresholds to the same value, ensuring that a touch (indicated by blue display squares) begins to be detected on these four squares. The value you enter in the GUI represents the *multiplier* value. The touch threshold for a specific channel is calculated as follows:

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

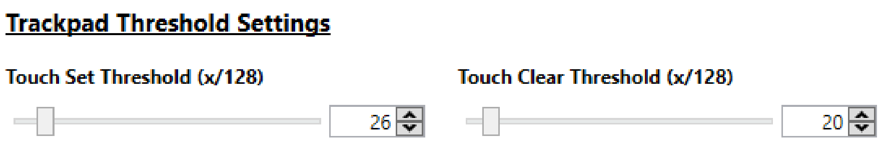


Figure 4.9: Touch Set and Clear Threshold

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

$$\text{Touch Set Threshold} = 250 \times (1 + \frac{26}{128}) = 300 \text{ counts (50 counts delta)}$$

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

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

4.3.2 ALP Threshold Settings

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

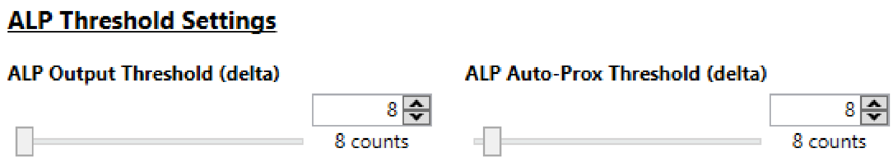


Figure 4.10: ALP Threshold

4.3.3 Snap Threshold Settings (*if used)

The Snap output is set when the channel's count value deviates from the Reference value by less than the selected threshold - thus a delta setting.

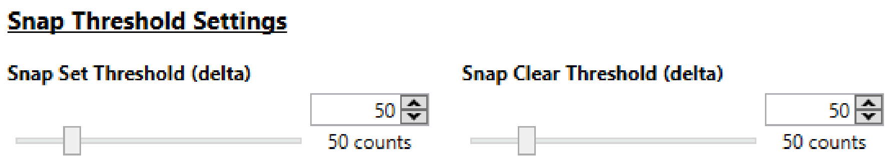


Figure 4.11: Snap Threshold

4.4 X&Y Output Flip and Switch

By default, the Rxs are columns (thus in the X direction), and Txs are rows (thus in the Y direction). If this is different, then the axes must be switched in the *'Trackpad Settings'* tab. This was not necessary for the AZP1364A1 trackpad.

By default, X positions are calculated from the first column to the last column. Y positions are by default calculated from the first row to the last row. The X and/or Y output can be flipped with *Flip X / Flip Y*, to allow the [0, 0] coordinate to be defined as desired. The X and Y axes can also be switched with *Switch XY Axis* allowing X to be the Txs, and Y to be along the Rxs.

Note: The channel numbers are still assigned the same way, first along the Rxs, then to the next Tx, it is not affected by this setting.

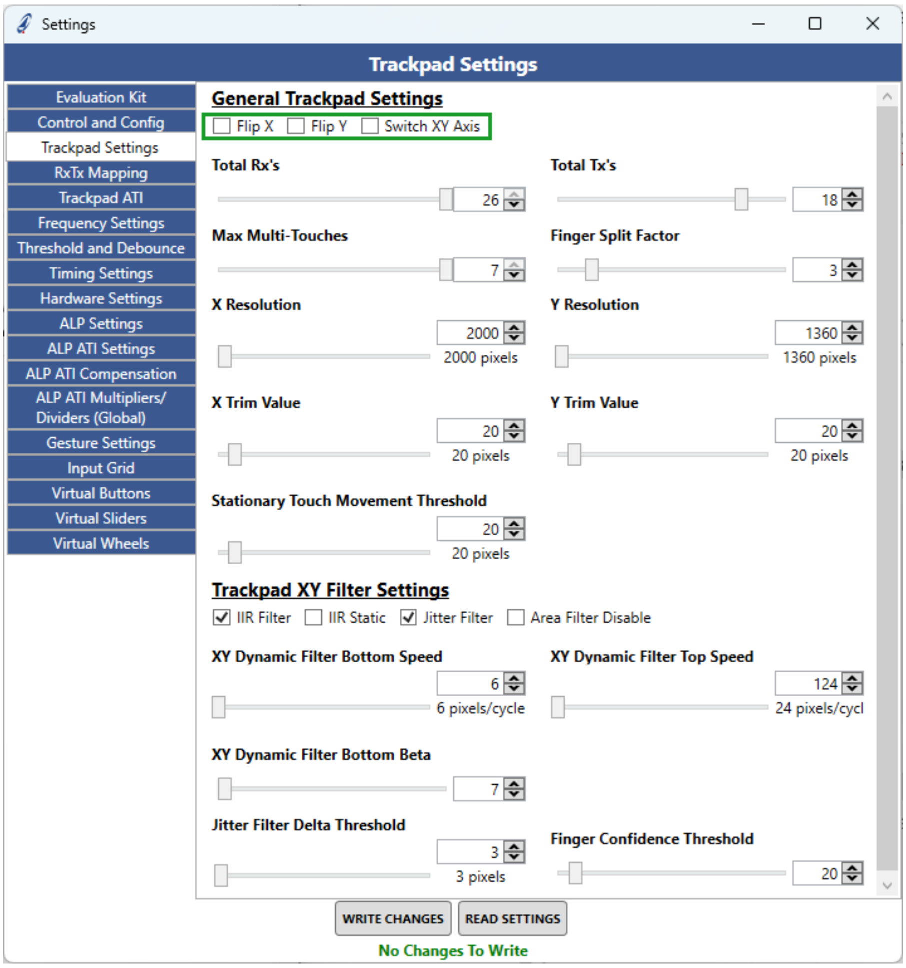


Figure 4.12: X&Y Output Flip and Switch

4.5 X&Y Resolution

The output resolution for the X and Y coordinates can be configured in the *Trackpad Settings* tab. The on-chip algorithms use 256 points between each row and column. For the AZP1364A1 hardware, the theoretical maximum resolution can be set to 6400x4352 (26 channels in the X direction and 18 channels in the Y direction). The channel display in the main window of the GUI updates when the resolution is modified and written to the IC.

The Active Area (A/A) of the trackpad extends from the midpoint of the first channel to the midpoint of the last channel, as illustrated in Figure 4.13 below. For the AZP1364A1 hardware, an X-resolution of 2000 pixels was selected.

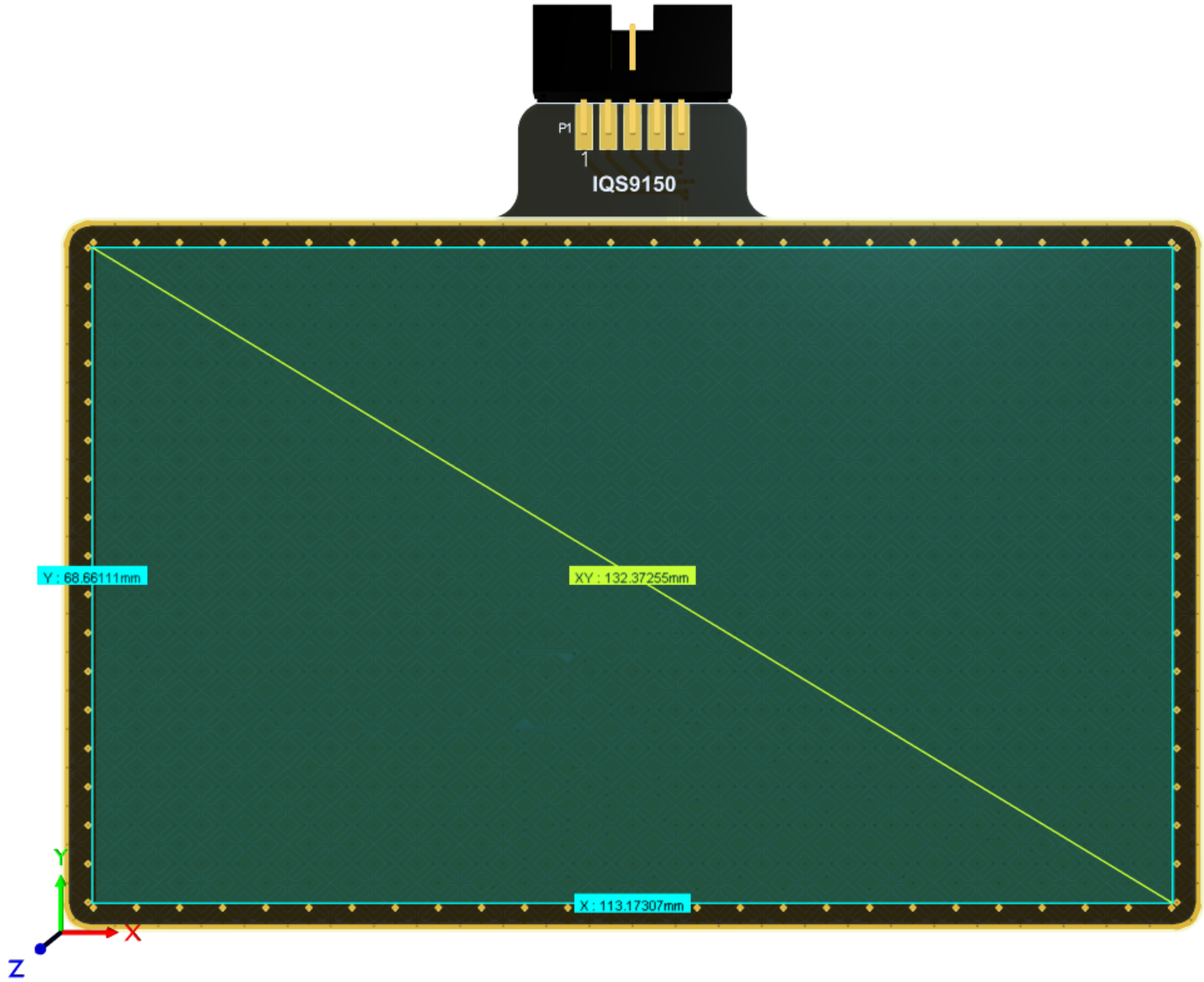


Figure 4.13: Illustration of IQS9150EV02 Active Area

If you plan to use gesture recognition, it is beneficial to ensure that the pixels per millimeter (pixels/mm) in the X and Y directions are approximately matched. This alignment will help maintain consistency in gesture distance parameters, allowing for effective matching in both the X and Y directions.

Given the X-active area and the X-resolution, we can calculate the X-pixels per millimeter as follows:

$$\text{X-Pixels per millimeter} = \frac{\text{X-Resolution in pixels}}{\text{X-Active Area in millimeter}} = \frac{2000}{113.17} \approx 17.67 \text{ pixels/mm}$$

Using the calculated X-pixels per mm, we can determine the appropriate Y-resolution needed to match the pixels per mm in both the X and Y directions:

$$\text{Y-Resolution in pixels} = \text{Y-Pixels per millimeter} \times \text{Y-Active Area in millimeter}$$

$$\text{Y-Resolution in pixels} = 17.67 \times 68.66 \approx 1213 \text{ pixels}$$

4.6 X&Y Trim

Due to boundary conditions at the edges of the trackpad, it is unlikely that the X and Y extreme values will be achievable (0 and X/Y Resolution). To be able to achieve this, the edges can be trimmed with configurable amount *(X Trim / Y Trim)* on-chip. For example, say *X Trim* is set to 0, and a finger on the left of the trackpad gives a minimum X output of 18, and a maximum of 1981 for a finger to the far right (for X resolution set to 2000). Then an X Trim = 20 could be used to trim away the 'dead' area, and the full 0 to 2000 range will be achievable.

4.7 Intermediate Setup Summary

The ATI parameters have been adjusted to allow for adequate sensing of user interaction. Thresholds have been set so that inputs are reliably detected, and accurate XY outputs are obtained.

The power modes of the device have not been changed, and at this point the power modes will cause the device to automatically make a transition from the Idle mode to the LP1 mode, and then further to the LP2 mode. The sampling periods of the different modes are also standard values for this configuration, and provide sufficient low power consumption.

At this point gesture outputs should also be visible. The gesture parameters still need to be optimised.

1. Check Rx/Tx Mapping
2. Configure the ATI Setup
3. Set the appropriate touch set/clear thresholds
4. Confirm correct XY coordinate output
5. Set the X and Y resolution
6. Check whether it is necessary to set X and Y trim values
7. Proceed to Section 5 if you require further assistance

5 Advanced Device Setup

Not many applications will require the user to configure the settings discussed in this section. Be sure to read the relevant *datasheet* before configuring these parameters.

5.1 Frequency Settings

The main oscillator frequency can be selected to be either 14MHz, 20MHz or 24MHz. If the 24MHz option is considered note that the minimum supply voltage is 2.2V.

The conversion frequency is also configurable. Setting the frequency too high can lead to non-ideal charge transfer.

If you notice significant changes in the counts (or compensation values after re-ATI) with increasing frequency, it indicates that the frequency is already too fast. Reduce the frequency to avoid this issue.

The slider in the GUI under the *Frequency Settings* tab allows you to select the conversion frequency in increments of 250kHz. Adjusting the slider will automatically update the values for *Fraction*, *Period1*, and *Period2*.

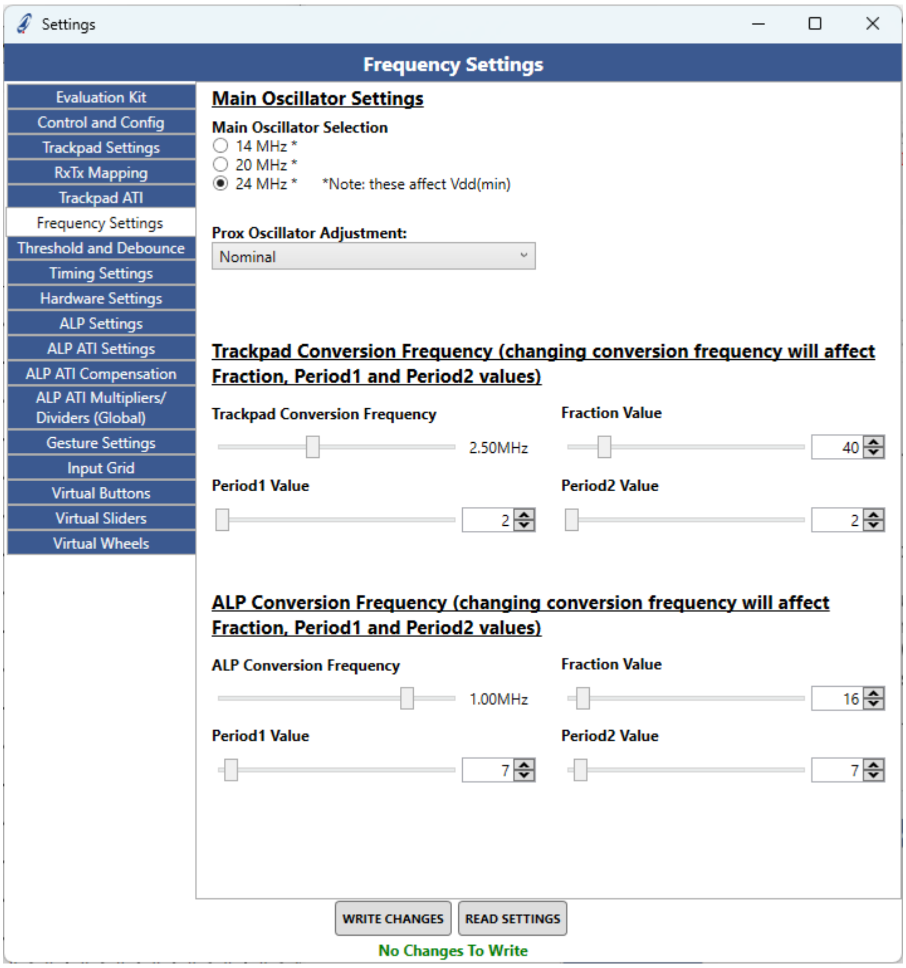


Figure 5.1: Frequency Settings

5.2 Mode Configuration

5.2.1 Sampling Periods

Remember to disable *Manual Control* under the *'Control and Config'* tab since the ATI setup is complete. The device will now transition to lower power modes with increased sampling periods to reduce current consumption. The sampling periods are configurable and the extent to which it can be adjusted, is determined by the application.

The mode settings are configured under the *'Timing Settings'* tab, as highlighted in the picture below.

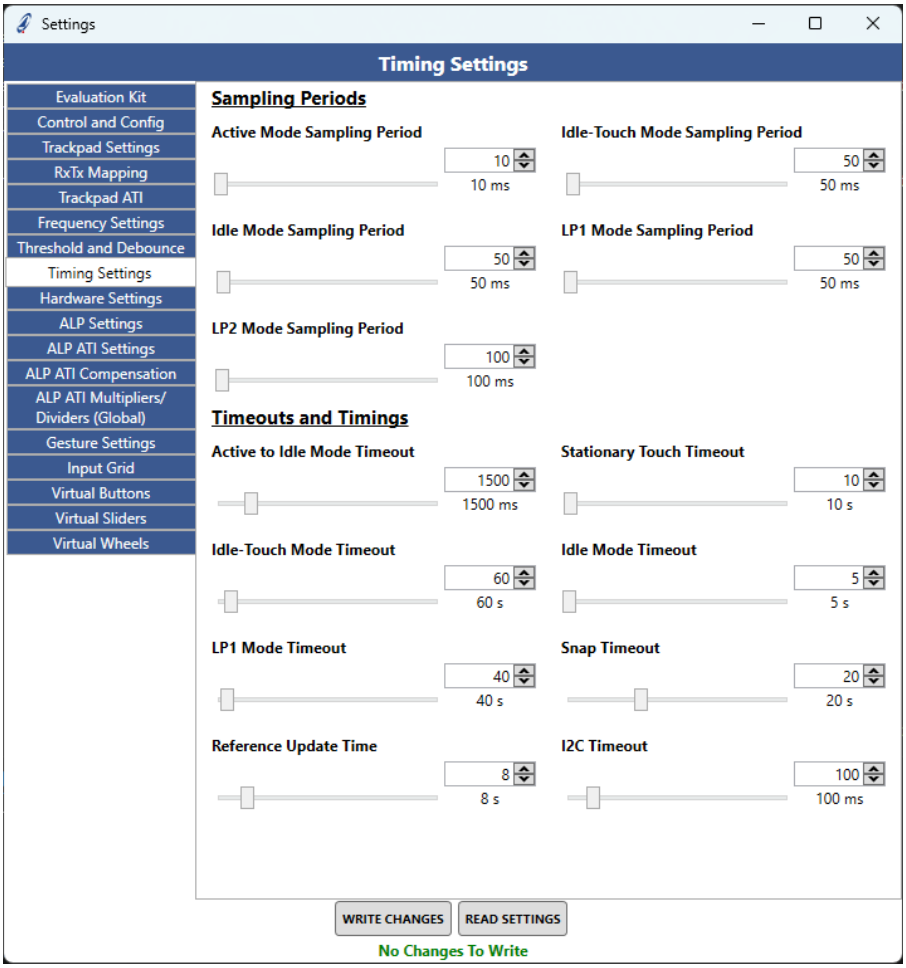


Figure 5.2: Timing Settings

The sampling period settings are normally driven by the power consumption budget of the design. A slow sampling period will reduce the average consumption because the IQS9150/IQS9151 will have longer periods of low power sleep added to obtain the selected sampling period. The reaction speed required on the trackpad must be considered when selecting the Active mode sampling period, and the wake-up capability from low power must be considered when setting the LP1 and LP2 sampling periods.

For the AZP1364A1 hardware, fast response is needed from the trackpad, so a 10ms sampling period is selected for *Active* mode. The *Idle* mode saves power when the finger is lifted, but must still give quick response when a gesture is performed, so 50ms is chosen. *LP1* = 50ms and *LP2* = 100ms was selected for this example. When a long stationary touch is detected, the system enters *Idle-Touch* mode, and its sampling period is set to 50ms.

Remember that streaming large amounts of I²C data in the GUI can cause the sampling period to not be achieved, or increases the current consumption, so data streamed must be kept to a minimum when doing such evaluations. Set the *Streaming Options* to stream out minimal data by clicking the *'None'* radio button and unticking the *'Touch'* checkbox.

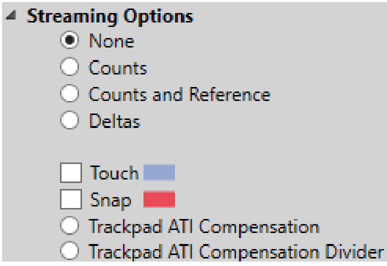


Figure 5.3: Minimal Streaming Options

5.2.2 Mode Timings

The timings responsible for transitions between the modes can be configured.

When in *Active* mode, and all touches are released, the system will transition to *Idle* mode once the *Active to Idle timeout* has elapsed. This typically short delay improves the recognition of double and triple tap gestures, as *Active* mode's fast sampling continues to detect successive taps effectively.

The *Active* Mode timeout selects how long a stationary finger must be sensed before stepping to *Idle-Touch* mode.

The *Idle-Touch* timeout sets how long a stationary finger in *Idle-Touch* will be allowed before it is seen as a 'stuck' condition, and a reseed is triggered. Often this is disabled and handled by the host, in this case, set this value to '0', meaning 'disabled'.

The *Idle* timeout sets how long the system stays in *Idle* mode before stepping to the next power state *(LP1)*. The *LP1* timeout determines the length of time spent in *LP1* before stepping to *LP2*. If *LP2* is configured as a very low power (and thus slow response) state, the *LP1* timeout is usually set quite long, so that this is only entered when the user has stopped using the device for a long time, and then extreme low power is entered.

5.3 Stationary Touch Setup

For applications where the user could rest his/her finger on the trackpad for long periods of time, it is beneficial for power consumption to utilise the *Idle-Touch* mode. From the system mode state diagram in the datasheet, it is clear that the system will remain in the *Active* mode during a touch if consistent finger movement is detected. However, if the finger becomes stationary for the length of time configured, then the mode will change to *Idle-Touch*. The number of pixels that the finger needs to move before it is classified as 'movement' can be configured in the *'Trackpad Settings'* tab, by changing the *Stationary Touch Movement Threshold*.

If movement is detected on the IQS9150/IQS9151 it is visible in a status flag (*Trackpad Movement*) which is displayed on the main window.

5.4 Gesture Settings

Please refer to the *datasheet* of the relevant device to configure the *Gesture* settings for optimal performance.

5.5 Hardware Settings

Not recommended to configure, unless under guidance of Azoteq support.

5.6 ATI and Re-ATI Conditions

5.6.1 Negative Re-ATI Delta Value

The negative delta re-ati parameter monitors for incorrect sensor behaviour.

In this case, since a mutual capacitive sensor's counts increase with user interaction, a decrease in count values on the trackpad is against expectation unless that channel is enabled for Snap detection. This parameter is a delta value below the reference. If 14 consecutive negative deltas are sensed below the min value delta, a Re-ATI is triggered.

The main scenario addressed by this parameter is when an ATI is configured while a user is touching / interacting with the trackpad. The count values affected by the user touch are higher than the normal (no touch) values. Therefore, to reach the ATI Target value, less ATI Compensation will be configured on the affected channels. When the touch is removed, the count values decrease, and their sensitivity is greatly reduced compared to other correctly configured channels. To recover from this, the decline in count values on channels will be detected after the finger removal, and a Re-ATI will trigger and correct the previous incorrect configuration. The threshold must thus be selected so that this scenario is correctly recovered from.

5.6.2 Positive Re-ATI Delta Value

This parameter is intended to allow for recovery from a snap button press, while the ATI has occurred. In a similar manner to the negative threshold, if the count value increases by more than this threshold for 14 consecutive cycles, then a Re-ATI is also triggered. This value should be selected much higher than even the largest legitimate user touch could increase the count values to.

5.6.3 Reference Drift Limit

The delta value that reference values can drift from the ATI Target before a Re-ATI is automatically triggered can be adjusted using this parameter. Choose this value to ensure that a reasonable deviation in counts is required before initiating a Re-ATI. This allows the sensors to recalibrate in response to drift, such as temperature changes. Recalibration helps maintain consistent sensor performance.

5.7 Max Multi-Touches

Set the total multi-touches that are required for the design (max 7) in the *'Trackpad Settings'* tab. Remember if more than the configured value is sensed, all outputs are cleared until the total is less than or equal to that configured. The *'Too Many Fingers'* flag will also be set. If post-processing will reject unwanted points, set this value higher so that XY outputs are still provided to the master device for post-processing.

5.8 Event Mode and Communication

Normally the master device is only interested in communication with the IQS9150/IQS9151 if certain events have taken place. At other times communication is thus not necessary. When the complete setup is done, enable *Event Mode* by clicking the *'Enter Event Mode'* button.

The different events that should cause I^{2}C communication to occur can be selected in the *'Control and Config'* tab. *Trackpad Touch Event* will typically only be selected if individual touch buttons are implemented, since they trigger an event when the touch status of a channel changes. *ALP Event* could be used to trigger some backlighting or other device wake-up actions since user interaction has been detected.

Typically, *Trackpad Events* are enabled since this causes communication when the system is in *Active* mode, i.e. when there is tracking and movement on the trackpad. *Gesture Events* are also a common option, triggering communication when a gesture is present.

For the AZP1364A1 hardware, only gestures, switch and trackpad events are required for the master device to obtain all useful information.

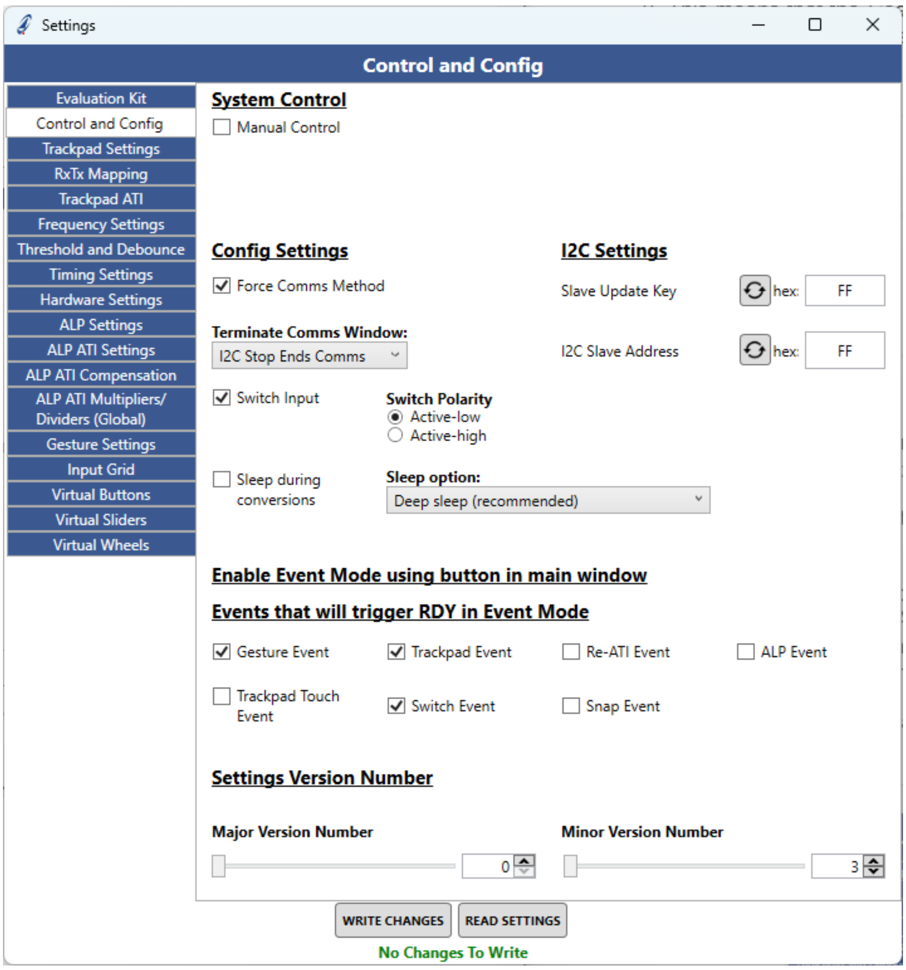


Figure 5.4: Event Mode Setup

Refer to the *datasheet* for more detail on I^{2}C communication.

5.9 Switch Setup

The switch can be configured under the *Control and Config* tab. Simply enable the Switch Input and select the appropriate Switch Polarity based on your application hardware.

Figure 5.5: Switch Settings

5.10 Virtual Sensors Setup

The IQS9150/IQS9151 allows for flexible configuration of virtual sensors including buttons, sliders, and wheels within the trackpad sensor area. These sensors can be set up using two methods: a rough setup achieved by reading XY coordinates while touching specific locations on the trackpad, and a precise setup that involves calculating coordinates based on pixels per millimeter and the coordinates in millimeter.

The following subsections will discuss both methods, using the IQS9150EV02 virtual mixer overlay as an example.

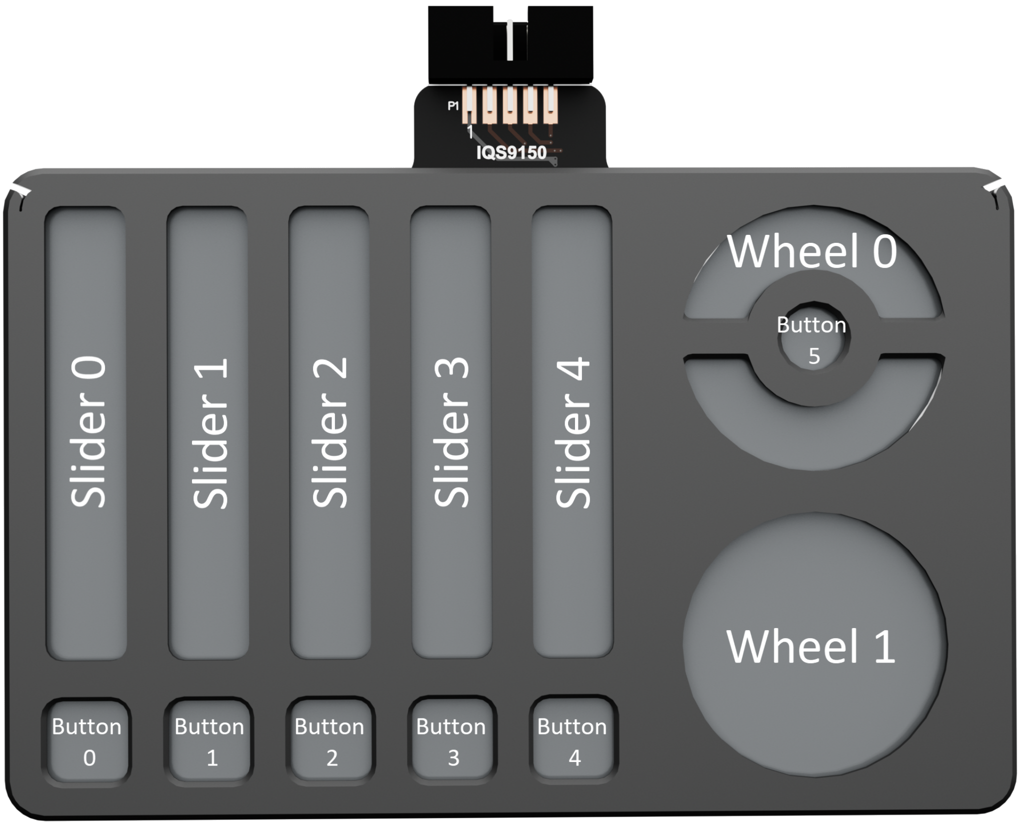


Figure 5.6: Virtual mixer overlay

5.10.1 Method 1: Rough Setup

For a quick initial setup of virtual **buttons** while streaming the IQS9150EV02 in the IQS9150_IQS9151 GUI, follow these steps:

1. Make a small touch in the top-left corner of the virtual button to determine those coordinates.
2. Next, touch the bottom-right corner of the button and note the coordinates shown in the GUI.
3. These two points will define the bounding box for the virtual button, which you will use to configure the relevant registers.
4. Navigate to the *Virtual Buttons* tab in *User Settings* and set the number of buttons to 6 for this example.
5. Enter the X- and Y-coordinates for the top-left and bottom-right corners of the bounding box for all buttons, as obtained from step 2.

Example: Touch the top left corner of virtual button 1. The coordinates displayed in the GUI will roughly read as x=270 and y=1090. Next, touch the bottom right corner of button 1, which will show the coordinates approximately as x=410 and y=1200. In the following section, you can compare the accuracy of this method with the calculated approach.

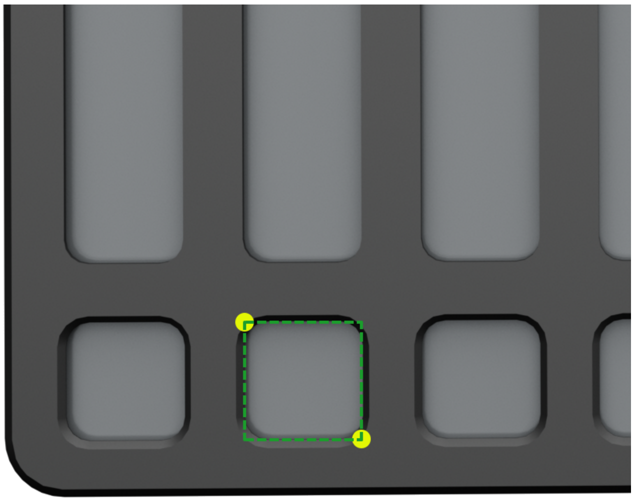


Figure 5.7: Virtual button rough setup

The setup for **sliders** follows the same steps as above, but with two additional configurable parameters:

- **Slider Deadzone**: This is a global parameter applicable to all virtual sliders and is configured based on trackpad pixels. It defines the trackpad coordinate distance that must be exceeded for the slider to begin adjusting its output. This feature allows users to rest their finger on the virtual slider and start sliding from position 0 to the maximum resolution, accommodating the fact that the user's finger may be obstructed from precisely reaching position 0 due to the finger guide.
- **Slider Resolution**: The output of each virtual slider ranges from 0 to the configured *Slider Resolution* value.

To determine the slider deadzone, follow these steps:

1. Begin by setting the deadzone parameter to 0.
2. Then, place your finger on the slider, ensuring a large area of contact.
3. Slide from position zero to the maximum, and read the minimum and maximum output values displayed in the GUI.
4. In this example, the outputs were approximately 50 and 450, so you would set the deadzone to 50 pixels.

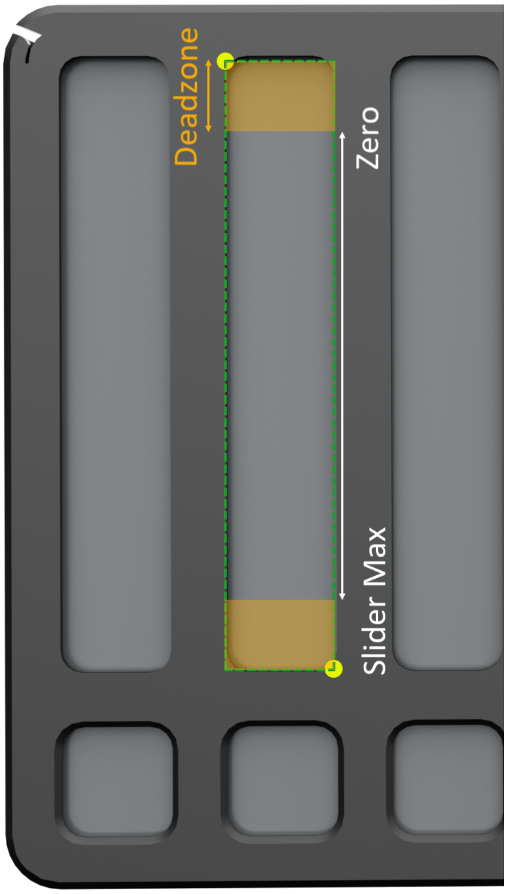


Figure 5.8: Virtual slider rough setup

The setup for virtual wheels is slightly different:

1. Touch the centre of the virtual wheel to register that point; the GUI will display the coordinates of this touch.
2. Next, touch the inner radius edge of the wheel directly above the centre point. Subtract this y-coordinate from the centre point's y-coordinate to determine the inner radius setting.
3. Touch the outer radius edge of the wheel and repeat the above calculation to establish the outer radius setting.
4. The centre point, along with the inner and outer radius, will define the bounding 'donut' shape for the virtual wheel.
5. Go to the *Virtual Wheel* tab in *User Settings* to configure the wheel settings, using the values obtained above.

Note: Since the trackpad X and Y coordinates are used to determine the virtual wheel, it is crucial to select the X and Y resolutions such that they yield identical pixels per mm. This ensures that the calculated virtual wheel results in a round shape rather than an elongated oval shape. For guidance on determining the X and Y resolutions, please refer to Section 4.5.

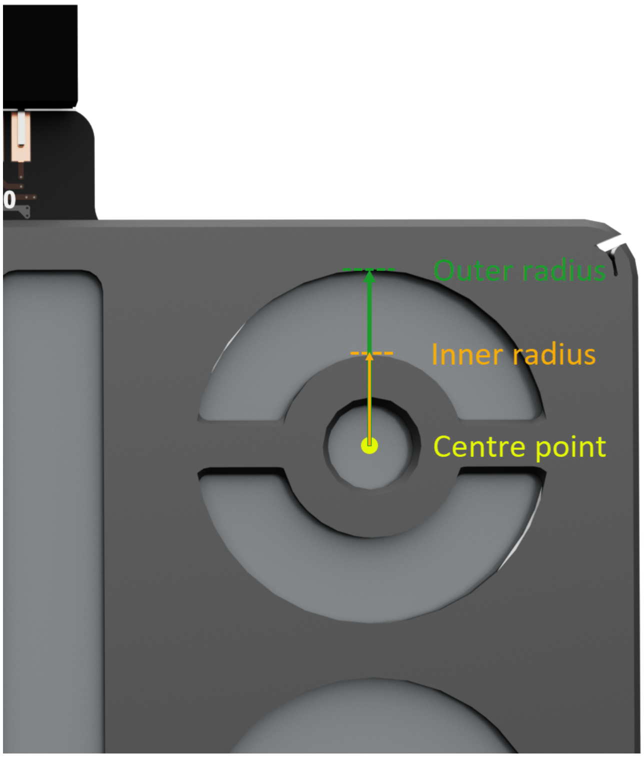


Figure 5.9: Virtual wheel rough setup

This method provides a quick way to establish the sensor areas without precise measurements.

5.10.2 Method 2: Calculated Setup

For a more accurate setup, it is beneficial to calculate the coordinates in pixels based on the coordinates in millimeter, the active area dimensions and the resolution:

1. Determine the dimensions of the trackpad active area as discussed in Section 4.5.
2. Determine the coordinates in millimeter of the virtual button, slider or wheel as indicated by the finger guide.
3. Calculate the both the x- and y-pixels per millimeter:

$$\text{Pixels per millimeter} = \frac{\text{Resolution in pixels}}{\text{Active area in millimeter}}$$

4. Calculate the x- and y-coordinates in pixels for each necessary point:

$$\text{Coordinate in pixels} = \text{Coordinate in millimeter} \times \text{Pixels per millimeter}$$

5. Finally, input these calculated coordinates into the relevant registers to configure the virtual sensor.

This method allows for precise mapping of the virtual sensors, ensuring that they align correctly with the intended touch areas on the physical trackpad.

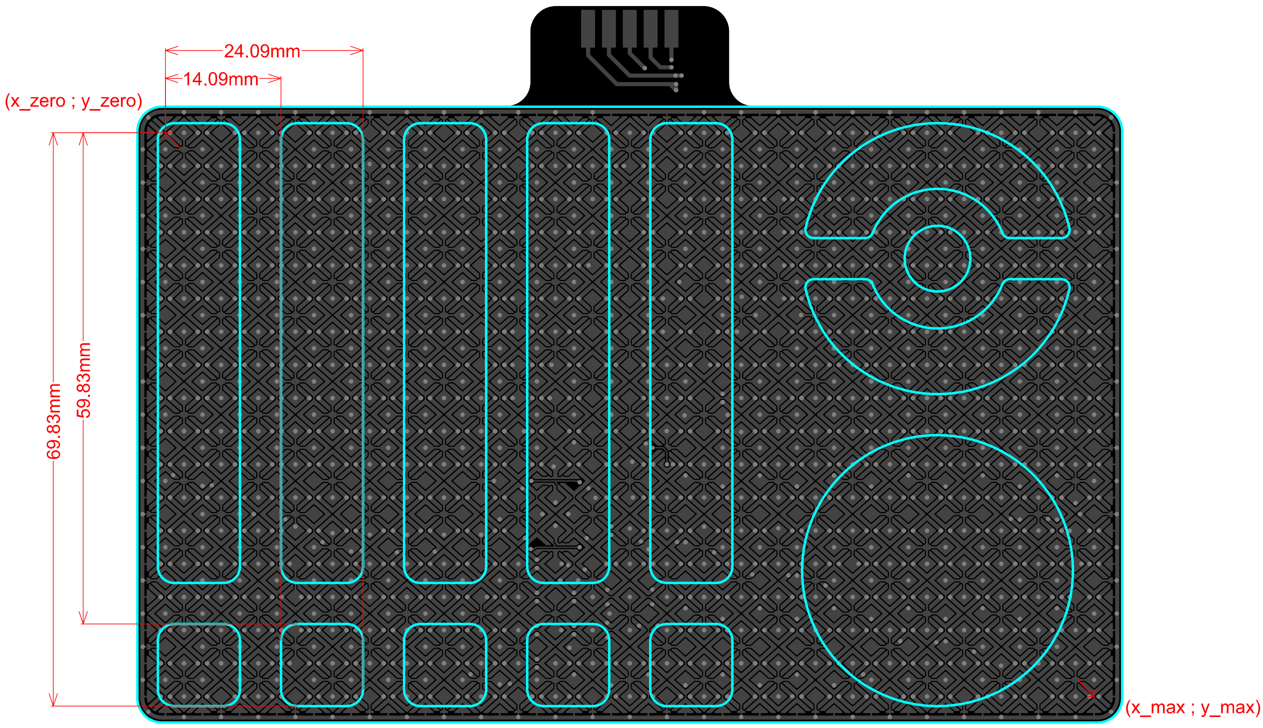


Figure 5.10: Example of Virtual Sensor Calculated Setup

Example setup of virtual button 1:

Step 1: Measure the X and Y dimensions of the active area as shown in Figure 4.13. For the IQS9150EV02, this is:

$$\text{X-active area} = 113.17 \text{ mm}$$

$$\text{Y-active area} = 68.66 \text{ mm}$$

Step 2: Measure the coordinates in millimeters for Virtual Button 1, as illustrated in Figure 5.10.

Step 3: Calculate the pixels per millimeter for both the X and Y axes:

$$\text{X-Pixels per millimeter} = \frac{2000}{113.17} \approx 17.67 \text{ pixels/mm}$$

$$\text{Y-Pixels per millimeter} = \frac{1213}{68.66} \approx 17.67 \text{ pixels/mm}$$

Step 4: Calculate the coordinates in pixels for Button 1:

$$\text{Button 1 Top-Left X} = 14.09 \times 17.67 \approx 249$$

$$\text{Button 1 Top-Left Y} = 59.83 \times 17.67 \approx 1057$$

$$\text{Button 1 Bottom-Right X} = 24.09 \times 17.67 \approx 426$$

$$\text{Button 1 Bottom-Right Y} = 69.83 \times 17.67 \approx 1234$$

Step 5: Navigate to the *Virtual Buttons* tab in *User Settings* to configure the button settings.

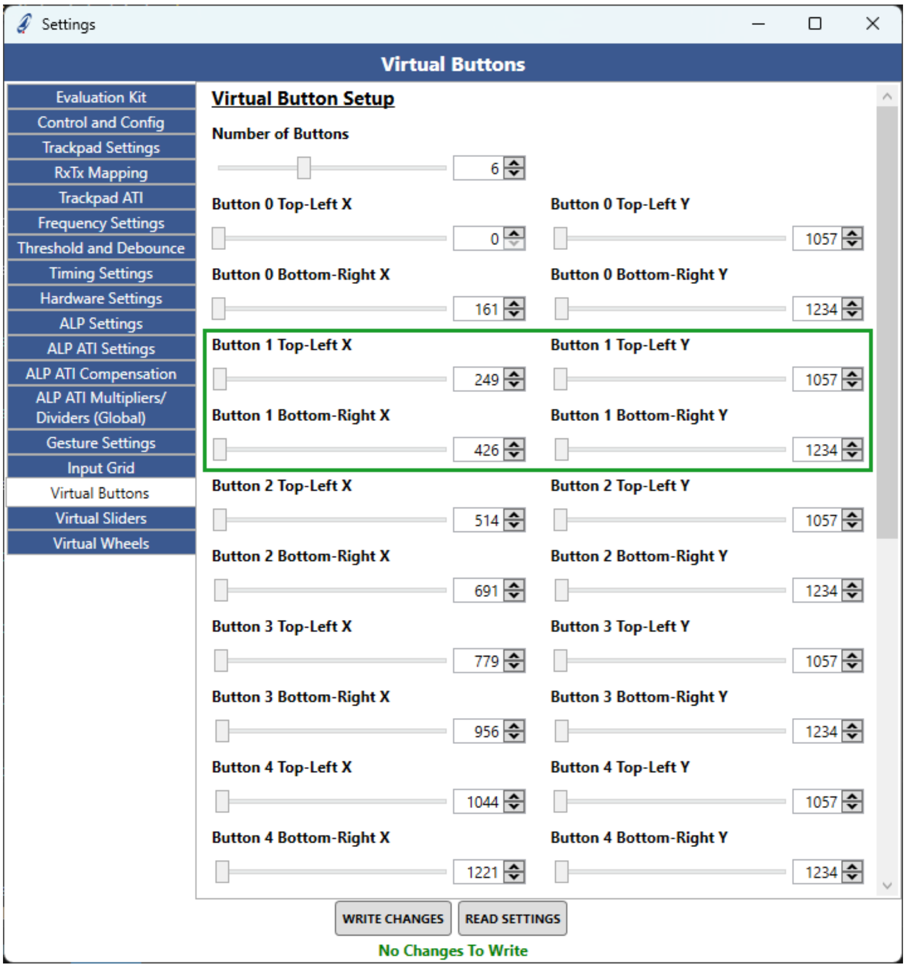


Figure 5.11: Virtual Buttons Settings

To calculate the *Slider Deadzone* setting, you first need to choose the deadzone in millimeters. In this case, it was taken into consideration that the average touch size is 8mm. Therefore, the deadzone should be at least half of the typical touch size, which is 4mm.

To ensure that both the minimum and maximum slider positions are easily reachable for all users, an additional 1.65mm was added, resulting in a total deadzone of 5.65mm.

You can then convert the deadzone from millimeters to pixels using the following formula:

$$\text{Slider Deadzone} = 5.65 \times 17.67 \approx 100$$

5.11 Advanced Setup Summary

At this point the following more advanced configurations (if needed) have also been covered.

1. Operating frequency setup
2. Mode configuration
3. Stationary touch setup
4. Gesture setup
5. Hardware settings
6. ATI and re-ATI conditions
7. Max multi-touches
8. Event mode and communication setup
9. Switch setup
10. Virtual sensor setup

6 Export Settings

The *Minor Version Number* and *Major Version Number* parameters are available under the *'Control and Config'* tab. These parameters are available so that the designer can label and identify the user selected settings. This allows the master to verify that the device firmware has the required configuration.

6.1 Export/Import Settings H-file

Once the device is correctly set up, the parameters can be used to create a new settings h-file. The GUI can export such an h-file, which can be used by the master MCU to write these settings during initial setup. This h-file can also be imported by the GUI software, which then writes the settings included in the file to the device under test. Click the *'Export H File'* button and click *Save* to save the file. Similarly, click the *'Import H File'* button and select the h-file you want to import.

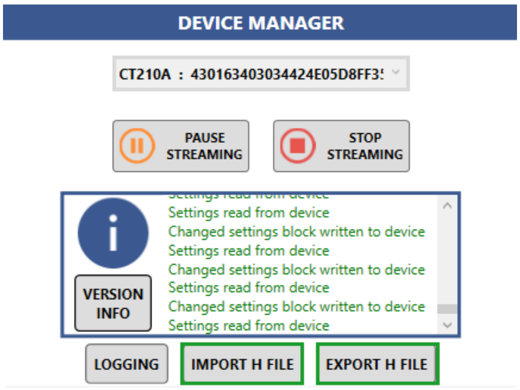


Figure 6.1: Export or Import H-file with GUI Software

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