IQS7221G User Guide

The user guide introduces the development tools available for the IQS7221G and guides the setup of certain key elements.

Contents

1 Introduction

This document provides an overview of the graphical user interface (GUI) for the IQS7221G Debug and Display software. The GUI can be used to configure the IQS7221G for a specific application and evaluate its performance in real time. This document uses the IQS7221GEV02 EV kit, shown below in Figure 1.1, as an example and thus does not cover all applications. Instead, it aims to equip users with the knowledge needed for configuring, debugging, data logging, and header file export using the GUI software to address their unique applications. For guidelines on the hardware and electrode design, please refer to the appropriate application notes. For IC-specific information, operation, and memory map details, please refer to the IQS7221G Datasheet.

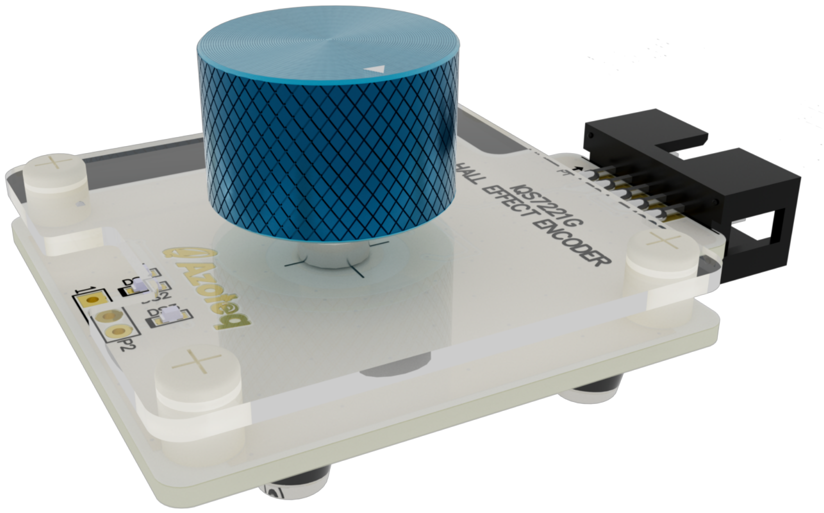

Figure 1.1: IQS7221GEV02 EV kit

2 Getting Started

This section describes the process of initial device and GUI set-up prior to application-specific tuning.

2.1 Step 1: GUI Software Installation

Download and install the Azoteq IQS7221G GUI PC Software from the Azoteq website under the Software and Tools page. Extract the downloaded zip file and follow the installation wizard procedure.

2.2 Step 2: Launch GUI Software

Launch the IQS7221G GUI software executable. The following window should appear:

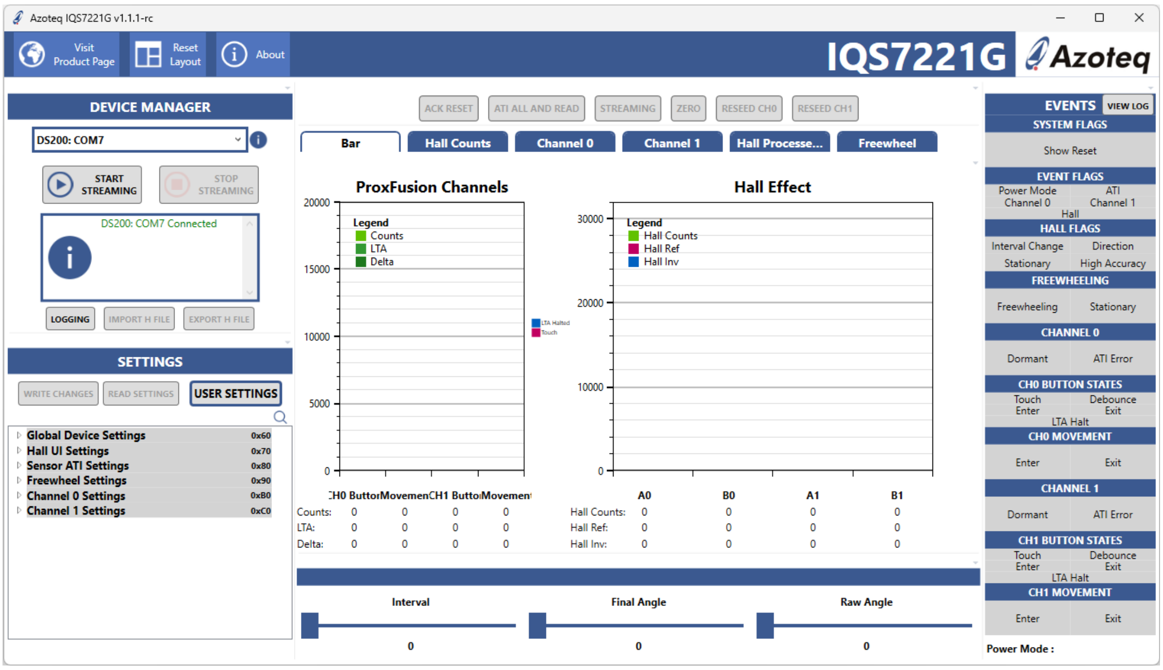

Figure 2.1: Main Window of the Azoteq IQS7221G GUI

2.3 Step 3: Hardware Connections

Connect the DS200 to your PC, using a standard type-C cable. The device under test (DUT), being either an IQS7221GEV02 EV kit or an application PCBA, can be interfaced with a suitable 10-to-10 pin ribbon cable connection (or application-specific connections), as shown in Figure 2.2 below.

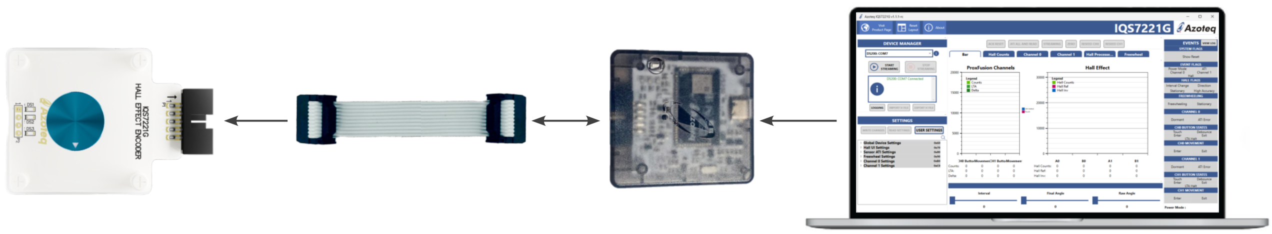

Figure 2.2: DS200 Connection for Streaming and Testing

Note: The CT210A can be used instead of the DS200, along with a standard USB-micro data cable and a suitable 20-to-10 pin ribbon cable connection, as shown in Figure 2.3 below.

Figure 2.3: CT210A Connection for Streaming and Testing

If a custom cable or hardware is used, please refer to Table 2.1 and Figure 2.4 for the required connections.

Table 2.1: DS200 Pin-out

IQS Pins	DS200 Pins
GND	Pin 1
VDD	Pin 3
SDA	Pin 7
SCL	Pin 9
RDY	Pin 10

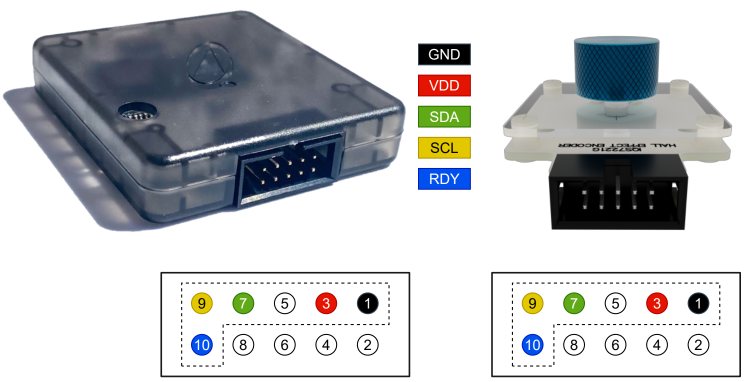

Figure 2.4: DS200 Power, I^2C and RDY Connections

2.4 Step 4: PC Connection Verification

After connecting the DS200 device to the computer, the GUI software will automatically install any necessary drivers. It will then verify the DS200 connection and firmware version, displaying a 'Device Connected' message in the configuration tool manager section, as shown in the red block in Figure 2.5.

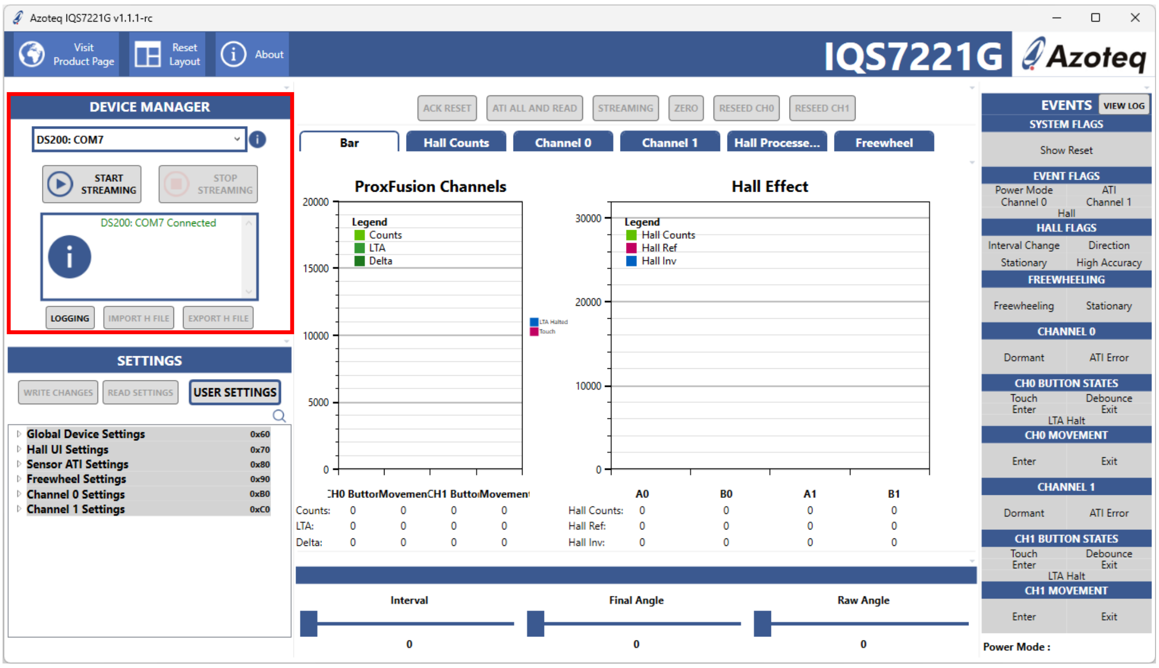

Figure 2.5: DS200 Recognition and Connection

Note: If the connected DS200 device firmware is out of date, an 'Update available' button should automatically appear next to the device enumeration. Click this button to launch the Azoteq firmware upgrade tool and update the firmware, as shown in Figure 2.6.

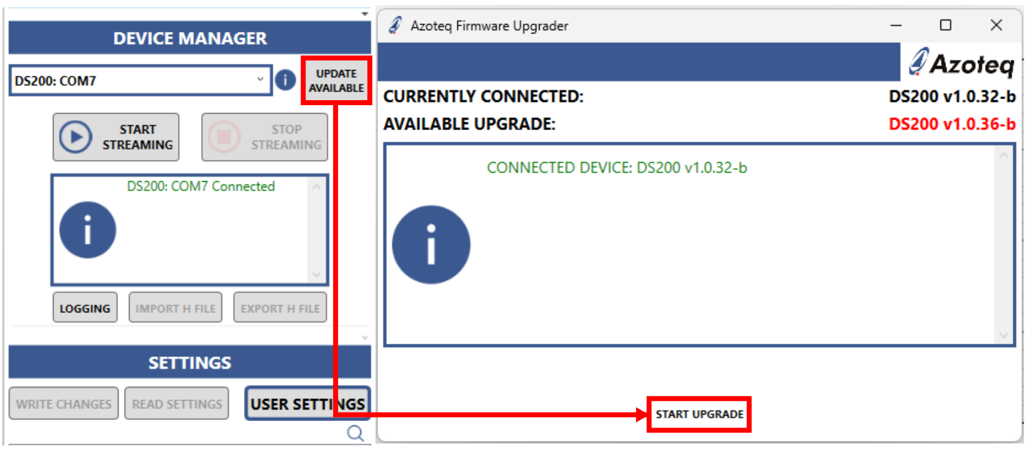

Figure 2.6: DS200 Firmware Upgrade

2.5 Step 5: Initiate I²C Communication (Streaming)

Click on 'Start Streaming' to initiate communications with the IQS7221G. Additional messages will appear and will provide the following information:

- Power status
- I²C address
- Device version information
- Settings and streaming confirmations or errors, as applicable

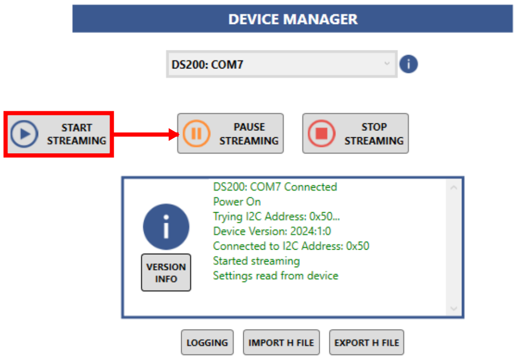

Figure 2.7: Message Dialogue Results from a Successful IQS7221G Connection

If an error is displayed, please ensure that the device is properly connected and that the IQS7221G's product and version numbers were verified successfully.

2.6 Step 6: Acknowledge Reset and Streaming Mode

Click on the red text button 'Ack Reset' to clear the reset event flag. The 'Ack Reset' text should change colour to black, indicating successful reset acknowledgement.

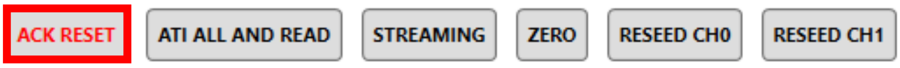

Figure 2.8: Ack Reset Button

Click the 'Streaming' button to enter I²C streaming mode.

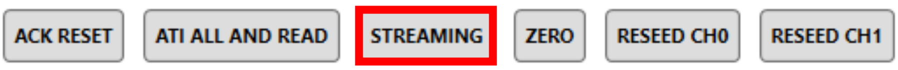

Figure 2.9: Enable Streaming Button

The IQS7221G will now stream all sensor data, as shown in Figure 2.10. The counts for the various channels should change as the control knob is rotated.

Figure 2.10: IQS7221G Streaming

2.7 Step 7: Load Pre-Configured H-File (Demo Button)

When using the standard IQS7221G EV kit hardware (AZP1439A1), one can simply open the “User Settings” window, navigate to the first tab named “Demo Settings”, and click on the image button of the kit to apply the predefined configuration settings for the demo. Refer to Figure 2.11.

The device may now be configured further by selecting the “User Settings” button to open the pop-up window with settings organized in menu tabs. Refer to Sections 4, 5 and 6 for more detail. The pop-up user settings window can be used to configure all the IQS7221G device parameters.

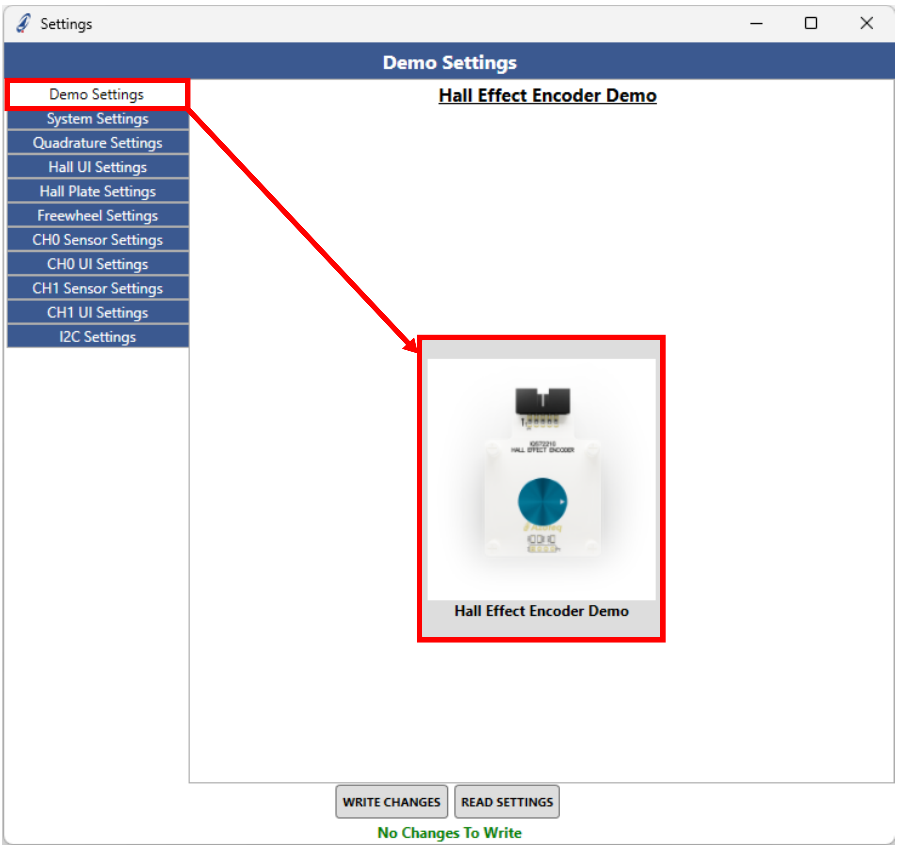

Figure 2.11: Importing the Predefined Demo Configuration

3 IQS7221G Debug and Display Software Overview

This section briefly explains the GUI elements such as the sensor graphs, device events, and commands, as well as some additional core functionality such as data logging and exporting of device settings.

3.1 IQS7221G Streaming Data

The IQS7221G GUI displays all the streaming data in the graph panel in the centre of the GUI. The default graph view is the bar graph, which plots the instantaneous counts of each channel. There are five additional scope views that plot additional information over time. These are explained later in this document, where relevant.

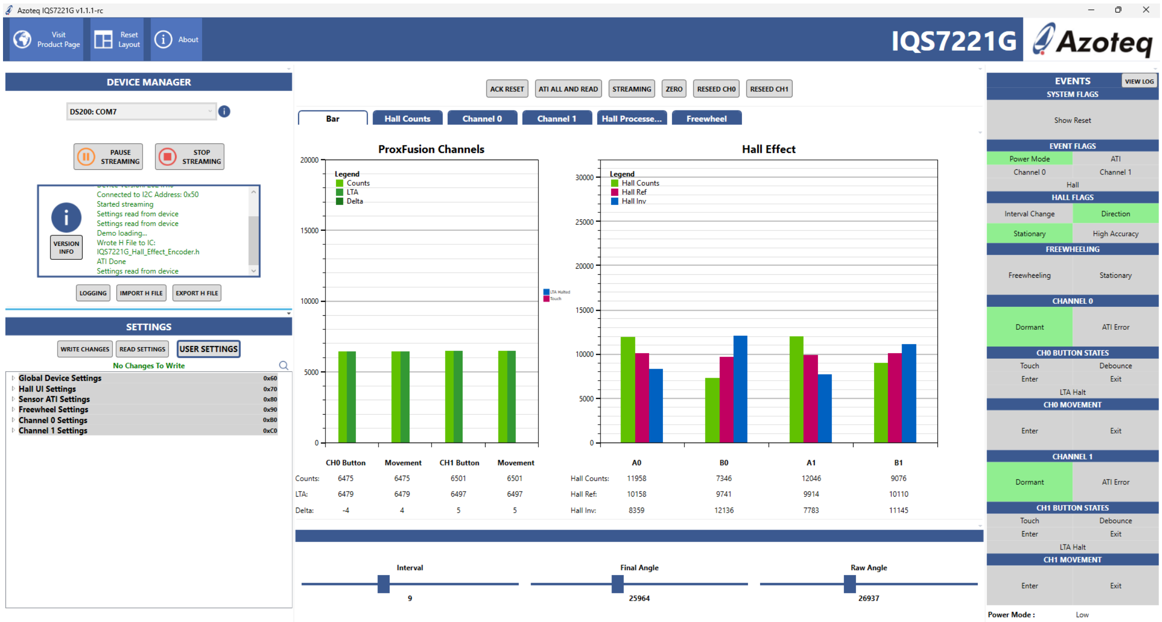

Figure 3.1: Streaming Graphs

The graph views can be manipulated with the following controls:

- Scroll wheel to zoom in and out.
- Hold and drag middle-mouse button to zoom to a bounding box.
- Hold and drag right-mouse button to pan.
- Double left-click to reset the graph view.

The IQS7221G has six channels in total; two ProxFusion® (or "touch") channels with a Button UI and Movement UI each, and four Hall channels, one for each of the Hall plates in the IC. The **counts** of a channel is a representation of the signal strength measured by the sensor. Specifically on the IQS7221G, the counts displayed are not the raw charge transfer measurements, but are instead **Linearised Counts** which are derived from the Raw Counts as follows:

$$\text{Linearised Counts} = \frac{3276750}{\text{Raw Counts}}.$$

Note: All the signals recorded in the graphs and sliders are read directly from the IC. For more information regarding the register map, please consult the IQS7221G datasheet.

3.1.1 ProxFusion Channels

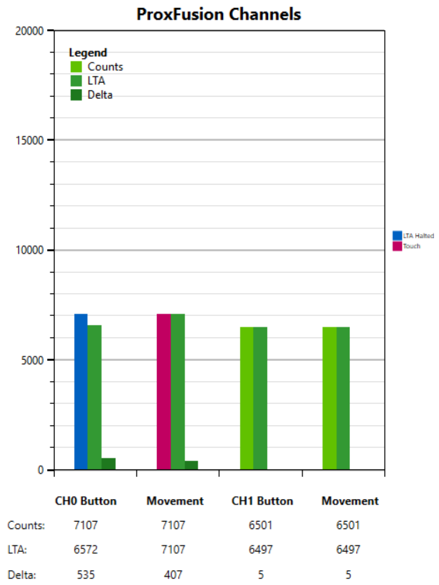

Figure 3.2: Button Channel Counts

Each ProxFusion channel shows the counts of the capacitive (or possibly an inductive) sensor. The **counts** value shows the raw measurement of the sensor, after filtering. The **LTA** is the Long Term Average of the counts signal. It tracks slow variations in the environment, and is used as a reference to detect movement; refer to AZD004 for more details. The **delta** is simply the difference between the LTA and the counts, and is used to detect activity or movement.

In the default configuration of the sensor, a user touching the capacitive sensor causes the counts to increase. On the EV kit, a copper pad on the PCB acts as the capacitive electrode. This couples capacitively to the metal knob. Therefore, touching the knob results in an increase in the overall capacitance of the pad to GND, resulting in an increase in counts on the channel. In this way, the IQS7221G can detect the proximity of the user's hand before the knob is rotated, allowing it to wake up and transition to a faster sampling rate to measure the rotation more accurately.

The ProxFusion channel detects two separate event types: button presses and movements. These two event types track their own LTA and delta values. The Button event compares the counts to a slow or static LTA to detect long-term presses. The Movement event uses a more dynamic LTA to detect brief changes in the rate of change of the counts.

3.1.2 Hall Channels

The four Hall plates are designated as **A0**, **B0**, **A1**, and **B1**. Each plate shows three sets of counts: **Normal**, **Reference**, and **Inverse**.

The Normal counts value represents a raw measurement of the vertical (or Z-axis) magnetic field strength at each plate. The Inverted counts value represents a second measurement on the same Hall plate, but with the polarity of the measurement inverted. Finally, the Reference counts value represents the midpoint between the two measurements; a DC value around which the normal and inverted counts swing. This Hall reference effectively represents the counts of the Hall plate if there was no external magnetic field.

These four Hall plates are used to calculate the absolute angle of a nearby magnet.

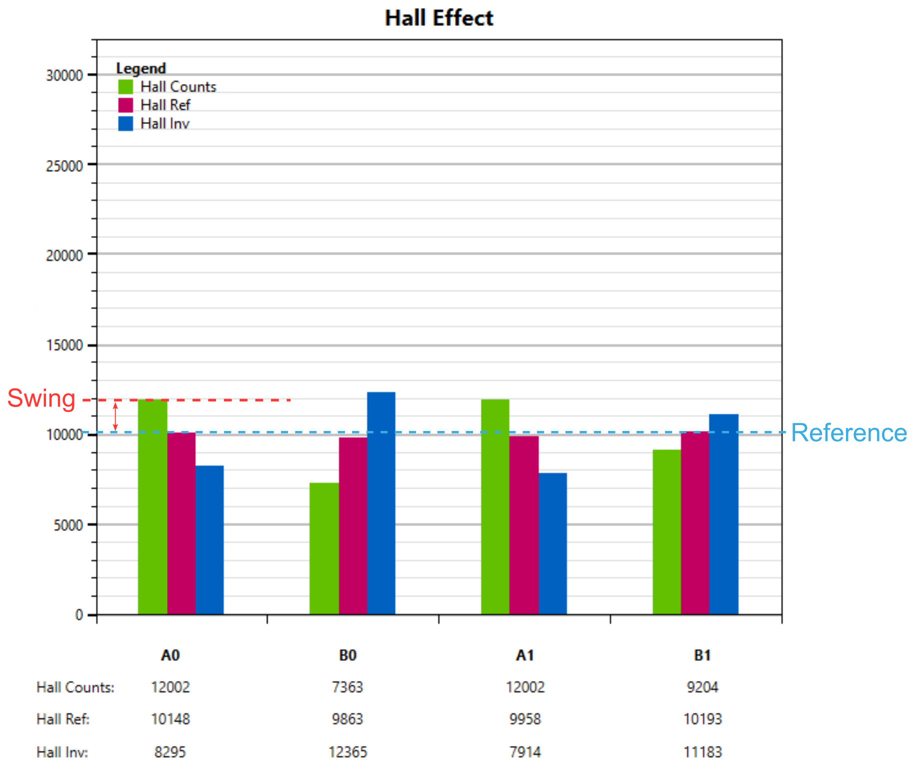

Figure 3.3: Hall Channel Counts

3.1.3 Angle Measurements

Three sliders at the bottom of the GUI show the output of the Hall encoder.

- **Interval** shows the coarse angle output of the Interval UI, and is derived from the final angle. This is the value that would typically be used if a discrete number of positions per rotation is required, such as in a mouse scroll wheel that uses 24 intervals per rotation.
- **Final Angle** shows the output angle as a 16-bit value, after filtering and auto zero compensation. This value may be significantly different from the raw angle, as an offset is added whenever the Hall sensor is "zeroed".
- **Raw Angle** shows the magnet angle calculated directly from the Hall counts.

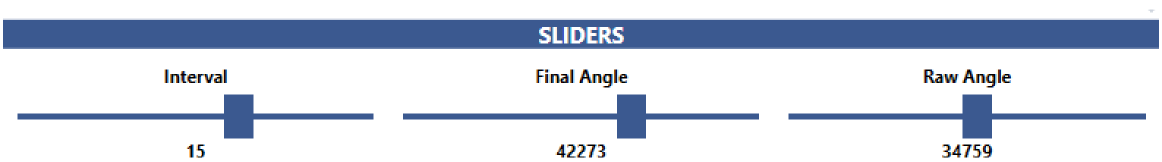

Figure 3.4: Angle Measurement Sliders

3.2 Data Logging

It may be necessary to save all the above streaming data to a file for debugging or testing purposes. The logging function allows the GUI to save all streaming data from the IQS7221G to a CSV file. Click the "Logging" button in the Configuration Tool Manager panel to open the logging window.

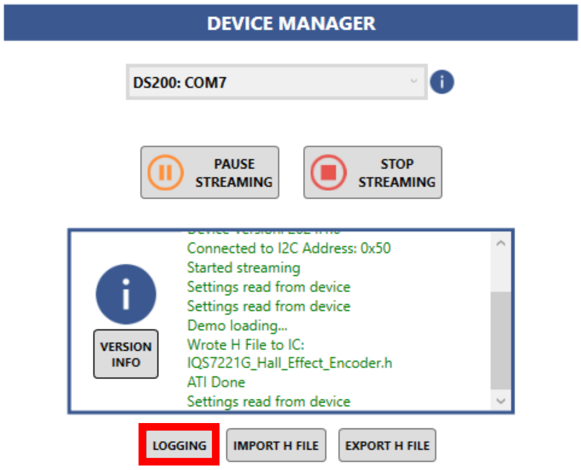

Figure 3.5: Logging Function Using the Configuration Tool Manager

From here, the desired variables from the IQS7221G can be enabled or disabled. To start logging, click the "Start Logging" button, and choose the destination of the CSV log file.

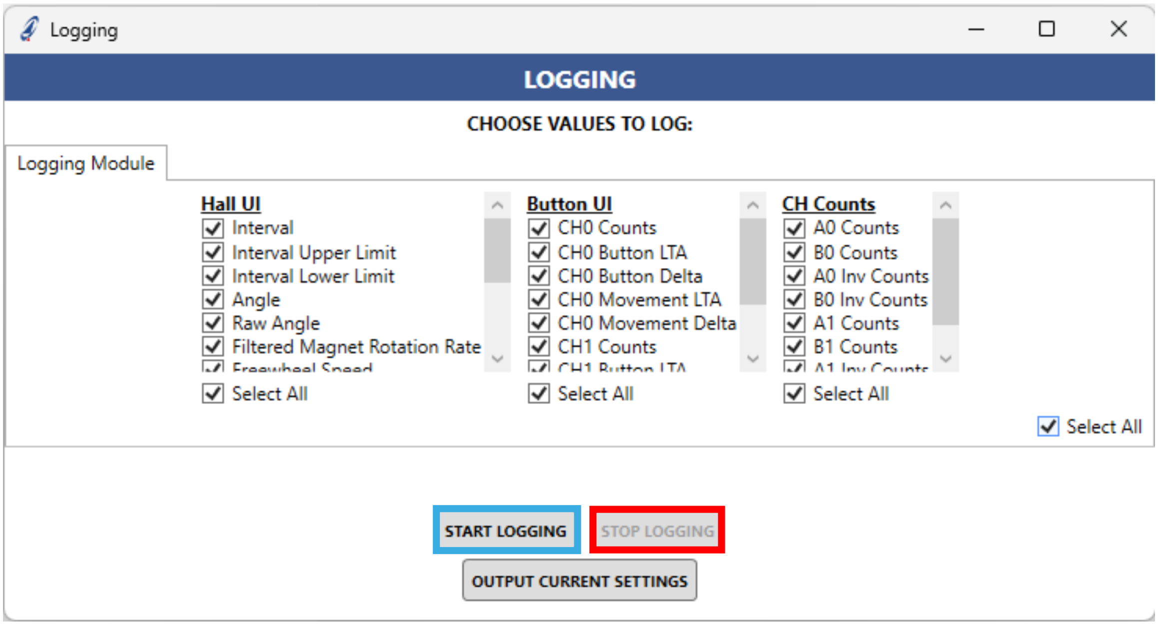

Figure 3.6: Logging Configuration Window

Once the file destination is confirmed, data logging will begin. To stop logging, click the "Stop Logging" button.

3.3 Export Device Configuration to H-File

After configuring the IQS7221G, you can export the new settings for safekeeping, sharing, or future use on the same or another device. The settings are exported as a *.h*-header file using the "Export H File" button.

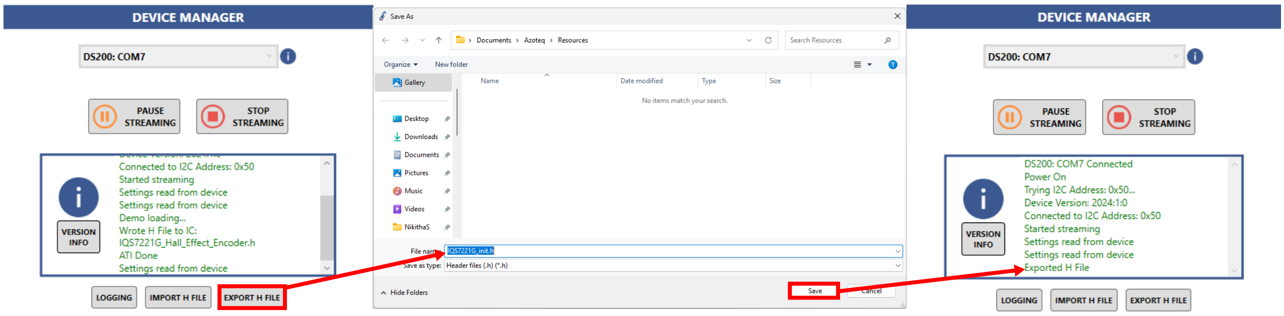

Figure 3.7: Exporting a Defined Configuration

3.4 Import Preconfigured H-File

If the device was previously configured and an associated .h-file was exported from the GUI, the file may now be imported into the GUI using the "Import H File" button. Additional information will be provided, verifying that the file was imported correctly:

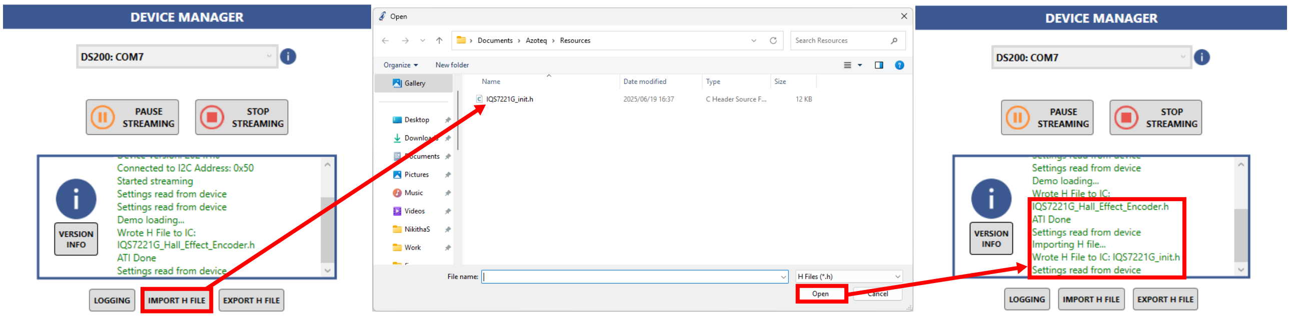

Figure 3.8: Importing a Predefined Configuration

3.5 Command Buttons

At the top centre of the GUI is a row of buttons that execute commonly-used commands.

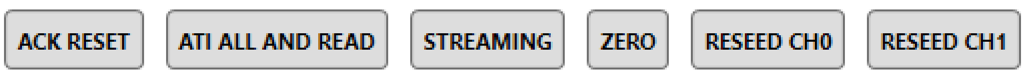

Figure 3.9: Command Buttons

3.5.1 Acknowledge Reset

On start-up, the IC will set its reset flag to indicate that a reset event has occurred. This indicates to the I^2C master that all settings on the IQS7221G have been reset to their defaults.

The "Ack Reset" button clears the IQS7221G's reset flag by writing the **Acknowledge Reset** bit to the IC. This should be the fist step after powering on any Azoteq IQS-device. The GUI will show that a reset has occurred by changing the Ack Reset button colour to red.

Note: After acknowledging a reset, it may sometimes appear that the device stops streaming. Since the IQS7221G is an I^2C-configurable chip, it always resets to I^2C streaming mode at start-up, and will remain in streaming mode until the reset flag has been cleared. However, the IQS7221G transitions into event mode as soon as the reset is acknowledged.

3.5.2 Streaming and Event Modes

The IQS7221G has two communication modes:

- **I²C Streaming Mode**: The IQS7221G regularly opens an I²C communications window, directly after it has performed a measurement. The "Streaming Mode" button places the IQS7221G into I²C streaming mode.
- **I²C Event Mode**: The IQS7221G only opens an I²C window if an event has occurred.

3.5.3 ATI All and Read

The "ATI All and Read" button writes the **Force ATI** command to the IQS7221G. The ATI routine is a calibration algorithm on the IC that will recalibrate all channels to their target or reference counts.

Once ATI is complete, the GUI reads all the IQS7221G settings to update any parameters that may have been changed by the ATI routine.

3.5.4 Zero

The "Zero" button resets the current interval to 0. This is done by adjusting the offset between the raw angle and the final angle so that the final angle sits at the centre of interval 0.

The Hall encoder can be zeroed on-chip by setting the **Zero Now** bit in the Hall UI Settings register.

3.5.5 Reseed CH0 and CH1

The "Reseed" command can be used to update the LTA of the ProxFusion channels by setting it equal to the current counts. Note that the Reseed command may trigger an ATI routine if the resulting LTA is significantly different from the target.

3.6 Events

The panel on the right-hand side of the GUI shows the current event flags that are set on the IC. On the IQS7221G, these flags can be found at registers 0x10 – 0x14.

3.6.1 System Flags

- **Show Reset**: Indicates that a recent power-on event has occurred, and should be cleared by sending an Acknowledge Reset command (Ack Reset button). This flag also indicates that all registers and settings of the device have been restored to their default states, and must be reconfigured.

3.6.2 Event Flags

- **Power**: The power mode of the device has changed.
- **ATI**: The touch channel or Hall channels have undergone an ATI routine. This would imply that the counts of the channels have changed, and some on-chip settings may have been altered.
- **Channel 0**: A Button or Movement event occurred on ProxFusion Channel 0.
- **Channel 1**: A Button or Movement event occurred on ProxFusion Channel 1.
- **Interval**: The Hall encoder has entered a new interval.

3.6.3 Hall Flags

These flags relate specifically to the Hall angle measurements.

- **Interval Change**: The Hall encoder has entered a new interval.
- **Direction**: Set to ‘1’ for a forward rotation (interval value increased), and ‘0’ for a reverse rotation (interval value decreased).
- **Stationary**: Is set if the current interval has not changed for some period of time. The IQS7221G will only transition into low power mode if this flag is set.
- **High Accuracy**: Indicates that the device is in high-accuracy power mode (a temporary high-report-rate mode that samples the Hall channels quickly to avoid potential rotation aliasing).

3.6.4 Freewheeling Flags

- **Freewheeling**: Indicates that a freewheeling gesture is currently active.
- **Stationary**: Indicates that the magnet stopped moving since the freewheeling gesture was initiated. This means that the IQS7221G is monitoring the magnet’s position, and any significant rotation will cancel the current freewheeling gesture.

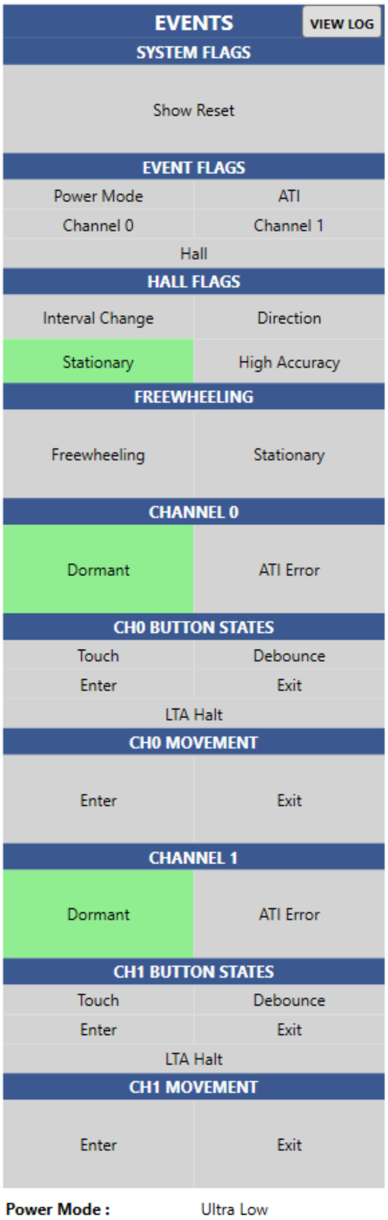

Figure 3.10: Events Panel

3.6.5 Channel Status

These flags are applicable to each of the ProxFusion channels.

- **Dormant**: The touch sensor has not been activated for some period of time. The IQS7221G will only enter low power mode if this flag (along with the Hall Stationary flag) is set.
- **ATI Error**: Set if the touch channel fails to recalibrate correctly. This indicates that the current output of the touch channel may be invalid.

3.6.6 Button Status

- **Touch**: The delta of the touch channel has exceeded the Button threshold. This flag indicates the user has touched or interacted with the touch sensor.
- **Debounce**: When crossing the Button threshold, the touch sensor will be sampled multiple times in rapid succession. This flag is set during this rapid sensing stage.
- **Enter**: Briefly set when the channel enters the touch state.
- **Exit**: Briefly set when the channel exits the touch state.
- **LTA Halt**: The delta of the touch channel has exceeded the LTA Halt threshold. In this state, the LTA is no longer updated to track environmental changes. This aids in increasing sensitivity of the Button event detection.

3.6.7 Movement Status

- **Enter**: The delta of the touch channel exceeded the Movement threshold in a positive direction. This indicates that the user approached the sensor.
- **Exit**: The delta of the touch channel exceeded the Movement threshold in a negative direction. This indicates that the user released or moved away from the sensor.
- **Debounce**: When crossing the Movement threshold, the touch sensor will be sampled multiple times in rapid succession. This flag is set during this rapid sensing stage.

3.6.8 Power Mode

Finally, the current **Power Mode** is displayed at the bottom of the events panel.

4 System Settings

This section quickly explains some of the basic system settings and commands that are not specific to any sensor or UI. These settings can be accessed in the "User Settings" window, on the second tab.

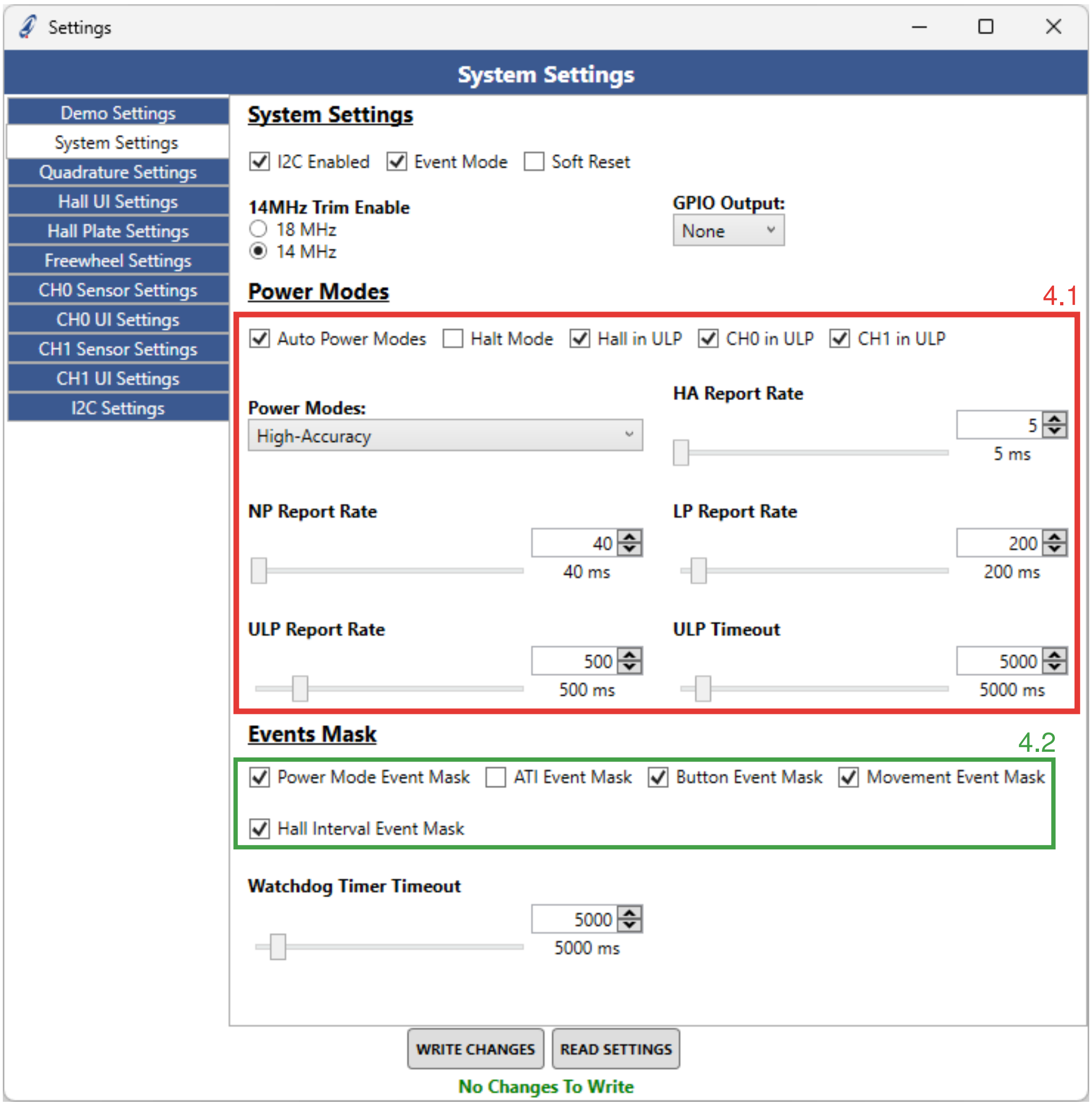

Figure 4.1: IQS7221G System Settings

4.1 Power Modes

The IQS7221G supports a number of different power modes. The current power mode of the IQS7221G can be set via the Power Modes dropdown menu in Figure 4.1.

- **High Accuracy (HA)**: Fastest sampling rate, used during rotation and ProxFusion debouncing to prevent aliasing.
- **Normal Power (NP)**: Fast report rate used during touch events and directly after a rotation (high accuracy) event.
- **Low Power (LP)**: Slower report rate for power saving.

- **Ultra Low Power (ULP)**: Slowest report rate. Sensing on certain channels may be disabled to reduce current consumption.

The sample rate of each power mode can be configured by changing the associated report rate. The report rate is the time between consecutive cycles, in milliseconds, where each cycle performs measurements on all channels. Higher power modes sample faster at the cost of higher current consumption.

The following power-mode-related settings are also available:

- **Automatic Power Modes**: Automatically switches between power modes based on touch events and Hall UI events. This allows the IQS7221G to choose the most applicable power mode, based on the Hall Stationary and ProxFusion Dormancy states. Automatic power mode will never set the device into halt mode.
- **Halt**: Sets the IC into the lowest power state where it does not perform any sensing. Note that only an I^{2}C force communications request (described in the datasheet) may wake the device from halt mode.
- **ULP Channels**: Each channel can be individually enabled or disabled in ULP mode. This allows for additional current consumption optimisation by disabling certain channels (e.g. Hall rotation) while in ULP.

4.2 Event Mask

The event mask is used to enable or disable specific events in event mode. Disabled events will not open new communication windows.

As an example, it is often useful to ignore ATI events. By clearing the ATI Event Mask bit, the IQS7221G will not open a communication window to report ATI events.

This only affects the behaviour of I^{2}C Event Mode — the associated event flags will still be set.

5 Hall Configuration

This section describes the steps to configure the Hall UI settings for the IQS7221G EV kit. It is recommended to force the device into normal power mode when experimenting with sensor settings, as it provides a consistent sample rate for evaluating the sensor performance. For this section, the device is set to Normal Power mode, with a 10 ms report period. See Section 4.1 regarding setting the current power mode.

5.1 IQS7221G Hall-Effect Sensing Overview

The IQS7221G has four integrated Hall plates that measure the strength of the vertical component of an external magnetic field. The magnetic field induces a Hall voltage on the Hall plates that may be positive or negative depending on the polarity of the magnetic field.

The IQS7221G measures the voltage on each plate and reports a counts value. However, the internal measurement circuit only measures positive voltages. The IQS7221G therefore applies a "Hall Plate Offset" to the Hall plate measurement to ensure that the measured voltages are always in the positive range. This offset determines the level of the Hall reference counts, around which the Hall counts and Hall inverse counts swing.

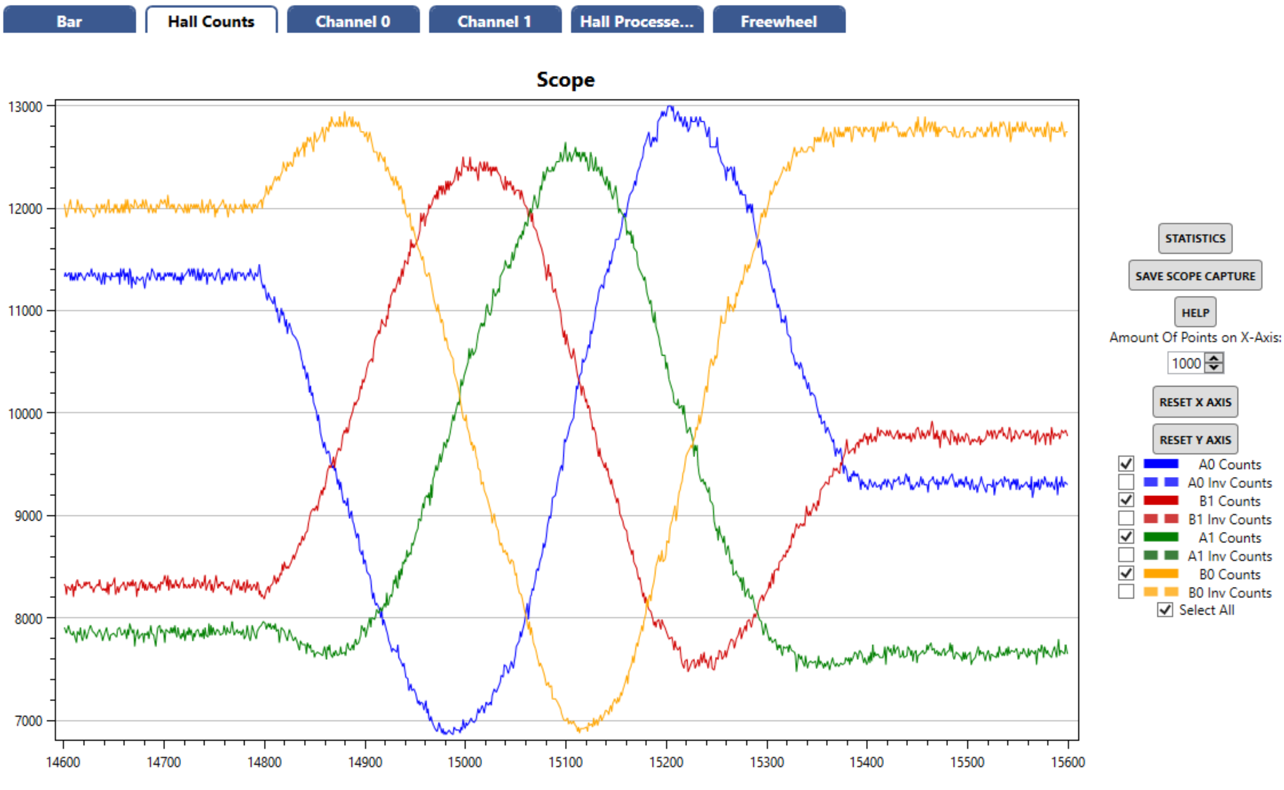

Figure 5.1: Hall Counts Over a Rotation

Figure 5.1 shows the counts of the Hall channels in the scope view, over a full rotation. The IQS7221G uses the strength and orientation of the magnetic fields at the Hall plates to calculate the magnet's angle relative to the IC, and then applies an angle offset and filtering to generate the final angle.

For more information regarding the Hall-rotation sensing principles, please refer to the AZD127 Application Note.

5.2 Adjusting Hall Sensitivity

The first step is to ensure that the magnet can induce enough swing in the counts to provide adequate signal for the angle calculation. Without sufficient signal strength, the angle output may be prone to jitter.

Initially, set the Hall Target to 10000, and click “ATI All”. This is a good baseline that balances resolution and current consumption. Now the magnet can be rotated, and the minimum and maximum counts on the Hall channels should be observed. A swing of roughly ±2000 to ±3000 counts around the target is recommended for an application with 24 intervals per rotation.

The amount of swing attained is dependent on the magnitude of the magnetic field. Using a stronger magnet, or bringing the magnet closer to the IC, will increase the counts swing. However, the gain of the Hall sensors can also be adjusted to increase the counts swing, specifically by changing the **Hall Gain** value. Increasing the gain value will increase the sensitivity of the Hall sensors, and results in larger counts swing.

The gain and target settings are found under “Hall Plate Settings”, shown below.

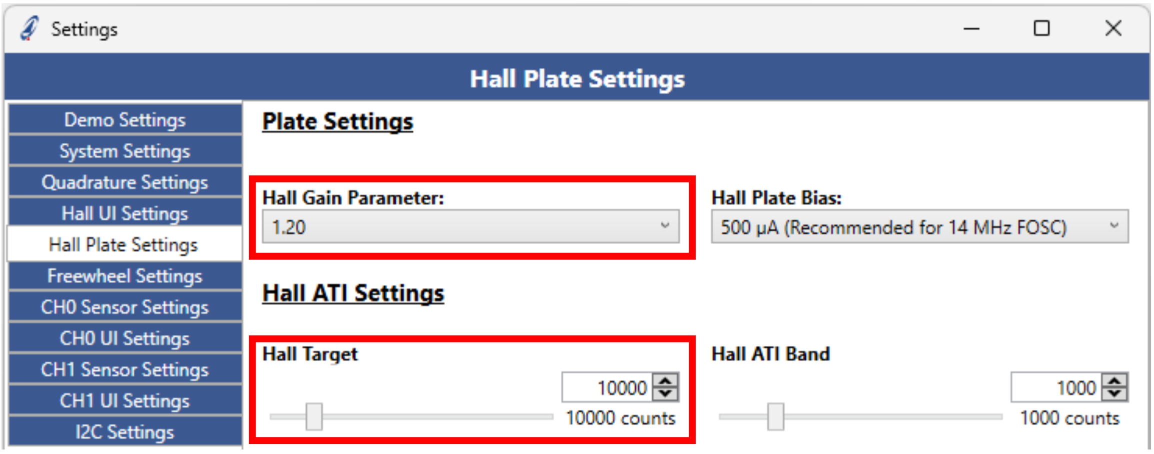

Figure 5.2: Hall Multipliers and Dividers

Note that changing the gain of the Hall sensors will also affect the counts reference. If the gain is increased, the Hall offset must be decreased to maintain the same counts reference. The Hall Automatic Tuning implementation (ATI) is able to re-adjust the offsets to maintain the correct reference. Any time the gain value is changed, click the “ATI All and Read” to update the Hall offsets.

The standard procedure for tuning the Hall channels’ sensitivity is as follows:

1. Rotate the magnet above the IC, and take note of the minimum and maximum counts values of the Hall channels.
2. Adjust the Gain value. If the observed swing is too low, increase the gain value. If the observed swing is too high, lower the gain value.
3. Perform an ATI routine. In the GUI, click the “ATI All and Read” button. This will recalculate applicable Hall offsets for each Hall channel.
4. Repeat from step 1 as necessary.

Note: If the Hall counts cannot achieve the desired swing, even with maximum gain, this is an indication that the Hall plates are not receiving a strong enough magnetic field. Please refer to the AZD127 Application Note for more details on magnet strength and positioning.

5.3 Evaluating the Angle Output

To view the angle output over time, switch to the "Hall Processed Data" scope view, and enable only the **Angle** and **Raw Angle** lines. Rotate the knob, and confirm that the angle changes as expected.

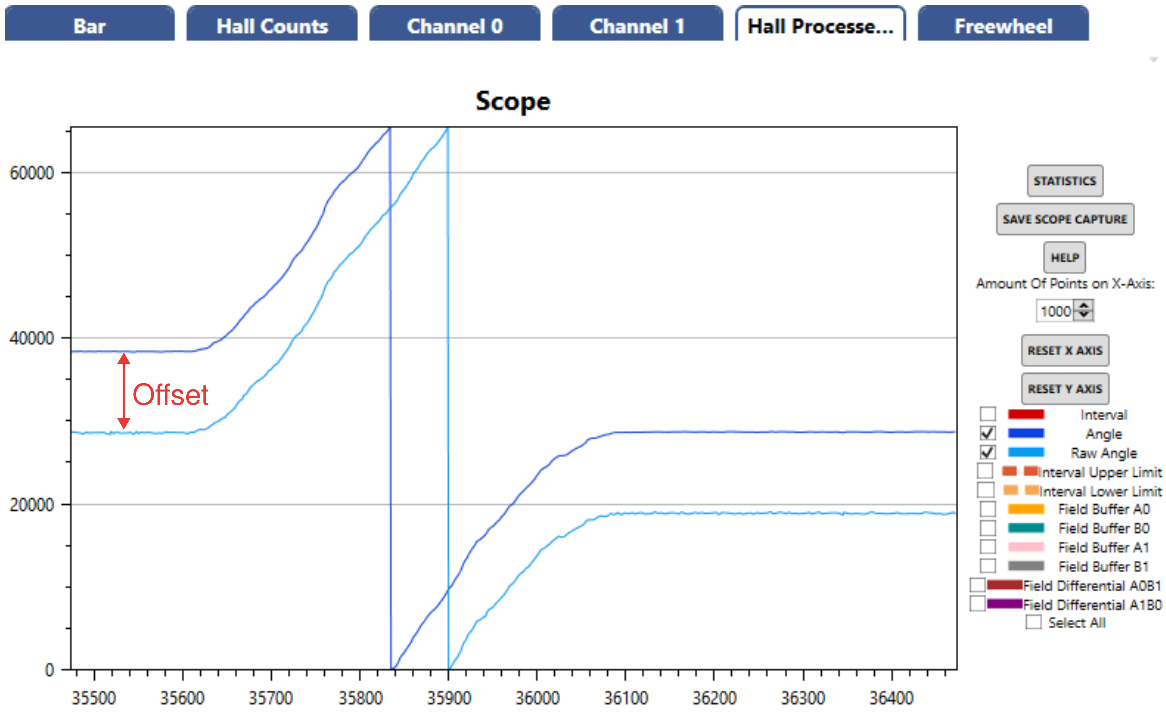

Figure 5.3: Scope View of Hall Angle

Figure 5.3 shows the scope view of the raw and final angle values over a full rotation. These angles are 16-bit values, where a full rotation from 0° to 360° maps to 0 – 65536. The raw angle is unfiltered, and represents the absolute angle of the magnet relative to the IC. The final angle value is filtered, and has an offset from the raw angle. As an example, the offset in Figure 5.3 is approximately 10000.

Note: While initially testing the Hall-rotation sensing, it may be useful to set the Auto Zero Mode setting to "Off". This setting is configured in Section 5.4.3.

5.3.1 Wheel-to-Magnet Angle Offset

The offset between the raw angle and final angle is set when the Zero command is given to the IQS7221G, but may also be changed automatically by the Auto Zero function. The offset can be read from the **Wheel-to-Magnet Angle Offset** register. In this example, the offset was set to 9801, which agrees with the observation from the scope view in Figure 5.3. This register can be overwritten, but altering this register during runtime is discouraged.

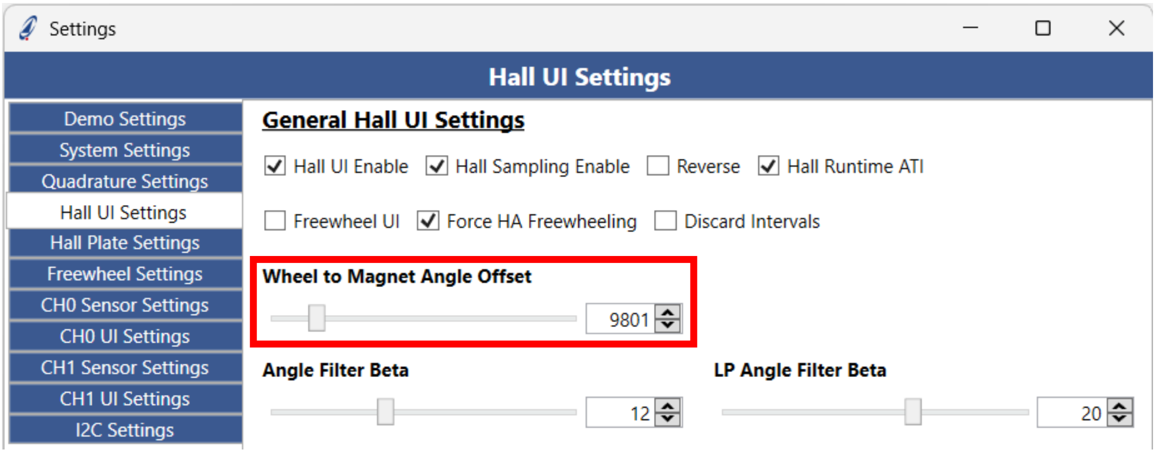

Figure 5.4: Angle Offset Setting

5.3.2 Angle Filtering

The output angle is filtered to reduce jitter. The strength of the filter can be adjusted by altering the Angle Beta value, which accepts a value between 0 and 31. Larger values reduce the bandwidth of the filter, reducing the jitter on the output angle, but also potentially increasing the filter's settling time.

Note that in LP and ULP, the IQS7221G instead uses the LP Angle Beta value, which should generally be set to a slighly higher value than the normal angle beta value.

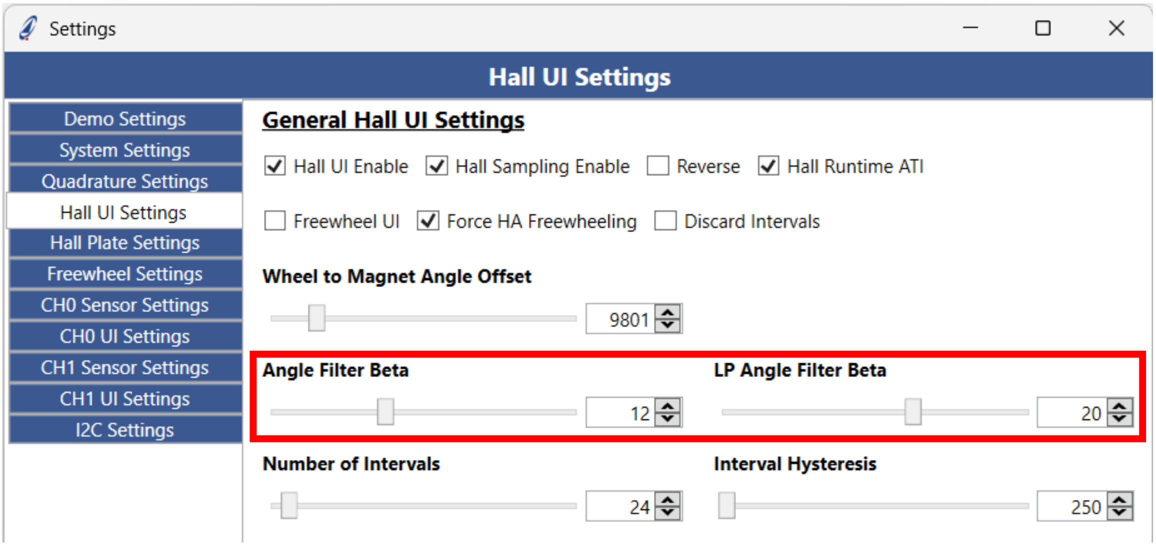

Figure 5.5: Angle Filter Beta Settings

5.3.3 Rotation Direction

Finally, the direction of the output rotation can be changed by setting the **Reverse Direction** bit. Note that this changes the direction of all output angles, from the raw angle to the interval output.

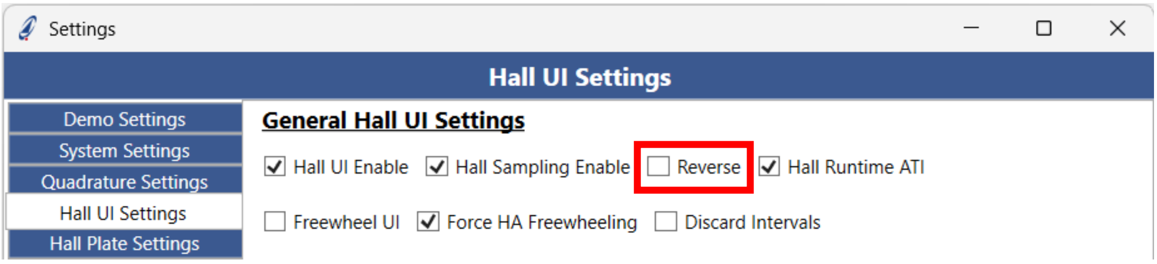

Figure 5.6: Reverse Hall Rotation Direction

5.4 Configuring the Interval UI

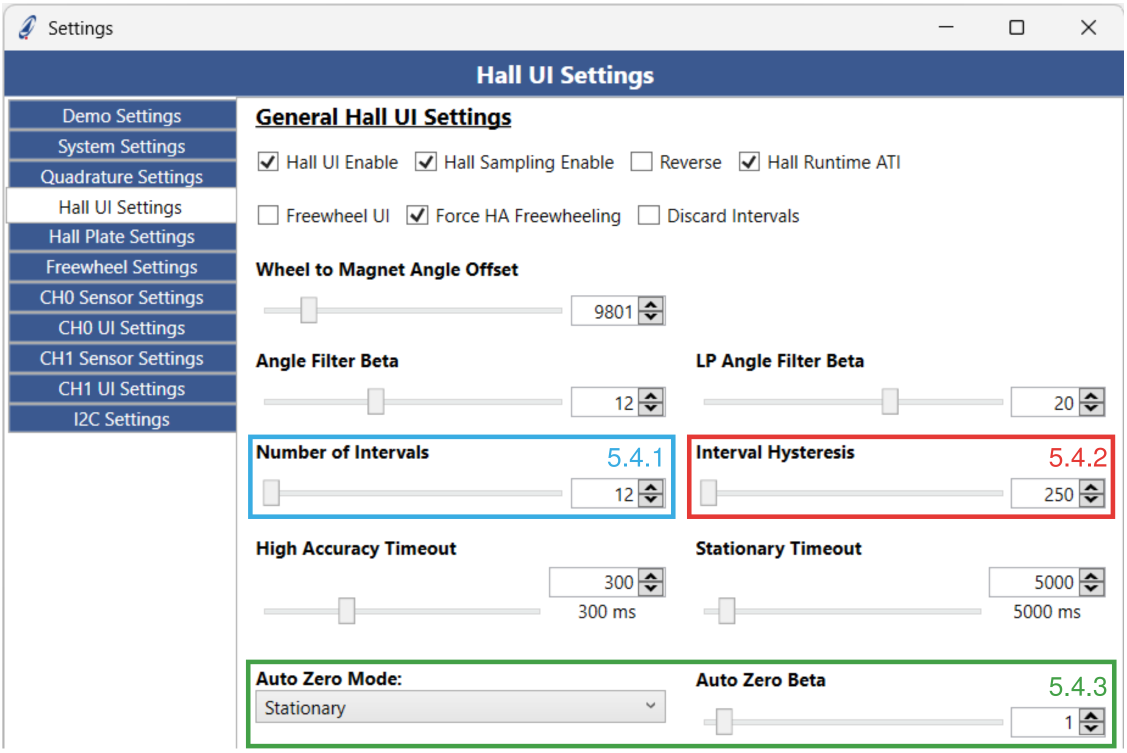

Figure 5.7: Interval UI Settings

5.4.1 Interval Size

The IQS7221G divides the 16-bit final angle into discrete intervals, based on the **Number of Intervals** setting. For example, a mouse scroll wheel may use a mechanical ratchet with 24 positions.

As an example, set the number of intervals for the EV kit to 12, as shown in Figure 5.7, then click the Zero button. Since the Interval UI divides the 16-bit final angle based on the number of intervals, the size of each interval can be calculated as:

$$\frac{2^{16}}{12} \approx 5461. \tag{1}$$

The interval size can be visualised in the "Hall Processed Data" scope view by enabling the **Interval Upper Limit** and **Interval Lower Limit** plots. These limits are the boundaries of the current interval, and if the final angle value crosses one of the limits, the current interval will change.

5.4.2 Interval Hysteresis

Interval Hysteresis provides a debouncing effect that prevents the interval output from jittering between two intervals when the final angle is near an interval boundary. The effect of hysteresis can be seen in Figure 5.8, where the angle switches from interval 4 to interval 3. As the angle crosses the lower limit of interval 4, the upper limits and lower limits shift down to indicate the edges of interval 3, but the new upper limit for interval 3 is slightly higher than before. The angle can now drift back upwards past the original threshold without triggering a new interval. This means the user has to rotate the magnet deliberately to move back to interval 4.

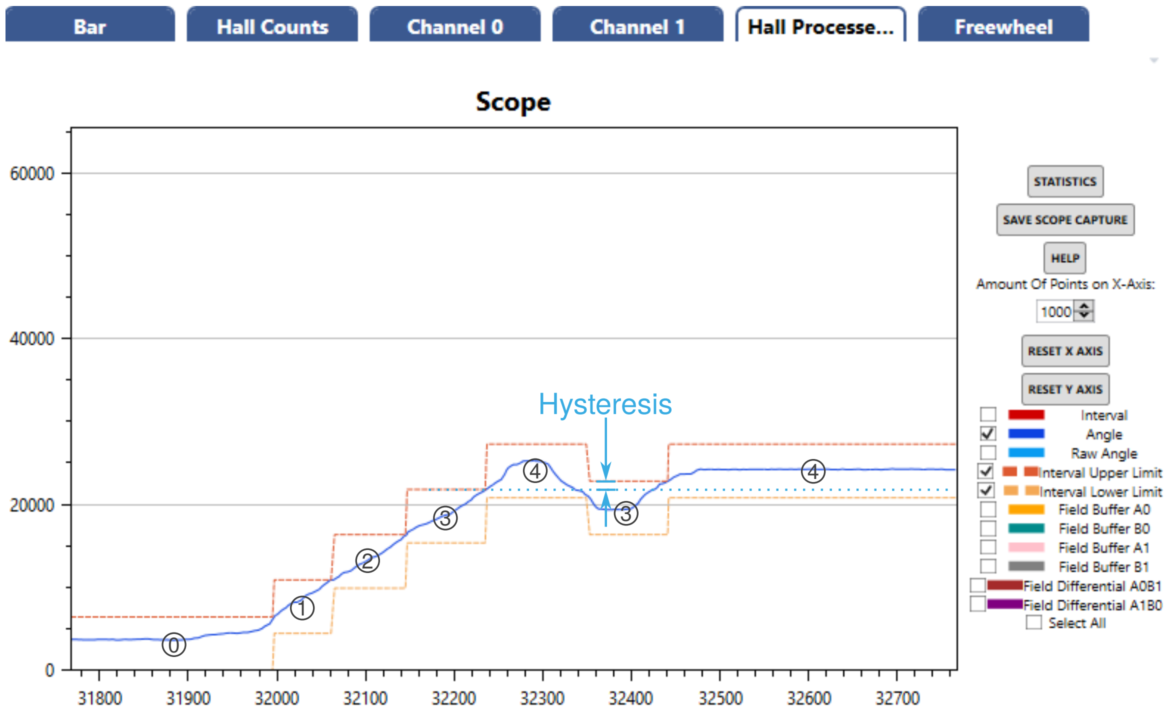

Figure 5.8: Scope View of Hall Angle and Intervals

The Interval Hysteresis setting can be found under "Hall UI Settings", as shown in Figure 5.7. In this example the hysteresis was set to 1000. Note that in practice this amount of hysteresis may be excessive, but is acceptable in this example that uses few intervals. The hysteresis value should always be significantly smaller than the size of the interval, which was calculated above as 5461.

5.4.3 Automatic Interval Centering

The final setting related to the Interval UI is the **Auto Zero** function. This feature attempts to align the centre of the IQS7221G's intervals with the mechanical intervals in a ratchet so that the transition between two intervals happens at the correct/expected place. Applications with a smooth rotation (without a ratchet) may also take advantage of this feature, as it will automatically adjust the current angle towards the centre of the current interval, effectively adding additional hysteresis and reducing the possibility of a false interval change. The Auto Zero settings are available on the "Hall UI Settings" tab, shown in Figure 5.7.

The default mode is the **Stationary Auto Zero** mode. Section 5.4.1 recommended disabling this feature temporarily. The reason for this can be seen in the following scope capture of a forward rotation with Stationary auto zero mode enabled:

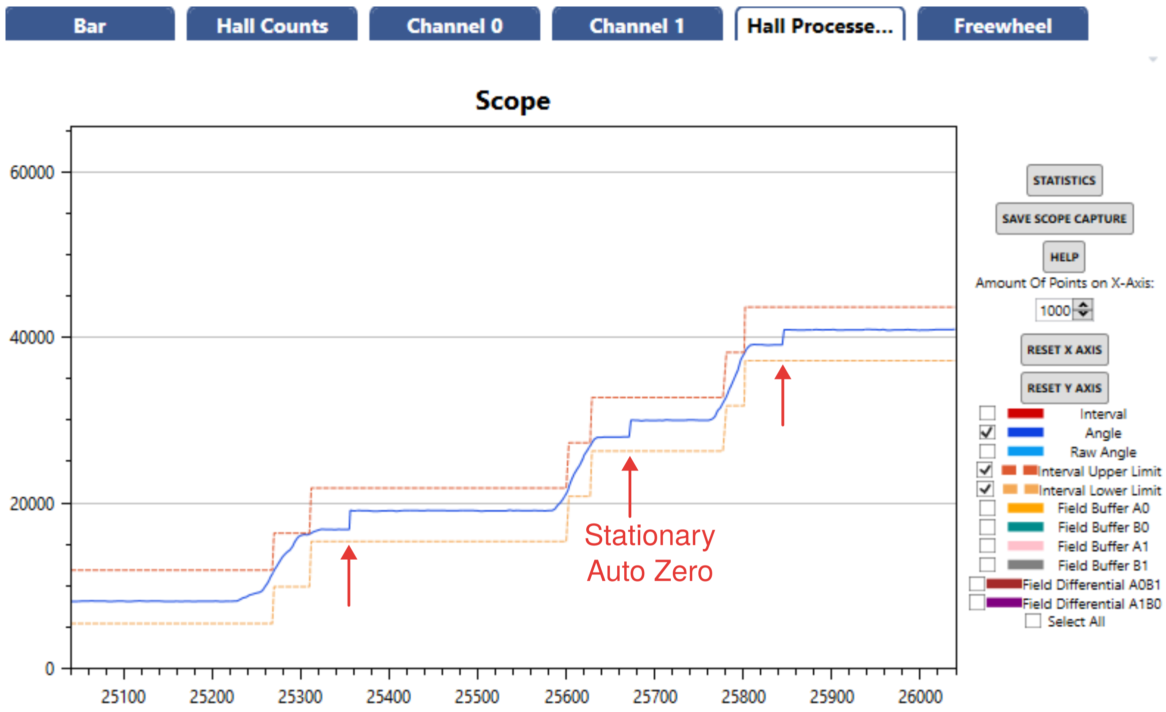

Figure 5.9: Stationary Auto Zero Adjustment

The Stationary auto zero mode applies a discrete step to the angle offset value shortly after a new interval is entered, moving the final angle towards the centre of the new interval. This causes the effect where the angle steps backwards or forwards suddenly, as seen in Figure 5.9. This adjustment only happens once, until the interval changes again. The size of the step adjustment is controlled by the **Auto Zero Beta** value.

This mode is intended for ratchet applications that have a discrete number of physical positions, where the auto zero update only happens after the wheel has settled in the centre of the new mechanical interval.

For the EV kit, and other applications with smoothly-rotating wheels, the **Continuous Auto Zero** mode is recommended. This mode continuously filters the offset towards the centre of the current interval, as shown in Figure 5.10. A higher Auto Zero Beta value, at least 10 or greater, is needed for this feature to work correctly.

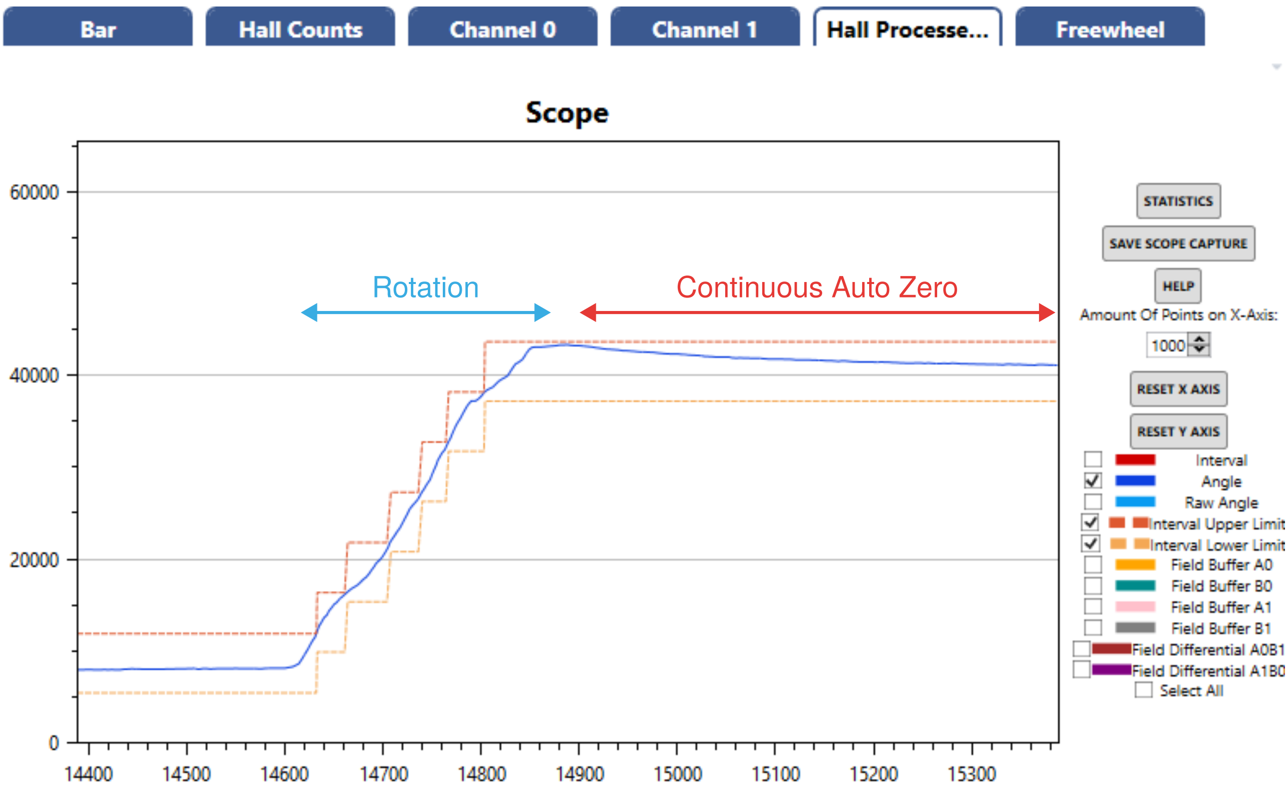

Figure 5.10: Continuous Auto-Zero Adjustment

5.5 Stationary Timeout

The **Stationary Timeout** is the duration that the IQS7221G will wait after an interval change before setting the Stationary flag. The Stationary flag determines when the IQS7221G may transition to low power mode.

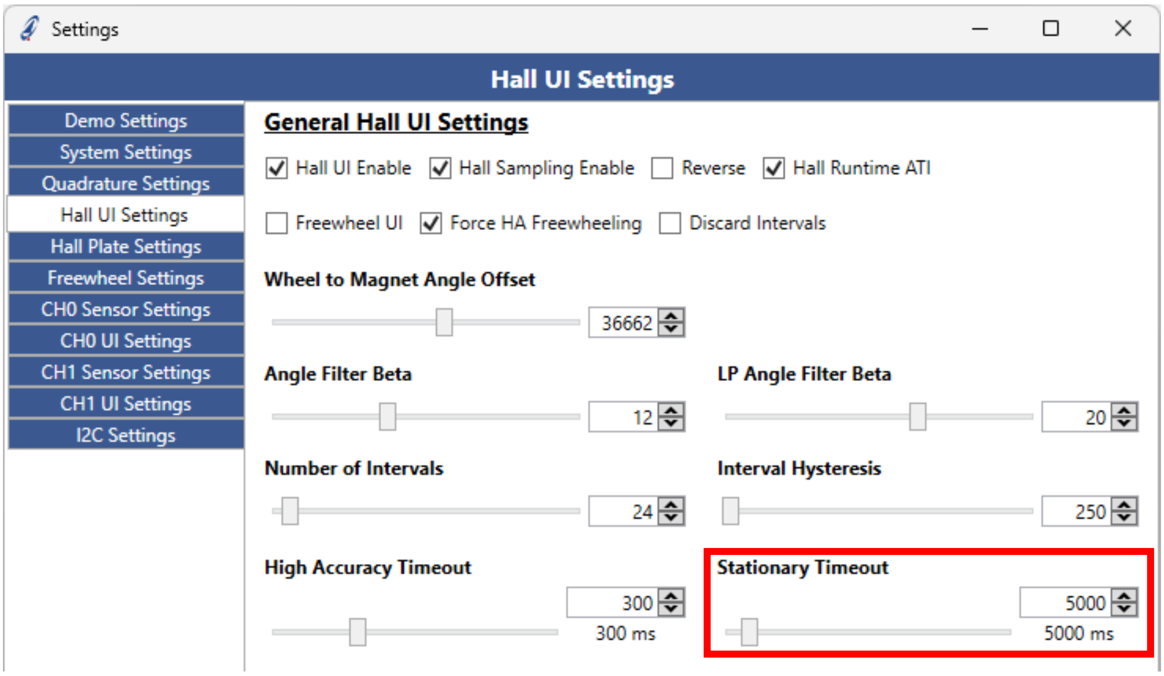

Figure 5.11: Stationary Timeout Setting

5.6 Quadrature Output

The IQS7221G features two quadrature output pins to report interval changes without the need for I^{2}C communication. With the quadrature outputs enabled, the IQS7221G can be placed in Standalone Mode, which aids in reducing current consumption.

On an interval change, the two quadrature outputs will both change state, with a short delay between them. The delay between the two pin changes is configurable via the **Quadrature Flank Delay** parameter. It may be necessary to set this value to at least 1 millisecond, depending on how quickly the MCU can react to pin interrupts.

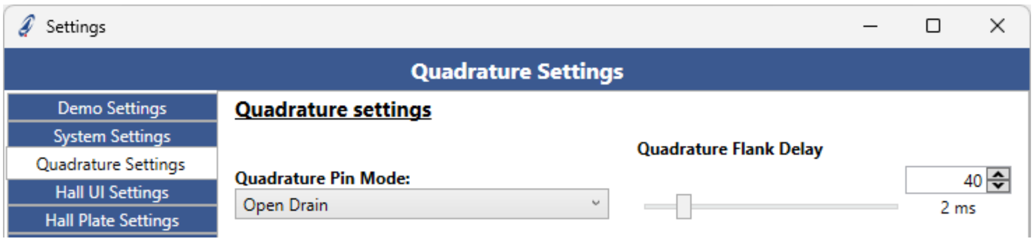

Figure 5.12: Quadrature Output Settings

6 Touch Channel Configuration

The IQS7221G supports two touch sensors that can be used for low power wake-up, or for touch button applications. The sensor can be configured as a self-capacitance or mutual-capacitance sensor or a resonated inductive sensor. Self-capacitance is a very simple sensor architecture, and the EV kit thus features an RX electrode connected to one of the available CRx pins. The capacitive sensor couples from the electrode on the PCB to the metal knob of the EV kit. The counts on the Button channel will increase when the user touches the sensor, indicating an increase in measured capacitance.

This section follows an example of configuring a single touch sensor on Channel 0.

6.1 Initial Touch Setup

Under "CH0 Sensor Settings", first make sure the touch sensor is enabled by checking the "Enable" bit, and selecting the "Self-capacitance" Sensing Mode. The correct Rx and Tx pins must also be selected. For self-capacitance, the same pin must be selected for the Rx and Tx pins. Please refer to Section 7.2 for the pin assignments for the IQS7221GEV02 kit.

It is recommended to keep all other settings at their defaults. This is shown in Figure 6.1.

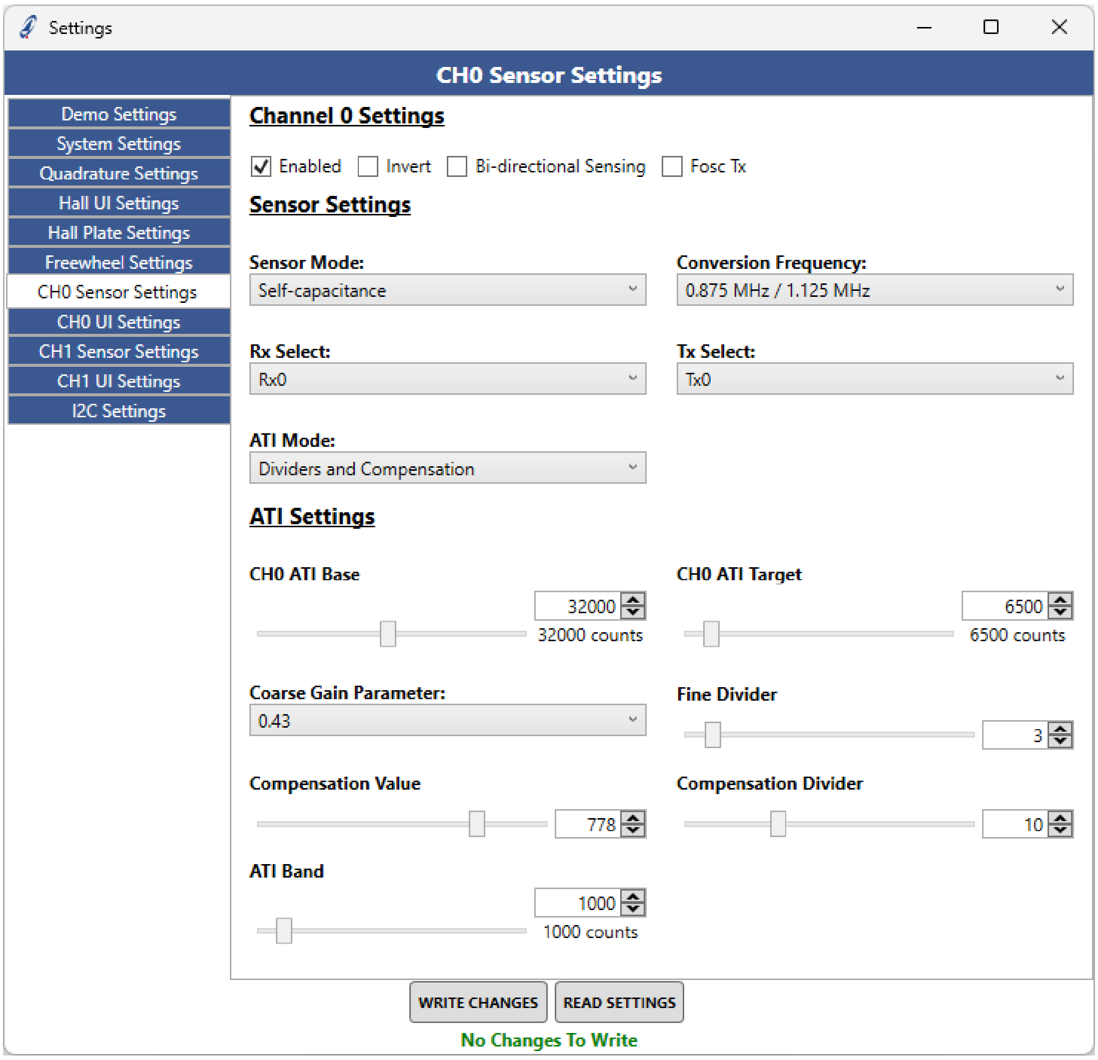

Figure 6.1: ProxFusion Sensor Settings

Note: This document assumes the application (e.g. IQS7221G EV kit) is using a self-capacitance sensor. The self-capacitance sensor experiences a increase in *Linearised Counts* (decrease in *Raw Counts*) on a touch, indicating an increase in capacitance. Mutual-capacitive and inductive sensors on the other hand are typically configured to measure a decrease in counts upon activation. The Inverse or Bi-Directional Sensing bits may need to be set in this case.

6.2 Adjusting Touch Sensitivity

The sensitivity of the touch channel can be adjusted by altering the **ATI Base** and **ATI Target** values under "CH0 Sensor Settings" in Figure 6.1. The ATI parameters' relationship to sensitivity is generally described as

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

To increase the sensitivity of the touch sensor, the Target value can be decreased. To reduce the sensitivity, the Base value can be decreased. Typical values for the Base value are between 10000 and 30000, while a target value between 3500 and 10000 is recommended. On the IQS7221G, the Base value should always be larger than the Target value.

Once the Base and Target values have been selected, adjust the Coarse Gain parameter and click ATI All until the Fine Divider parameter is between '4' and '28'.

6.3 Thresholds

The **Button** and **Movement Thresholds** can be changed under the "CH0 UI Settings" tab, as shown in Figure 6.2. These thresholds determine the levels at which the Button state is entered, and the size of the movement required to trigger the Movement Enter and Exit states.

6.4 Button Filter Betas

The final touch sensor settings to be discussed are the **Filter Betas**, highlighted in Figure 6.2. The filter betas determine the strength of the filtering on the touch channel. Larger beta values remove more high-frequency content from the signals, and tend to cause the filter to respond more slowly to changes.

Both the counts and the two LTA values are filtered with beta filters.

- The counts filter should react quickly to user input, and the beta value should therefore be kept at smaller values, typically 5 or less.
- The Button LTA is meant to track slowly-changing environmental effects, but not user interactions, so beta values of 7 or larger are recommended. The Button LTA filter is halted during a Button event, or while the Button delta is larger than the LTA Halt threshold. This means that the LTA will not be updated, but will keep its value fixed so long as the channel is in activation.
- The Movement LTA also slowly tracks environmental changes using the LTA Beta, but switches to the Fast LTA Beta during activations, in order to be able to detect rapid touch and release events.

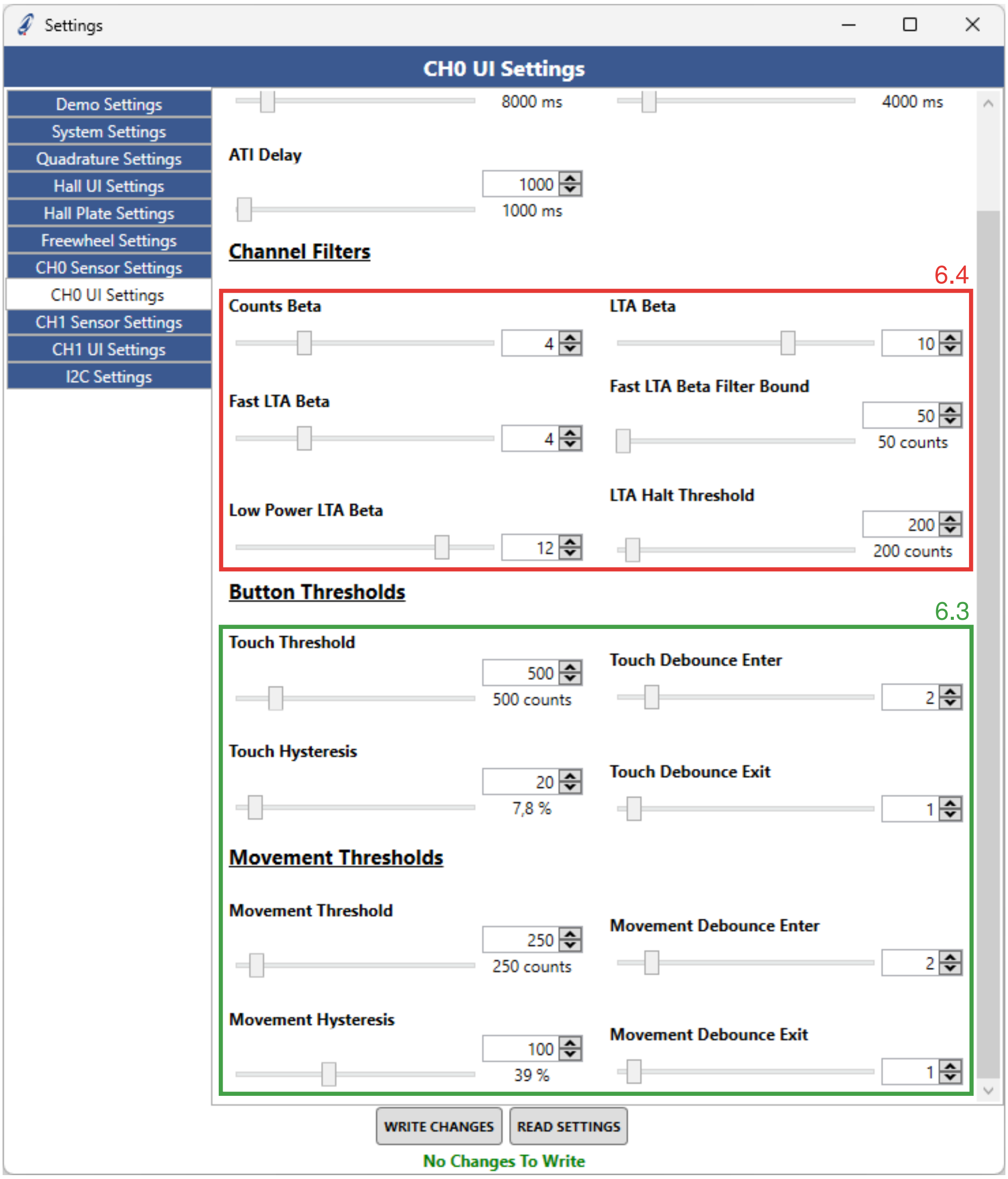

Figure 6.2: Button Thresholds

6.5 Channel Timeouts

The **Touch Timeout** parameter determines for how long the touch channel may stay in the Button Active state before resetting and performing an ATI routine. This is meant to clear stuck states automatically.

The **Dormancy Timeout** determines how soon after the most recent Button or Movement event the Dormant flag will be set. Recall that the device will enter lower power modes as soon as the magnet is *stationary* and the touch channel is *dormant*.

The timeout settings are available under the "CH0 UI Settings" tab, shown in Figure 6.3.

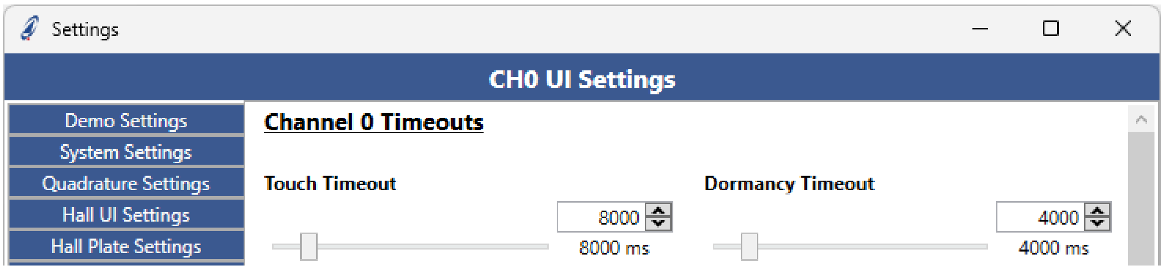

Figure 6.3: CH0 Timeout Settings

6.6 GPIO Indication

The IQS7221G can be configured to indicate the Button state of either Channel 0 or Channel 1 on GPIO4. This is for use in applications that do not use I^2C. The GPIO output can be enabled under "System Settings".

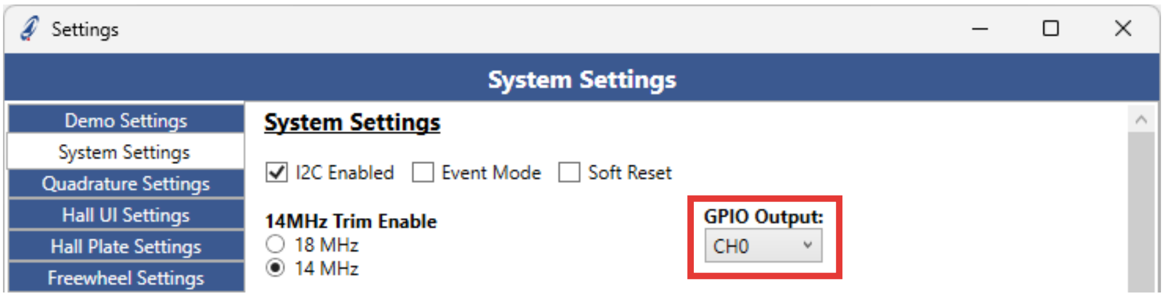

Figure 6.4: CH0 GPIO Output Enabled

7 Reference Design

This section provides a brief overview of the IQS7221G Hall-Rotation Evaluation Kit design.

7.1 Assembly

The IQS7221G EV kit illustrates the design of a control knob that combines two sensors; the magnet in the shaft supplies the diametric magnetic field to measure the angle of the knob, and the metal body of the knob allows it to act as a capacitive touch sensor. The capacitive electrode on the PCB couples to the metal shaft and magnet. A user that touches anywhere on the metal knob adds a large capacitance to earth.

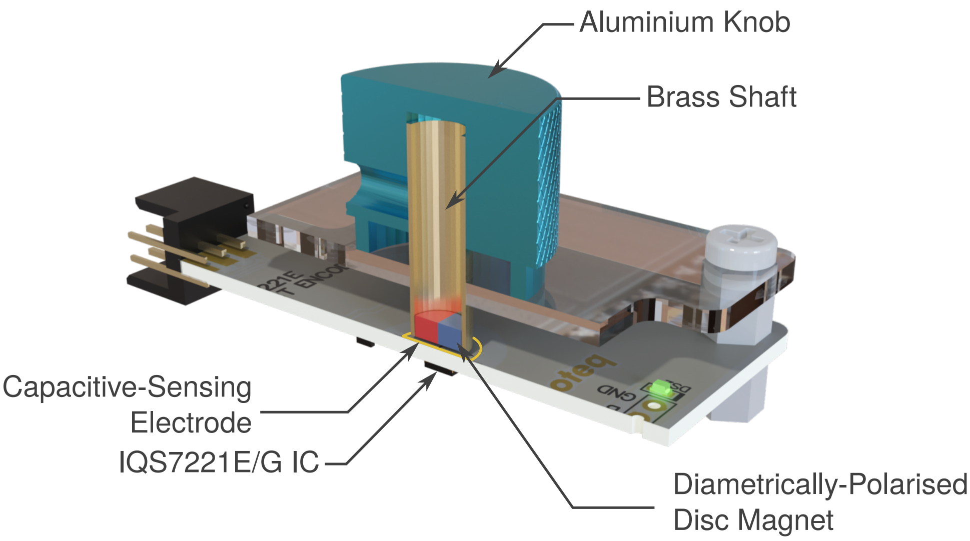

Figure 7.1: Cross-Section View of IQS7221E/G EV Kit

This design allows for an incredibly simple assembly, but requires both the IQS7221G IC and the capacitive electrode to be directly below the magnet. The EV kit places the IC on the bottom side of the PCB, away from the magnet, leaving the PCB's top layer free for the capacitive electrode to be directly beneath the magnet for strong capacitive coupling. This provides good sensitivity on the touch channel, but reduces the strength of the measured magnetic field. Not only does this force the Hall plates further away from the magnet, but a drop in measured magnetic field strength of approximately 15 % can be expected when measuring magnet fields from the underside of the IC. This low magnetic field strength is apparent when adjusting the sensitivity of the Hall sensors as described in Section 5.2, as the EV kit requires a large amount of gain to achieve sufficient swing on the Hall counts.

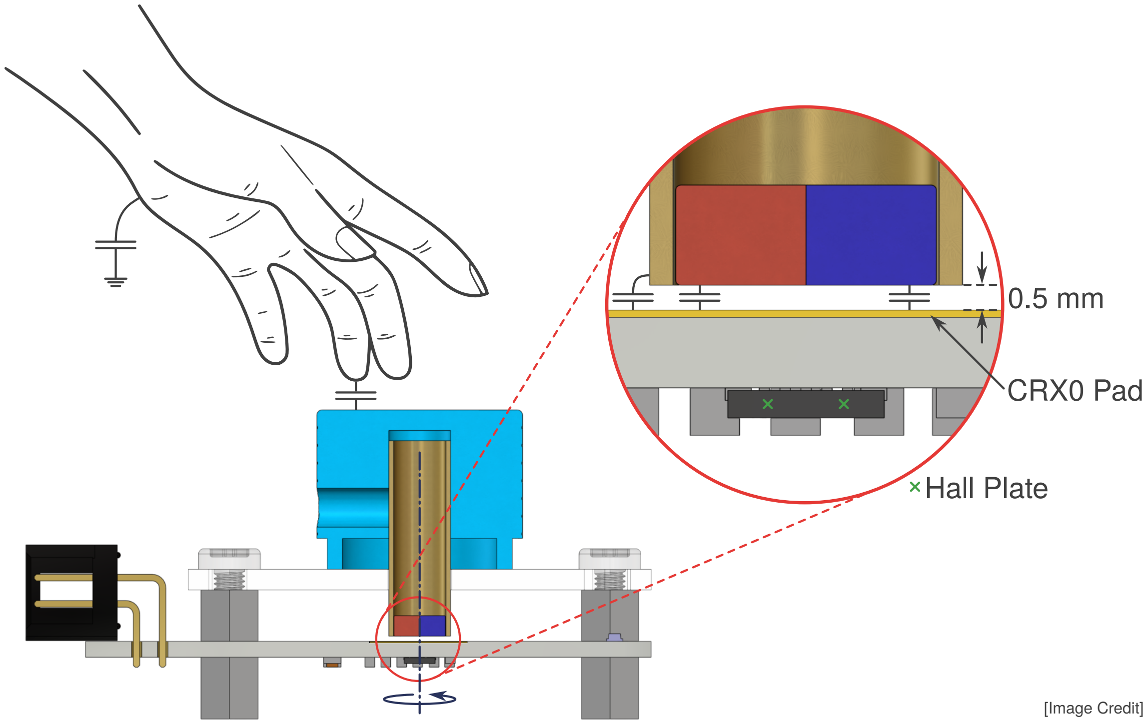

Figure 7.2: Cross-Section View of IQS7221G EV Kit

To increase the Hall signals for a higher-resolution application, the design may be altered in the following ways:

- Use a stronger magnet.
- Move the magnet closer to the IC. This can be done by reducing the 0.5 mm gap shown in Figure 7.2 or by reducing the PCB thickness. Reducing the gap will also increase the capacitive coupling.
- Place the IC on the top layer of the PCB, on the same side as the magnet. This option will require a different capacitive electrode design, or if it is not needed, the capacitive sensor can be removed altogether.

7.2 Reference Schematic

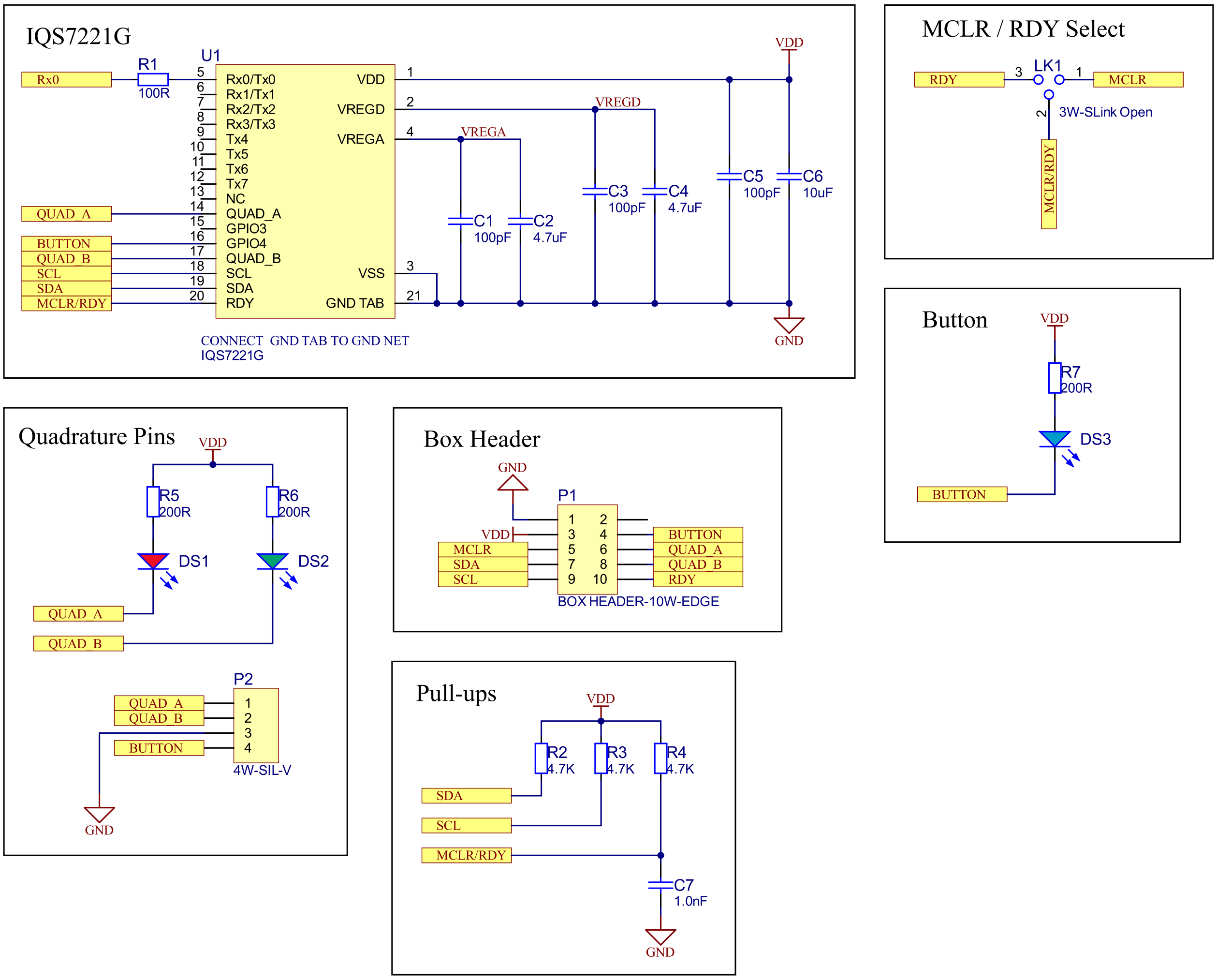

Figure 7.3: IQS7221G Reference Schematic

Contact Information

	South Africa (Headquarters)	China
Physical Address	1 Bergsig Avenue Paarl 7646 South Africa	Room 501A, Block A T-Share International Centre Taoyuan Road, Nanshan District Shenzhen, Guangdong, PRC
Tel	+27 21 863 0033	+86 755 8303 5294 ext 808
Email	info@azoteq.com	info@azoteq.com

	USA	Taiwan
Physical Address	7000 North Mopac Expressway Suite 200 Austin TX 78731 USA	Xintai 5th Road, Sec. 1 No. 99, 9F-12C Xizhi District 221001 New Taipei City Taiwan
Tel	+1 512 538 1995	+886 932 219 444
Email	info@azoteq.com	info@azoteq.com

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