# IQS624 DATASHEET

Combination sensor including: Hall-effect rotation sensing, along with dual-channel capacitive proximity/touch sensing, or single-channel inductive sensing.

The IQS624 ProxFusion® IC is a multifunctional capacitive and Hall-effect sensor designed for applications where any or all the technologies may be required. The two Hall-effect sensors calculate the angle of a magnet rotating parallel with the sensor. The sensor is fully I²C compatible and on-chip calculations enable the IC to stream the current angle of the magnet without extra calculations.

## Features

- Hall effect angle sensor:
  - On-chip Hall plates
  - 360° Absolute Output
  - 1° Resolution*, calculated on chip
  - Relative rotation angle.
  - Detect movement and the direction of movement.
  - Raw data: can be used to calculate degrees on external processor.
  - Wide operational range
  - No external components required
- Partial auto calibration:
  - Continuous auto-calibration, compensation for wear or small displacements of the sensor or magnet.
  - Flexible gain control
  - Automatic Tuning Implementation (ATI) – Performance enhancement (10 bit).
- Capacitive sensing
  - Full auto-tuning with adjustable sensitivity
  - 2pF to 200pF external capacitive load capability
- Inductive sensing
  - Only external sense coil required (PCB trace)
- Multiple integrated UI
  - Proximity / Touch
  - Proximity wake-up
  - Event mode
  - Wake Hall sensing on proximity
- Minimal external components
- Standard I²C interface
- Optional RDY indication for event mode operation
- Low power consumption:
  - 240uA (100Hz response, Hall),
  - 55uA (100Hz response, capacitive),
  - 65uA (20Hz response, Hall)
  - 15uA (20Hz response, capacitive)
  - 5uA (5Hz response, capacitive)
- Supply Voltage: 2.0V to 3.6V**


**DFN10** **WLCSP-9**

Representations only, not actual markings

*Optimal conditions

**5V solution available on demand.

## Applications

- Anemometer
- Dial or Selector knob
- Mouse wheel
- Measuring wheel
- Digital angle gauge
- Speedometer for bicycle

| Available Packages | | |
|---|---|---|
| TA | DFN(3x3)-10 | WLCSP-9 |
| -20°C to 85°C | IQS624-xzyy[1] | IQS624-32yy |

[1]All versions

## Contents

## List of abbreviations

PXS – ProxSense®

ATI – Automatic Tuning Implementation

LTA – Long term average

Thr – Threshold

UI – User interface

AC – Alternating current

DSP – Digital signal processing

RX – Receiving electrode

TX – Transmitting electrode

CS – Sampling capacitor

C – Capacitive

NP – Normal power

LP – Low power

ULP – Ultra low power

ACK – $I^2C$ Acknowledge condition

NACK – $I^2C$ Not Acknowledge condition

FG – Floating gate

# 1 Introduction

## 1.1 ProxFusion®

The ProxFusion® sensor series provide all the proven ProxSense® engine capabilities with additional sensors types. A combined sensor solution is available within a single platform.

## 1.2 Packaging and Pin-Out

### 1.2.1 DFN(3x3)-10

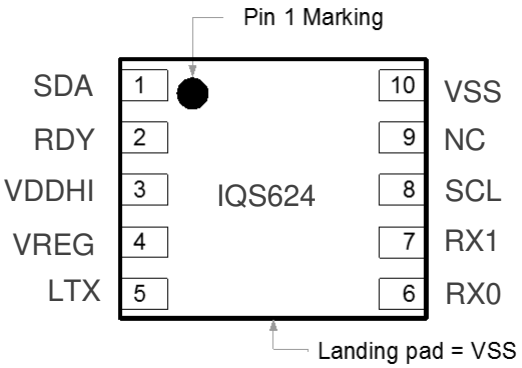



Figure 1.1 Pin out of IQS624 DFN (3X3)-10 package.

Table 1.1 IQS624 Pin-out

| IQS624 Pin-out | | | |
|---|---|---|---|
| **Pin** | **Name** | **Type** | **Function** |
| **1** | SDA | Digital Input / Output | I²C: SDA Output |
| **2** | RDY | Digital Output | I²C: RDY Output |
| **3** | VDDHI | Supply Input | Supply Voltage Input |
| **4** | VREG | Regulator Output | Internal Regulator Pin |
| **5** | LTX | Analogue | Transmit Electrode 1 |
| **6** | CRX0 | Analogue | Sense Electrode 0 |
| **7** | CRX1 | Analogue | Sense Electrode 1 |
| **8** | SCL | Digital Input / Output | I²C: SCL Output |
| **9** | NC | Not connect | Not connect |
| **10** | VSS | Supply Input | Ground Reference |

### 1.2.2 WLCSP-9

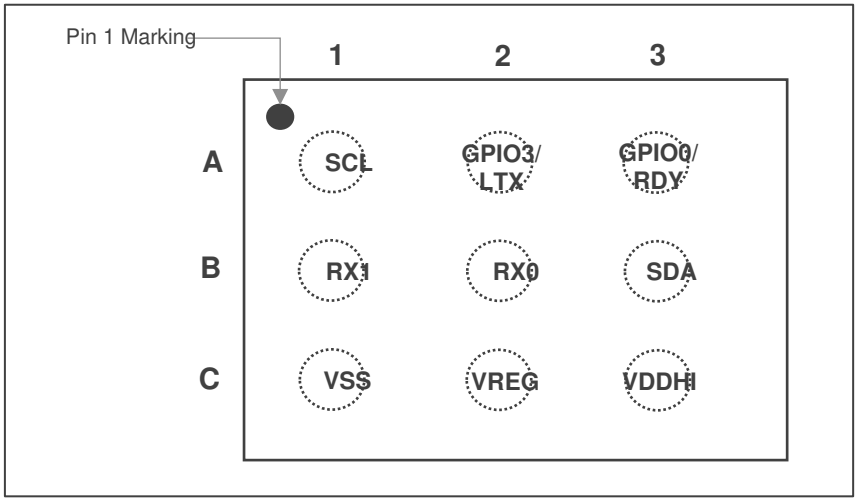



Figure 1.2 IQS624 pin-out (WLCSP-9 package top view; markings may differ)

Table 1.2 WLCSP-9 pin-out description

**IQS620A in WLCSP-9**

| Pin | Name | Type | Function |
|---|---|---|---|
| A1 | SCL | Digital input / output | **SCL** ($I^2C$ Clock signal) |
| A2 | GPIO3 / LTX | Digital output / Analogue transmitter electrode | Connect to inductive sensor's transmitting coil |
| A3 | GPIO0 / RDY | Digital output Open drain active low logic | **RDY** ($I^2C$ Ready interrupt signal) |
| B1 | RX1 | Analogue receiving electrode | Sense Electrode 1 |
| B2 | RX0 | Analogue receiving electrode | Sense Electrode 0 |
| B3 | SDA | Digital input / output | **SDA** ($I^2C$ Data signal) |
| C1 | VSS | Supply input | Common ground reference |
| C2 | VREG | Voltage regulator output | Regulates the system's internal voltage Requires external capacitors to ground |
| C3 | VDDHI | Supply input | Supply Voltage Input |

## 1.3 Reference schematic

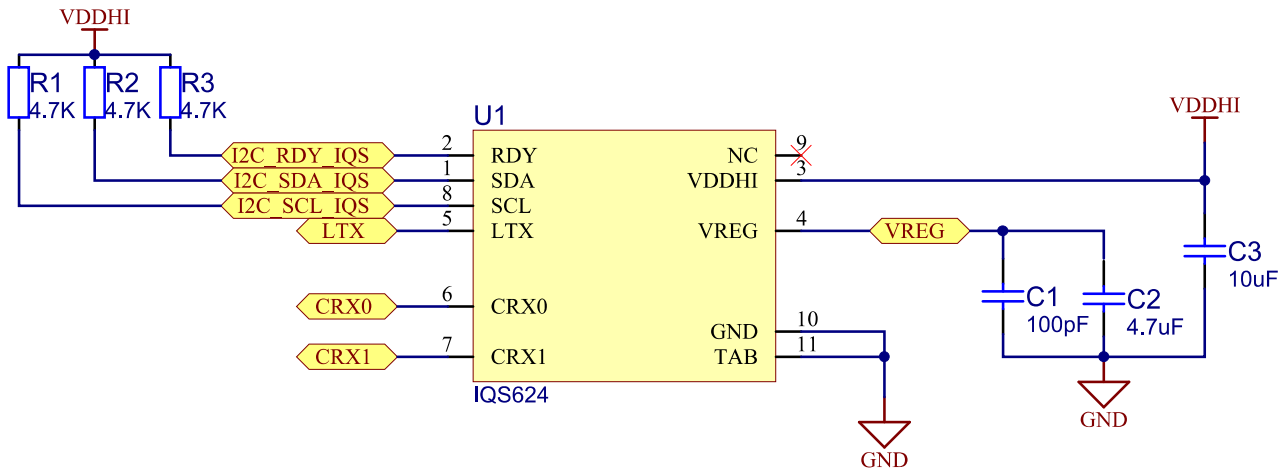



Figure 1.3 IQS624 reference schematic

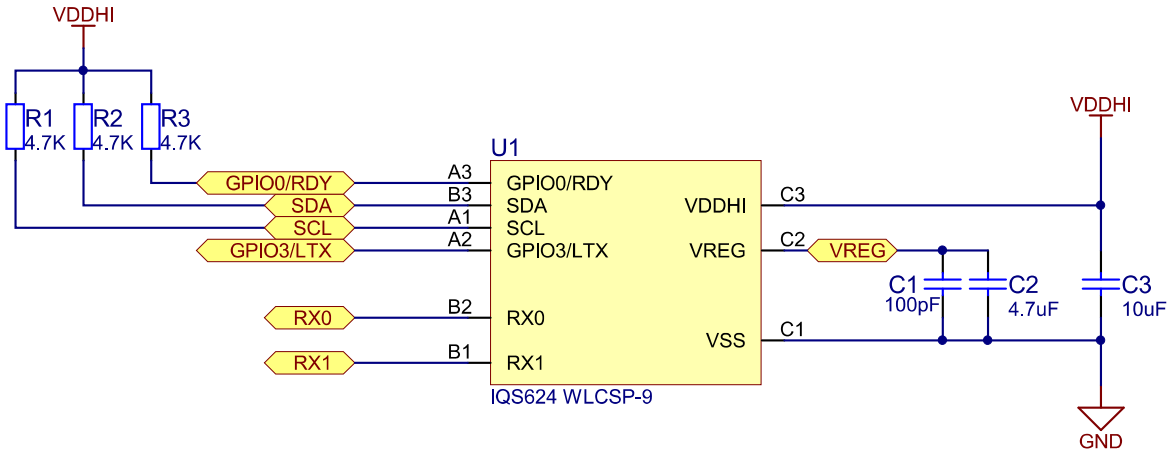



Figure 1.4 IQS624 WLCSP-9 reference schematic

## 1.4 Sensor channel combinations

The table below summarizes the IQS624's sensor and channel associations.

Table 1.3 Sensor - channel allocation

| Sensor type | CH0 | CH1 | CH2 | CH3 | CH4 | CH5 |
|---|---|---|---|---|---|---|
| **Discreet Self Capacitive** | ○ | ○ | | | | |
| **Hall effect rotary UI** | | | • 1st plate Positive | • 1st plate Negative | • 2nd plate Positive | • 2nd plate Negative |
| **Mutual Inductive** | ○ | ○ | | | | |

Key:

- ○ Optional implementation
- • Fixed use for UI

## 1.5 ProxFusion® Sensitivity

The measurement circuitry uses a temperature stable internal sample capacitor ($C_S$) and internal regulated voltage ($V_{REG}$). Internal regulation provides for more accurate measurements over temperature variation. The size of the sample capacitor can be decreased to increase sensitivity on the capacitive channels of the IQS624.

$$Sensitivity \propto \frac{1}{C_s}$$

The Automatic Tuning Implementation (ATI) is a sophisticated technology implemented on the ProxFusion® series devices. It allows for optimal performance of the devices for a wide range of sense electrode capacitances, without modification or addition of external components. The ATI functionality ensures that sensor sensitivity is not affected by external influences such as temperate, parasitic capacitance and ground reference changes.

The ATI process adjusts three values (Coarse multiplier, Fine multiplier, Compensation) using two parameters (ATI base and ATI target) as inputs. A 10-bit compensation value ensures that an accurate target is reached. The base value influences the overall sensitivity of the channel and establishes a base count from where the ATI algorithm starts adding compensation. A rough estimation of sensitivity can be calculated as:

$$Sensitivity \propto \frac{Target}{Base}$$

As seen from this equation, the sensitivity can be increased by either increasing the Target value or decreasing the Base value. A lower base value will typically result in lower multipliers and more compensation would be required. It should, however, be noted that a higher sensitivity will yield a higher noise susceptibility. Refer to Appendix B and Appendix C for more information on Hall ATI.

# 2 Capacitive sensing

## 2.1 Introduction

Building on the previous successes from the ProxSense® range of capacitive sensors, the same fundamental sensor engine has been implemented in the ProxFusion® series.

## 2.2 Channel specifications

The IQS624 provides a maximum of 2 channels available to be configured for capacitive sensing. Each channel can be setup separately using the channel's associated settings registers.

Table 2.1 Capacitive sensing - channel allocation

| Sensor type | CH0 | CH1 | CH2 | CH3 | CH4 | CH5 |
|---|---|---|---|---|---|---|
| **Discreet Self Capacitive** | ○ | ○ | | | | |

Key:

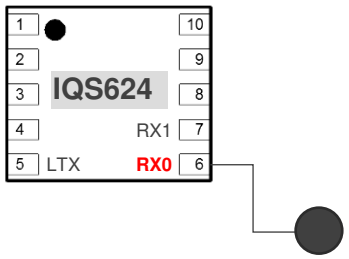
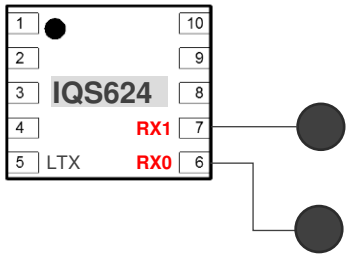
Optional implementation

- ○ Optional implementation
- • Fixed use for UI

## 2.3 Hardware configuration

In the table below are two options of configuring sensing (Rx) electrodes.

Table 2.2 Capacitive hardware description

| | Self-capacitive configuration |
|---|---|
| 1 button |  |
| 2 buttons |  |

## 2.4 Register configuration

### 2.4.1 Registers to configure for the capacitive sensing:

Table 2.3 Capacitive sensing settings registers

| Address | Name | Description | Recommended setting |
|---|---|---|---|
| 0x40, 0x41 | Ch0/Ch1 ProxFusion Settings 0 | Sensor mode and configuration of each channel. | Sensor mode should be set to capacitive mode<br>An appropriate RX should be chosen and no TX |
| 0x42 | Ch0&Ch1 ProxFusion Settings 1 | Global settings for the ProxFusion sensors | None |
| 0x43, 0x44 | Ch0/Ch1 ProxFusion Settings 2 | ATI settings for ProxFusion sensors | ATI target should be more than ATI base to achieve an ATI |
| 0x45 | Ch0&Ch1 ProxFusion Settings 3 | Additional Global settings for ProxFusion sensors | AC filter should be enabled |
| 0x50, 0x52 | Proximity threshold | Proximity Threshold for UI | Preferably more than touch threshold |
| 0x51, 0x53 | Touch threshold | Touch Threshold for UI | None |

### 2.4.2 Proximity Thresholds

A proximity threshold for both channels can be selected for the application, to obtain the desired proximity trigger level. The proximity threshold is selectable between 1 (most sensitive) and 255 (least sensitive) counts. These threshold values (i.e. 1-255) are specified in Counts (CS) in the

Ch0 Proximity threshold (0x50) and Ch1 Proximity threshold (0x51) registers for the discreet button UI.

### 2.4.3 Touch Thresholds

A touch threshold for each channel can be selected by the designer to obtain the desired touch sensitivity and is selectable between 1/256 (most sensitive) to 255/256 (least sensitive). The touch threshold is calculated as a fraction of the Long-Term Average (LTA) given by,

$$T_{THR} = {}^{x}/_{256} \times LTA$$

With lower target values (therefore lower LTA's) the touch threshold will be lower and vice versa.

Individual touch thresholds can be set for each channel, by writing to the Ch0 Touch threshold (0x51) and Ch1 Touch threshold (0x53) for the discreet button UI.

### 2.4.4 Example code:

Example code for an Arduino Uno can be downloaded at:

www.azoteq.com//images/stories/software/IQS62x_Demo.zip

## 2.5 Sensor data output and flags

The following register should be monitored by the master to detect capacitive sensor output.

a) The **Proximity/Touch UI Flags (0x12)** provide more detail regarding the outputs. A proximity and touch output bit for each channel 0 and 1 is provided in the Proximity/Touch UI Flags register.

| Proximity/Touch UI Flags (0x12) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | **5** | **4** | 3 | 2 | **1** | **0** |
| Data Access | Read | | | | | | | |
| Name | | | **Chan 1 Touch out** | **Chan 0 touch out** | | | **Chan 1 proximity out** | **Chan 0 proximity out** |

# 3 Inductive sensing

## 3.1 Introduction to inductive sensing

The IQS624 provides inductive sensing capabilities to detect the presence of metal/metal-type objects.

## 3.2 Channel specifications

The IQS624 requires 3 sensing lines for mutual inductive sensing.

A single inductance user interface is available.

a) Discreet proximity/touch UI (always enabled)

Table 3.1 Mutual inductive sensor – channel allocation

| Mode | CH0 | CH1 | CH2 | CH3 | CH4 | CH5 |
|---|---|---|---|---|---|---|
| **Mutual inductive** | ○ | ○ | | | | |

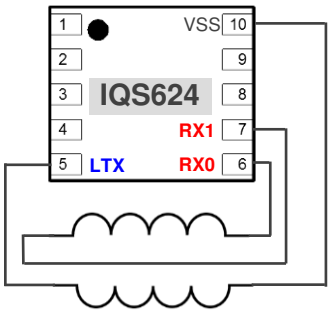
Key:

○ - Optional implementation
• - Fixed use for UI

## 3.3 Hardware configuration

Rudimentary hardware configurations (to be completed).

Table 3.2 Mutual inductive hardware description

| | **Mutual inductive** |
|---|---|
| **Mutual inductance** |  |

## 3.4 Register configuration

Table 3.3 Inductive sensing settings registers.

| Address | Name | Description | Recommended setting |
|---|---|---|---|
| 0x40, 0x41 | Ch0/Ch1 ProxFusion Settings 0 | Sensor mode and configuration of each channel. | Sensor mode should be set to Inductive mode<br>Choose one channel and deactivate the other channel<br>Enable both RX for the activated channel |
| 0x42 | Ch0&Ch1 ProxFusion Settings 1 | Global settings for the ProxFusion sensors | CS divider should be enabled |
| 0x43, 0x44 | Ch0/Ch1 ProxFusion Settings 2 | ATI settings for ProxFusion sensors | ATI target should be more than ATI base to achieve an ATI |
| 0x45 | Ch0&Ch1 ProxFusion Settings 3 | Additional Global settings for ProxFusion sensors | None |
| 0x50, 0x52 | Proximity threshold | Proximity Threshold for UI | Less than touch threshold |
| 0x51, 0x53 | Touch threshold | Touch Threshold for UI | None |

### 3.4.2 Example code:

Example code for an Arduino Uno can be downloaded at:

www.azoteq.com//images/stories/software/IQS62x_Demo.zip

## 3.5 Sensor data output and flags

The following register should be monitored by the master to detect capacitive sensor output.

a) The **Proximity/Touch UI Flags (0x12)** provide more detail regarding the outputs. A proximity and touch output bit for each channel 0 and 1 is provided in the Proximity/Touch UI Flags register.

| Proximity/Touch UI Flags (0x12) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | **5** | **4** | 3 | 2 | **1** | **0** |
| Data Access | Read | | | | | | | |
| Name | | | **Chan 1 Touch out** | **Chan 0 touch out** | | | **Chan 1 proximity out** | **Chan 0 proximity out** |

# 4 Hall-effect sensing

## 4.1 Introduction to Hall-effect sensing

The IQS624 has two internal Hall-effect sensing plates (on die). No external sensing hardware is required for Hall-effect sensing.

The Hall-effect sensor measures the generated voltage difference across the plate, which can be modelled as a Wheatstone bridge. The voltage difference is converted to a current using an operational amplifier in order to be measured by the same ProxSense® sensor engine.

Advanced digital signal processing is performed to provide sensible output data.

- Calculates absolute position in degrees.
- Auto calibration attempts to linearize degrees output on the fly
- Differential Hall-Effect sensing:
    - Removes common mode disturbances

Refer to the Errata for correct setup of the IC.

## 4.2 Channel specifications

Channels 2 to 5 are dedicated to Hall-effect sensing. Channel 2 & 4 performs the positive direction measurements while channel 3 & 5 handle all measurements in the negative direction. Differential data is obtained from these four channels. This differential data is used as input data to calculate the output angle of the Hall-effect rotation UI. Channel 2 & 3 is used for the one plate and channel 4 & 5 for the second plate.

Table 4.1 Hall-effect sensor – channel allocation

| Mode | CH0 | CH1 | CH2 | CH3 | CH4 | CH5 |
|---|---|---|---|---|---|---|
| **Hall rotary UI** | | | ● 1st plate Positive | ● 1st plate Negative | ● 2nd plate Positive | ● 2nd plate Negative |

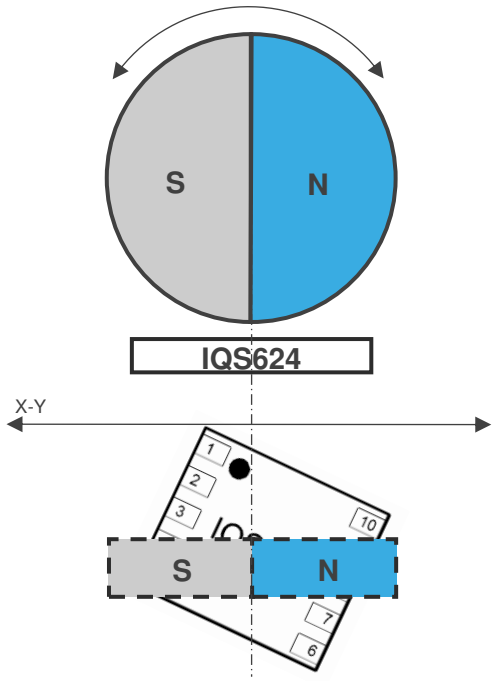
Key:

○ - Optional implementation

● - Fixed use for UI

## 4.3 Hardware configuration

Rudimentary hardware configurations. For more detail and alternative placement options, refer to Appendix A.

| | Diametrically polarized magnet (rotational purposes) |
|---|---|
| **Hall Rotation UI** |  |

## 4.4 Register configuration

For more detail on the setup of the IQS624 refer to Appendix B.

Table 4.2 Table 4-1 Hall sensing settings registers

| Address | Name | Description | Recommended setting |
|---|---|---|---|
| 0x70 | Hall Rotation UI Settings | Hall wheel UI settings | Hall UI should be enabled for degree output; enable Auto Calibration |
| 0x71 | Hall sensor settings | Auto ATI and charge frequency settings | Auto ATI should be enabled for temperature drift compensation |
| 0x72,0x73 | Hall ATI Settings[1] | Hall channels ATI settings | ATI Target should be more than base |
| 0x78 | Hall ratio Settings | Invert Direction setting for Hall UI | None |
| 0x79 | Sin(phase) constant | Sin phase calibration value | Calculate this value using the GUI or the calculations in the Appendix A |
| 0x7A | Cos(phase) constant | Cos phase calibration value | Calculate this value using the GUI or the calculations in the Appendix A |

[1] Refer to the errata and Appendix B

| | | | |
|---|---|---|---|
| 0x7B[1] | Wheel Filter Beta | Degree filter value | Adjust filter value based on the amount of noise on the degree value |
| 0x7C[1] | Wheel Wake Preload | Wheel wakeup settings | Use default values |
| 0x7D[1] | Interval UI Divider | Divider for filtered degree values | Depending on the application (should be equal or greater than 3) |
| 0x7E[1] | Wheel Offset | Wheel offset from zero position | Can be used for accurate intervals |

### 4.5 Example code:

Example code for an Arduino Uno can be downloaded at:

www.azoteq.com//images/stories/software/IQS62x_Demo.zip

For ARM mbed resources refer to:

https://os.mbed.com/components/IQS624/

### 4.6 Sensor data output and flags

a) The **Hall UI Flags (0x14) register.** Bit7 is dedicated to indicating a movement of the magnet. Bit6 indicates the direction of the movement. Bit 1 is set when the movement counts are negative and bit 0 is set when the relative angle is negative. Bit 6 can be used to determine the magnet direction. Please note that these bits will be set for small movements, therefore jitter may change the direction of movement bit.

| Hall UI Flags (0x14) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | **7** | **6** | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read | | | | | | | |
| Name | **Wheel movement** | **Movement direction** | | | | | | |

b) The **Filtered Degree Output (0x17-0x16)** [1] A 16-bit value for the filtered degrees can be read from these registers. (0-359 degrees)

| Filtered Degree Output[1] (0x17-0x16) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit Number | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read | | | | | | | | | | | | | | | |
| Name | **Degrees High Byte** | | | | | | | | **Degrees Low Byte** | | | | | | | |

Bit definitions:

- 0-360: Filtered absolute degree position of magnet

c) The **Interval Number (0x18)** [1] An 8-bit value for the current interval number can be read from this register.

[1] Only Available on IQS624-32

| Interval Number[1] (0x18) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | |
| Name | **Current Interval Number** | | | | | | | |

- Bit 7-0: Current interval number

d) The **Degree Output (0x81-0x80).** A 16-bit value for the degrees can be read from these registers. (0-360 degrees)

| Degree Output (0x81-0x80) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit Number | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | | | | | | | | | |
| Name | **Degrees High Byte** | | | | | | | | **Degrees Low Byte** | | | | | | | |

e) The **Relative Rotation Angle (0x8E).** The delta in degrees from the previous cycle to the current cycle can be read from this register. (0-180 degrees)

| Relative Rotation Angle (0x8E) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | |
| Name | **Relative degrees** | | | | | | | |

## 4.7 IQS624-32 Interval UI

The IQS624-32 offers a new on-chip interval UI specifically designed for applications with discreet mechanical intervals or reduced resolution requirements.

### 4.7.1 Interval UI Features

> Adjustable interval size (3°-180°)
> The wheel can be zeroed at startup
> Adjustable wheel offset value
> An event is generated for changes to the Interval Number Register (0x18)

### 4.7.2 Interval UI Settings Registers

| Hall Rotation UI Settings (0x70) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | |
| Name | Hall Wheel UI disable | Interval UI disable[1] | **Zero Wheel[1]** | Hall Wheel Event disable[1] | **Interval Event Disable[1]** | Auto calibration | - | Wheel wakeup |
| UI Setting | 0 | 0 | **0** | **1** | **0** | 1 | - | 0 |

Bit definitions:

- Bit 5: Zero Wheel angle[1]
  - 1: Zero angle, automatically cleared by firmware
- Bit 3: Interval UI Event disable[1]
  - 0: Event UI is enabled
  - 1: Event UI is disabled

| Interval UI Divider[1] (0x7D) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | |
| Name | Interval size in degrees | | | | | | | |
| Default | 3 | | | | | | | |

Bit definitions:

- Bit 7-0: Interval size in degrees (>= 3° and <=180°)
  - The **Interval Number (0x18)** [1] An 8-bit value for the current interval number can be read from this register.

| Wheel Offset[2] (0x7E-0x7F) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit Number | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read | | | | | | | | | | | | | | | |
| Name | Wheel Offset High Byte | | | | | | | | Wheel Offset Low Byte | | | | | | | |
| Default | 0 | | | | | | | | | | | | | | | |

Bit definitions:

[1] Only Available on IQS624-32

- 0-360: Wheel offset in degrees

### 4.7.3 Interval UI Output Register

| Interval Number[1] (0x18) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Data Access | Read/Write | | | | | | | |
| Name | Current Interval Number | | | | | | | |

- Bit 7-0: Current interval number

## 4.8 IQS624-32 Example

Figure 4.1 illustrates an example wheel with 10 intervals. The IQS624-32 can be configured to generate an event on each interval. Configure the following registers for setup:

1. Disable Hall Wheel Event and Enable Interval Event in Hall Rotation Settings (0x70)
   - Write 0x14 to register 0x70
2. Set Interval UI Divider (0x7D) to 36D (360°/36° = 10 intervals)
   - Write 0x24 to register to 0x7D
3. If required, the wheel can be zeroed at startup in Hall Rotation UI Settings (0x70)
   - Set Bit5 in 0x70
4. The interval register will increment every 36 degrees. If the wheel is zeroed using discrete mechanical intervals (Figure 4-1), half an interval should be added to the Wheel Zero Offset (0x7E-0x7F). With this offset, the interval register should increment when the wheel has moved half of the interval as shown by B in Figure 4.2.
5. Enable Event Mode in General System Settings (0xD0)
   - Set Bit5 in 0xD0
6. The interval can be read from the Interval Number (0x18) register.

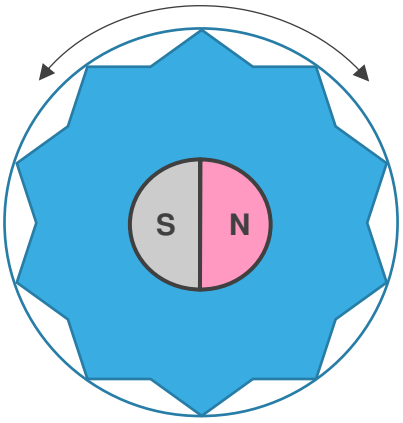



Figure 4.1 Discrete Mechanical Intervals

A 1-degree hysteresis is applied in the direction of rotation, resulting in two degrees of hysteresis at the interval change. This reduces the influence of jitter. In Figure 4.2, the interval will increase when

point C is reached and will only decrease when the wheel moves back to point A. In this example A = 35°; B = 36°; C = 37°.

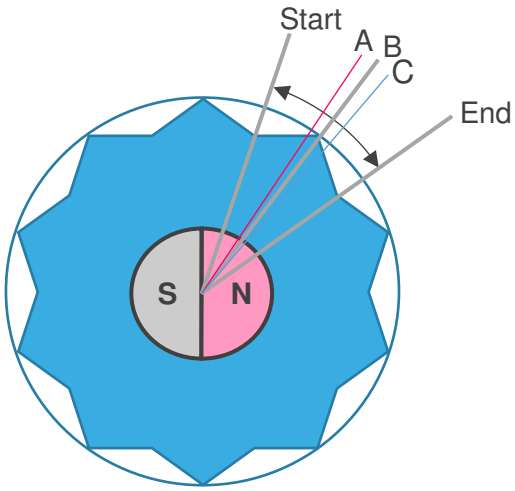



Figure 4.2 Interval UI Hysteresis

## 4.9 IQS624-32 Wheel Wake Preload (0x7C)

This register was added to improve performance. This register is compared to the Movement counter/timer (0x8F) register. The wheel will wake up if the counter value reaches the counter threshold value before the timer reaches 0. The timer in register 0x8F will count down from the value set in the **Wheel Wake Timer Preload.** The **Counter Threshold** is the amount of degrees the wheel has to move before an event is generated for movement. The wheel movement and movement direction bits in the Hall UI Flags (0x14) register also responds to this register.

The **Wheel Wake Timer Preload** can also be set to zero. In this mode the wheel will wake up if the wheel has moved the amount of degrees specified in the **Counter Threshold.** When the wheel is awake, 31 will be loaded in the **Wheel Wake Timer Preload**.

## 4.10 IQS624-32 Event Mode Options

The IQS624-32 provides three event mode options, these are:

### 4.10.1 Touch on Wheel Wakeup enabled (Bit0, 0x70)

> The device wakes up from the low-power modes when there is a touch on Ch0.
> In normal power mode events are only generated when there is a touch on Ch0. Ready events will be continuously generated as long as there is a touch on Ch0. If Touch on Wheel is enabled Interval and Hall Wheel Events are ignored.

### 4.10.2 Interval Event (Bit3, 0x70)

> The device wakes up from low-power modes when the wheel increment or decrement the interval register.
> Ready events are generated in normal power mode when the interval changes. If Interval Events and Hall Wheel Events (below) are enabled the IC will respond to Hall Wheel Events.

### 4.10.3 Hall Wheel Event (Bit4, 0x70)

> The device wakes up based on the conditions described in Section 4.7. The wheel will wake up if the counter value reaches the counter threshold value before the timer reaches 0.

> Events are generated on the same condition when the device is in low power mode. If Hall Wheel Events and Interval Events are enabled the IC will respond to Hall Wheel Events.

The device can also be set to **Stream in Normal Power (Bit5, 0xD9).** With this bit set the device will wake up from either of the selected modes above. Events will be generated based on the Normal Power Report Rate during Normal Power mode. The device will stop streaming when low-power mode is entered.

Table 4.3 : Hall Rotation UI Settings

| | **Hall Rotation UI Settings (0x70)** |
|---|---|
| **Touch on Wheel Wakeup** | 0x1D |
| **Interval Event** | 0x14 |
| **Hall Wheel Event** | 0x0C |

If all these modes are disabled, there will be no events generated for wheel movements.

# 5 Device clock, power management and mode operation

## 5.1 Device main oscillator

The IQS624 has a **16MHz** main oscillator (default enabled) to clock all system functionality.

An option exists to reduce the main oscillator to 8MHz. This will result in charge transfers to be slower by half of the default implementations.

To set this option:

- As a software setting – Set the General System Settings (0xD0): bit4 = 1, via an I²C command.
- As a permanent setting – Set the OTP option in FG Bank 0: bit2 = 1, using Azoteq USBProg program.

The ProxFusion® channels charges at half of the main oscillator frequency. Therefore the frequency multiplier selected in Ch0&1 ProxFusion Settings 1 (0x42; bit 4-5) and Hall sensor settings (0x71; bit 4-5) is multiplied by half of the main oscillator frequency.

## 5.2 Device modes

The IQS624 supports the following modes of operation;

- **Normal mode** (Fixed report rate)
- **Low Power mode** (Reduced report rate, no UI execution)
- **Ultra-Low Power mode** (Only channel 0 is sensed for a prox)
- **Halt Mode** (Suspended/disabled)
- *Note: Auto modes must be disabled to enter or exit halt mode.*

The device will automatically switch between the different operating modes by default. However, this Auto mode feature may be disabled by setting the Disable Auto Modes bit (Power Mode Settings 0xD2; bit 5) to confine device operation to a specific power mode. The Power Mode bits (Power Mode Settings 0xD2; bit 3-4) can then be used to specify the desired mode of operation.

### 5.2.1 Normal mode

Normal mode is the fully active sensing mode to function at a fixed report rate specified in the Normal Mode report rate (0xD3) register. This 8-bit value is adjustable from 0ms – 255ms in intervals of 1ms.

### 5.2.2 Low power mode

Low power mode is a reduced sensing mode where all channels are sensed but no UI code are executed. The sample rate can be specified in the Low Power Mode report rate (0xD4) register. The 8-bit value is adjustable from 0ms – 255ms in intervals of 1ms. Reduced report rates also reduce the current consumed by the sensor.

### 5.2.3 Ultra-low power mode

Ultra-low power mode is a reduced sensing mode where only channel 0 is sensed and no other channels or UI code are executed. Set the Enable ULP Mode bit (Power Mode Settings 0xD2; bit 6) to enable use of the ultra-low power mode. The sample rate can be specified in the Low Power Mode report rate (0xD5) register. The 8-bit value is adjustable from 0ms – 4sec in intervals of 16ms.

When in Ultra-low power mode the IQS624 can be configured to update all channels at a specific rate defined in Power Mode Settings (0xD2) register. A flag will be set in the System flags (0x10; bit 0) register when a normal power update is performed. Wake up will occur on proximity detection on channel 0. Ultra-low power mode will not function properly if channel 0 is not enabled.

### 5.2.4 Halt mode

Halt mode will suspend all sensing and will place the device in a dormant or sleep state. The device requires an I²C command from a master to explicitly change the power mode out of the halt state before any sensor functionality can continue.

### 5.2.5 Mode time

The mode time is specified in the Auto Mode Timer (0xD6) register. The 8-bit value is adjustable from 0ms – 2 min in intervals of 500ms.

### 5.2.6 Streaming and event mode:

Streaming mode is the default. Event mode is enabled by setting bit 5 in the General System Settings (0xD0) register.

#### Streaming mode

The ready is triggered every cycle and per the report rate.

#### Event mode

The ready is triggered only when an event has occurred.

The events which trigger the ready can be configured to:

- Hall wheel movement (If the hall UI is enabled)
- Touch or proximity events on channel 0 or 1
- Interval Event1

Note: Both these events have built in hysteresis which filters out very slow changes.

[1] Only available on IQS624-32

# 6 Report rates

## 6.1 Normal Power Maximum Report rate

*Note: Assuming normal mode report rate set to 0 (maximum speed) and Auto Power Modes turned off.*

| Hall UI State | Channels | Register Address | Bytes | Functionality[1] | Report Rate[2] |
|---|---|---|---|---|---|
| **On** | 2 x Prox<br>4 x Hall | 0x02 (PXS Flags)<br>0x80-0x81 (Degrees) | 3 | On-chip calculation of rotation angle and prox channels. | 4.87 ms |
| **On** | 4 x Hall | 0x80-0x81 (Degrees) | 2 | On-chip calculation of rotation angle. | 3.29 ms |
| **Off** | 2 x Prox<br>4 x Hall | 0x02 (PXS Flags)<br>0x24-0x2B (Counts) | 9 | Off-chip calculation of rotation angle and on-chip prox channels. | 3.93 ms |
| **Off** | 4 x Hall | 0x24-0x2B (Counts) | 8 | Off-chip calculation of rotation angle. | 2.94 ms |
| **Off** | 1 x Hall<br>2 x Prox | 0x24 (CH2 Counts)<br>0x02 (PXS Flags) | 3 | Off-chip RPM-calculation and 2 Prox channels on-chip | 2.25 ms |
| **Off** | 1 x Hall<br>1 x Prox | 0x24 (CH2 Counts)<br>0x02 (PXS Flags) | 3 | Off-chip RPM-calculation and 1 Prox channels on-chip | 1.63 ms |
| **Off** | 1 x Hall | 0x24 (CH2 Counts) | 2 | Off-chip RPM-calculation | 0.82 ms |

- Report rates are not necessarily an accurate indication of maximum observable rotation rate. On-chip calculations are only accurate at low rotation rates.

(1) Contact Azoteq for further information on functionality.
(2) These values were calculated by design and not by testing.

# 7 System reset

The IQS624 device monitor's system resets and events.

a) Every device power-on and reset event will set the Show Reset bit in the System Flags (0x10; bit 7) register and the master should explicitly clear this bit by setting the Ack Reset bit in the General System Settings (0xD0; bit 6) register.

b) The system events will also be indicated with the Event bit in the System Flags (0x10; bit 1) register if any system event occur such as a reset. This event will continuously trigger until the reset has been acknowledged.

# 8 Communication

The **IQS624** device interfaces to a master controller via a 3-wire (SDA, SCL and RDY) serial interface bus that is I²C™ compatible with a maximum communication speed of 400 kHz. The communications interface of the IQS624 supports the following:

- Streaming data as well as event mode.
- The master may address the device at any time. If the IQS624 is not in a communication window, the device returns an ACK after which clock stretching is induced until a communication window is entered. Additional communication checks are included in the main loop in order to reduce the average clock stretching time.
- The provided interrupt line (RDY) is push-pull active low on IQS624-3001 and open-drain active low on IQS624-32. The RDY indicates a communication window.

## 8.1 Control Byte

The Control byte indicates the 7-bit device address (44H default) and the Read/Write indicator bit. The structure of the control byte is shown in Figure 8.1.

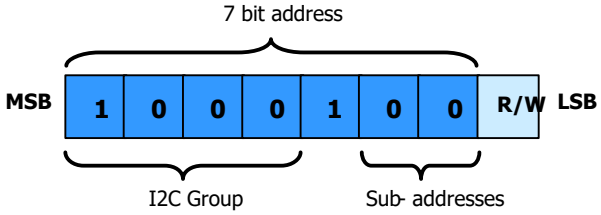



Figure 8.1 IQS624 Control Byte

The I²C device has a 7 bit Slave Address (default 0x44H) in the control byte. To confirm the address, the software compares the received address with the device address. Sub-address values can be set by OTP programming options.

## 8.2 I2C Read

To read from the device a *current address read* can be performed. This assumes that the address-command is already setup as desired.

Current Address Read

| Start | Control Byte | | Data n | | Data n+1 | | Stop |
|---|---|---|---|---|---|---|---|
| S | | ACK | | ACK | | NACK | S |

Figure 8.2 Current Address Read

If the address-command must first be specified, then a *random read* must be performed. In this case a WRITE is initially performed to setup the address-command, and then a repeated start is used to initiate the READ section.

Random Read

| Start | Control Byte | | Address-command | | Start | Control Byte | | Data n | | Stop |
|---|---|---|---|---|---|---|---|---|---|---|
| S | Adr + WRITE | ACK | | ACK | S | Adr + READ | ACK | | NACK | S |

Figure 8.3 Random Read

## 8.3 I2C Write

To write settings to the device a *Data Write* is performed. Here the Address-Command is always required, followed by the relevant data bytes to write to the device.

DATA WRITE

| Start | Control Byte | | Address-Command | | Data n | | Data n+1 | | Stop |
|---|---|---|---|---|---|---|---|---|---|
| S | Adr + WRITE | ACK | | ACK | | ACK | | ACK | S |

Figure 8.4 I²C Write

## 8.4 End of Communication Session / Window

Similar to other Azoteq I²C devices, to end the I²C communication session, a STOP command is given. When sending numerous read and write commands in one communication cycle, a repeated start command must be used to stack them together (since a STOP will jump out of the communication window, which is not desired).

The STOP will then end the communication, and the **IQS624** will return to process a new set of data. Once this is obtained, the communication window will again become available (RDY set LOW).

## 8.5 Stop-bit disable option(IQS624-32)

The IQS624-32 part offer:

- an additional I²C settings register (0xD9) specifically added for stop-bit disable functionality,
- as well as a RDY timeout period register (0xD8) in order to set the required timeout period for termination of any communication windows (RDY = Low) if no I²C activity is present on SDA and SCL pins.

Customers using an MCU with a binary serial-encoder peripheral which is not fully I²C compatible (but provide some crude serial communication functions) can use this option to configure the IQS624-32 so that any auto generated stop command from the serial peripheral can be ignored by the IQS624-32 I²C hardware. This will restrict the IQS624-32 from immediately exiting a communication window during event mode (reduced communication only for events) until all required communication has been completed and a stop command can correctly be transmitted. Please refer to the figures below for serial data transmission examples.

Please note:

1. Stop-bit disable and enable must be performed at the beginning and end of a communication window. The first and last I²C register to be written to ensure no unwanted communication window termination.
2. Leaving the Stop-bit disabled will result in successful reading of registers but will not execute any commands written over I2C in a communication window being terminated after a RDY timeout and with no IQS recognised stop command.
3. The default RDY timeout period for IQS624-32 is purposefully long (10.24ms) for slow responding MCU hardware architectures. Please set this register according to your requirements/preference.
4. These options are only available on IQS624-32 parts and not for IQS624-3001.

**Stop-bit Disable**

| Communication window open | Start | Control byte | | Address-Command | | Disable stop-bit | | Ignored stop | Continue with reads / writes |
|---|---|---|---|---|---|---|---|---|---|
| **RDY = ↓LOW** | **S** | **Addr + WRITE** | **ACK** | **0xD9** | **ACK** | **0x81** | **ACK** | **S** | **…** |

Figure 8.5 I²C Stop-bit Disable

**Stop-bit Enable**

| Reads / Writes Finished | Start | Control byte | | Address-Command | | Enable stop-bit | | Stop | Communication window closed |
|---|---|---|---|---|---|---|---|---|---|
| **…** | **S** | **Addr + WRITE** | **ACK** | **0xD9** | **ACK** | **0x01** | **ACK** | **S** | **RDY = ↑HIGH** |

Figure 8.6 I²C Stop-bit Enable

## 8.6 Device address and sub-addresses

The default device address is **0x44 = DEFAULT_ADDR**.

Alternative sub-address options are definable in the following one-time programmable bits: **OTP Bank0 (bit3; 0; bit1; bit0) = SUB_ADDR_0** to **SUB_ADDR_7**

a) Default address: **0x44 = DEFAULT_ADDR OR SUB_ADDR_0**
b) Sub-address: **0x45 = DEFAULT_ADDR OR SUB_ADDR_1**
c) Sub-address: **0x46 = DEFAULT_ADDR OR SUB_ADDR_2**
d) Sub-address: **0x47 = DEFAULT_ADDR OR SUB_ADDR_3**
e) Sub-address: **0x4C = DEFAULT_ADDR OR SUB_ADDR_4**
f) Sub-address: **0x4D = DEFAULT_ADDR OR SUB_ADDR_5**
g) Sub-address: **0x4E = DEFAULT_ADDR OR SUB_ADDR_6**
h) Sub-address: **0x4F = DEFAULT_ADDR OR SUB_ADDR_7**

## 8.7 Additional OTP options

All one-time-programmable device options are located in FG bank 0.

| Floating Gate Bank0 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Name | - | Comms ATI | - | - | Sub address 2 | 8MHz | Sub address 0-1 | |
| Default | - | 0 | - | 0 | 0 | 0 | 0 | 0 |

Bit definitions:

- Bit 6: Comms mode during ATI
  - 0: No streaming events are generated during ATI
  - 1: Comms continue as setup regardless of ATI state.
- Bit 2: Main Clock frequency selection
  - 0: Run FOSC at 16MHz
  - 1: Run FOSC at 8MHz

- Bit 0,1,3: I2C sub-address
  - I2C address = 0x44

All calibration data are located in FG bank 3 for the latest IQS624-3001 and all IQS624-32 IC's.

| Floating Gate Bank3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bit Number | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Name | - | | | | Hall Plate Calibration Data | | | |
| Default | - | | | | 15-1 | | | |

Bit definitions:

- Bit 3-0: Hall Plate Calibration Data
  - 15-1: The calibration bin of the IC
  - 0: The IC is not calibrated (Before June 2018)

Please refer to

Appendix B: Magnet calibration for information regarding hall plate calibration.

## 8.8 Request Communication Window

The master or host MCU has the capability to request a communication window at any time, by writing the device address to the IQS624. The communication window will open directly following the current conversion cycle.

## 8.9 I²C Specific Commands

### 8.9.1 Show Reset

After start-up, and after every reset event, the "Show Reset" flag will be set in the System Flags register (0x10H; bit 7).

The "Show Reset" bit can be read to determine whether a reset has occurred on the device (it is recommended to be continuously monitored). This bit will be set '1' after a reset.

The "Show Reset" flag will be cleared (set to '0') by writing a '1' into the "Ack reset" bit in the General system settings register (0xD0; bit 6) . A reset will typically take place if a timeout during communication occurs.

### 8.9.2 I2C Timeout

If no communication is initiated from the master/host MCU within the first $t_{COMMS}$ ($t_{COMMS}$ = 2.038 ms default) of the RDY line indicating that data is available (i.e. RDY = low), the device will resume with the next cycle of charge transfers and the data from the previous conversions will be lost. The RDY timeout period register (0xD8) can be adjusted on IQS624-32. There is also a timeout ($t_{I2C}$) that cannot be disabled, for when communication has started but not been completed, for example when the bus is being held by another device ($t_{I2C}$ = 33 ms).

## 8.10 Recommended communication and runtime flow diagram

The following is a basic master program flow diagram to communicate and handle the device. It addresses possible device events such as output events, ATI and system events (resets).

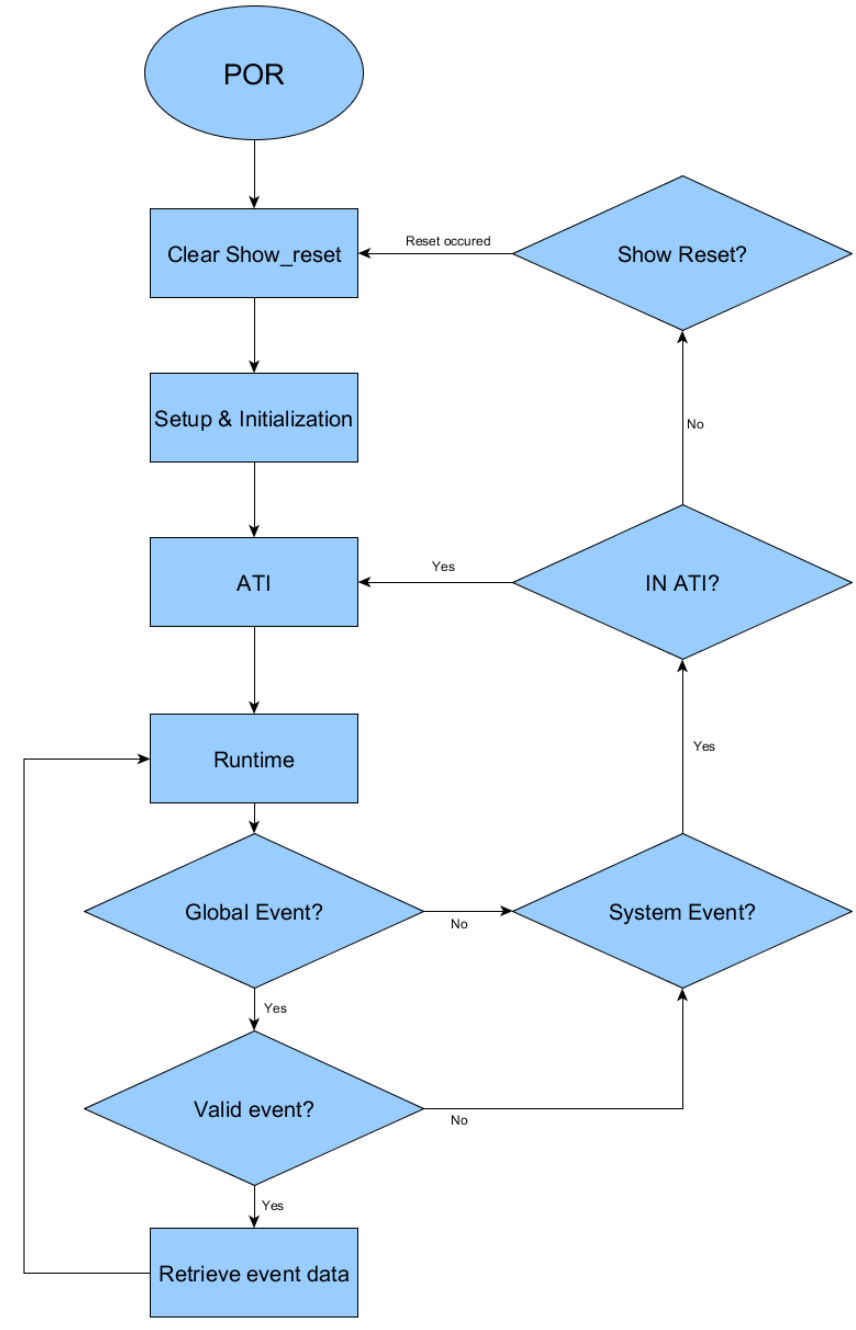



Figure 8.7 Figure 8-1 Master command structure and runtime event handling flow diagram

It is recommended that the master verifies the status of the System Flags (0x10) bits to identify events and resets. Detecting either one of these should prompt the master to the next steps of handling the IQS624.

Streaming mode communication is used for detail sensor evaluation during prototyping and/or development phases. Event mode communication is recommended for runtime use of the IQS624.

# 9 IQS624 Memory map

Table 9.1 IQS624 Register map

| Register Address | Group | Register Name |
|---|---|---|
| 0x00 | Device Information | Product Number |
| 0x01 | | Software Number |
| 0x02 | | Hardware Number |
| 0x10 | Device Specific Data | System Flags |
| 0x12 | | Proximity/Touch UI Flags |
| 0x14 | | HALL UI Flags |
| 0x15 | | Hall Ratio Flags |
| 0x16 (IQS624-32) | | Filtered Degree Output (Low byte) |
| 0x17 (IQS624-32) | | Filtered Degree Output (High byte) |
| 0x18 (IQS624-32) | | Interval Number Output |
| 0x20 | Count Data | CH0 CS Low |
| 0x21 | | CH0 CS High |
| 0x22 | | CH1 CS Low |
| 0x23 | | CH1 CS High |
| 0x24 | | CH2 CS Low |
| 0x25 | | CH2 CS High |
| 0x26 | | CH3 CS Low |
| 0x27 | | CH3 CS High |
| 0x28 | | CH4 CS Low |
| 0x29 | | CH4 CS High |
| 0x2A | | CH5 CS Low |
| 0x2B | | CH5 CS High |
| 0x30 | | CH0 LTA Low |
| 0x31 | | CH0 LTA High |
| 0x32 | | CH1 LTA Low |
| 0x33 | | CH1 LTA High |
| 0x40 | ProxFusion sensor settings | Ch0 ProxFusion Settings 0 |
| 0x41 | | Ch1 ProxFusion Settings 0 |
| 0x42 | | Ch0&1 ProxFusion Settings 1 |
| 0x43 | | Ch0 ProxFusion Settings 2 |
| 0x44 | | Ch1 ProxFusion Settings 2 |
| 0x45 | | Ch0&1 ProxFusion Settings 3 |
| 0x46 | | Ch0 Compensation |
| 0x47 | | Ch1 Compensation |
| 0x48 | ProxFusion sensor settings | Ch0 Multipliers |
| 0x49 | | Ch1 Multipliers |
| 0x50 | Touch / Proximity UI settings | Ch0 Proximity threshold |
| 0x51 | | Ch0 Touch threshold |
| 0x52 | | Ch1 Proximity threshold |
| 0x53 | | Ch1 Touch threshold |
| 0x54 | | UI Halt period |
| 0x70 | | Hall Rotation UI Settings |

| | | |
|---|---|---|
| 0x71 | HALL Sensor Settings | Hall Sensor Settings |
| 0x72 | | Ch2&3 Hall ATI Settings |
| 0x73 | | Ch4&5 Hall ATI Settings |
| 0x74 | | Ch2&3 Compensation |
| 0x75 | | Ch4&5 Compensation |
| 0x76 | | Ch2&3 Multipliers |
| 0x77 | | Ch4&5 Multipliers |
| 0x78 | | Hall Ratio Settings |
| 0x79 | | Sin Constant |
| 0x7A | | Cos Constant |
| 0x7B (IQS624-32) | | Wheel Filter Beta |
| 0x7C (IQS624-32) | | Wheel Wake Preload |
| 0x7D (IQS624-32) | | Interval UI Divider |
| 0x7E (IQS624-32) | | Wheel Offset (Low byte) |
| 0x7F (IQS624-32) | | Wheel Offset (High byte) |
| 0x80 | HALL Wheel Output | Degree Output (Low byte) |
| 0x81 | | Degree Output (High byte) |
| 0x82 | | Ratio Output (Low byte) |
| 0x83 | | Ratio Output (High byte) |
| 0x84 | | Numerator of Ratio (Low byte) |
| 0x85 | | Numerator of Ratio (High byte) |
| 0x86 | | Denominator of Ratio (Low byte) |
| 0x87 | | Denominator of Ratio (High byte) |
| 0x88 | | Rotation Correction factor (Low byte) |
| 0x89 | | Rotation Correction factor (High byte) |
| 0x8A | | Max Numerator of Ratio (Low byte) |
| 0x8B | | Max Numerator of Ratio (High byte) |
| 0x8C | | Max Denominator of Ratio (Low byte) |
| 0x8D | HALL Wheel Output | Max Denominator of Ratio (High byte) |
| 0x8E | | Relative Rotation Angle |
| 0x8F | | Movement counter/timer |
| 0xD0 | Device and Power mode Settings | General System Settings |
| 0xD1 | | Active Channels |
| 0xD2 | | Power Mode Settings |
| 0xD3 | | Normal mode report rate |
| 0xD4 | | Low power mode report rate |
| 0xD5 | | Ultra-low power mode report rate |
| 0xD6 | | Auto Mode time |
| 0xD8 (IQS624-32) | | RDY Timeout Period |
| 0xD9 (IQS624-32) | | I2C Settings |

## 9.2 Device Information

### 9.2.1 Product Number

| Product Number (0x00) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Device Product Number | | | | | | | |

Bit definitions:

- Bit 7-0: Device Product Number = D’67’

### 9.2.2 Software Number

| Software Number (0x01) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Device Software Number | | | | | | | |

Bit definitions:

- Bit 7-0: IQS624-3yy1 - Device Software Number = D’02’
- Bit 7-0: IQS624-3yy2 - Device Software Number = D’14’ (Backwards compatible)
- Bit 7-0: IQS624-5yy1 - Device Software Number = D’02’

### 9.2.3 Hardware Number

| Hardware Number (0x02) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Device Hardware Number | | | | | | | |

Bit definitions:

- Bit 7-0: IQS624-3yy1 - Device Hardware Number = D’130’
- Bit 7-0: IQS624-3yy2 - Device Hardware Number = D’130’
- Bit 7-0: IQS624-3yy2 - Device Hardware Number = D’146’
- Bit 7-0: IQS624-5yy1 - Device Hardware Number = D’162’

## 9.3 Device Specific Data

### 9.3.1 System Flags

| System flags (0x10) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Show Reset | | | Current power mode | | ATI Busy | Event | NP Segment Active |

Bit definitions:

- Bit 7: Reset Indicator:
  - 0: No reset event
  - 1: A device reset has occurred and needs to be acknowledged
- Bit 4-3: Current power mode indicator:
  - 00: Normal power mode
  - 01: Low power mode
  - 10: Ultra-Low power mode
  - 11: Halt power mode
- Bit 2: ATI Busy Indicator:
  - 0: No channels are in ATI
  - 1: One or more channels are in ATI
- Bit 1: Global Event Indicator:
  - 0: No new event to service
  - 1: An event has occurred and should be handled
- Bit 0: Normal Power segment indicator:
  - 0: Not performing a normal power update
  - 1: Busy performing a normal power update

### 9.3.2 Proximity/Touch UI Flags

| Proximity/Touch UI Flags (0x12) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | | | Chan 1 Touch out | Chan 0 touch out | | | Chan 1 proximity out | Chan 0 proximity out |

Bit definitions:

- Bit 5: Channel 1 touch indicator:
  - 0: Channel 1 delta below touch threshold
  - 1: Channel 1 delta above touch threshold
- Bit 4: Channel 0 touch indicator:
  - 0: Channel 0 delta below touch threshold
  - 1: Channel 0 delta above touch threshold
- Bit 1: Channel 1 Proximity indicator:
  - 0: Channel 1 delta below proximity threshold
  - 1: Channel 1 delta above proximity threshold
- Bit 0: Channel 0 Proximity indicator:
  - 0: Channel 0 delta below proximity threshold
  - 1: Channel 0 delta above proximity threshold

### 9.3.3 Hall UI Flags

| Hall UI Flags (0x14) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Wheel movement | Movement direction | | | | | | |

Bit definitions:

- Bit 7: Wheel movement indicator:
  - 0: No wheel movement detected
  - 1: Wheel movement detected
- Bit 6: Movement direction indicator:
  - 0: If movement is detected it is in positive direction
  - 1: If movement is detected it is in negative direction

> Please note that these bits will be set for small movements, therefore jitter may change the direction of movement bit.

### 9.3.4 Hall Ratio Flags

| Hall Ratio Flags (0x15) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | | | | | | Move counter full | Max Denominator set | Max Numerator set |

Bit definitions:

- Bit 2: Move counter full indicator:
  - 0: Movement counter is not full
  - 1: Movement counter is full
- Bit 1: Max Denominator set indicator:
  - 0: Max denominator has not changed
  - 1: Max denominator has changed (used for auto calibration)
- Bit 0: Max Numerator set indicator:
  - 0: Max Numerator has not changed
  - 1: Max Numerator has changed (used for auto calibration)

### 9.3.5 Filtered Degree Output1

| Filtered Degree Output[1] (0x17-0x16) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Degrees High Byte | | | | | | | | Degrees Low Byte | | | | | | | |

Bit definitions:

- 0-360: Filtered absolute degree position of magnet

[1] Only available on IQS624-32

### 9.3.6 Interval Number[1]

| Interval Number[1] (0x18) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Current Interval Number | | | | | | | |

- Bit 7-0: Current interval number

## 9.4 Count Data

### 9.4.1 Count CS Values

| Count CS values (0x20/0x21-0x2A/0x2B) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Count High Byte | | | | | | | | Count Low Byte | | | | | | | |

Bit definitions:

- Bit 15-0: Counts
  - AC filter or raw value

### 9.4.2 LTA Values

| LTA values (0x30/0x31-0x32/0x33) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | LTA High Byte | | | | | | | | LTA Low Byte | | | | | | | |

Bit definitions:

- Bit 15-0: LTA Values
  - LTA filter value

## 9.5 ProxFusion sensor settings

### 9.5.1 Ch0/1 ProxFusion Settings 0

#### 9.5.1.1 Capacitive Sensing

| Ch0/1 ProxFusion Settings 0 (0x40/0x41) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Sensor mode | | | | TX select | | RX select | |
| **Default** | 0 | 0 | 0 | 0 | 0 | 0 | | |

Bit definitions:

- Bit 7-4: Sensor mode select:
  - 0000: Self capacitive mode
- Bit 3-2: TX-select:
  - 00: TX 0 and TX 1 is disabled
- Bit 1-0: RX select:
  - 00: RX 0 and RX 1 is disabled
  - 01: RX 0 is enabled
  - 10: RX 1 is enabled
  - 11: RX 0 and RX 1 is enabled

#### 9.5.1.2 Inductive Sensing

| Ch0/1 ProxFusion Settings 0 (0x40/0x41) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Sensor mode | | | | TX select | | RX select | |
| **Default** | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |

Bit definitions:

- Bit 7-4: Sensor mode select:
  - 1001: Mutual Inductive mode
- Bit 3-2: TX-select:
  - 00: TX 0 and TX 1 is disabled
- Bit 1-0: RX select:
  - 11: RX 0 and RX 1 is enabled

### 9.5.2 Ch0&1 ProxFusion Settings 1

| Ch0&1 ProxFusion Settings 1 (0x42) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | - | CS PXS | Charge Freq | | Proj bias pxs | | Auto ATI Mode | |
| **Default** | 0x5B | | | | | | | |

Bit definitions:

- Bit 6: ProxFusion Sensing Capacitor size select:
  - 0: ProxFusion Sensing capacitor size is 15 pF
  - 1: ProxFusion Sensing capacitor size is 60 pF

- Bit 5-4: Charge Frequency select:
  - 00: 1/2
  - 01: 1/4
  - 10: 1/8
  - 11: 1/16
- Bit 3-2: Projected bias:
  - 00: 2.5µA / 88kΩ
  - 01: 5µA / 66kΩ
  - 10: 10µA / 44kΩ
  - 11: 20µA / 22kΩ
- Bit 1-0: Auto ATI Mode select:
  - 00: ATI Disabled
  - 01: Partial ATI (Multipliers are fixed)
  - 10: Semi Partial ATI (Coarse multipliers are fixed)
  - 11: Full ATI

### 9.5.3 Ch0 ProxFusion Settings 2

| Ch0 ProxFusion Settings 2 (0x43) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | ATI Base | | ATI Target | | | | | |
| **Default** | 0x50 | | | | | | | |

Bit definitions:

- Bit 7-6: ATI Base value select:
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: ATI Target:
  - ATI Target is 6-bit value x 32

### 9.5.4 Ch1 ProxFusion Settings 2

| Ch1 ProxFusion Settings 2 (0x44) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | ATI Base | | ATI Target | | | | | |
| **Default** | 0x50 | | | | | | | |

Bit definitions:

- Bit 7-6: ATI Base value select:
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: ATI Target:
  - ATI Target is 6-bit value x 32

### 9.5.5 Ch0&1 ProxFusion Settings 3

| Ch0&1 ProxFusion Settings 3 (0x45) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | - | CS Div | Two sided PXS | ACF Disable | LTA Beta | | ACF Beta | |
| **Default** | 0x00 | | | | | | | |

Bit definitions:

- Bit 6: CS divider
  - 0: Sampling capacitor divider disabled
  - 1: Sampling capacitor divider enabled
- Bit 5: Two sided ProxFusion Sensing
  - 0: Bidirectional detection disabled
  - 1: Bidirectional detection enabled
- Bit 4: ACF Disable
  - 0: AC Filter Enabled
  - 1: AC Filter Disabled
- Bit 3-2: LTA Beta 0
  - 00: 7
  - 01: 8
  - 10: 9
  - 11: 10
- Bit 1-0: ACF Beta 1
  - 00: 1
  - 01: 2
  - 10: 3
  - 11: 4

### 9.5.6 Ch0/Ch1 Compensation

| Ch0/Ch1 Compensation (0x46,0x47) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Compensation (7-0) | | | | | | | |

Bit definitions:

- Bit 7-0: 0-255: Lower 8 bits of the Compensation Value

Register addresses:

- 0x46: Channel 0 Lower 8 bits of the Compensation Value
- 0x47: Channel 1 Lower 8 bits of the Compensation Value

### 9.5.7 Ch0/Ch1 Multipliers values

| Ch0/1 Multipliers values(0x48/0x49) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Compensation (9-8) | | Coarse multiplier | | Fine multiplier | | | |

Bit definitions:

- Bit 7-6: Compensation upper two bits
  - 0-3: Upper 2-bits of the Compensation value.
- Bit 5-4: Coarse multiplier Selection:
  - 0-3: Coarse multiplier selection
- Bit 3-0: Fine Multiplier Selection:
  - 0-15: Fine Multiplier selection

Register addresses:

- 0x48: Channel 0 Multipliers Value
- 0x49: Channel 1 Multipliers Value

## 9.6 Touch / Proximity UI settings

### 9.6.1 Ch0/1 Proximity/touch threshold

| Proximity/touch threshold Ch0/1(0x50-0x53) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Threshold | | | | | | | |

Bit definitions:

- Bit 7-0: Proximity and touch thresholds:
  If a difference between the LTA and counts value would exceed this threshold the appropriate event would be flagged (either Touch or Proximity Event).

Register addresses:

- 0x50 Channel 0 Proximity Threshold Value
- 0x51 Channel 0 Touch Threshold Value
- 0x52 Channel 1 Proximity Threshold Value
- 0x53 Channel 1 Touch Threshold Value

### 9.6.2 UI Halt period

| UI Halt period (0x54) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | UI Halt period | | | | | | | |
| **Default** | 0x28 = 20 sec | | | | | | | |

Bit definitions:

- Bit 7-0: Halt time in 500 ms ticks

## 9.7 HALL Sensor Settings

### 9.7.1 Hall Rotation UI Settings

| Hall Rotation UI Settings (0x70) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Hall Wheel UI disable | Interval UI disable[1] | Zero Wheel[1] | Hall Wheel Event disable[1] | Interval Event Disable[1] | Auto calibration | - | Wheel wakeup |
| **Default** | 0 | 0 | 0 | 0 | 1 | 1 | - | 0 |

Bit definitions:

- Bit 7: Hall Wheel UI disable
  - 0: Hall wheel UI is enabled
  - 1: Hall wheel UI is disabled
- Bit 6: Interval UI disable[1]
  - 0: Interval UI is enabled
  - 1: Interval UI is disabled
- Bit 5: Zero Wheel angle[1]
  - 1: Zero angle, automatically cleared by firmware
- Bit 4: Hall Wheel UI Event disable[1]
  - 0: Event UI is enabled
  - 1: Event UI is disabled
- Bit 3: Interval UI Event disable[1]
  - 0: Event UI is enabled
  - 1: Event UI is disabled
- Bit 2: Auto calibration
  - 0: Auto calibration disabled
  - 1: Auto calibration enabled
- Bit 0: Wheel wakeup select
  - 0: Wheel wakeup mode disabled
  - 1: Wheel wakeup mode enabled (wakes up on Ch0 touch).

### 9.7.2 Hall Sensor Settings

| Hall Sensor Settings (0x71) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | ACF Enable[1] | - | Charge Freq | | - | - | Auto ATI mode Hall | |
| **Default** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Bit definitions:

- Bit 7: ACF Enable: Enable filter on the individual Hall channels[1]
  - 0: Filter disabled
  - 1: Filter Enabled

[1] Only available on IQS624-32

- Bit 5-4: Charge Frequency: The rate at which our measurement circuit samples
  - 00: 1/2
  - 01: 1/4
  - 10: 1/8
  - 11: 1/16
- Bit 1-0: Auto ATI Mode[1]
  - 00: ATI disabled: ATI is completely disabled
  - 01: Partial ATI: Only adjusts compensation
  - 10: Semi-Partial ATI: Only adjusts compensation and the fine multiplier.
  - 11: Full-ATI: Compensation and both coarse and fine multipliers is adjusted

### 9.7.3 Ch2/3, Ch4/5 Hall ATI Settings2

| Ch2/3, Ch4/5 Hall ATI Settings (0x72/0x73) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | ATI Base | | ATI Target | | | | | |
| **Default** | 0x73 | | | | | | | |

Register addresses:

- 0x72: Channel 2 & 3 ATI settings
- 0x73: Channel 4 & 5 ATI settings

Bit definitions:

- Bit 7-6: ATI Base value select:
  - 00: 75
  - 01: 100
  - 10: 150
  - 11: 200
- Bit 5-0: ATI Target:
  - ATI Target is 6-bit value x 32

### 9.7.4 Ch2/3, Ch4/5 Hall Compensation

| Ch2/3, Ch4/5 Hall Compensation (0x74,0x75) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Compensation (7-0) | | | | | | | |

Bit definitions:

- Bit 7-0: 0-255: Lower 8 bits of the compensation value

[1] Refer to the Errata

[2] See Appendix B for more information

### 9.7.5 Ch2/3, Ch4/5 Hall Multipliers

| Ch2/3, Ch4/5 Hall Multipliers (0x76-0x77) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Compensation 9-8 | | Coarse Multiplier | | Fine Multiplier | | | |

Bit definitions:

- Bit 7-6: Compensation 9-8:
  - 0-3: Upper 2-bits of the compensation value
- Bit 5-4: Coarse multiplier selection
  - 0-3: Coarse multiplier selection
- Bit 3-0: Fine multiplier selection
  - 0-15: Fine multiplier selection

### 9.7.6 Hall Ratio Settings

| Hall ratio settings (0x78) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | Read/Write | Read | | |
| **Name** | - | Octant flag | Y negative | - | Direction invert / Cos negative | Ratio Negative | Denominator negative | Numerator negative |

Bit definitions:

- Bit 6-5: Quadrature output for octant changes (per 45 degrees)
  - 0-3: Quadrature output
- Bit 3: Invert direction of degrees
  - 0 – Invert not active
  - 1 – Invert active
- Bit 2: Ratio negative (Used for on-chip angle calculation)
  - 0 – Ratio is positive
  - 1 – Ratio is negative
- Bit 1: Denominator negative (Used for on-chip angle calculation)
  - 0 – Denominator is positive
  - 1 – Denominator is negative
- Bit 0: Numerator negative (Used for on-chip angle calculation)
  - 0 – Numerator is positive
  - 1 – Numerator is negative

### 9.7.7 Sin Constant

| Sin constant (0x79) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Sin constant | | | | | | | |

Bit definitions:

- Bit 7-0: Sin (phase difference) x 255

### 9.7.8 Cos Constant

| Cos constant (0x7A) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Cos constant | | | | | | | |

Bit definitions:

- Bit 7-0: Cos (phase difference) x 255

Phase difference:

Phase difference measured between the signals obtained from the two Hall sensor plates. This can be calculated with a simple calibration, see Appendix B.

### 9.7.9 Wheel Filter Beta1

| Wheel Filter Beta[1] (0x7B) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Wheel Filter Beta | | | | | | | |
| **Default** | 0x08 | | | | | | | |

Bit definitions:

- Bit 7-0: Initial value used during calculation of wheel filter beta.

### 9.7.10 Wheel Wake Preload[1]

| Wheel Wake Preload[1] (0x7C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Counter Threshold | | | Timer Preload | | | | |
| **Default** | 7 | | | 31 | | | | |

Bit definitions:

- Bit 7-5: Wheel Wake Counter Threshold
  - 0-7: The wheel will wake up if the counter value reaches the counter threshold value before the timer reaches 0.
- Bit 4-0: Wheel Wake Timer Preload
  - 0: Stop timer when wheel is in sleep. Load 31 when wheel is awake.
  - 1-31: Preload Value loaded into Movement Timer (0x8F). The wheel will wake up if the Movement Counter value (0x8F) reaches the Counter Threshold value before the timer reaches 0.

[1] Only available on IQS624-32

### 9.7.11 Interval UI Divider[1]

| Interval UI Divider[1] (0x7D) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Interval size in degrees | | | | | | | |
| **Default** | 0x03 | | | | | | | |

Bit definitions:

- Bit 7-0: Interval size in degrees (>= 3° and <=180°)

### 9.7.12 Wheel Offset[1]

| Wheel Offset[1] (0x7E-0x7F) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Wheel Offset High Byte | | | | | | | | Wheel Offset Low Byte | | | | | | | |
| **Default** | 0x00 | | | | | | | | | | | | | | | |

Bit definitions:

- 16-bit value: Wheel offset in degrees (0°- 359°)

## 9.8 Hall Wheel Output

### 9.8.1 Degree Output

| Degree Output (0x81-0x80) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Degrees High Byte | | | | | | | | Degrees Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Absolute degree position of magnet (0°- 359°)

### 9.8.2 Ratio Output

| Ratio Output (0x83-0x82) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Degrees High Byte | | | | | | | | Degrees Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Ratio used to calculate degrees

### 9.8.3 Numerator

| Numerator (0x85-0x84) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Numerator High Byte | | | | | | | | Numerator Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Numerator used to calculate ratio

### 9.8.4 Denominator

| Denominator (0x87-0x86) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Denominator High Byte | | | | | | | | Denominator Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Denominator used to calculate ratio

### 9.8.5 Rotation Correction factor

| Rotation Correction factor (0x89-0x88) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Rotation Correction Factor High Byte | | | | | | | | Rotation Correction Factor Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Used for auto calibration

### 9.8.6 Max Numerator

| Max Numerator (0x8B-0x8A) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Max Numerator High Byte | | | | | | | | Max Numerator Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Used during auto calibration

### 9.8.7 Max Denominator

| Max Denominator (0x8D-0x8C) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | | | | | | | | | |
| **Name** | Max Denominator High Byte | | | | | | | | Max Denominator Low Byte | | | | | | | |

Bit definitions:

- 16-bit value: Used during auto calibration

### 9.8.8 Relative Rotation Angle

| Relative Rotation Angle (0x8E) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Relative degrees | | | | | | | |

Bit definitions:

- Bit 7-0: Delta in degrees from previous cycle (0°-180°)

### 9.8.9 Movement counter/timer

| Movement counter/timer (0x8F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read | | | | | | | |
| **Name** | Movement Counter | | | Movement Timer | | | | |

Bit definitions:

- Bit 7-4: Movement Counter
  - 0-7: Counter used to detect movement
- Bit 3-0: Movement Timer
  - 0-31: Timer used to detect movement

## 9.9 Device and Power Mode Settings

### 9.9.1 General System Settings

| General System Settings (0xD0) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Soft reset | Ack reset | Event mode | 8Mhz | Comms in ATI | Small ATI band | Redo ATI all | Do reseed |
| **Default** | | | 0 | 0 | 0 | 0 | | |

Bit definitions:

- Bit 7: Soft Reset **(Set only, will clear when done)**
  - 1 – Causes the device to perform a WDT reset
- Bit 6: Acknowledge reset **(Set only, will clear when done)**
  - 1 – Acknowledge that a reset has occurred. This event will trigger until acknowledged
- Bit 5: Communication mode select:
  - 0 – Streaming communication mode enabled
  - 1 – Event communication mode enabled
- Bit 4: Main clock frequency selction
  - 0 – Run FOSC at 16Mhz
  - 1 – Run FOSC at 8 Mhz
- Bit 3: Communication during ATI select:
  - 0 – No communication during ATI
  - 1 – Communications continue regardless of ATI state
- Bit 2: ATI band selection
  - 0 – Re-ATI when outside 1/8 of ATI target
  - 1 – Re-ATI when outside 1/16 of ATI target
- Bit 1: Redo ATI on all channels (Set only, will clear when done)
  - 1 – Start the ATI process
- Bit 0: Reseed All Long term filters (Set only, will clear when done)
  - 1 – Start the Reseed process

### 9.9.2 Active Channels Mask

| Active Channels Mask (0xD1) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | | | CH5 | CH4 | CH3 | CH2 | CH1 | CH0 |
| **Default** | 0x3F | | | | | | | |

Bit definitions:

- Bit 5: CH5 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 4: CH4 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 3: CH3 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 2: CH2 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 1: CH1
  - 0: Channel is disabled
  - 1: Channel is enabled
- Bit 0: CH0
  - 0: Channel is disabled
  - 1: Channel is enabled

### 9.9.3 Power Mode Settings

| Power Mode Settings (0xD2) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | - | Enable ULP Mode | Disable Auto Modes | Power mode | | NP segment rate | | |
| **Default** | 0x03 | | | | | | | |

Bit definitions:

- Bit 6: Enable Ultra-Low Power Mode
  - 0: ULP is disabled during auto-mode switching
  - 1: ULP is enabled during auto-mode switching
- Bit 5: Disable auto mode switching
  - 0: Auto mode switching is enabled
  - 1: Auto mode switching is disabled
- Bit 4-3: Manually select Power Mode (***note: bit 5 must be set***)
  - 00: Normal Power mode. The device runs at the normal power rate, all enabled channels and UIs will execute.
  - 01: Low Power mode. The device runs at the low power rate, all enabled channels and UIs will execute.
  - 10: Ultra-Low Power mode. The device runs at the ultra-low power rate, Ch0 is run as wake-up channel. The other channels execute at the NP-segment rate.
  - 11: Halt Mode. No conversions are performed; the device must be removed from this mode using an I2C command. Disable Auto Mode switching by setting Bit 5.
- Bit 2-0: Normal Power Segment update rate
  - 000: ½ ULP rate
  - 001: ¼ ULP rate
  - 010: 1/8 ULP rate
  - 011: 1/16 ULP rate
  - 100: 1/32 ULP rate
  - 101: 1/64 ULP rate
  - 110: 1/128 ULP rate
  - 111: 1/256 ULP rate

### 9.9.4 Normal/Low/Ultra-Low power mode report rate

| Normal/Low/Ultra-Low power mode report rate (0xD3 - 0xD5) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Normal/Low power/Ultra-low power mode report rate | | | | | | | |

Register addresses:

- 0xD3: Normal mode report rate in ms (Default: 10 ms) ***(note: LPOSC timer has +- 4 ms accuracy)***
- 0xD4: Low power mode report rate in ms (Default: 48 ms) ***(note: LPOSC timer has +- 4 ms accuracy)***
- 0xD5: Ultra-low power mode report rate in 16 ms ticks (Default: 128 ms)

### 9.9.5 Auto Mode Time

| Auto Mode Time (0xD6) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | Mode time | | | | | | | |
| **Default** | 0x14 = 10 sec | | | | | | | |

Bit definitions:

- Bit 7-0: Auto modes switching time in 500 ms ticks

### 9.9.6 RDY timeout period[1]

| RDY timeout period[1] (0xD8) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | | | | | | | |
| **Name** | RDY timeout period value | | | | | | | |
| **Default** | 0x20 = 10.24 ms | | | | | | | |

Bit definitions:

- Bit 7-0: RDY timeout period = RDY timeout period value * 0.32 ms
  - 0 – 81.6 ms: RDY timeout period

*Default RDY timeout on IQS624V1 is 2.038 ms and cannot be changed.*

### 9.9.7 I²C Settings[1]

| I²C Settings[1] (0xD9) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Bit Number** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| **Data Access** | Read/Write | Read/Write | Read/Write | - | | | | |
| **Name** | Stop Disable | R/O Check Disable | NP Stream Enable | Reserved | | | | |
| **Default** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Bit definitions:

- Bit 7: Stop disable
  - 0: Stop enabled: Stop bit will exit the communication window.
  - 1: Stop disabled: Stop bit will not exit the communication window. No start within the RDY timeout period (0xD8) will exit the communication window without executing commands.
- Bit 6: Disable Read Only Check
  - 0: Normal R/O check is performed.
  - 1: R/O check is disabled.
- Bit 5: Always stream in Normal Power Mode
  - 0: Streaming override disabled
  - 1: Always stream in NP
- Bit 4 – 1: Reserved
  - Do not configure, leave cleared.
- Bit 0: Reserved
  - Must always be set (bit 0 = 1).

[1] Only Available on IQS624-32

# 10 Electrical characteristics

## 10.1 Absolute Maximum Specifications

The following absolute maximum parameters are specified for the device:

*Exceeding these maximum specifications may cause damage to the device.*

Table 10.1 Absolute maximum specification

| Parameter | IQS624-3yy | IQS624-5yy |
|---|---|---|
| **Operating temperature** | -20°C to 85°C | |
| **Supply voltage range (VDDHI – GND)** | 2.00V - 3.6V | 2.4V - 5.5V |
| **Maximum pin voltage** | VDDHI + 0.5V (may not exceed VDDHI max) | |
| **Maximum continuous current (for specific Pins)** | 10mA | |
| **Minimum pin voltage** | GND - 0.5V | |
| **Minimum power-on slope** | 100V/s | |
| **ESD protection** | ±4kV (Human body model) | |

## 10.2 Voltage regulation specifications

Table 10.2 Internal regulator operating conditions

| Description | Chipset | Parameter | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **Supply Voltage** | IQS624-3yy | $V_{DDHI}$ | 2 | - | 3.6 | V |
| **Internal Voltage Regulator** | | $V_{REG}$ | 1.63 | 1.66 | 1.69 | V |
| **Supply Voltage** | IQS624-5yy | $V_{DDHI}$ | 2.4 | - | 5.5 | V |
| **Internal Voltage Regulator** | | $V_{REG}$ | 1.67 | 1.7 | 1.73 | V |

## 10.3 Reset Conditions

Table 10.3 Start-up and shut-down slope Characteristics

| DESCRIPTION | Conditions | PARAMETER | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Power On Reset | $V_{DDHI}$ Slope ≥ 100V/s[1] | $POR_{VDDHI}$ | 0.3[2] | 1.7 | V |
| VDDHI Brown Out Detect | $V_{DDHI}$ Slope ≥ 100V/s[1] | $BOD_{VDDHI}$ | N/A | 1.7 | V |
| VREG Brown Out Detect | $V_{DDHI}$ Slope ≥ 100V/s[1] | $BOD_{VREG}$ | N/A | 1.58[3] | V |

[1]Applicable to full “operating temperature” range

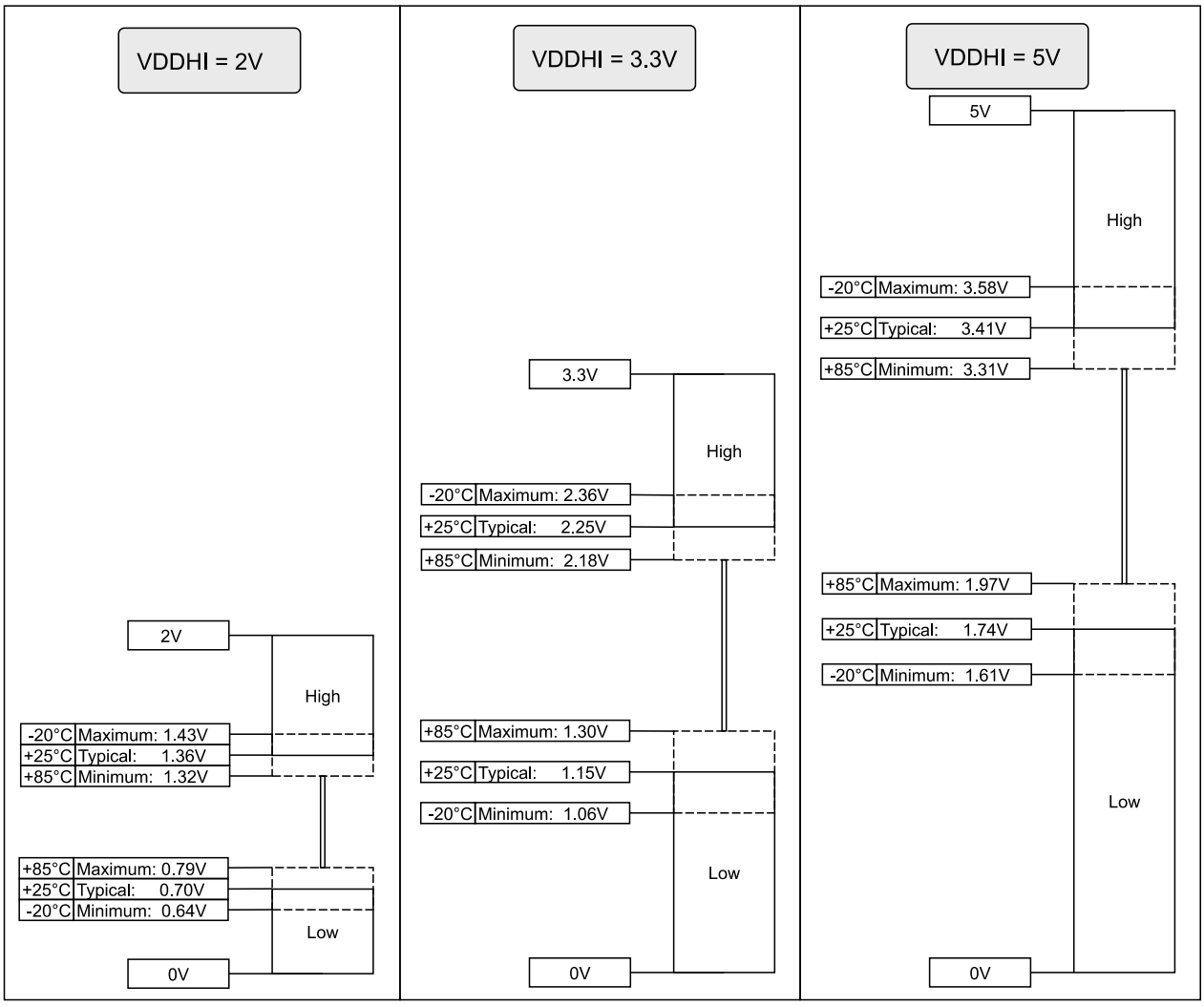
[2]For a power cycle, ensure lowering VDDHI below the minimum value before ramping VDDHI past the maximum POR value

[3]Reference schematic - Capacitors C1 & C2 should be chosen to comply with this specification

## 10.4 Digital input/output trigger levels

Table 10.4 Digital input/output trigger level specifications

| Description | Conditions | Parameter | Temperature | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **Input low level voltage** | 400kHz I²C clock frequency | $V_{in\_LOW}$ | -20°C | 32.12 | | | % of VDDHI |
| | | | +25°C | | 34.84 | | |
| | | | +85°C | | | 39.39 | |
| **Input high level voltage** | | $V_{in\_HIGH}$ | -20°C | | | 71.51 | |
| | | | +25°C | | 68.18 | | |
| | | | +85°C | 66.06 | | | |
| **Output low level voltage** | | $V_{out\_LOW}$ | -20°C – +85°C | | 0 | | |
| **Output high level voltage** | | $V_{out\_HIGH}$ | -20°C – +85°C | | 100 | | |



## 10.5 Current consumptions

Table 10.5 IC subsystem current consumption

| Description | TYP | MAX | UNIT |
|---|---|---|---|
| **Core active** | 339 | 377 | µA |
| **Core sleep** | 0.63 | 1 | µA |
| **Hall sensor active** | 1.5 | 2 | mA |

Table 10.6 IC subsystem typical timing

| Description | Core active | Core sleep | Hall sensor active | Total | Unit |
|---|---|---|---|---|---|
| **Normal** | 5 | 5 | 0.5 | 10 | ms |
| **Low** | 5 | 43 | 0.5 | 48 | ms |
| **Ultra-low** | 1.75 | 128 | 0 | 129.75 | ms |

### 10.5.2 Capacitive sensing alone

Table 10.7 Capacitive sensing current consumption

| Solution | Power mode | Conditions | Report rate | TYPICAL | UNIT |
|---|---|---|---|---|---|
| **3.3V** | NP mode | VDD = 2.0V | 10 ms | 43.5 | µA |
| | NP mode | VDD = 3.3V | 10 ms | 44.4 | µA |
| | LP mode | VDD = 2.0V | 48 ms | 13.3 | µA |
| | LP mode | VDD = 3.3V | 48 ms | 13.8 | µA |
| | ULP mode | VDD = 2.0V | 128 ms | 3.9 | µA |
| | ULP mode | VDD = 3.3V | 128 ms | 4.5 | µA |
| **5V** | NP mode | VDD = 2.5V | 10 ms | 51.3 | µA |
| | NP mode | VDD = 5.5V | 10 ms | 52.3 | µA |
| | LP mode | VDD = 2.5V | 48 ms | 14.5 | µA |
| | LP mode | VDD = 5.5V | 48 ms | 15.5 | µA |
| | ULP mode | VDD = 2.5V | 128 ms | 3.9 | µA |
| | ULP mode | VDD = 5.5V | 128 ms | 5.1 | µA |

-These measurements where done on the default setup of the IC

### 10.5.3 Hall-effect sensing alone

Table 10.8 Hall-effect current consumption

| Solution | Power mode | Conditions | Report rate | TYPICAL | UNIT |
|---|---|---|---|---|---|
| **3.3V** | NP mode | VDD = 2.0V | 10 ms | 215.2 | µA |
| **3.3V** | NP mode | VDD = 3.3V | 10 ms | 212.6 | µA |
| **3.3V** | LP mode | VDD = 2.0V | 48 ms | 58.3 | µA |
| **3.3V** | LP mode | VDD = 3.3V | 48 ms | 55.1 | µA |
| **3.3V** | LP mode | VDD = 2.0V | 128 ms | TBA | µA |
| **3.3V** | LP mode | VDD = 3.3V | 128 ms | 19.65 | µA |
| **5V** | NP mode | VDD = 2.5V | 10 ms | 240.0 | µA |
| **5V** | NP mode | VDD = 5.5V | 10 ms | 239.3 | µA |
| **5V** | LP mode | VDD = 2.5V | 48 ms | 64.1 | µA |
| **5V** | LP mode | VDD = 5.5V | 48 ms | 64.8 | µA |

-These measurements where done on the default setup of the IC

*It is not advised to use the IQS624 in ULP without capacitive sensing. This is due to the Hall-effect sensor being disabled in ULP.*

### 10.5.4 Halt mode

Table 10.9 Halt mode current consumption

| Solution | Power mode | Conditions | TYPICAL | UNIT |
|---|---|---|---|---|
| **3.3V** | Halt mode | VDD = 2.0V | 1.6 | µA |
| **3.3V** | Halt mode | VDD = 3.3V | 1.9 | µA |
| **5V** | Halt mode | VDD = 2.5V | 1.1 | µA |
| **5V** | Halt mode | VDD = 5.5V | 2.2 | µA |

## 10.6 Start-up timing specifications

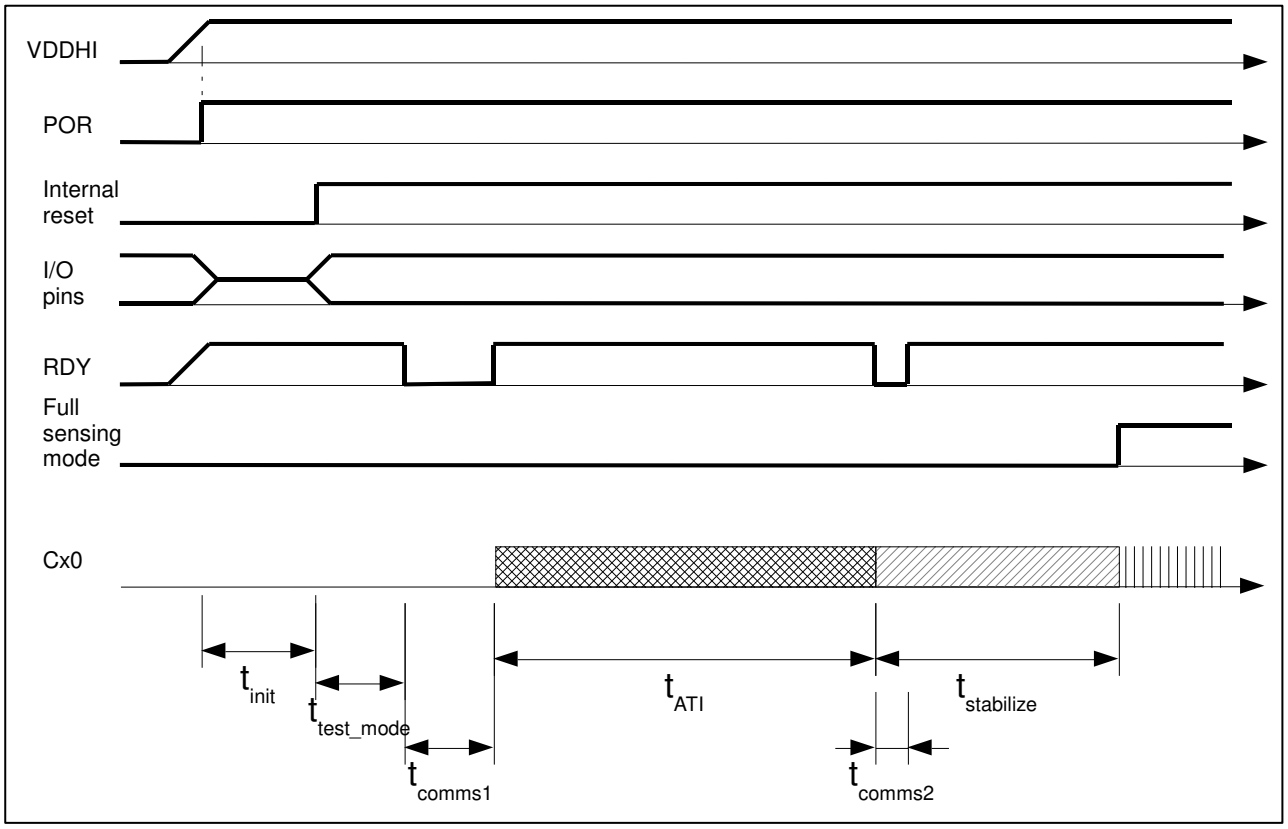



**Figure 10.1 IQS624 start-up timing diagram**

Table 10.10 Timing values for IQS624 start-up timing diagram

| Timing | Min | Typical | Max |
|---|---|---|---|
| $t_{init}$ | | 6ms | |
| $t_{test\_mode}$ | | 5ms | |
| $t_{comms1}$ (16 MHz) | until I2C stop bit | | 10ms (time-out) |
| $t_{comms1}$ (4 MHz) | until I2C stop bit | | 40ms (time-out) |
| $t_{ATI}$ (1 6MHz) | | 110ms (default settings) | |
| $t_{ATI}$ (4 MHz) | | 420ms (default settings) | |
| $t_{comms2}$ (event mode enabled – system event) | until I2C stop bit | | Time-out value defined in register 0xD8 (x4 for 4 MHz mode) |
| $t_{stabilize}$ (16 MHz) | 40ms | 70ms (default settings) | |
| $t_{stabilize}$ (4 MHz) | 120ms | 140ms (default settings) | |
| $t_{full\_sensing\_mode}$ (16 MHz) | | 201ms (from POR) | |
| $t_{full\_sensing\_mode}$ (4 MHz) | | 611ms (from POR) | |

# 11 Package information

## 11.1 DFN10 package and footprint specifications

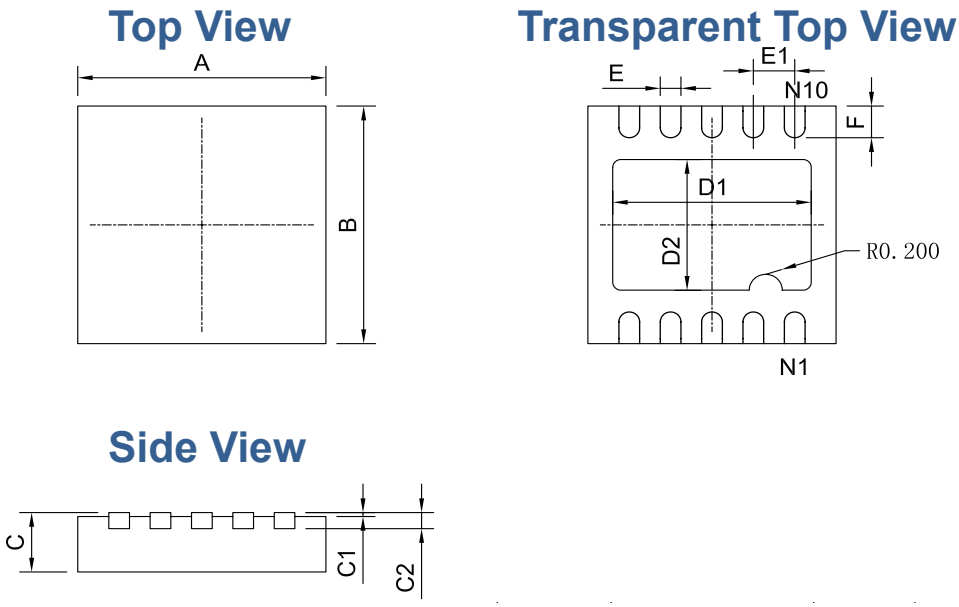



Table 11.1 QFN(3x3)–10 Package Dimensions

| Dimension | [mm] | Dimension | [mm] |
|---|---|---|---|
| A | 3.0±0.1 | D1 | 2.4±0.05 |
| B | 3.0±0.1 | D2 | 1.65±0.05 |
| C | 0.75±0.05 | E | 0.25±0.05 |
| C1 | 0.025±0.025 | E1 | 0.5±0.05 |
| C2 | 0.203±0.05 | F | 0.4±0.05 |

Table 11.2 DFN-10 Landing dimensions

| Dimension | [mm] |
|---|---|
| **A** | 2.4 |
| **B** | 1.65 |
| **C** | 0.8 |
| **D** | 0.5 |
| **E** | 0.3 |
| **F** | 3.2 |

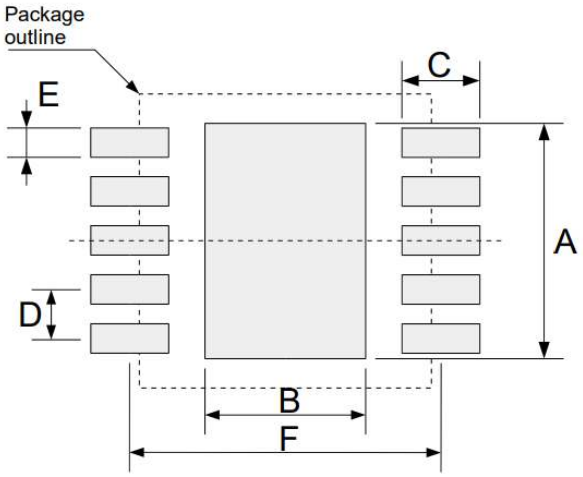
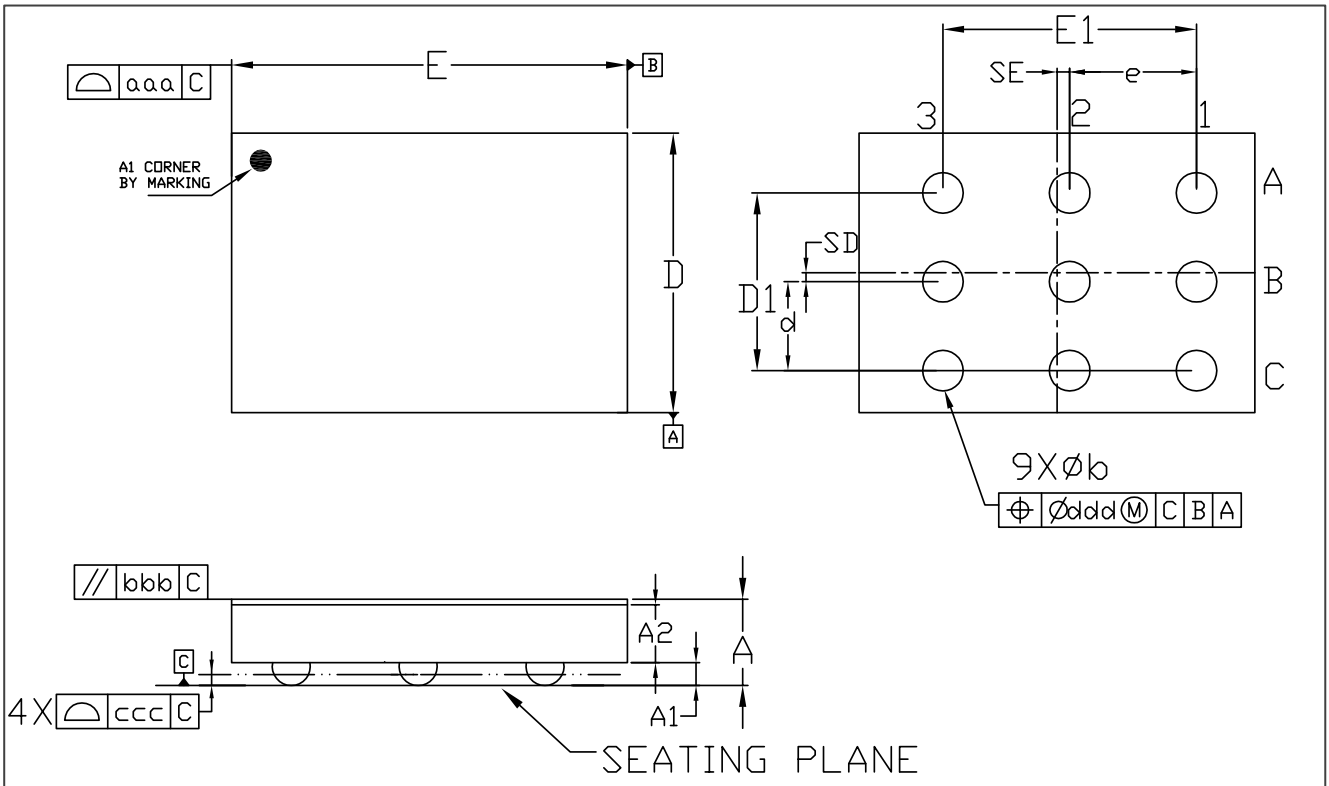



Figure 11.1 DFN-10 Landing dimension

## 11.2 WLCSP-9 package and footprint specifications




Notes

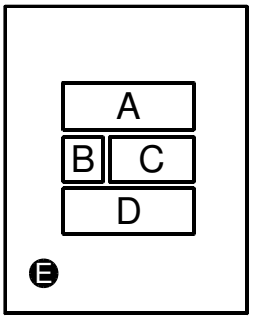
1. All dimensions are in millimeters (angles in degrees).
2. Dimensioning and tolerancing per ANSI Y14.5M-1994.

| Dimensional Ref. | | | |
|---|---|---|---|
| REF. | Min. | Nom. | Max. |
| A | 0.300 | 0.340 | 0.380 |
| A1 | 0.075 | 0.090 | 0.105 |
| A2 | 0.205 | 0.230 | 0.255 |
| D | 1.055 | 1.070 | 1.085 |
| E | 1.515 | 1.530 | 1.545 |
| D1 | 0.650 | 0.70 | 0.750 |
| E1 | 0.950 | 1.000 | 1.050 |
| b | 0.135 | 0.160 | 0.185 |
| d | 0.350 BSC | | |
| e | 0.500 BSC | | |
| SD | 0.035 | | |
| SE | 0.050 | | |
| Tol. of Form&Position | | | |
| aaa | 0.10 | | |
| bbb | 0.10 | | |
| ccc | 0.05 | | |
| ddd | 0.05 | | |

Figure 11.2 Figure 11-1 IQS624 WLCSP-9 package dimensions

## 11.3 Device marking and ordering information

### 11.3.1 Device marking:

| DFN(3x3)-10 | WLCSP-9 |
|---|---|
|  |  |
| **IQS624-xy yz t P WWYY**<br>A B C D E | **6243 2yyt XXX**<br>A B C D |
| A. Device name: IQS624-xyy<br>x – Version<br>3: 3V version<br>5: 5V version(1)<br>yy – Config(2)<br>00: 44H sub-address<br>01: 45H sub-address<br>B. IC revision number: z<br>1 – SW Version 1<br>2 – SW Version 2<br>C. Temperature range: t<br>i: -40° to 85°C<br>I: -20° to 85°C<br>D. For internal use<br>E. Date code: WWYY<br>F. Pin 1: Dot | A. Device name: IQS6243-2<br>B. Config(2): yy<br>00: 44H sub-address<br>01: 45H sub-address<br>C. Temperature range: t<br>i: -40° to 85°C<br>I: -20° to 85°C<br>D. Batch code: XXX<br>E. Pin 1: Dot |

Notes:
(1) 5V Special order Part up to 198k, reach out to sales for more information
(2) Other sub-addresses available on special request, see Section 8.6.

### 11.3.2 Ordering Information:

**IQS624-xzyyppb**

x – Version
3 or 5
z – IC Revision
blank or 2
yy – Config
00 or 01
pp – Package type
DN: DFN (3x3)-10
CS: WLCSP-9
b – Bulk packaging
R (3k per reel, MOQ=1 Reel)

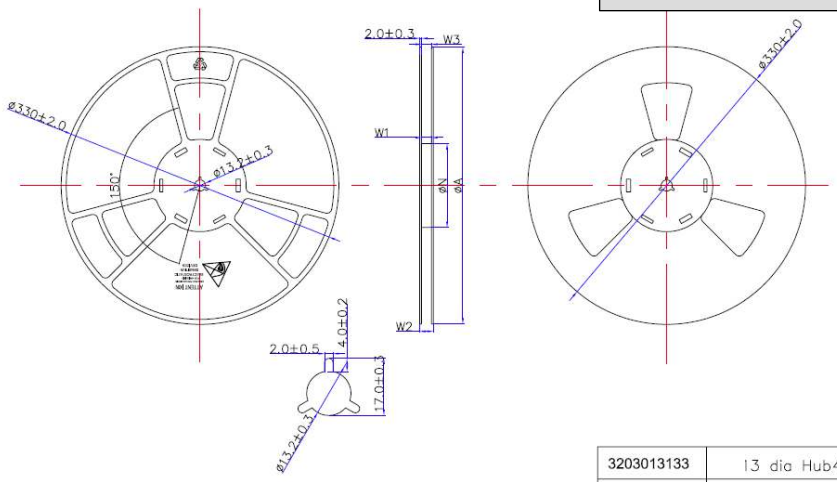
**Example:**
IQS624-3200DNR

- 3 - refers to 3V version
- 2 - refers to software version 2
- 00 - config is default (44H sub-address)
- DN - DFN(3x3)-10 package
- R - packaged in Reels of 3k (has to be ordered in multiples of 3k)

## 11.4 Tape and reel specification

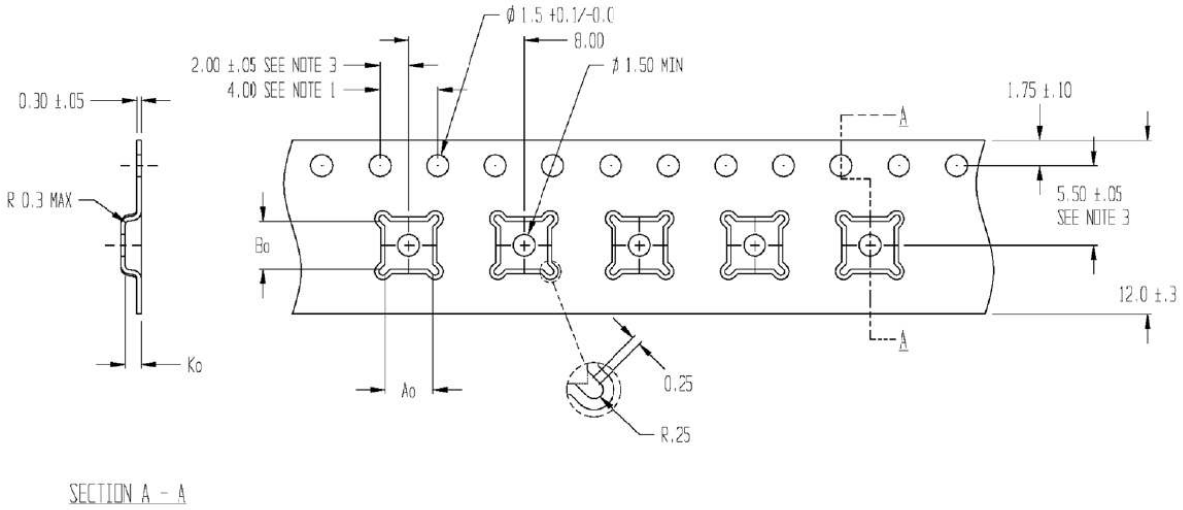
### 11.4.1 DFN(3x3)-10

13” diameter reel, W = 12mm (width)




| | |
|---|---|
| 3203013133 | 13 dia Hub4 12mm width PS B |
| 3203013213 | 13 dia Hub4 16mm width PS B |
| 3203013253 | 13 dia Hub4 24mm width PS B |

| PRODUCT SPECIFICATIONS | | | | | |
|---|---|---|---|---|---|
| TYPE WIDTH | øA | øN | W1(Min) | W2(Max) | W3(Max) |
| 12MM | 330±2.0 | 100±1.0 | 12.4 | 18.4 | 15.4 |
| 16mm | 330±2.0 | 100±1.0 | 16.4 | 22.4 | 19.4 |
| 24MM | 330±2.0 | 100±1.0 | 24.4 | 30.4 | 27.4 |

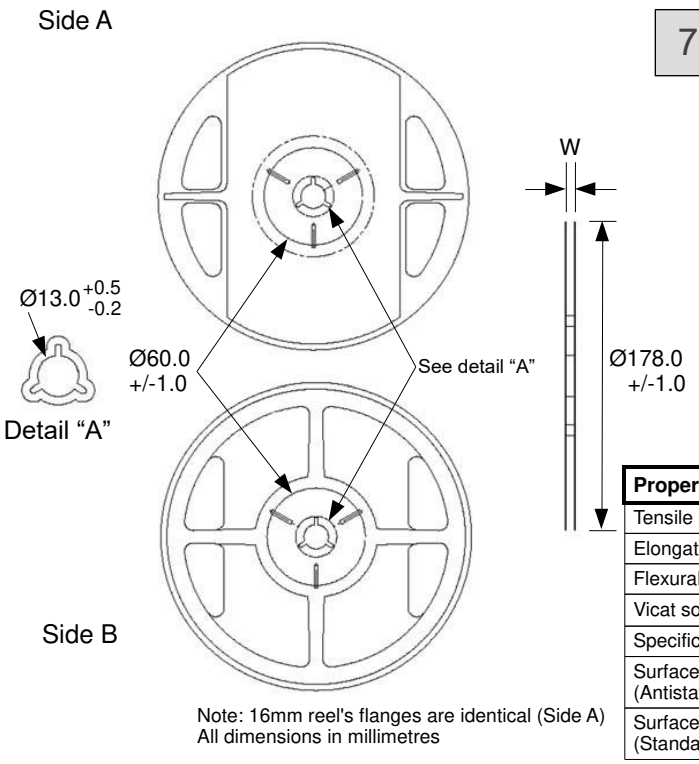



SECTION A - A

A0=3.30
B0=3.30
K0=1.10

NOTES:
1、10 SPROCKET HOLE PITCH CUMULATIVE TOLERANCE ±0.2
2、CAMBER IN COMPLIANCE WITH EIA 481
3、POCKET POSITION RELATIVE TO SPROCKET HOLE
MEASURED AS TRUE POSITION OF POCKET, NOT POCKET HOLE

### 11.4.2 WLCSP-9




| Property | Typical value | Test Method/Standard |
|---|---|---|
| Tensile strength | > 200 kg/cm² | ASTM D 638 |
| Elongation | >= 30% | ASTM D 638 |
| Flexural modulus | > 1.0 kg/cm² | ASTM D 790 |
| Vicat softening | 98° C | ASTM D 1525 |
| Specific gravity | 1.05 g/cc | ASTM D 792 |
| Surface resistivity (Antistatic) | <= $10^{11}$ Ohms/square | ASTM D 257<br>Static dissipative per EIA541 |
| Surface resistivity (Standard) | <= $10^{12}$ Ohms/square | ASTM D 257 |

## 11.5 MSL Level

**Moisture Sensitivity Level** (MSL) relates to the packaging and handling precautions for some semiconductors. The MSL is an electronic standard for the time period in which a moisture sensitive device can be exposed to ambient room conditions (approximately 30°C/85%RH see J-STD033C for more info) before reflow occur.

| Package | Level (duration) |
|---|---|
| DFN(3x3)-10 | MSL 1 (Unlimited at ≤30°C / 85% RH)<br>Reflow profile peak temperature < 260°C for < 25 seconds<br>Number of reflows < 3 |
| WLSCP-9 | MSL 1 (Unlimited at ≤30°C / 85% RH)<br>Reflow profile peak temperature < 260°C for < 25 seconds<br>Number of reflows < 3 |

# 12 Datasheet revisions

## 12.1 Revision history

| | | |
|---|---|---|
| V0.1 – | Preliminary structure | |
| V1.03a – | Preliminary datasheet | |
| V1.04a – | Corrected: | Updated 0x43-0x44 registers: ATI base is [7:6] and not [7:5] |
| | | Added 0x72 and 0x73 registers: ATI settings for CH 2-5 |
| | | Added Streaming and event mode chapters |
| | | Added 5V and 3.3V solution |
| V1.05a- | Corrected: | Changed ESD rating |
| | | Added calibration and magnet orientation appendix |
| | | Added induction to summary page |
| | | Updated schematic |
| | | Updated disclaimer |
| | | Updated software and hardware number |
| V1.10 – | Changed from preliminary to production datasheet | |
| | Added: | Hall ATI Explanation |
| | | Current measurements for power modes |
| | | Register Configuration |
| | Updated: | Calibration calculations |
| | | Current consumption on overview |
| | | Appendices |
| | | Pinout update, pin 9 - NC |
| V1.11 – | Added: | Device markings, order information |
| | | Relative/ absolution summary to appendix |
| | Updated: | Supply voltage range |
| | | Reference schematic |
| | | Updated MSL data |
| V1.12 – | Updated: | Title |
| | | Images |
| V1.14 – | Updated: | Corrected low and high byte order in Register table |
| V1.15 – | Updated: | Corrected minimum temperature and voltage spec |
| V1.16 – | Updated: | Corrected magnet specification |
| V1.17 – | Updated: | Updated magnet spec in appendix |
| V.1.18 – | Added: | Normal Power Maximum report rate |
| V1.19 – | Added: | Errata: Hall ATI values |
| | | I2C Protocol |
| | Updated: | IQS624 Memory Map |
| | Removed: | Small User Interaction Detection UI |
| V1.20 – | Updated: | Errata: Hall ATI values |
| | | IQS624 Memory Map |
| V1.21 – | Updated: | MSL Data |
| | | Appendix A |
| | | Errata: Hall ATI values |
| V1.22 – | Added: | Voltage regulation specification |
| V1.23 – | Removed: | Ready Active High Configuration |
| | Added: | ProxFusion® Sensitivity (Section 1) |
| | | Digital input/output trigger levels (Section 8) |
| | Updated: | Errata: Hall ATI values |
| | | Minor updates |
| V2.00 - | Added: | New Software V2 Registers in Memory Map |
| V2.01 - | Removed: | UI Flags, 0x11 (Unused on FW) |
| | Updated: | Appendix B: Magnet Calibration |
| | | Reference Schematic |
| | Added: | FG Bank 3 Calibration Data |
| | | Section 6.5 Stop-bit Disable Option |
| | | Section 4.6 Interval UI |
| | | Section 4.7 Wheel Wake Preload |
| | | Section 4.8 Event Mode Options |
| V2.02 | Updated: | Section 9: Package Information |
| V2.03 | Updated: | Section 8: Reset Conditions |
| | Added: | WLCSP-9 Information |
| V2.04 | Updated: | Template, 5V order information |
| V2.05 | Added: | IQS624 start-up timing diagram |
| V2.06 | Updated: | Appendix A: Magnet Orientation |
| V2.07 | Updated: | Hardware numbers clarified and new IQS624-3yy2 instance added |
| | | USA & China office contact info updated |

## 12.2 Errata

### 12.2.1 Hall ATI values (Not Required for IQS624-32)

A software setup change is required for the hall ATI compensation values. During setup of the IQS624, wait for the ATI busy flag to clear in the System flags (10H) register. The following sequence should be followed after the ATI busy flag is cleared:

1. I2C Start
2. Write 0xD4 to register 0xF0
3. Write 0xFF to register 0xF1
4. I2C Stop
5. I2C Start
6. Write 0xD5 to register 0xF0
7. Write 0x00 to register 0xF1
8. I2C Stop

This setup change will fix errors regarding the hall ATI algorithm that may occur under certain conditions. This setup requires one rotation for the compensation values to be accurately adjusted. The following procedure should be followed if an accurate absolute degree value is required at startup.

- Follow the startup procedure as usual – write the registers and do an ATI
- Rotate the wheel 360 degrees
- Read the updated compensation values
    - I2C Start
    - Write 0xD4 to register 0xF0
    - I2C Stop
    - I2C Start
    - Read from register 0xF1
    - I2C Stop
    - I2C Start
    - Write 0xD5 to register 0xF0
    - I2C Stop
    - I2C Start
    - Read from register 0xF1
    - I2C Stop
- The two values that has been read should replace 0xFF and 0x00 respectively in the procedure described in 10.2.1. This calibration only needs to be done once and the absolute degree value at startup should be correct. See On-Chip Compensation for more details.

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|---|---|---|---|
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# 13 Appendices

## 13.1 Appendix A: Magnet orientation

The IQS624 can calculate the angle of a magnet using two Hall sensors which are located in two corners of the die within the package. The two Hall sensors gather data of the magnet field strength in the z-axis. The difference between the two Hall sensors' data can be used to calculate a phase. This phase difference can then be transformed to degrees.

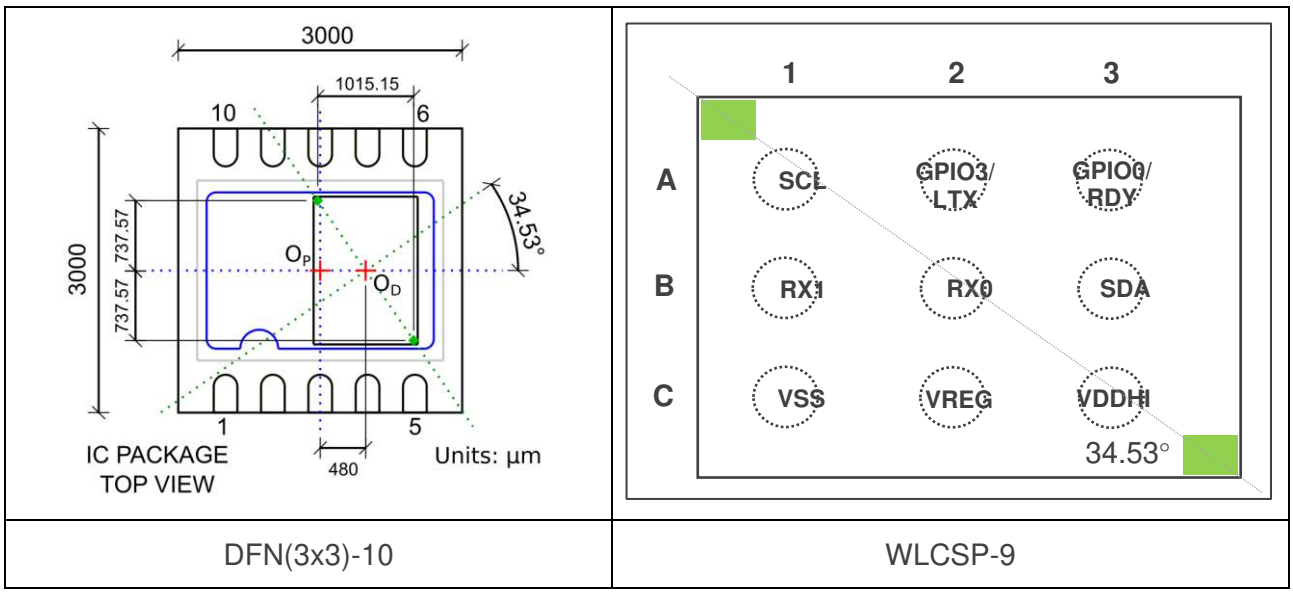
Key considerations for the IQS624:

- There must be a phase difference of 20º to 50° between the two Hall sensors.
- It's impossible to calculate the angle if the phase difference is 0° or 180°.
- Reasonable N/S swing on each Hall sensor
- A reasonable peak to peak signal is needed on the plates to ensure optimal on-chip angle calculation.

Table 13.1 Typical recommended magnet

| Outer Radius | Inner Radius | Width | Grade | Distance between IC and Magnet axis |
|---|---|---|---|---|
| 2.5 mm | 1 mm | 3 mm | N40 | 4 mm |

- Note: Increasing the width of the magnet can improve error caused by movement in the axis direction.
- Ideal design considerations:
  - Stable phase difference – This helps with the linearity of the maths.
  - Big phase difference – The maths involved has better results with bigger phase difference.
  - Distance between the sensors and the magnet should be the same for both – this ensures that the magnet fields observed on both sensors are relatively the same.




DFN(3x3)-10 | WLCSP-9

Figure 13.1 Figure 13-1 - Technical Drawing showing DIE placement within the package. The Hall-Plates are shown as the two green pads in the corners of the DIE. Package axis and hall-plate axis are also shown.

### 13.1.2 Absolute or relative applications

There are two general applications for a Hall sensor, absolute and relative.

An **absolute application** requires the physical absolute angle of the magnet as an input. It is only possible to obtain the physical angle from a **dipole magnet**.

A **relative application** requires the difference between two positions of the magnet as an input. This makes it possible to use either a **dipole or multipole magnet**. The relative application can also be referred to as an incremental application.

### 13.1.3 Absolute off-axis magnet position relative to IC:

The IQS624 can be used as an off-axis hall rotation sensor. This means that the IC is placed on a PCB with the PCB parallel to the axis which it is measuring.

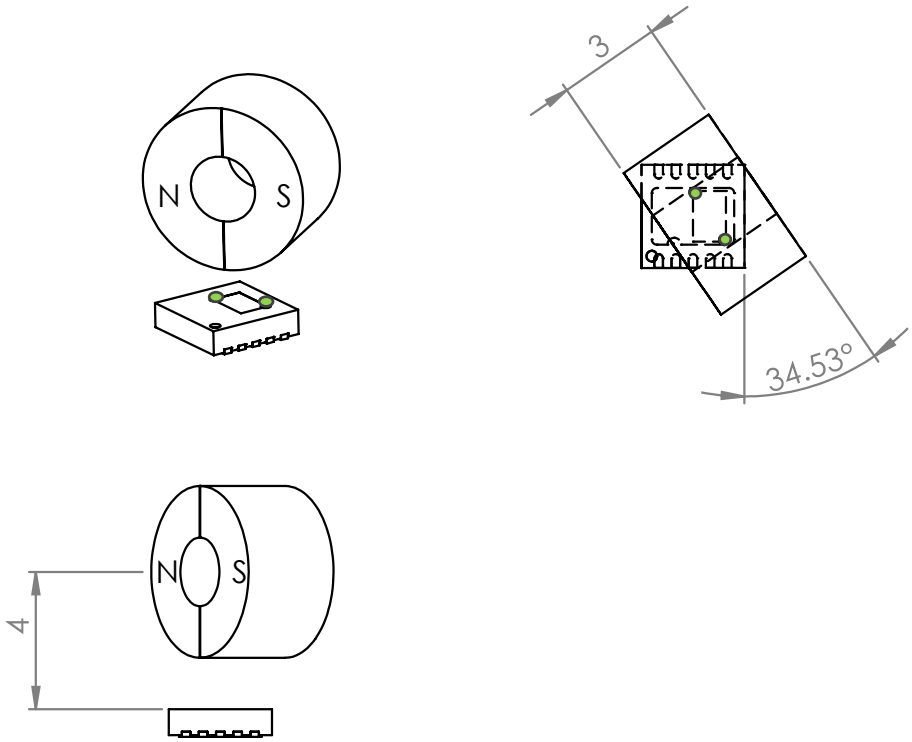



Figure 13.2 Magnet's postion reletave to IC with off-axis orientation

Table 13.2 Typical specifications of off-axis magnet position

| | Variables | Typical |
|---|---|---|
| A | Outer radius | 2.5 - 3 mm |
| B | Inner radius | 1 - 1.5 mm |
| C | Thickness of magnet | 2-3 mm |
| D | Distance between IC and Magnet Axis | 4 - 5 mm |
| E | Angle of magnet relative to IC | 34.53 degrees |
| F | Residual inductance ($B_r$) | 1.25 T |
| G | Polarization | Diametrical |
| H | Magnetic grading | N40 - N52 |

### 13.1.4 Relative on-axis magnet position relative to IC:

The IQS624 as an on-axis hall rotation sensor. This means that the IC is placed on a PCB with the PCB perpendicular to the axis which it is measuring. It should be noted that with this orientation the magnet linearity, mechanical tolerances and wobble on the axis greatly influence the linearity of the output signal. IC's with 4 hall plates can be used for this orientation.

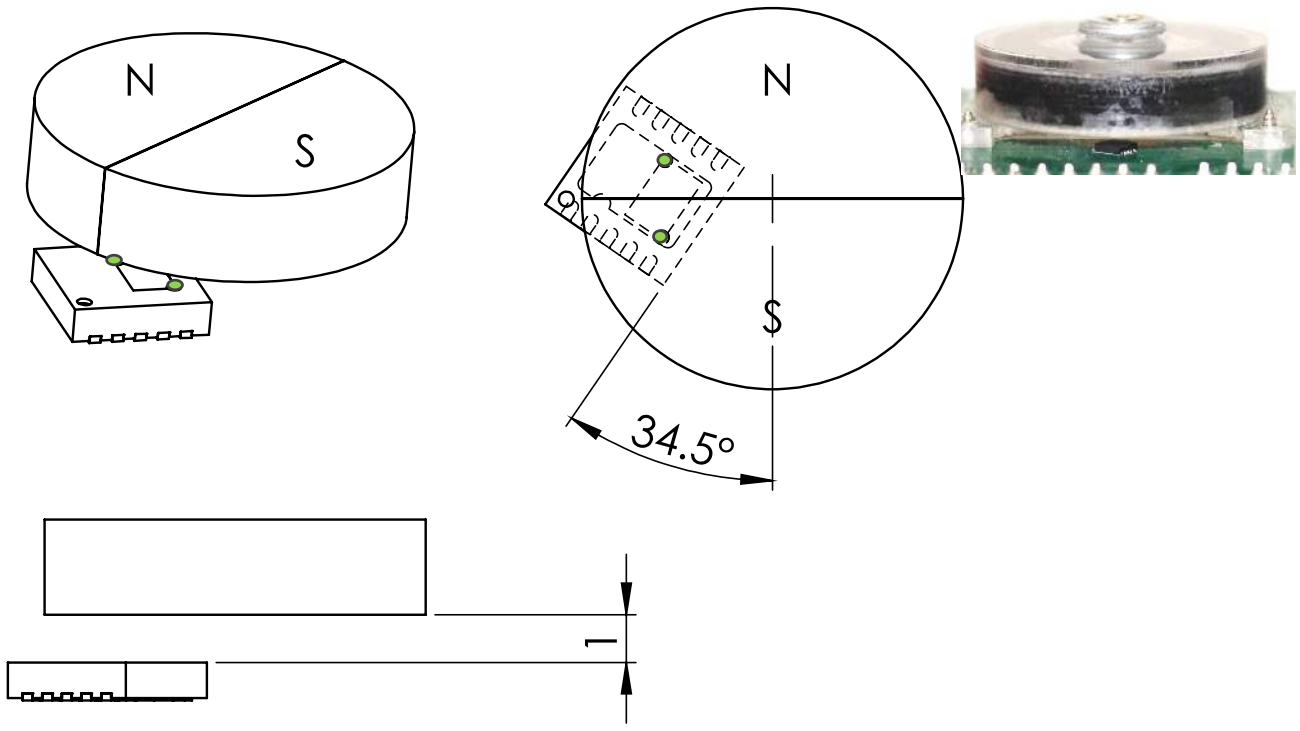



Figure 13.3 Figure 13-2 Magnet's postion relative to IC with on-axis orientation

Figure 13.4 Table 13-1 Typical specifications of on-axis magnet position

| | Variables | Typical |
|---|---|---|
| A | Outer radius | 1.5 – 2.5 mm |
| B | Thickness of magnet | 1 - 3 mm |
| C | Distance between IC and Magnet | 1 mm |
| D | Residual inductance ($B_r$) | 1.25 T |
| E | Polarization | Diametrical |
| F | Magnetic grading | N40 – N52 |

### Preferred magnet orientation comments

Both solutions promote the ideal conditions. However, the EV kit with the magnet parallel with the IC could be more ideal as shown previously. This design was chosen to display the ease of placement our product offers with the built-in corrections and linearization algorithms.

Small movements of the magnet have less impact on the phase difference.

The distance between the magnet and the two sensors are relatively equivalent.

## 13.2 Appendix B: Magnet calibration

The phase angle and the hall channels need to be calibrated on the IQS624. This can be done by a single rotation using the IQS624 GUI. The phase angle needs to be calibrated to calculate the angle between the magnet and IC while the hall channels need to be calibrated to determine the strength of the magnet.

### 13.2.1 Calibration During IC Production

The IQS624 is calibrated during IC production. The calibration ensures a more accurate and linear relation between the magnet and hall plates. Each IC is assigned to a calibration bin between 1 and 15. The bin index is stored in the lower nibble of Floating Gate 3. It is advised to use the bin index to ensure better accuracy over production. The calibration procedure was designed to ensure that the correct Hall ATI Settings are chosen for each setup.

The ATI target of each hall plate needs to be calibrated for the specific magnet strength of the application. Using the calibration data the signal is calculated using the equation below:

$$i_a = I \times N_B(N_T^{-1} - n_z^{-1})$$

Where:

$i_a = Signal$

$I = DC\ Current$

$N_B = Base\ Value\ Counts$

$N_T = ATI\ Target$

$n_z = Maximum\ Counts$

It is not necessary to implement this equation on FW. The procedure below describes 5 easy steps to calibrate each application. The equation is used to generate a calibration table in the GUI which can be implemented in product FW. Therefore, the bin value of each IC is used to find the correct value in the Hall Wheel Calibration table generated by the GUI.

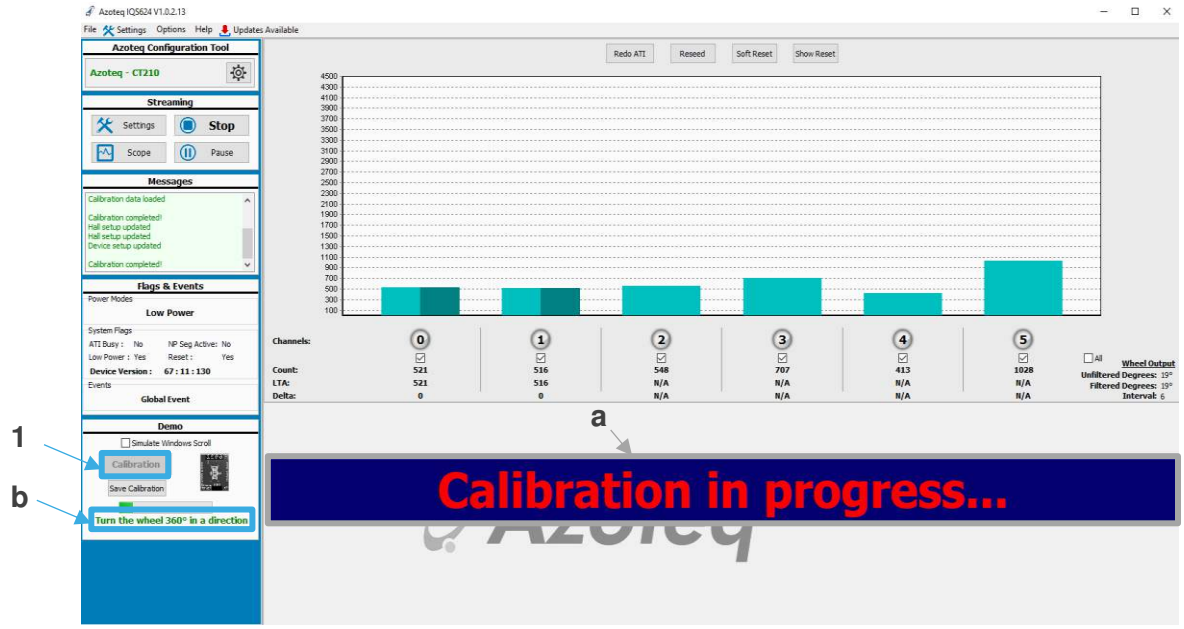
### 13.2.2 How to calibrate using the IQS624 GUI

Each application/setup (not every single IC) should be calibrated with a single rotation to calculate the phase angle and ATI target values. The IQS624 GUI (from V1.0.2.13) should be used to calculate the correct calibration table for each application. A default “Max Counts” of 1500 is suggested. It should be noted that IC which were not calibrated during IC production will not be able to be calibrated for hall ATI settings. This procedure can still be used for phase angle calibration.

#### 13.2.2.1 Step 1: Click on the Calibration button in the GUI.

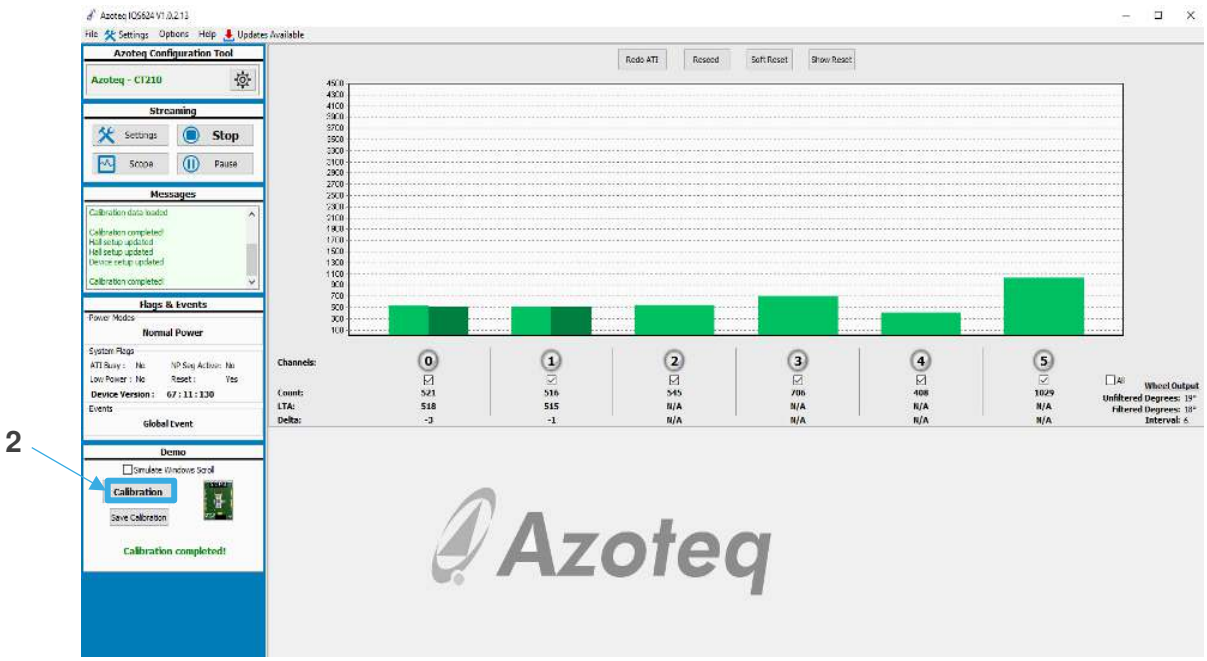
a) This banner indicates that the calibration progress has started.
b) The user must rotate the wheel on the IQS624 device 360 degrees.

*(It is encouraged that the wheel must be rotated at a constant and low speed)*




#### 13.2.2.2 Step 2: Complete one full rotation until the “Calibration Completed” message is received.

*(Repeat step 1 if the message: “Calibration Failed” is received.)*



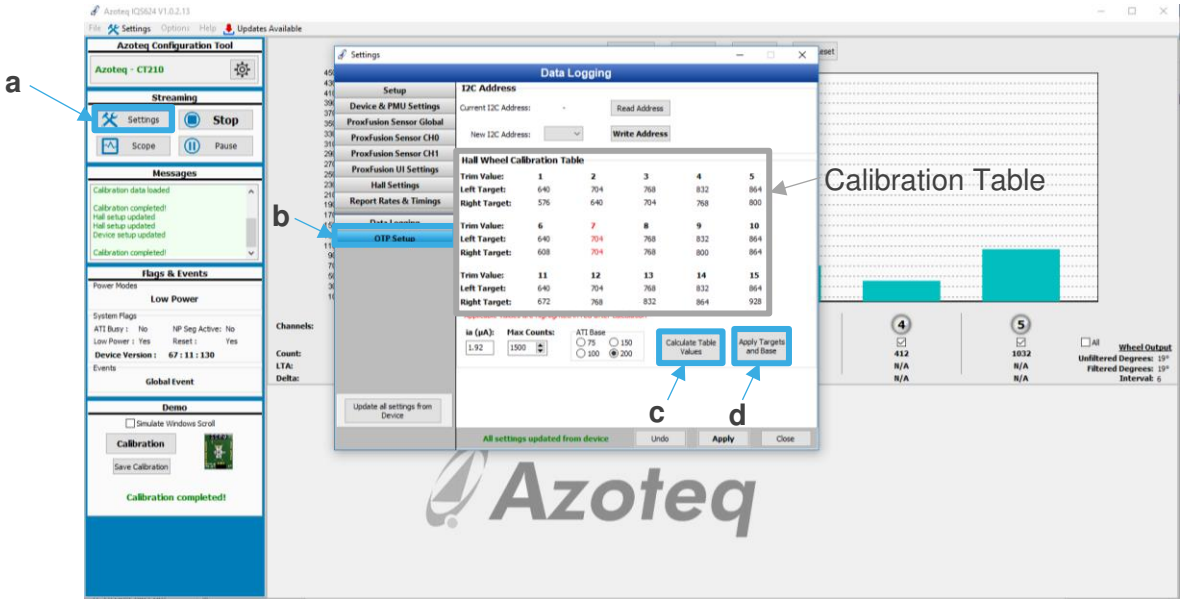
#### 13.2.2.3 Step 3: Obtaining the Hall ATI Settings

a) Click on Settings

b) Click on OTP Setup

c) Click on Calculate Table Values

d) Click on Apply Targets and Base



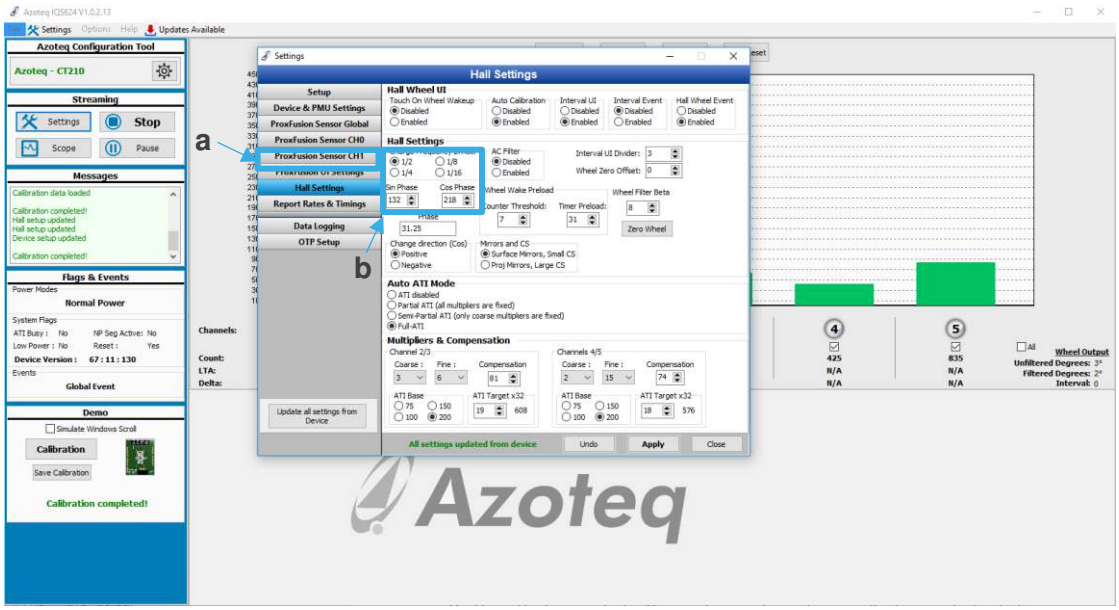

#### 13.2.2.4 Step 4: Inspect the channels

Check if the “Max Counts” selected for this application is reached (default = 1500). The base values or the Max Counts can be adjusted if this is not the case. Repeat Step 1-3 after the base values are adjusted.

#### 13.2.2.5 Step 5: Obtaining the phase angle calibration constants

a) Click on Hall Settings

b) The phase angle calibration constants The Sin phase and Cos phase are the two constants which are written to the device. The phase (displayed in degrees) can also be used to obtain both constants.




If the user is satisfied an h-file can be generated which includes the Hall ATI Settings for each IC. Click on File → Export H File

If this calibration is done on a product the constants obtained from the calibration can be used for projects with the same physical layout and magnet. This means that only one calibration is needed per product.

### 13.2.3 MCU Implementation

Before implementing the calibration data on an MCU the procedure described in Section 13.2.2 should be followed. Implement the steps below during initialisation of the MCU.

1. Power-up
2. Read the calibration index from Floating Gate 3.
    a. I2C Start
    b. Write 0x13 to register 0xF0
    c. I2C Stop
    d. I2C Start
    e. Read from register 0xF1 and store calibration data
    f. I2C Stop
3. Use the lower nibble of the floating gate to find the Hall ATI Settings in the Hall Wheel Calibration Table Values in the exported h-file from Section 13.2.2.
4. Write the Hall ATI Settings to registers 0x72 and 0x73 during setup of the IC.
5. Write the Cos and Sin constants to registers 0x79 and 0x7A.

For example:

- Lower nibble of Floating Gate 3 is 0x07.
- The exported Hall Wheel Calibration Table Values:

*/* Hall Wheel Calibration Table Values */*

*const static uint8_t Ch2_3_HALL_ATI_SETTINGS[] = {0xD0, 0xD3, 0xD5, 0xD6, 0xD8, 0xD0, 0xD3, 0xD5, 0xD6, 0xD8, 0xD0, 0xD3, 0xD5, 0xD6, 0xD8};*

*const static uint8_t Ch4_5_HALL_ATI_SETTINGS[] = {0xCF, 0xD1, 0xD3, 0xD4, 0xD6, 0xD0, 0xD2, 0xD4, 0xD6, 0xD7, 0xD2, 0xD4, 0xD6, 0xD8, 0xD9};*

- The 7th value of each table is 0xD3 and 0xD2.
- During initialization write 0xD3 to register 0x72 and 0xD2 to register 0x73. (Hall ATI Settings)
- During initialization write 0x83 to register 0x79 and 0xDA to register 0x7A. (Phase Angle Constants)

### 13.2.4 How to calculate the phase angle using the raw data

There are two Hall Plates that make up the sensor, separated by a fixed distance in the IC package, as described previously. These plates, designated Plate 1 & Plate 2, each have two associated data channels that sense the North-South magnetic field coincident on the plates.

For Plate 1: CH2 is the non-inverted channel, and CH3 is the inverted channel.

For Plate 2: CH4 is the non-inverted channel, and CH5 is the inverted channel.

E.g. on Plate 1, if CH2 increases in value in the presence of an increasing North field, then CH3 decreases in value in the presence of an increasing North field.

The phase delta observed between the plates can be calculated from either the non-inverted, or the inverted channel pairs.

To calculate the phase delta:

#### Symbols

| | |
|---|---|
| $P_n$ | Non-inverted channel of Plate n: $where\ P_1 = CH_2, and\ P_2 = CH_4$ |
| $P_n'$ | Inverted channel of Plate n: $P_1' = CH_3, and\ P_2' = CH_5$ |
| $P_n\|_{max}$ | Max value of the channel |
| $P_n\|_{min}$ | Min value of the channel |
| $\theta_\Delta$ | Phase observed between the plates |

#### Calculations

To calculate the phase, for at least one full rotation of the magnet, capturing all four channels:

First normalize the data for each channel, to obtain.

$$N(CH_n) = \frac{\frac{CH_n|_{max} - CH_n}{CH_n}}{\frac{CH_n|_{max} - CH_n|_{min}}{CH_n|_{min}}} \quad (1)$$

The data will now range between 0 – 1.

For the non-inverted pair: $\{P_2, P_1\} = \{CH_4, CH_2\}$ sample both channels where $N(CH_4) \approx 0.5$. With these values, the phase delta can be calculated:

$$\theta_\Delta = sin^{-1}(|N(CH_4) - N(CH_2)| \cdot 2) \quad (2)$$

Likewise, the phase delta can be calculated from the inverted pair: $\{P_2', P_1'\} = \{CH_5, CH_3\}$ sample both channels where $N(CH_5) \approx 0.5$.

$$\theta'_{\Delta} = sin^{-1}(|N(CH_5) - N(CH_3)| \cdot 2) \quad (3)$$

And, while the phase angles are theoretically equal, due to misalignments, $\theta_{\Delta} \approx \theta'_{\Delta}$.

To increase accuracy of the observed phase, the two calculated phases can be averaged, leading the final Observed phase as:

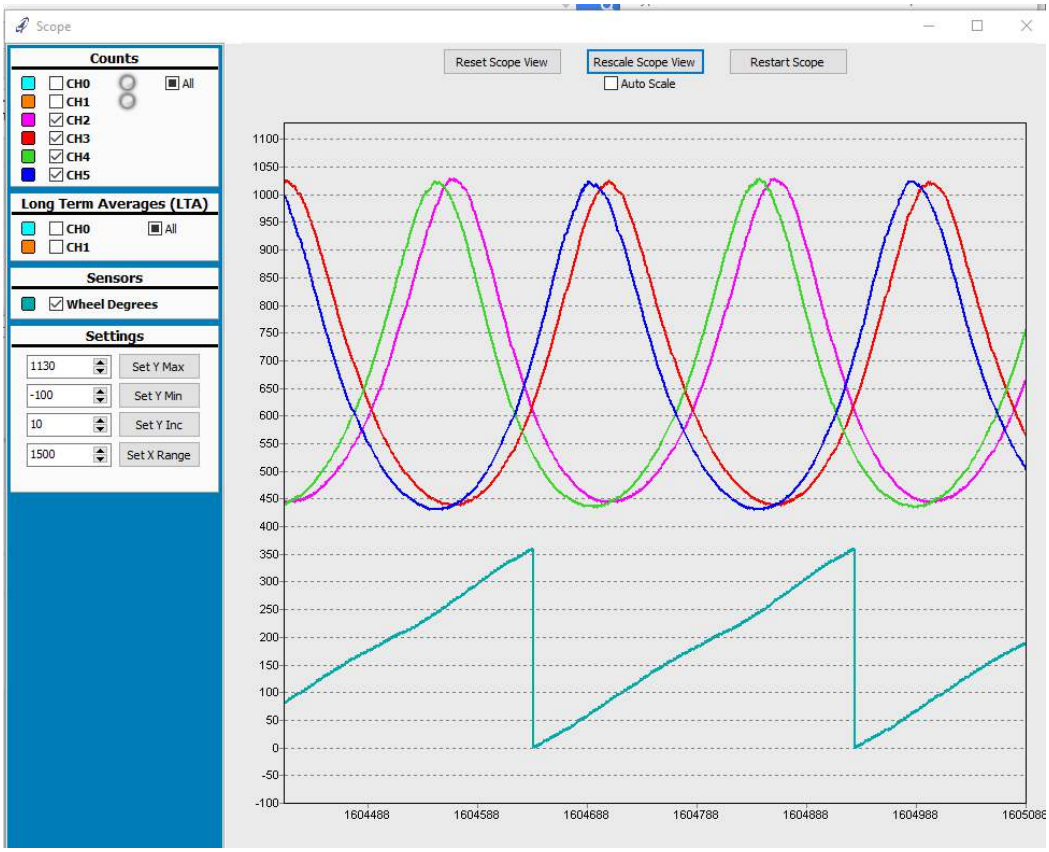
$$\theta_{\Delta} = \frac{sin^{-1}(|N(CH_4) - N(CH_2)| \cdot 2) + sin^{-1}(|N(CH_5) - N(CH_3)| \cdot 2)}{2} \quad (4)$$

**NB:** Remember that $\{CH_4, CH_2\}$ are evaluated at $N(CH_4) \approx 0.5$. While separately, $\{CH_5, CH_3\}$ are evaluated at $N(CH_5) \approx 0.5$. Even when used together in Equation (4).

The IQS624 uses this phase delta as a constant to calculate the angle. The phase delta is saved on the IC after it has been converted to $(sin(\theta_{\Delta}) \cdot 256)$ and $(cos(\theta_{\Delta}) \cdot 256)$. This is done to lessen computations and memory usage on the chip.

This means that if the phase were to change, the constants would need to be recalculated. If the application of this IC ensures nothing or little movement, the master device would only need to write the values each time the IC resets and would not need to re-calculate it. Making it possible to calculate the phase delta once before production and using that value for the application.

An example of well aligned channels, the phase offset visible between the inverted and non-inverted channel pairs of the two plates:




Experimentally, jog the XYZ alignment of the magnet relative to the IC and perform at least one full rotation of the magnet, assess the peaks of the channels; repeat this until all channels have approximately the same amplitude.

To change the sensitivity of the ProxEngine to Magnetic Field Strength, the ATI parameters on the IC can be adjusted as described in the following section.

## 13.3 Appendix C: Hall ATI

Azoteq's ProxFusion® Hall technology has ATI Functionality, which ensures stable sensor sensitivity. The ATI functionality is similar to the ATI functionality found in ProxSense® technology. The difference is that the Hall ATI requires two channels for a single plate.

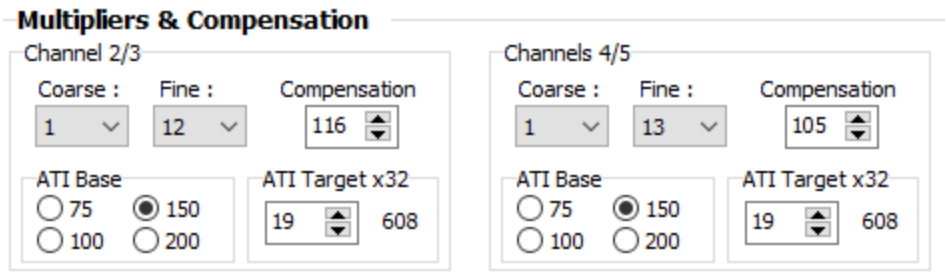
Using two channels ensures that the ATI can still be used in the presence of the magnet. The two channels are the inverse of each other, this means that the one channel will sense North and the other South. The two channels being inverted allows the capability of calculating a reference value which will always be the same regardless of the presence of a magnet.

### 13.3.1 Hall reference value:

The equation used to calculate the reference value, per plate:

$$Ref_n = \frac{1}{2 \cdot \left(\frac{1}{P_n} + \frac{1}{P_n'}\right)}$$

### 13.3.2 ATI parameters:




The ATI process adjusts three values (Coarse multiplier, Fine multiplier, Compensation) using two parameters per plate (ATI base and ATI target). The ATI process is used to ensure that the sensor's sensitivity is not severely affected by external influences (Temperature, voltage supply change, etc.).

### 13.3.3 Coarse and Fine multipliers:

In the ATI process the compensation is set to 0 and the coarse and fine multipliers are adjusted such that the counts of the reference value $(Ref)$ are roughly the same as the ATI Base value. This means that if the base value is increased, the coarse and fine multipliers should also increase and vice versa.

### 13.3.4 ATI-Compensation:

After the coarse and fine multipliers are adjusted, the compensation is adjusted till the reference value $(Ref)$ reaches the ATI target. A higher target means more compensation and therefore more sensitivity on the sensor.

The ATI-Compensation adjusts chip sensitivity; and, must not be confused with the On-chip Compensation described below. On-chip Compensation corrects minor displacements or magnetic non-linearities. This compensation ensures that both channels of each plate – which represent North and South individually – have the same swing. On-chip compensation is performed in the UI and is not observable on the raw channel data.

The ATI process ensures that long term temperature changes, or bulk magnetic interference (e.g. the accidental placement of another magnet too close to the setup), do not affect the sensor's ability to detect the rotating magnet.

### 13.3.5 Recommended parameters:

There are recommended parameters to ensure optimal use. Optimally the settings would be set up to have a max swing of 1000 from peak to peak and a reference value below 1000 counts.

The recommended parameters are:

- ATI Base: 150 or 200
- ATI Target: 500 – 1000

It is not assured that these settings will always set up the channels in the optimal region, but it is recommended to rather adjust the magnet's position a little as this also influences the signal received. If the magnet is too close to the IC the swing will be too large, and thus it is recommended to increase the distance between the IC and the Magnet. Refer to

Appendix B: Magnet calibration for more information when choosing the ATI target.

### 13.3.6 On-Chip Compensation

During a rotation of the magnet, the chip tracks important positions, 0/360° and 180°, as well as the MIN & MAX positions of the two plate equations $R_b$ & $R_t$

Because the chip requires that the channels be aligned to the same amplitudes, the on-chip equations are as follows:

$$R_t = \frac{1}{CH_4} - \frac{1}{CH_2}$$

$$R_b = \frac{1}{CH_5} - \frac{1}{CH_3}$$

$$R = \frac{R_t}{R_b}$$

The Compensation Constant ($\kappa$) is tracked as:

$$\kappa = \frac{Max(R_b)}{Max(R_t)}$$

With R updated as

$$R = \kappa \cdot \frac{R_t}{R_b}$$

The update is only applied under certain conditions, both the $maxima$ or $minima$ of $\{R_b\ ,\ R_t\}$ before crossing either 0° or 180° in a portion of the rotation. This means if the device wiggles between 150° & 200°, but does cross both maxima, the compensation is not updated.

At start-up, there is no compensation available and $\kappa = 1$

**NOTE:** After calibration, a rotation of the magnet is required to update the compensation value.

The following calibration procedure should be followed if an accurate absolute degree value is required at startup for IQS624-3001.

> Follow the startup procedure as usual – write the registers and do an ATI
> Rotate the wheel 360 degrees
> Read the updated compensation values
  - I2C Start
  - Write 0xD4 to register 0xF0
  - I2C Stop
  - I2C Start

- Read from register 0xF1 and store *comp1*
- I2C Stop
- I2C Start
- Write 0xD5 to register 0xF0
- I2C Stop
- I2C Start
- Read from register 0xF1 and store *comp2*
- I2C Stop

This calibration only needs to be done once. When these compensation values are known they can be written to the device every time on startup.

> Follow the startup procedure as usual – write the registers and do an ATI
> Wait for the ATI busy flag to clear in the System flags (10H) register.

- I2C Start
- Write 0xD4 to register 0xF0
- Write *comp1* to register 0xF1
- I2C Stop
- I2C Start
- Write 0xD5 to register 0xF0
- Write *comp2* to register 0xF1
- I2C Stop