IQS624 Datasheet

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

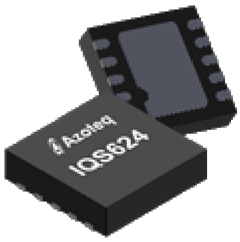
The IQS624 ProxFusion™ IC is a multifunctional capacitive and Hall-effect sensor designed for applications where any or all of the technologies may be required. The two Hall-effect sensors calculate the angle of a magnet rotating parallel with the sensor. The sensor is fully I²C compatible and on-chip 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° 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.
  - Operational range 10mT – 100mT
  - No external components required
- **Partial auto calibration:**
  - Continuous auto-calibration, compensation for wear or small displacements of the sensor or magnet.
  - Flexible gain control
  - **A**utomatic **T**uning **I**mplementation (**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
  - QRD (Quick release detection)
  - 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: 1.8V to 3.6V*****

***5V solution available on demand.**



DFN10

Representations only, not actual markings

Applications

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

Available Packages	
T_A	DFN(3x3)-10
-40°C to 85°C	IQS624-xyy

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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

SUID – Small user interaction detection

QRD – Quick release detection

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

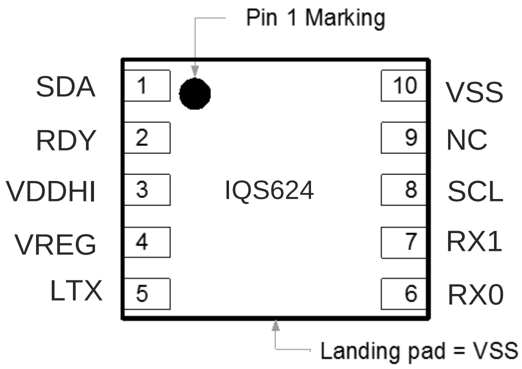


Figure 1.1 Pin out of IQS624 DFN(3X3)-10 package.

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 (Connect 1µF bypass capacitor)
5	LTX	Analogue	Transmit Electrode 1
6	RX0	Analogue	Sense Electrode 0
7	RX1	Analogue	Sense Electrode 1/ Transmit Electrode 0
8	SCL	Digital Input / Output	I²C: SCL Output
9	NC	Not connect	Not connect
10	VSS	Supply Input	Ground Reference

1.3 Reference schematic

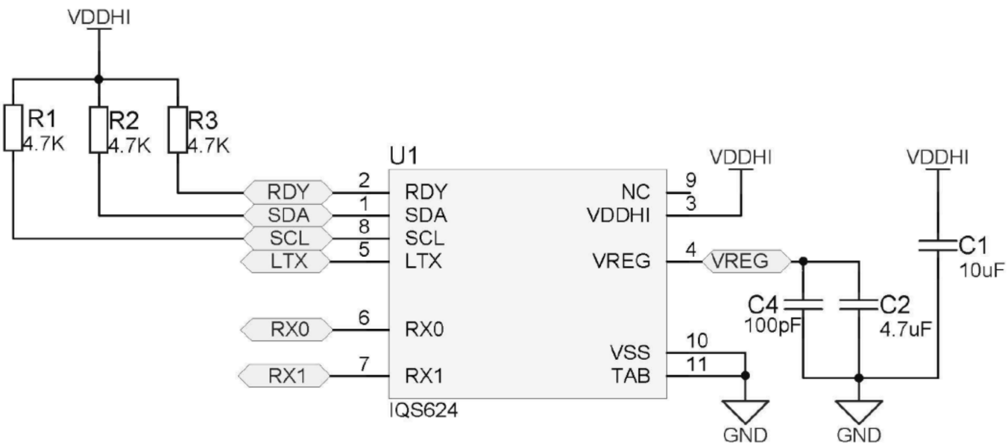


Figure 1.2 IQS624 reference schematic

1.4 Sensor channel combinations

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

Table 1.2 Sensor - channel allocation

Sensor type	CH0	CH1	CH2	CH3	CH4	CH5
Discreet Self Capacitive	○	○				
Small User interaction detection UI	• Main	• Movement				
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

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.

The capacitive sensing capabilities of the IQS624 include:

- Maximum of 2 capacitive channels to be individually configured.
  - Prox and touch adjustable thresholds
  - Individual sensitivity setups
  - Alternative ATI modes
- Small user interaction detection user interface:
  - Movement sensing to distinguish between stationary in-contact objects and human interference
  - Quick release feature
- Discreet button UI:
  - Fully configurable 2 level threshold setup – traditional prox & touch activation levels.
  - Customizable filter halt time

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 per the channel's associated settings registers.

There are two distinct capacitive user interfaces available to be used.

a) Discreet proximity/touch UI (always enabled)
b) Small user interaction UI

When the Small User interaction UI is activated (ProxSense / Capacitive Sensing Settngs4: bit7):

- Channel 0 is used as the main capacitive sensing channel.
- Channel 1 is used for capacitive movement detection. This is used to implement the quick release detection.

Table 2.1 Capacitive sensing - channel allocation

Sensor type	CH0	CH1	CH2	CH3	CH4	CH5
Discreet Self Capacitive	○	○				
Small user interaction detection	• Main	• Movement				

Key:

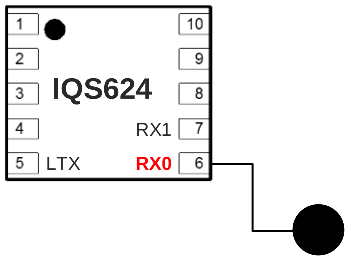
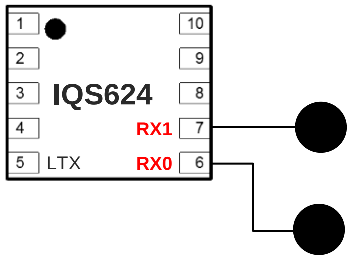
Optional implementation

- ○ Optional implementation
- • Fixed use for UI

2.3 Hardware configuration

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

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	ProxSense / Capacitive Sensing Setting 0	Sensor mode and configuration of each channel.	Sensor mode should be set to capacitive mode An appropriate RX should be chosen and no TX
0x42	ProxSense / Capacitive Sensing Setting 1	Global settings for the ProxSense sensors	None
0x43, 0x44	ProxSense / Capacitive Sensing Setting 2	ATI settings for ProxSense sensors	ATI target should be more than ATI base to achieve an ATI
0x45	ProxSense / Capacitive Sensing Setting 3	Additional Global settings for ProxSense sensors	SUID should be enabled for SUID UI
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 Registers to configure for the Small User interaction UI:

Table 2.4 Small User interaction UI settings registers

Address	Name	Description
0x60	Small user interaction detection Setting 0	Filter settings
0x61	Small user interaction detection Setting 1	Timeout and threshold settings
0x62	Release Threshold	Release Threshold
0x63	Small user interaction detection Proximity threshold	Proximity Threshold
0x64	Small user interaction detection Touch threshold	Touch Threshold
0x65	Halt timer	SUID Halt timer

2.4.3 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 registers should be monitored by the master to detect capacitive sensor output and SUID activations.

a) The **UI Flags register (0x11)** will show the IQS624's main events. Bit0&1 is dedicated to the ProxSense activations, bit0 indicates a proximity event and bit1 indicates a touch event. Bit2 is provided to indicate if the Small User interaction detection UI is activated.

UI Flags(0x11)								
Bit Number	7	6	5	4	3	**2**	**1**	**0**
Data Access	Read							
Name						**Small User interaction detection**	**PXS Touch out**	**PXS proximity out**

b) The **Proximity/Touch UI Flags (0x12)** and **Small User interaction detection UI Flags (0x13)** provide more detail regarding the outputs. A proximity and touch output bit for each channel 0 and 1 is provided in the PRX UI Flags register.

c) The **Small User interaction detection UI Flags (0x13)** register will show detail regarding the state of the small user interaction output as well as Quick release toggles, movement activations and the state of the filter (halted or not).

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**

Small User interaction detection UI Flags (0x13)								
Bit Number	7	6	5	**4**	3	**2**	**1**	**0**
Data Access	Read							
Name				**Proximity**		**Quick release**	**Movement**	**Filter halt**

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.

There's only one distinct inductance user interfaces 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	○	○				

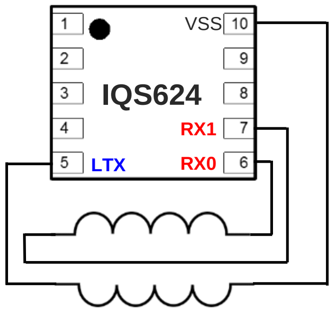
Key:

○ - 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	ProxSense / Capacitive Sensing Setting 0	Sensor mode and configuration of each channel.	Sensor mode should be set to Inductive mode Deactivate one channel Enable both RX for the activated channel
0x42	ProxSense / Capacitive Sensing Setting 1	Global settings for the ProxSense sensors	CS divider should be enabled
0x43, 0x44	ProxSense / Capacitive Sensing Setting 2	ATI settings for ProxSense sensors	ATI target should be more than ATI base to achieve an ATI
0x45	ProxSense / Capacitive Sensing Setting 3	Additional Global settings for ProxSense sensors	None
0x46, 0x47	Proximity threshold	Proximity Threshold for UI	Less than touch threshold
0x48, 0x49	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

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 measurement is essentially a current measurement of the induced current through the Hall-effect-sensor plates produced by the magnetic field passing perpendicular through each plate.

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

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

4.2 Channel specifications

Channels 2 to 5 are dedicated to Hall-effect sensing. Channel 2 & 4 performs the positive direction measurements and channel 3 & 5 will handle all measurements in the negative direction. Differential data can be 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.

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

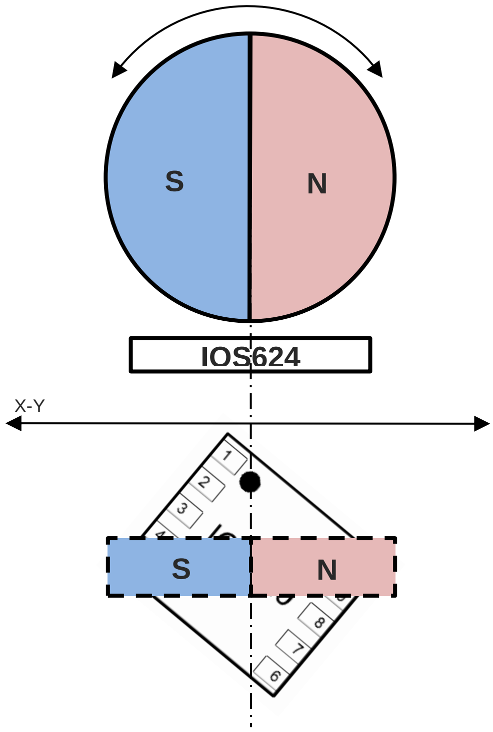
Key:

○ - 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

Table 4.2 Hall sensing settings registers

Address	Name	Description	Recommended setting
70H	Hall Rotation UI Settings	Hall wheel UI settings	Hall UI should be enabled for degree output
71H	Hall sensor settings	Auto ATI and charge frequency settings	Auto ATI should be enabled for temperature drift compensation
72H, 73H	Hall ATI Settings	Hall channels ATI settings	ATI Target should be more than base
78H	Hall ratio Settings	Invert Direction setting for Hall UI	None
79H	Sin(phase) constant	Sin phase calibration value	Calculate this value using the GUI or the calculations in the appendix A
7AH	Cos(phase) constant	Cos phase calibration value	Calculate this value using the GUI or the calculations in the appendix A

4.4.2 Example code:

Example code for an Arduino Uno can be downloaded at:

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

4.5 Sensor data output and flags

a) The **Hall UI Flags (0x14).** Bit7 is dedicated to indicating a movement of the magnet. Bit6 indicates the direction of the movement.

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

b) 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**							

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 this:

- As a software setting – Set the System_Settings: bit4 = 1, via an I^{2}C command.
- As a permanent setting – Set the OTP option in FG Bank 0: bit2 = 1, using Azoteq USBProg program.

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 DSBL_AUTO_MODE bit (Power mode Settings 0xD2: bit5) to confine device operation to a specific power mode. The POWER_MODE bits (Power mode Settings 0xD2: bit4-3) 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.

Note: The device's low power oscillator has an accuracy as specified in section 9.

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.

Note: The device's low power oscillator has an accuracy as specified in section 9.

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 EN_ULP_MDE bit (Power mode Settings: bit6) 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.

Wake up will occur on proximity detection on channel 0.

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 I^2C 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.

5.3 Streaming and event mode:

Streaming mode is the default. Event mode is enabled by setting bit 5 in register 0xD0.

5.3.1 Streaming mode

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

5.3.2 Event mode

The ready is triggered only when an event has occurred.

The events which trigger the ready:

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

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

5.4 Report rates

5.4.1 Calculation of each mode's report rate

Normal Power Segment rate

To be completed.

Auto modes change rates

To be completed.

Streaming/event mode rates

To be completed.

5.5 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 (System Flags 0x10: bit7) and the master should explicitly clear this bit by setting the ACK_RESET (bit6) in System Settings 0.

b) The system events will also be indicated with the Global Events register's SYS bit (Global Events 0x11: bit4) if any system event occur such as a reset. This event will continuously trigger until the reset has been acknowledged.

6 Communication

6.1 I^{2}C module specification

The device supports a standard two wire I^{2}C interface with the addition of an RDY (ready interrupt) line. 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 open-drain active low implementation and indicates a communication window.

6.2 Device address and sub-addresses

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

Alternative sub-address options are available to be defined in the OTP Bank0 (bit3; 0; bit1; bit0)

a) Default address: **0x44**
b) Sub-address: 0x45
c) Sub-address: 0x46
d) Sub-address: 0x47
e) Sub-address: 0x4C
f) Sub-address: 0x4D
g) Sub-address: 0x4E
h) Sub-address: 0x4F

6.3 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	-	Rdy active high	Sub address 2	8MHz	Sub address 0-1	

Bit definitions:

- Bit 0,1,3: I2C sub-address
  - I2C address = 0x44 OR (0, 0, 0, 0, I2C_SUB_ADR_3, 0, I2C_SUB_ADR_1, I2C_SUB_ADR_0)
- Bit 2: Main Clock frequency selection
  - 0: Run FOSC at 16MHz
  - 1: Run FOSC at 8MHz
- Bit 4: Rdy active high
  - 0: Rdy active low enabled
  - 1: Rdy active high enabled
- Bit 6: Comms mode during ATI
  - 0: No streaming events are generated during ATI
  - 1: Comms continue as setup regardless of ATI state.

6.4 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).

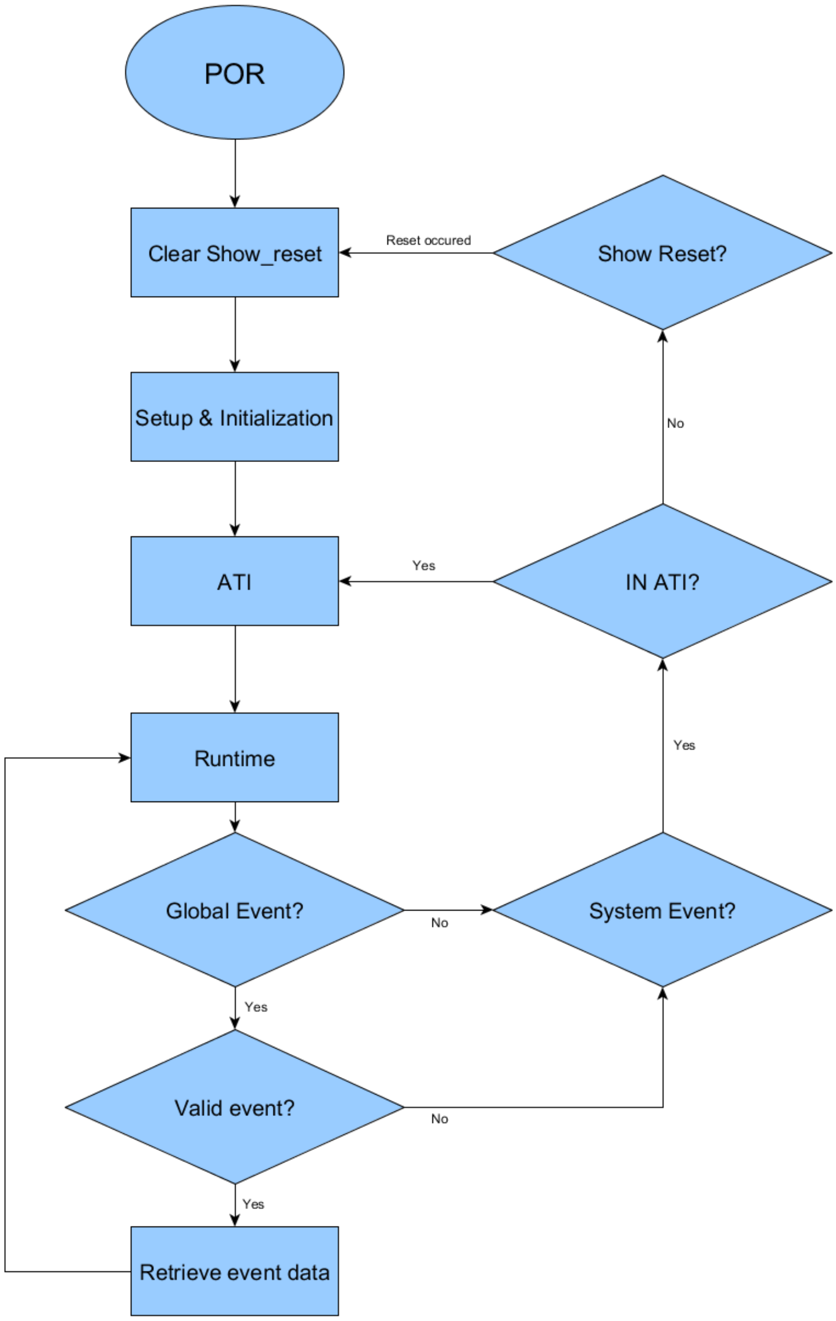


Figure 6.1 Master command structure and runtime event handling flow diagram

It is recommended that the master verifies the status of the System_Flags0 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. Streaming mode communication is used for detail sensor evaluation during prototyping/development.

7 IQS624 Memory map

Table 7.1 : IQS624 Register map

Register Address	Group	Register Name
00H	Device Information	Product Number
01H		Hardware Number
02H		Software Number
10H	Device Specific Data	Sys_flags0
11H		UI Flags
12H		Touch/Prox Flags
13H		SUID UI Flags
14H		HALL UI Flags
20H	Count Data	CH0 CS High
21H		CH0 CS Low
22H		CH1 CS High
23H		CH1 CS Low
24H		CH2 CS High
25H		CH2 CS Low
26H		CH3 CS High
27H		CH3 CS Low
28H		CH4 CS High
29H		CH4 CS Low
2AH		CH5 CS high
2BH		CH5 CS low
30H		CH0 LTA high
31H		CH0 LTA low
32H		CH1 LTA high
33H		CH1 LTA low
40H	Touch / Proximity sensor settings	Ch0 ProxSense / Capacitive Sensing Settings 0
41H		CH1 ProxSense / Capacitive Sensing Settings 0
42H		CH0&1 ProxSense / Capacitive Sensing Setting 1
43H		Ch0 ProxSense / Capacitive Sensing Settings 2
44H		CH1 ProxSense / Capacitive Sensing Settings 2
45H		CH0/1 ProxSense / Capacitive Sensing Setting 3
46H		Ch0 Compensation
47H		Ch1 Compensation
48H		Ch0 Multipliers
49H		Ch1 Multipliers
50H	Touch / Proximity UI settings	Ch0 Proximity threshold
51H		Ch0 Touch threshold
52H		Ch1 Proximity threshold
53H		Ch1 Touch threshold
54H		UI Halt timer

Register Address		Register Name
60H	Small User interaction detection	Small user interaction detection Setting 0
61H		Small user interaction detection Setting 1
62H		Release Threshold
63H		Small user interaction detection Proximity threshold
64H		Small user interaction detection Touch threshold
65H		Halt timer
70H	HALL Sensor Settings	Hall Rotation UI Settings
71H		Hall sensor settings
72H		CH2&3 Hall ATI Settings
73H		CH4&5 Hall ATI Settings
74H		CH2&3 Compensation
75H		CH4&5 Compensation
76H		CH2&3 Multipliers
77H		CH4&5 Multipliers
78H		Hall ratio Settings
79H		Sin(phase) constant
7AH		Cos(phase) constant
80H	HALL Wheel Output	Degree Output (Low byte)
81H		Degree Output (High byte)
82H		Ratio Output (Low byte)
83H		Ratio Output (High byte)
84H		Numerator of Ratio (Low byte)
85H		Numerator of Ratio (High byte)
86H		Denominator of Ratio (Low byte)
87H		Denominator of Ratio (High byte)
88H		Rotation Correction factor (Low byte)
89H		Rotation Correction factor (High byte)
8AH		Max Numerator of Ratio (Low byte)
8BH		Max Numerator of Ratio (High byte)
8CH		Max Denominator of Ratio (Low byte)
8DH		Max Denominator of Ratio (High byte)
8EH		Relative rotation angle
8FH		Movement counter/timer
D0H	Device and Power mode Settings	General system settings
D1H		Active channels
D2H		Power mode settings
D3H		Normal mode report rate
D4H		Low power mode report rate
D5H		Ultra-low power mode report rate
D6H		Mode time

7.2 Memory Registers Description

7.2.1 Device Information

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

Bit definitions:

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

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

Bit definitions:

- Bit 0-7: Device Software Number = D'02'

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

Bit definitions:

- Bit 0-7: Device Hardware Number = D'162' for 5V solution, D'130' for 3.3V solution

7.2.2 Device Specific Data

System flags (0x10)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read							
Name	Show Reset	Ready active high		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 6: Ready Active High
  - 0: Ready active Low set (Default)
  - 1: Ready active High set
- 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 serviced
- Bit 0: Normal Power segment indicator:
  - 0: Not performing a normal power update
  - 1: Busy performing a normal power update

UI Flags(0x11)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read							
Name						Small User interaction detection	PXS Touch out	PXS proximity out

Bit definitions:

- Bit 2: Small User interaction indicator:
  - 0: No event to report
  - 1: A Movement event has occurred and should be handled
- Bit 1: ProxSense / Capacitive Sensing Touch indicator:
  - 0: No event to report
  - 1: A touch event has occurred and should be handled
- Bit 0: ProxSense / Capacitive Sensing proximity indicator:
  - 0: No event to report
  - 1: A proximity event has occurred and should be handled

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

Small User interaction detection UI Flags (0x13)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read							
Name				Proximity		Quick release	Movement	Filter halt

Bit definitions:

- Bit 4: Proximity indicator:
  - 0: Delta below proximity threshold
  - 1: Delta above proximity threshold
- Bit 2: Quick release indicator:
  - 0: No quick release detected
  - 1: Quick release detected
- Bit 1: Movement indicator:
  - 0: No movement detected
  - 1: Movement detected
- Bit 0: Filter halt indicator:
  - 0: Delta below filter halt level
  - 1: Delta above filter halt level

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

Bit definitions:

- Bit7: Wheel movement indicator:
  - 0: No wheel movement detected
  - 1: Wheel movement detected
- Bit6: Movement direction indicator:
  - 0: If movement is detected it is in negative direction
  - 1: If movement is detected it is in positive direction
- Bit1: Count sign:
  - 0: Indicates that the movement counts are positive
  - 1: Indicates that the movement counts are negative
- Bit0: Difference sign:
  - 0: Indicates that the angle delta is positive
  - 1: Indicates that the angle delta is negative

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
- Bit 0: Max Numerator set indicator:
  - 0: Max Numerator has not changed
  - 1: Max Numerator has changed

7.2.3 Count Data

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

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

7.2.4 Touch / Proximity sensor settings

Proximity/touch Mode settings (0x40-0x41)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	Sensor mode				TX select		RX select	

Bit definitions:

- Bit 7-4: Sensor mode select:
  - 0000: Self capacitive mode
  - 1001: Mutual Inductance mode
- Bit 3-2: TX-select:
  - 00: TX 0 and TX 1 is disabled
  - 01: TX 0 is enabled
  - 10: TX 1 is enabled
  - 11: TX 0 and TX 1 is enabled
- 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

Proximity/touch settings (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	

Bit definitions:

- Bit 6: ProxSense / Capacitive Sensing Capacitor size select:
  - 0: ProxSense storage capacitor size is 15 pF
  - 1: ProxSense storage 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: 2.5 µA
  - 01: 5 µA
  - 10: 10 µA
  - 11: 20 µA
- 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

ATI settings(0x43-0x44)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	ATI Base		ATI Target					

Different addresses:

- 0x43: Channel 0 ATI settings
- 0x44: Channel 1 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

CH0/1 ProxSense / Capacitive Sensing Setting 3 (0x45)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	SUID Enable	CS Div	Two sided PXS	ACF Disable	LTA Beta		ACF Beta	

Bit definitions:

- Bit 7: Small user interactions detection UI Enable:
  - 0: Small user interactions detection UI is disabled
  - 1: Small user interactions detection UI is enabled
- Bit 6: CS divider
  - 0: CS divider disabled
  - 1: CS divider enabled
- Bit 5: Two sided ProxSense / Capacitive 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

Compensation Ch0,1 (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

Different addresses:

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

Multipliers values Ch0,1(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

7.2.5 Touch / Proximity UI settings

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

- [50H-53H] Proximity and touch thresholds, bit7-0:
  If a difference between the LTA and counts value would exceed this threshold the appropriate event would be flagged. (either Touch or Proximity Event)

Different addresses:

- 0x50 Ch0 Proximity Threshold Value
- 0x51 Ch0 Touch Threshold Value
- 0x52 Ch1 Proximity Threshold Value
- 0x53 Ch1 Touch Threshold Value

ProxSense / Capacitive Sensing halt period (0x54)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	ProxSense / Capacitive Sensing halt period							

Bit definitions:

- Bit 7-0: Halt time in 0.5 second ticks

7.2.6 Small User interaction detection

Small User interaction detection settings 0(0x60)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name		Quick release detection beta			Movement detection beta			

Bit definitions:

- Bit 6-4: Quick release detection
  - 0-7: Quick release filter beta value
- Bit 3-0: Movement detection Beta
  - 0-15: Movement filter beta value

Small User interaction detection settings 1(0x61)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	LTA Halt Prox timeout				Movement detection threshold			

Bit definitions:

- Bit 7-4: LTA Halt Prox timeout
  - 0-15: LTA Halt timeout in no Prox in 500 ms ticks
- Bit 3-0: Movement detection threshold
  - 0-15: Movement Threshold Value

Proximity/touch threshold (0x62,0x63-0x64)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	Threshold							

- [62H] Release threshold, bit7-0:

  In SUID mode. If a difference between the LTA and counts value would exceed this threshold the appropriate event would be flagged. (either Quick release, Touch or Proximity Event)

- [63H-64H] Proximity and touch thresholds, bit7-0:
  If a difference between the LTA and counts value would exceed this threshold the appropriate event would be flagged. (either Touch or Proximity Event)

Different addresses:

- 0x63: SUID Proximity threshold
- 0x64: SUID Touch threshold

Small User interaction detection Halt timer period (0x65)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	SUID Halt timer period							

Bit definitions:

- Bit 7-0: LTA Halt Prox timeout after QRD
  - LTA Halt timeout after a Quick release event with no movement in 500 ms ticks

7.2.7 HALL Sensor Settings

Hall Wheel UI Settings 0 (0x70)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	Hall Wheel UI disable					Auto calibration		Wheel wakeup

Bit definitions:

- Bit 7: Hall Wheel UI disable
  - 0: Hall wheel UI is enabled
  - 1: Hall wheel 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

Hall sensor settings (0x71)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name			Charge Freq				Auto ATI mode Hall	

Bit definitions:

- 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
  - 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

ATI settings(0x72-0x73)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	ATI Base		ATI Target					

Different 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

Compensation Ch2/3,4/5 (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

Different addresses:

- 0x74: Channel 2/3 Lower 8 bits of the compensation Value
- 0x75: Channel 4/5 Lower 8 bits of the compensation Value

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

Different addresses:

- 0x76 – Channel 2/3 Multipliers selection
- 0x77 – Channel 4/5 Multipliers selection

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

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
  - 0 – Ratio is positive
  - 1 – Ratio is negative
- Bit 1: Denominator negative
  - 0 – Denominator is positive
  - 1 – Denominator is negative
- Bit 0: Numerator negative
  - 0 – Numerator is positive
  - 1 – Numerator is negative

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 constant:
  - Sin (phase difference) x 255

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 constant:
  - 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.

7.2.8 HALL Wheel 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/Write															
Name	Degrees High Byte								Degrees Low Byte							

Bit definitions:

- 0-360: Absolute degree position of magnet

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/Write															
Name	Degrees High Byte								Degrees Low Byte							

Bit definitions:

- 16-bit value: Ratio used to calculate degrees

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

Bit definitions:

- 16-bit value: Numerator used to calculate ratio

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

Bit definitions:

- 16-bit value: Denominator used to calculate ratio

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/Write															
Name	Rotation Correction Factor High Byte								Rotation Correction Factor Low Byte							

Bit definitions:

- 16-bit value: Used for auto calibration

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/Write															
Name	Max Numerator High Byte								Max Numerator Low Byte							

Bit definitions:

- 16-bit value: Used during auto calibration

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/Write															
Name	Max Denominator High Byte								Max Denominator Low Byte							

Bit definitions:

- 16-bit value: Used during auto calibration

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

Bit definitions:

- 0-180: Delta in degrees from previous cycle

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

Bit definitions:

- Bit 7-4: Movement Timer
  - 0-15: Timer used to detect movement
- Bit 3-0: Movement Counter
  - 0-15: Counter used to detect movement

7.2.9 Device and Power Mode 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

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 selct:
  - 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

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

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 enabled
  - 1: Channel is disabled
- Bit 4: CH4 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 3: CH3 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 2: CH2 (***note: Ch2, Ch3, Ch4 and Ch5 must all be enabled for Hall effect rotation UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 1: CH1 (***note: Ch0 and Ch1 must both be enabled for Small user interaction detection UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled
- Bit 0: CH0 (***note: Ch0 and Ch1 must both be enabled for Small user interaction detection UI to be functional***)
  - 0: Channel is enabled
  - 1: Channel is disabled

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		

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.
- 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

Normal/Low/Ultra-Low power mode report rate (0xD3,0xD4)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	Normal/Low power mode report rate							

Different addresses:

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

Auto Mode time (0xD6)								
Bit Number	7	6	5	4	3	2	1	0
Data Access	Read/Write							
Name	Mode time							

Bit definitions:

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

8 Electrical characteristics

8.1 Absolute Maximum Specifications

The following absolute maximum parameters are specified for the device:

Exceeding these maximum specifications may cause damage to the device.

Table 8.1 **Absolute maximum specification**

Parameter	IQS624-3yy	IQS624-5yy
Operating temperature	-40°C to 85°C	
Supply voltage range (VDDHI – GND)	1.78V - 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)	

8.2 Power On-reset/Brown out

Table 8.2 Power on-reset and brown out detection specifications

Description	Conditions	Parameter	MIN	MAX	UNIT
Power On Reset	V_{DDHI} Slope ≥ 100V/s @25°C	POR	1.15	1.6	V
Brown Out Detect	V_{DDHI} Slope ≥ 100V/s @25°C	BOD	1.2	1.6	V

8.3 Current consumptions

8.3.1 IC subsystems

Table 8.3 IC subsystem current consumption

Description	TYPICAL	MAX	UNIT
Core active	339	377	µA
Core sleep	0.63	1	µA
Hall sensor active	1.5	2	mA

Table 8.4 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

8.3.2 Capacitive sensing alone

Table 8.5 Capacitive sensing current consumption

Solution	Power mode	Conditions	Report rate	TYPICAL	UNIT
3.3V	NP mode	VDD = 1.8V	10 ms	43.5	µA
3.3V	NP mode	VDD = 3.3V	10 ms	44.4	µA
3.3V	LP mode	VDD = 1.8V	48 ms	13.3	µA
3.3V	LP mode	VDD = 3.3V	48 ms	13.8	µA
3.3V	ULP mode	VDD = 1.8V	128 ms	3.9	µA
3.3V	ULP mode	VDD = 3.3V	128 ms	4.5	µA
5V	NP mode	VDD = 2.5V	10 ms	51.3	µA
5V	NP mode	VDD = 5.5V	10 ms	52.3	µA
5V	LP mode	VDD = 2.5V	48 ms	14.5	µA
5V	LP mode	VDD = 5.5V	48 ms	15.5	µA
5V	ULP mode	VDD = 2.5V	128 ms	3.9	µA
5V	ULP mode	VDD = 5.5V	128 ms	5.1	µA

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

8.3.3 Hall-effect sensing alone

Table 8.6 Hall-effect current consumption

Solution	Power mode	Conditions	Report rate	TYPICAL	UNIT
3.3V	NP mode	VDD = 1.8V	10 ms	215.2	µA
3.3V	NP mode	VDD = 3.3V	10 ms	212.6	µA
3.3V	LP mode	VDD = 1.8V	48 ms	58.3	µA
3.3V	LP mode	VDD = 3.3V	48 ms	55.1	µA
3.3V	ULP mode	VDD = 1.8V	128 ms	N/A (1)	µA
3.3V	ULP mode	VDD = 3.3V	128 ms	N/A (1)	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
5V	ULP mode	VDD = 2.5V	128 ms	N/A (1)	µA
5V	ULP mode	VDD = 5.5V	128 ms	N/A (1)	µA

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

(1) –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.

8.3.4 Halt mode

Table 8.7 Halt mode current consumption

Solution	Power mode	Conditions	TYPICAL	UNIT
3.3V	Halt mode	VDD = 1.8V	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

8.4 Capacitive loading limits

To be completed.

8.5 Hall-effect measurement limits

To be completed.

9 Package information

9.1 DFN10 package and footprint specifications

Table 9.1 DFN-10 Package dimensions (bottom)

Dimension	[mm]
A	3 ±0.1
B	0.5
C	0.25
D	n/a
F	3 ±0.1
L	0.4
P	2.4
Q	1.65

Table 9.2 DFN-10 Package dimensions (side)

Dimension	[mm]
G	0.05
H	0.65
I	0.7-0.8

Table 9.3 DFN-10 Landing dimensions

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

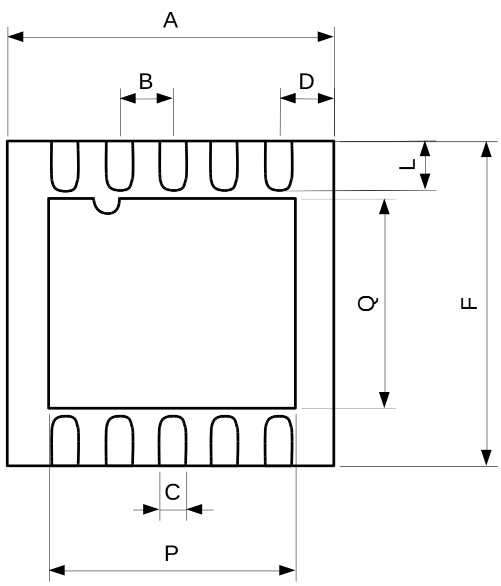


Figure 9.1 **DFN-10 Package dimensions (bottom). Note that the saddle need to be connected to GND on the PCB.**

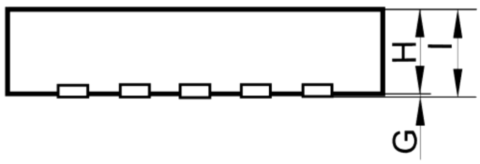


Figure 9.2 DFN-10 Package dimensions (side)

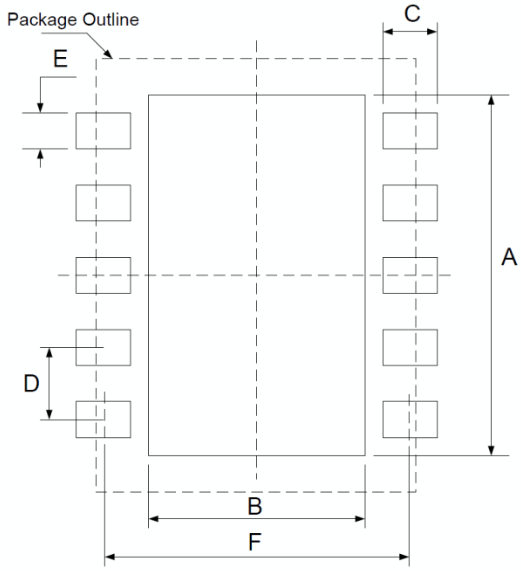


Figure 9.3 DFN-10 Landing dimension

9.2 Device marking and ordering information

9.2.1 Device marking:

IQS624-xyy z t P WWYY

A B C D E

A. Device name: IQS624-xyy
   - x – Version
     - 3: 3V version
     - 5: 5V version(1)
   - yy – Config(2)
     - 00: 44H sub-address
     - 01: 45H sub-address

B. IC revision number: z

C. Temperature range: t
   - i: industrial, 40° to 85°C

D. For internal use

E. Date code: WWYY

F. Pin 1: Dot

Notes:

(1) 5V version is not in mass production, only available on special request.

(2) Other sub-addresses available on special request, see section 6.2.

9.2.2 Ordering Information:

IQS624-xyyppb

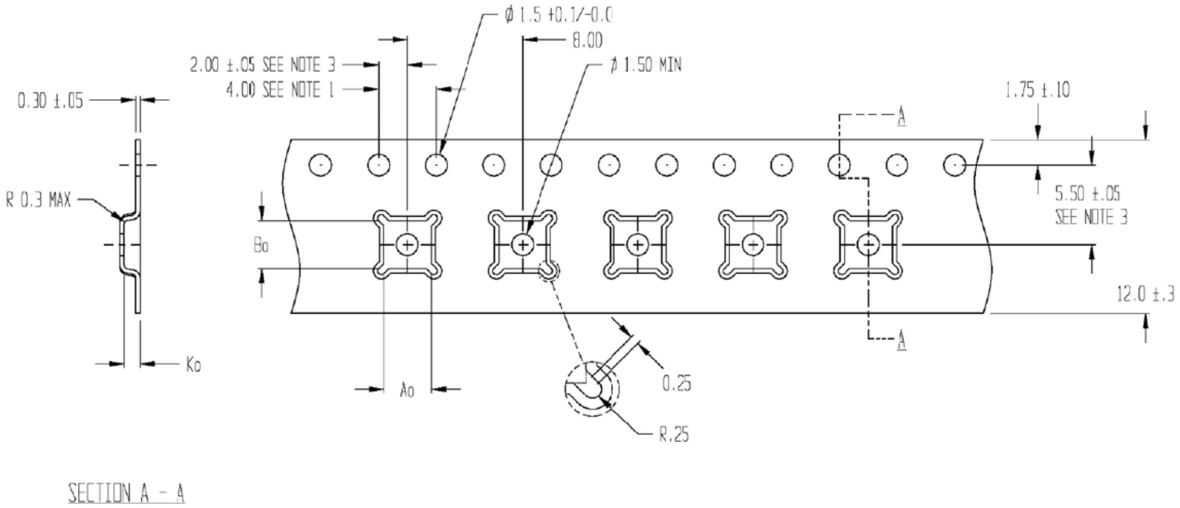
- x – Version
  - 3 or 5
- yy – Config
  - 00 or 01
- pp – Package type
  - DN (DFN(3x3)-10)
- b – Bulk packaging
  - R (3k per reel, MOQ=1 Reel)

Example:

IQS624-300DNR

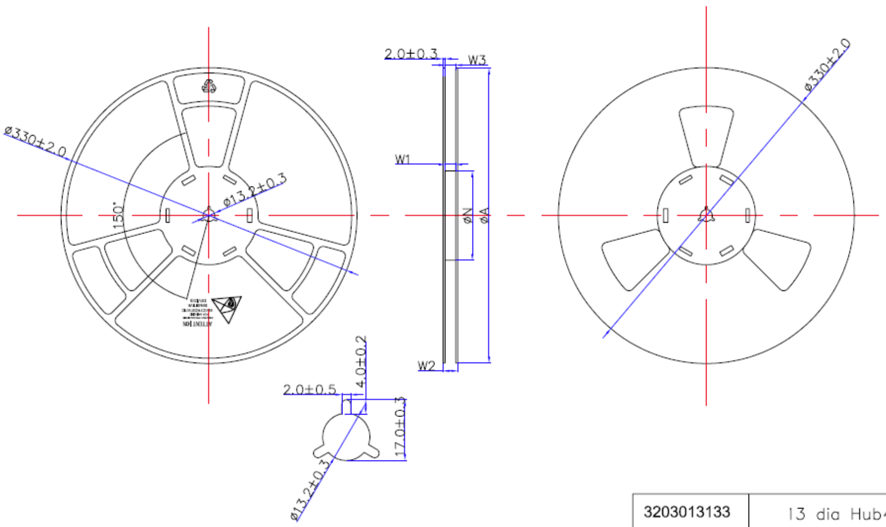
- 3 - refers to 3V version
- 00 - config is default (44H sub-address)
- DN - DFN(3x3)-10 package
- R - packaged in Reels of 3k (has to be ordered in multiples of 3k)

9.3 Tape and reel specification



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



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	ϕA	ϕN	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

9.4 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 2 (1 year @ < 30/60% RH) Reflow profile peak temperature < 260 °C for < 30 seconds

10 Datasheet revisions

10.1 Revision history

V0.1 – Preliminary structure
V1.03a – Preliminary datasheet
V1.04a – Corrected the following:
- 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 the following:
- 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 – Updated datasheet
- Added:
  - Device markings, order information
  - Relative/ absolution summary to appendix
- Updated:
  - Supply voltage range
  - Reference schematic
  - Updated MSL data

V1.12 – Minor updates
- Updated:
  - Titel
  - Images

10.2 Errata

11 Contact Information

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Tel	+1 512 538 1995	+86 755 8303 5294 ext 808	+27 21 863 0033
Fax	+1 512 672 8442		+27 21 863 1512
Email	info@azoteq.com	info@azoteq.com	info@azoteq.com

*Please visit **www.azoteq.com** for a list of distributors and worldwide representation.*

12 Appendices

12.1 Appendix A: Magnet orientation and calibration

The IQS624 is able to 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 1º-179° between the two Hall sensors.
  It's impossible to calculate the angle if the phase difference is 0° or 180°.
- 20mT peak N/S on each Hall sensor
  A minimum of 20mT peak to peak signal is needed on the plates to ensure optimal on-chip angle calculation.

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 insures that the magnet fields observed on both sensors are relatively the same.

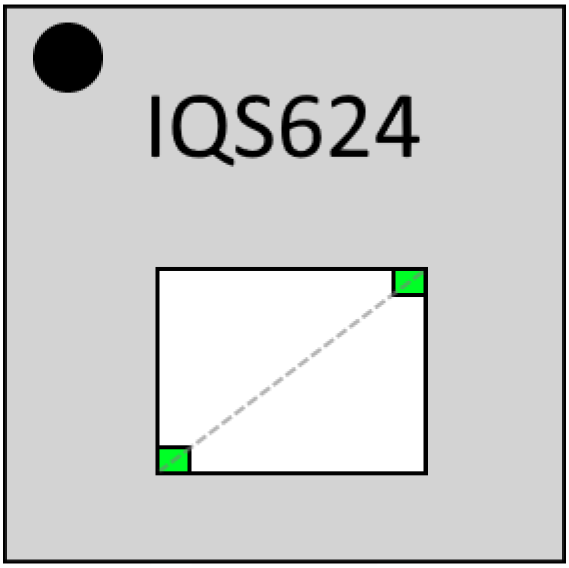


**Figure 1 - A layout of the IQS624 die in a DFN10 package.
Note the Hall sensors at two of the corners.**

Please note: The rectangles which represent the hall sensors in these diagrams are only approximations of where the hall sensors can be found and is not to scale.

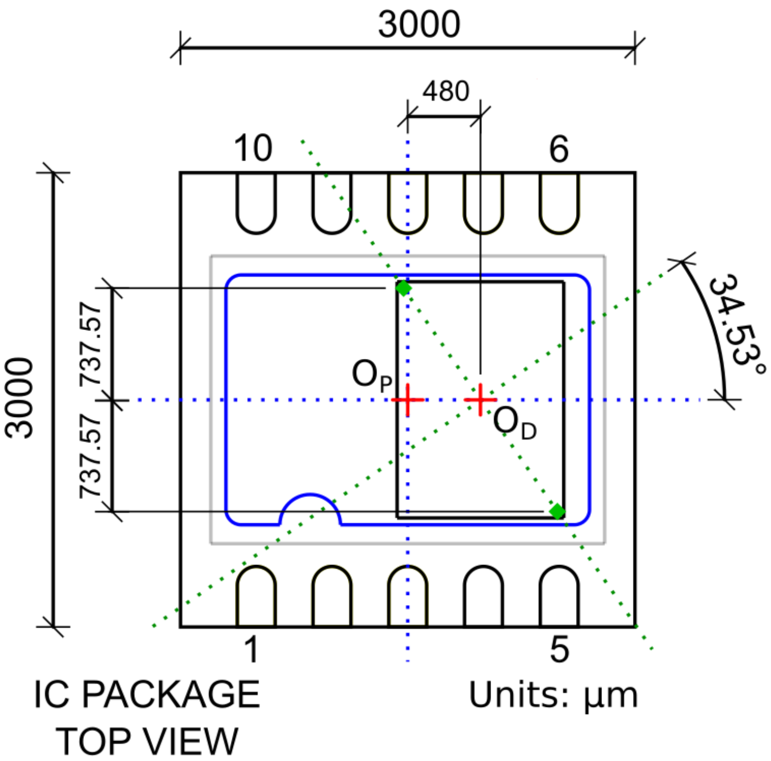


**Figure 2 - Technical Drawing showing DIE placement within the package.
The Hall-Plates are shown as the two green pads in the corners of the DIE.
Package axis and hall-plate axis are also shown.**

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.

Preferred magnet orientation

The preferred or ideal magnet placement would be if the magnet was centred over the die with the axis of the magnet centred between the two Hall sensors.

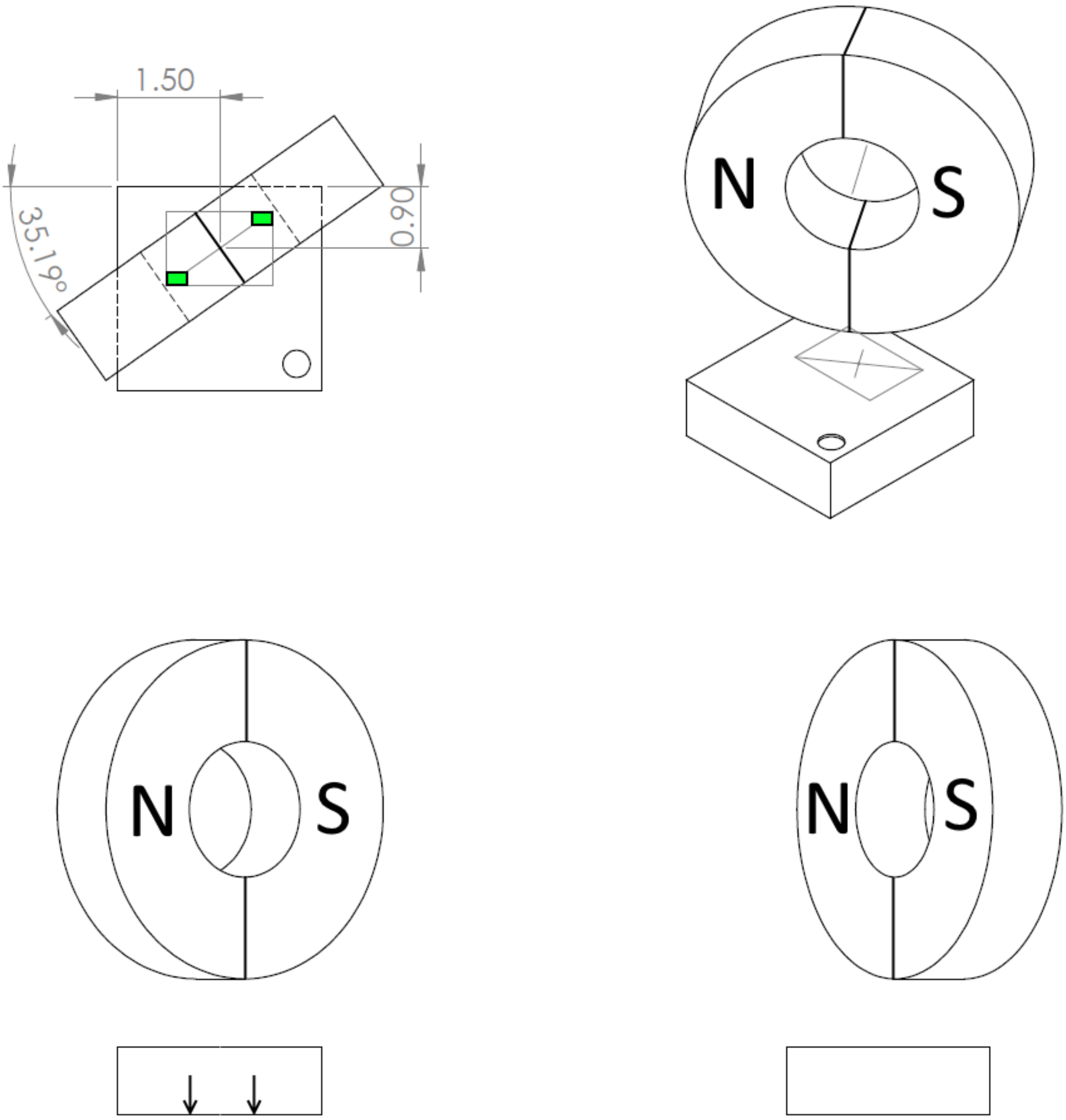


Figure 3 - A magnet placed ideally over the DFN10 package. Note that the magnet field strength is measured in the z-axis.

Evaluation kit magnet orientation

There are two orientations which are used for the evaluation kits, one of which has the magnet axis perpendicular with the IQS624 and the other has the magnet axis parallel with the IQS624.

Parallel magnet solution

A diametric polarised magnet parallel with the IQS624.

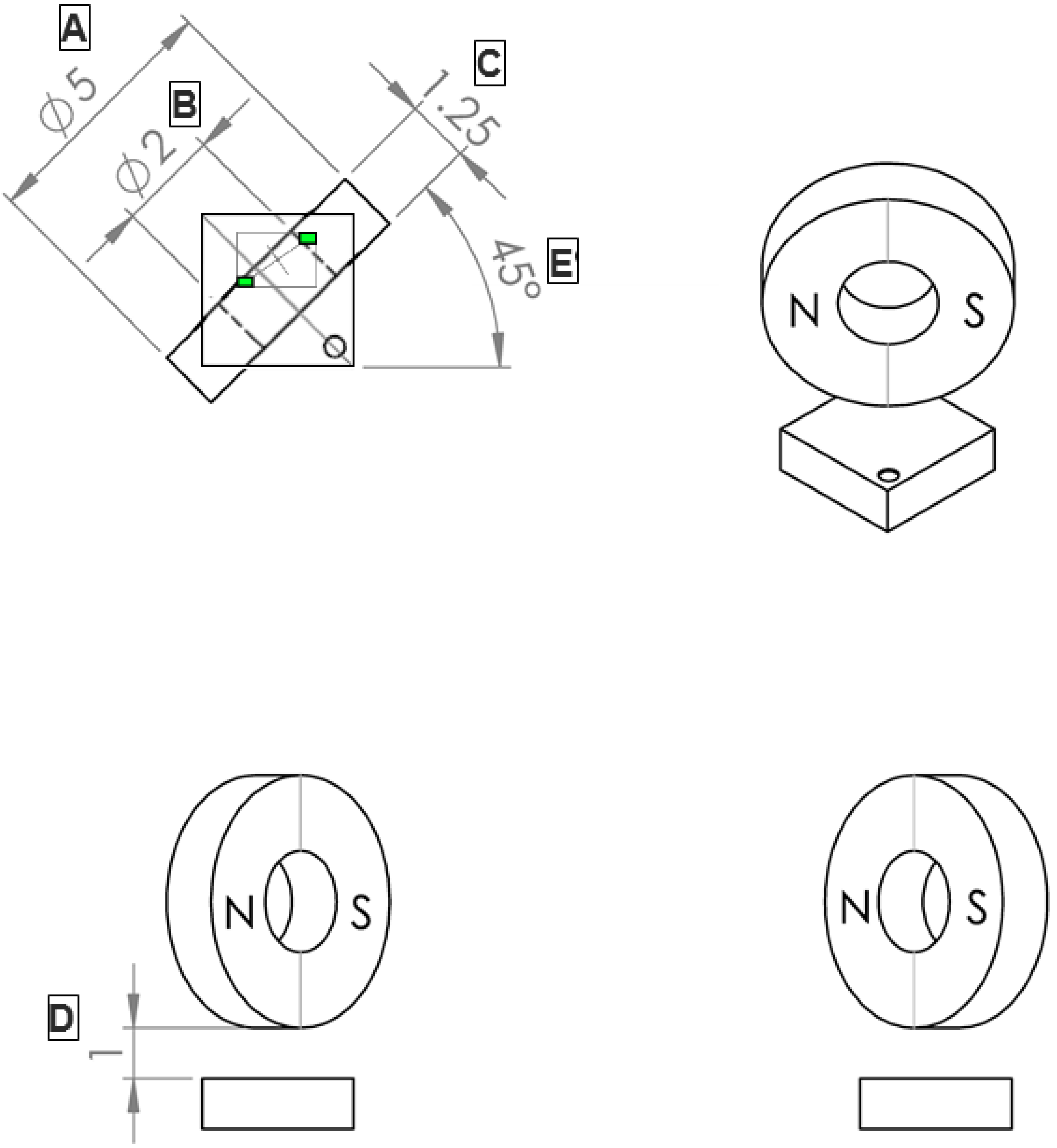


Figure 4 - A diagram showing the Hall sensors relative to the magnet.

Please note: The rectangles which represent the hall sensors in these diagrams are only approximations of where the hall sensors can be found and is not to scale.

Perpendicular magnet solution

A multipole diametric polarised magnet perpendicular but off-centre with the IQS624. This is a typical orientation for a relative application.

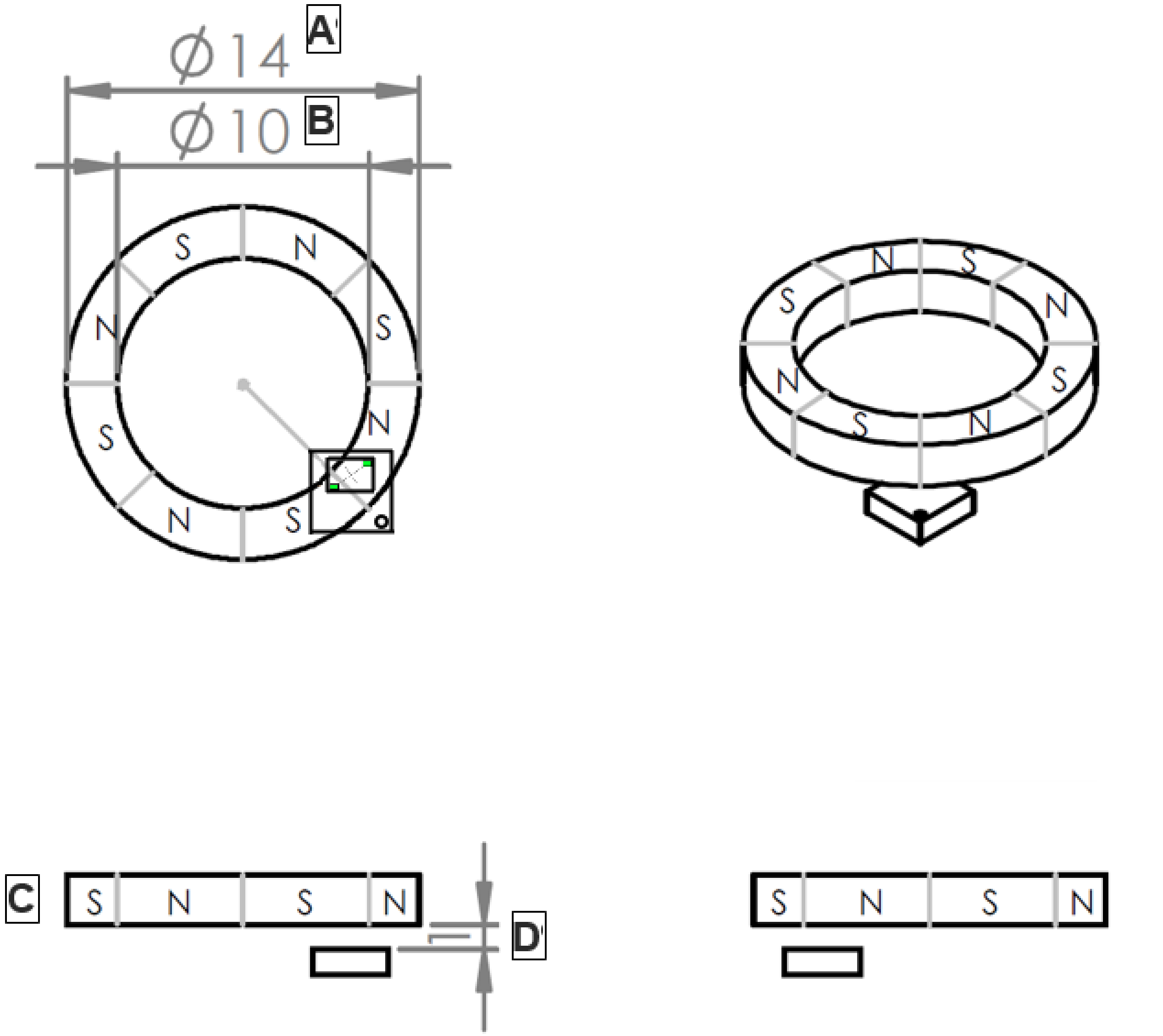


Figure 5 - A diagram showing the Hall sensors relative to the multipole magnet.

Please note: The rectangles which represent the hall sensors in these diagrams are only approximations of where the hall sensors can be found and is not to scale.

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.

Alternative orientation

Off-centred perpendicular diametrical magnet

Here are two possible solutions. Note that both are off-centred. This is to ensure that a phase difference between the two signals are detected.

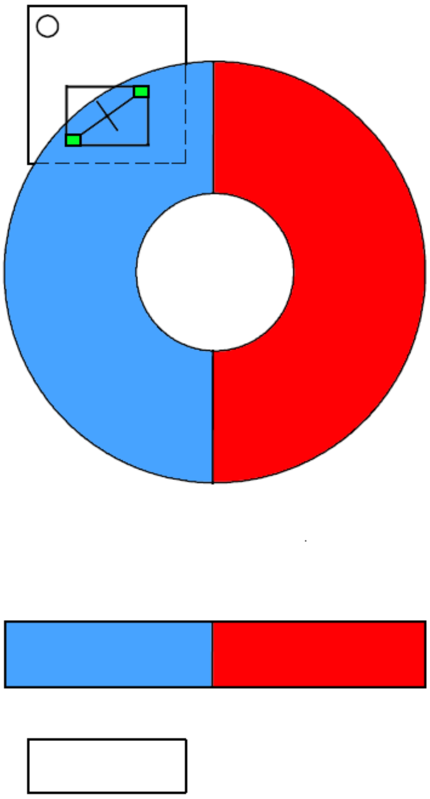


Figure 3 - A slightly off centred diametrical ring magnet

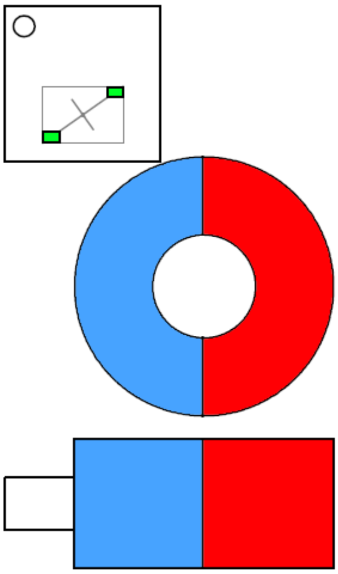


Figure 4 - A diametrical barrel magnet next to the IC. The distance between the sensor and the magnet is greater in this solution, thus a stronger magnet is suggested.

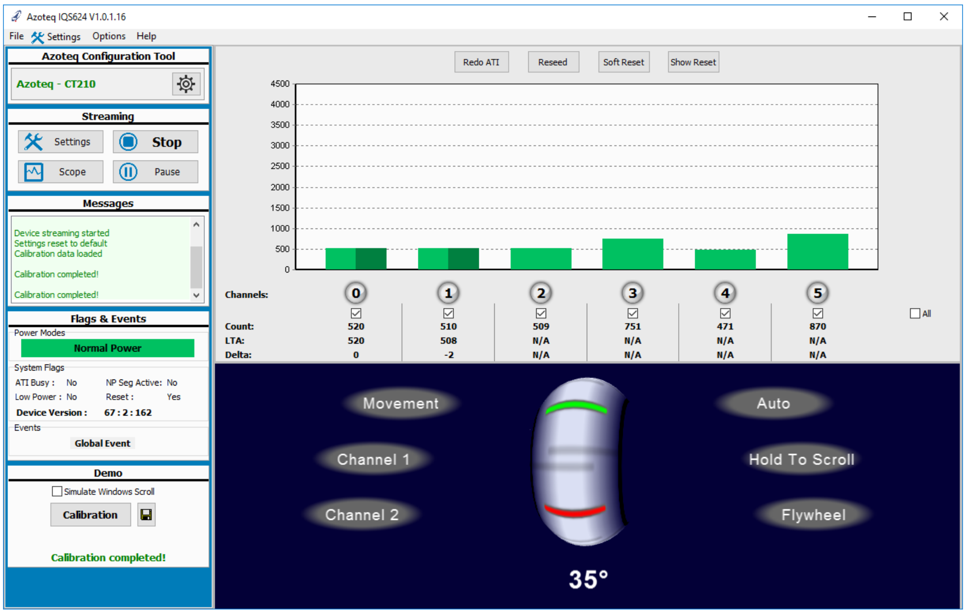
Please note: The rectangles which represent the hall sensors in these diagrams are only approximations of where the hall sensors can be found and is not to scale.

Even though these solutions will work we do not encourage their use. We designed this product with the idea to promote easy usage and fewer physical restrictions to the usage. These solutions require more critical design on the physical layout and rigidness in the final project.

Calibration of the IQS624

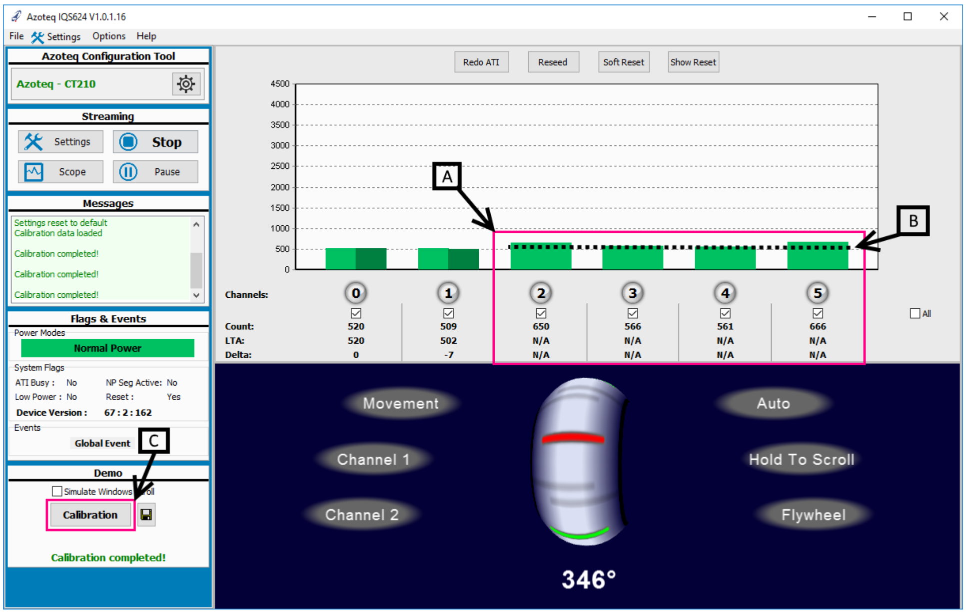
How to calculate the calibration constants using the IQS624 GUI

Step 1: Open the IQS624 GUI, connect the device and start.



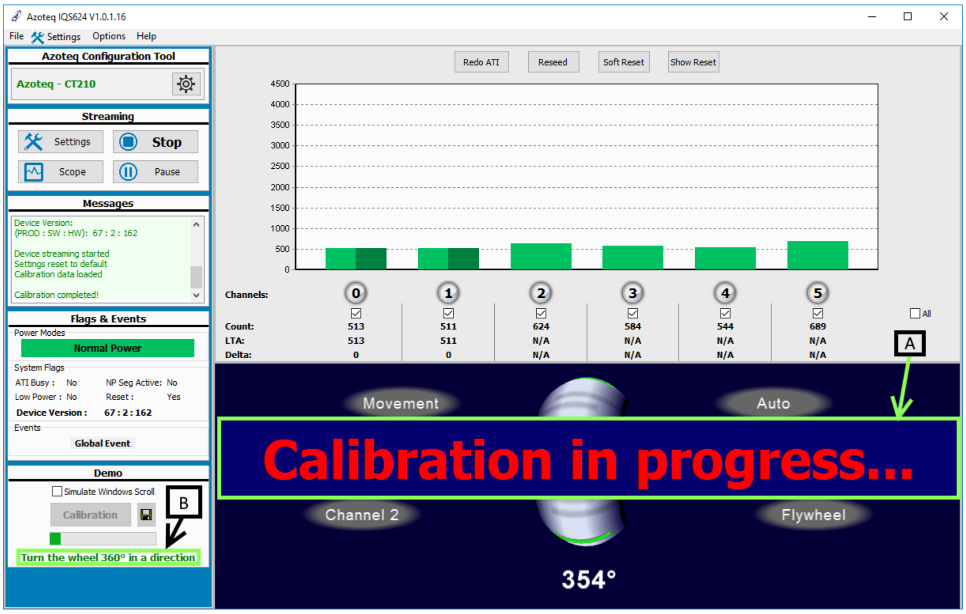
If the IQS624 device is connected the GUI should look like the previous figure.

Step 2: Align the Hall sensor channels and start the calibration



A. The four Hall channels.
B. The channels should be lined up or as lined up as possible. This step can be skipped but it has been observed that better results has been obtained by adding this step.
C. The calibration button. If this button is clicked, the calibration process will start.

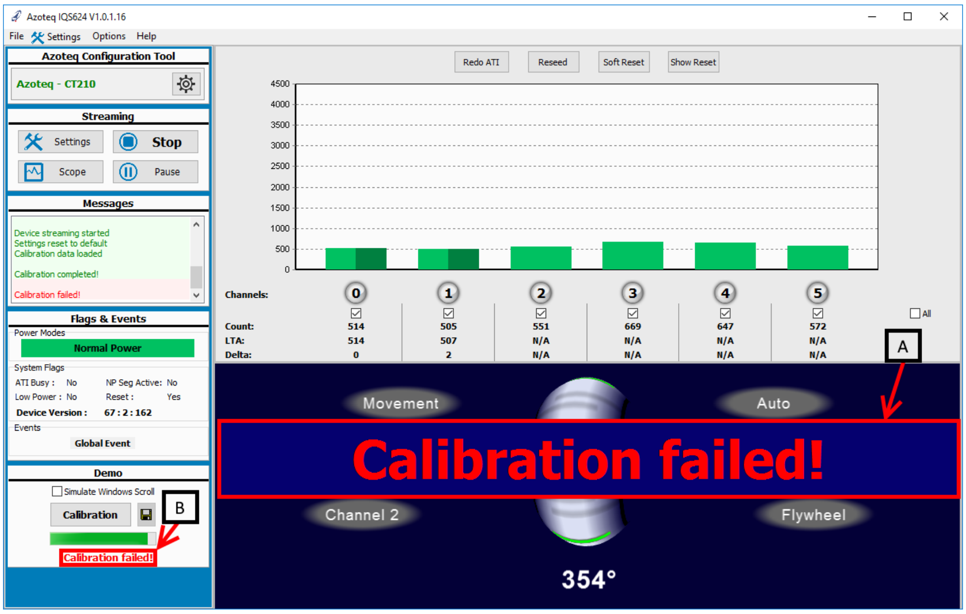
Step 3a: Calibrating the device



A. This banner indicates that the calibration progress has started.
B. Like this text instructs, 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.

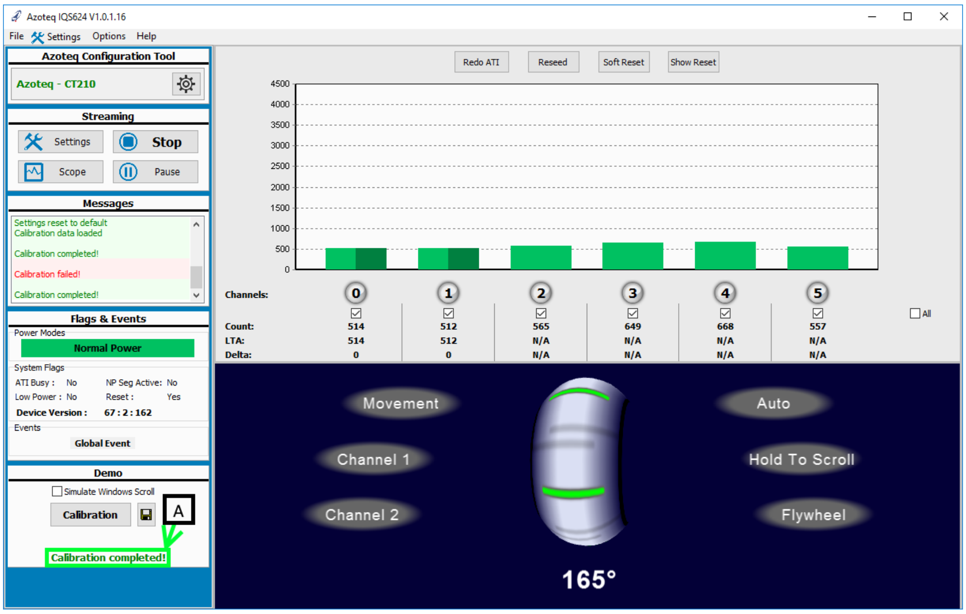
Step 3b: Calibration failure



A. If this banner pop's up while rotating the wheel an error was received while calibrating the device.
B. This text also informs an error has occurred.

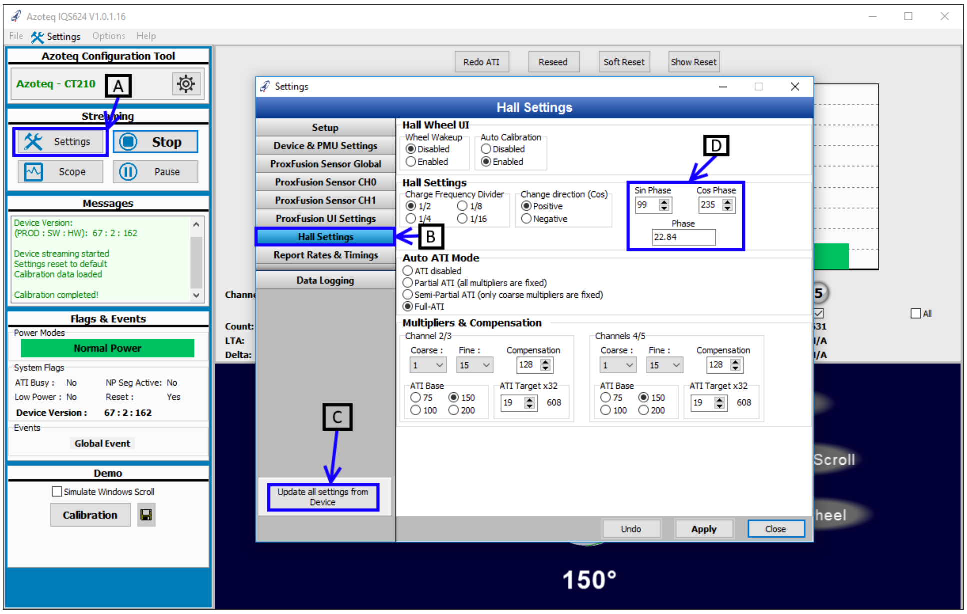
If an error occurs step 2-3a should be repeated.

Step 3c: Calibration complete and successful



A. This text confirms that the calibration is completed and successful and that the constants have been written to the device.

Step 4: Obtaining the calibration constants



A. The settings button to open the settings window.
B. The Hall settings tab which contains all the settings for the Hall UI
C. This button updates the settings window from the connected device. Its recommended that this button should be clicked before the values are used from this window.
D. The calibration constants. The sin phase and cos phase are the two constants which are written to the device. The phase (its displayed in degrees) can also be used to obtain both of these constants.

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.

How to calculate the calibration constants using the raw data

There are two Hall Plates that make up the sensor, separated by a fixed distanced 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
θ_Δ	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.

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

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:

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

Likewise, the phase delta can be calculated from the inverted pair: $\{P'_2, P'_1\} = \{CH_5, CH_3\}$ sample both channels where $N(CH_5) \approx 0.5$.

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

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:

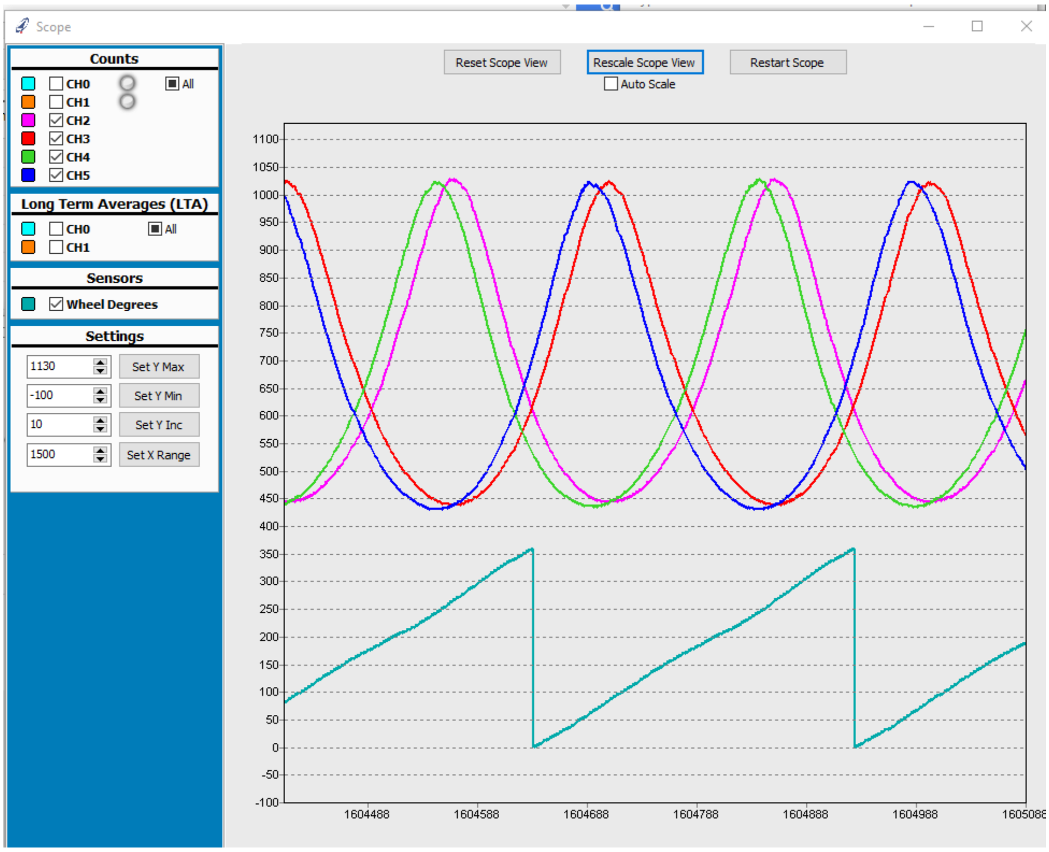
$$\theta_\Delta = \frac{sin^{-1}(|N(CH_4) - N(CH_2)| \cdot 2) + sin^{-1}(|N(CH_5) - N(CH_3)| \cdot 2)}{2} \tag{4}$$

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.

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.

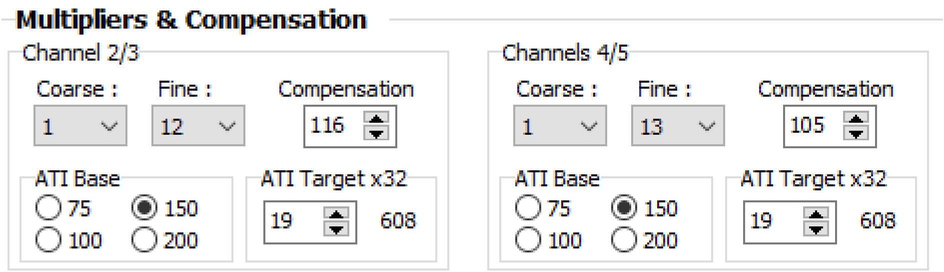
Using two channels ensures that the ATI can still be used in the presence of the magnet. The two channels are the inverse of each other, this means that the one channel will sense North and the other South. The two channels being inverted allows the capability of calculating a reference value which will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

Hall reference value:

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

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

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.).

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.

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.

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: 100 or 150
- 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.