IQS624 Application Note

1 Introduction

The IQS624 can be used off-axis and on-axis. Absolute degrees can be obtained from the counts if a two pole magnet is used, this is the typical magnet for the off axis. If a magnet with 4 or 8 poles is used only relative counts will be available. The 8 pole magnet is typical for the on-axis.

Typical Uses

Off-axis hall sensor

- Mouse wheel
- Revolution counter
- Measuring wheel

On-axis hall sensor

- Thermostat control
- Volume knob
- Motor PID control

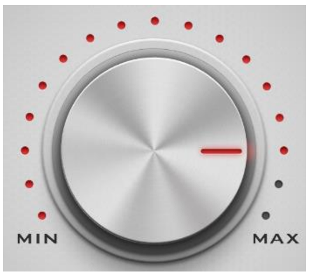
Real life applications with off axis sensors

Mouse wheel

Measuring wheel

Real life applications with on axis sensors

Thermostat control



Volume knobs

Motors

1.1 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.

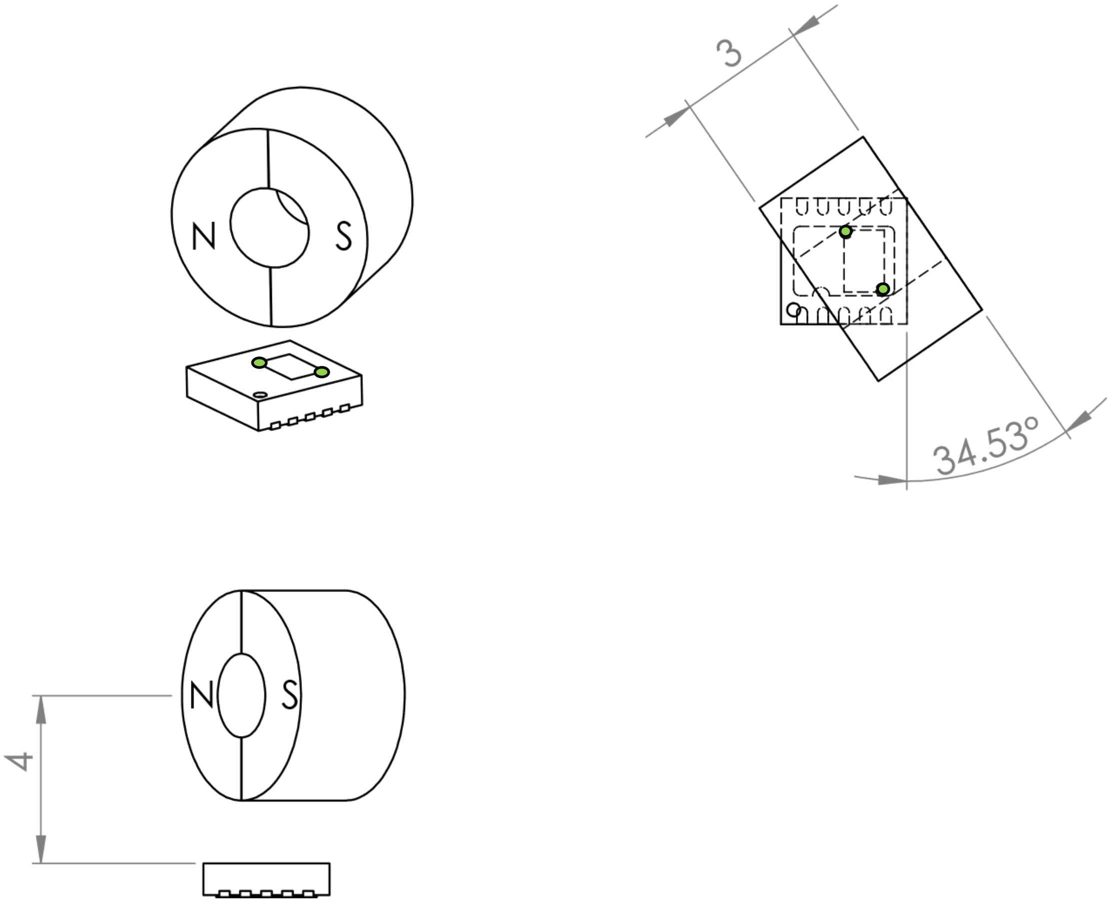


Figure 1.1 Magnet's postion reletave to IC with off-axis orientation

Table 1.1: Typical specifications of off-axis magnet position

	Variables	Typical
A	Outer radius	2.5 mm
B	Inner radius	1 mm
C	Thickness of magnet	1.25 mm
D	Distance between IC and Magnet Axis	3.5 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

1.2 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.

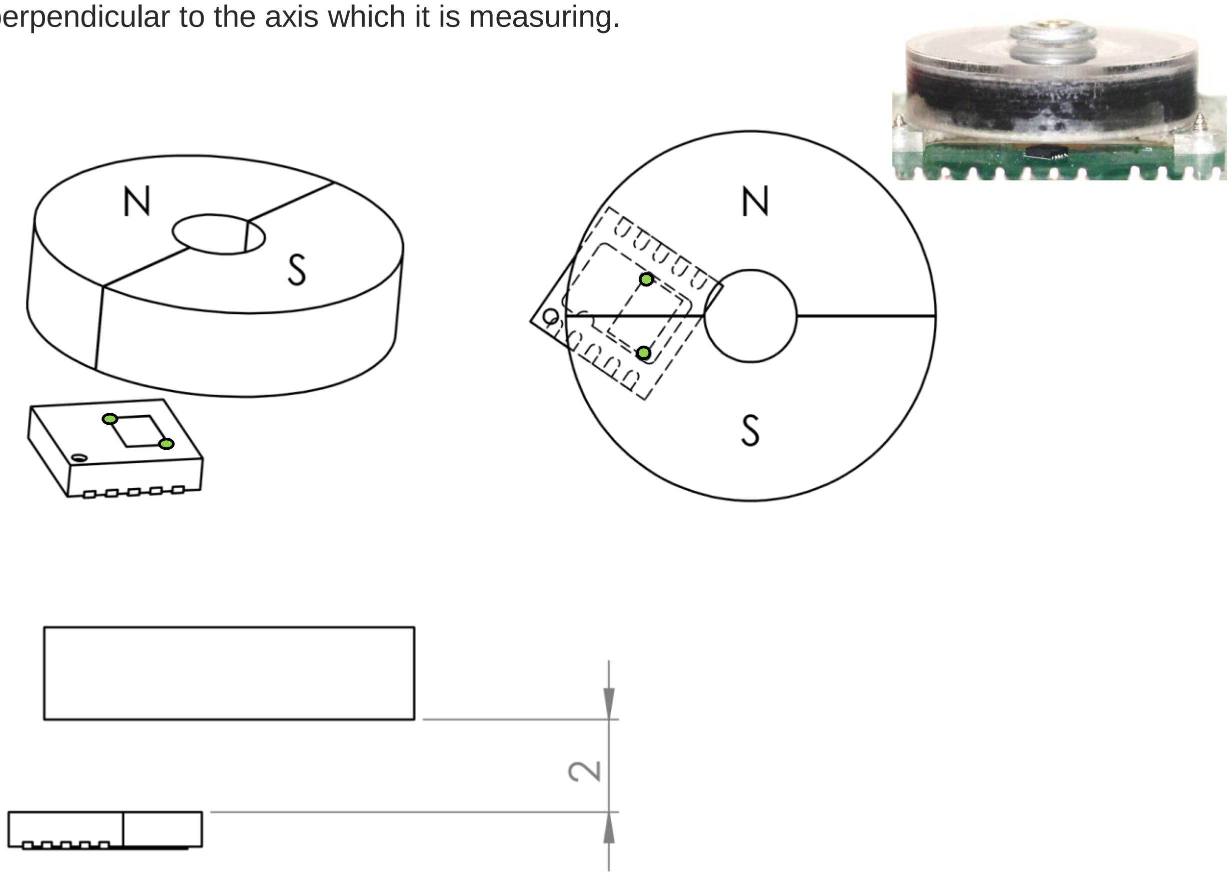


Figure 1.2 Magnet's postion relative to IC with on-axis orientation

Table 1.2: Typical specifications of on-axis magnet position

	Variables	Typical
A	Outer radius	4 mm
B	Inner radius	1 mm
C	Thickness of magnet	2 mm
D	Distance between IC and Magnet	2 mm
E	Residual inductance (B_r)	1.25 T
F	Polarization	Diametrical
G	Magnetic grading	N40

Typical schematic for IQS624:

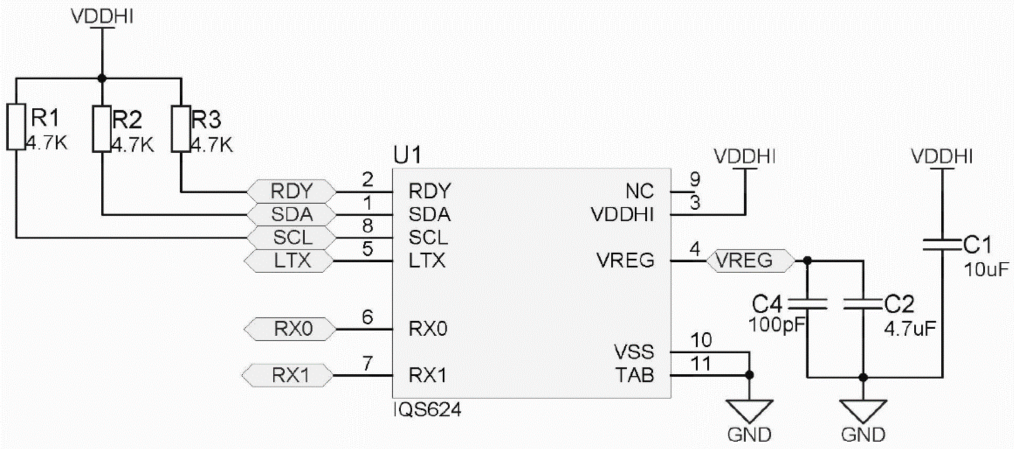


Figure 1.3 Typical Schematic

Capacitive touch- and hall rotation sensor modes

Low power mode

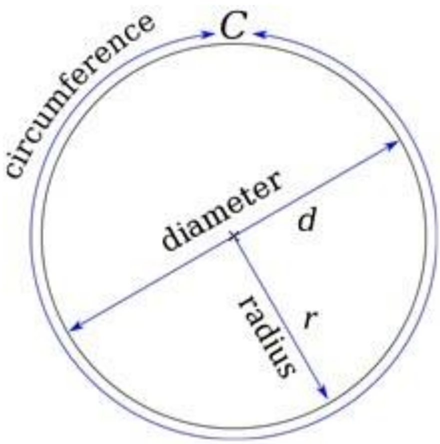
The report rate of the IC slows down after a set period of in-activity. The IC re-enters normal mode with any event, restoring the report rate to the normal report rate. The events triggering normal mode can be either a touch/proximity event or a rotation event.

Wake wheel mode (Enable wheel with capacitive touch)

When this mode active, the hall rotation sensors will only update when there is a touch event on the CRX0. This mode also ensures that a rotation event would not be triggered with no touch/proximity event. Once the wheel is activated and the wheel keeps rotating after the touch and proximity event has occurred, the rotation sensor will stay active and only deactivate when the wheel stops. See the communication protocol to learn how to activate this mode.

2 Hall Sensor Design Guide

The energy of a magnet is defined by the material, geometry and position. The design variables for a hall sensor assembly includes the above-mentioned characteristics as well as the distance from the magnet to the hall IC. A design guide for an off-axis hall rotation sensor is discussed in this section. It should be noted that in this section the inner radius and outer radius of the magnet will be used instead of the diameter. The relationship between radius and diameter can be seen in Figure 2-1.



$$r = \frac{d}{2}$$

$$d = r \times 2$$

$$C = \pi d \text{ or } 2\pi r$$

Figure 2-1: Relation between diameter and radius

2.1 Choose Magnet Material

Different magnet materials are compared in Table 2.1. A magnet should be chosen based on the requirements of the application. Azoteq recommend the use of an NdFeB N40 magnet for most applications.

Table 2.1: Magnet Comparison

	low			high
Costs	Ferrite	AlNiCo	NdFeB	SmCo
Energy (WxHmax)	Ferrite	AlNiCo	SmCo	NdFeB
Temperature	NdFeB	Ferrite	SmCo	AlNiCo
Corrosion resistant	NdFeB	SmCo	AlNiCo	Ferrite
Opposing field resistant	AlNiCo	Ferrite	NdFeB	SmCo
Mechanical strenth	Ferrite	SmCo	NdFeB	AlNiCo
Temperauture coefficient	AlNiCo	SmCo	NdFeB	Ferrite

(Source: www.meder.com)

2.2 NdFeB Design considerations

For the Hall Plates on the IC to function, the magnetic field strength coincident to the plates should be in the range of: $10\ mT \leq B_h \leq 50\ mT$, note that the field should not exceed $100\ mT$ as the sensor begins to saturate.

It is important to position the magnet above the sensor to meet this requirement; however, it is not easy to determine this position accurately using theory – this is due to the complexity of determining the magnetic field of a permanent magnet. The following suggestions serves as a guideline for selecting a magnet for your application.

The magnetic field strength at a distance away from the magnetic field axis is inversely proportional to the cube of the distance from the magnet, this means that the magnetic field rapidly decreases with distance. This implies that small misalignments can have a larger than expected influence.

The grade of neodymium (NdFeB) magnets is measured in MGOe. A magnet with a N40 grading has a maximum energy product of 40 MGOe. Therefore the higher the grading the higher the flux density. A N40 magnet was used as example but the same procedure can be applied to ferrite, AlNiCo and SmCo magnets.

The magnetic flux density (B) at the surface of the IC is dependent off the maximum energy product (BH_max), magnet geometry and the distance between the IC and the magnet axis (D in Figure 1.1). A simulation was done to calculate the effect of magnetic flux density on the design variables. Four different NdFeB magnets were used with a fixed inner radius of 2 mm, as seen in Figure 2-2.

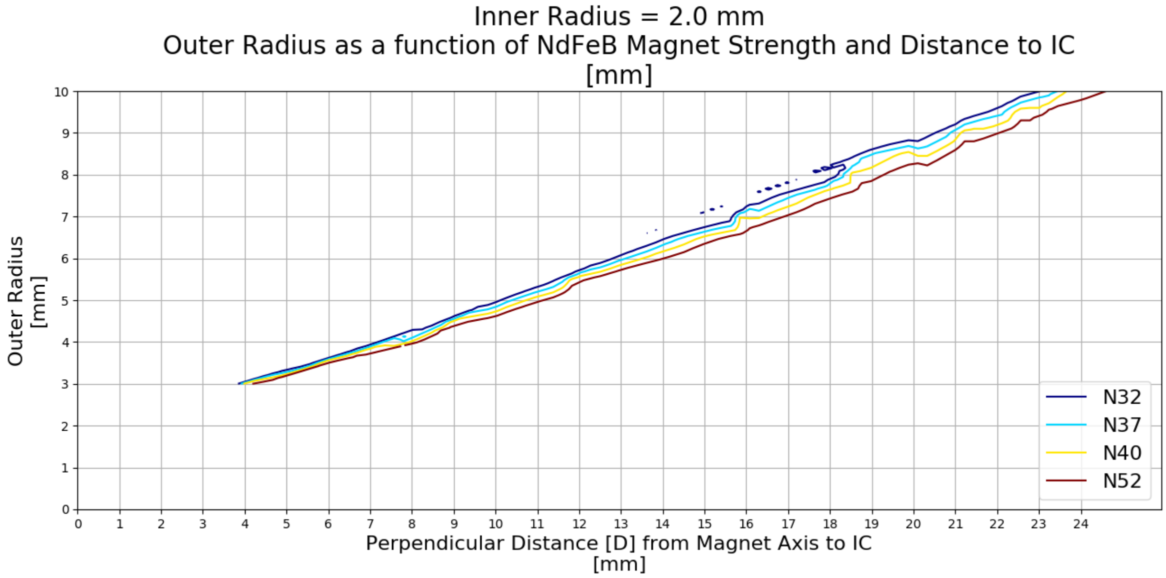


Figure 2-2: Comparison of Magnet strength (NdFeB)

It can be seen that if the magnetic flux density is increased from 32 MGOe to 52 MGOe the magnet could be placed further away. It should be noted that this difference is never greater than 1.5 mm.

Figure 2.3 shows the relationship between the outer radius, inner radius and perpendicular distance [D] from magnet axis to IC. These calculations were done at 100 mT with a 40 MGOe magnet. As seen from Figure 2-2 the magnet grading does not have a significant influence on the distance D therefore if a magnet with a different grading is chosen use a tolerance of +-0.75 mm on the x axis of Figure 2-3.

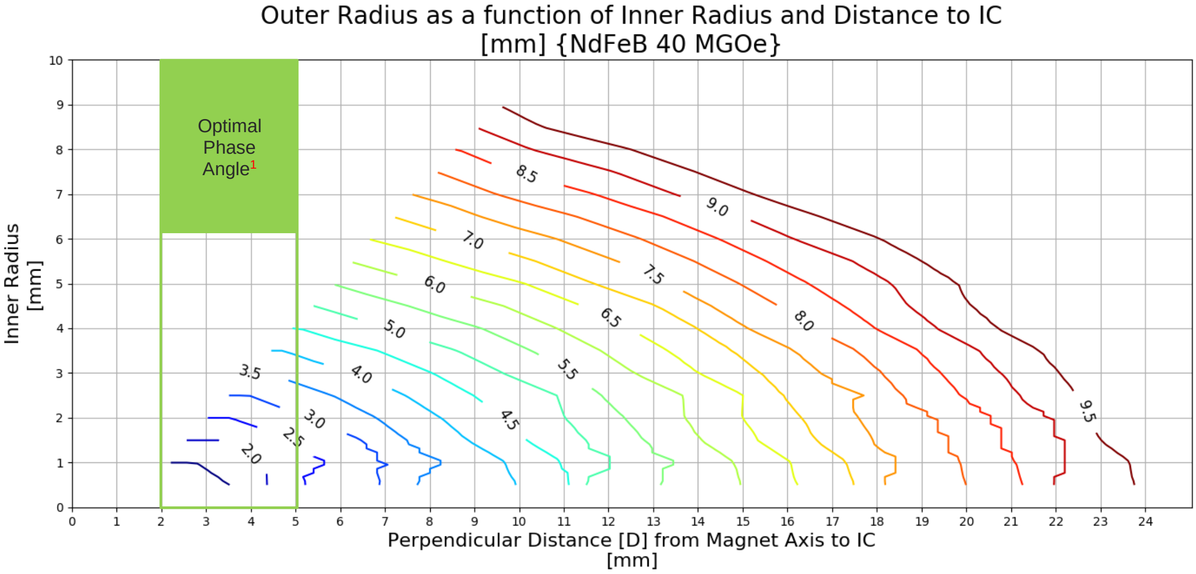


Figure 2-3: NdFeB 40 MGOe Magnet Simulation

(1) - Optimal phase region is not yet fully confirmed, further experiments are being undertaken to confirm this region and explore its extent. Current region is the result of numerical simulation.

The designer should choose two of the design variables according to the application or geometry restrictions and use Figure 2-3 to select the third variable. If the graph does not satisfy the requirements of the application, the designer must re-iterate the process to find a magnet that will fit the application.

The phase angle should be between 20º and 50º to ensure a good signal from the hall plates. A simulation was done to determine the phase angle between the hall plates and can be seen in Figure 2-4.

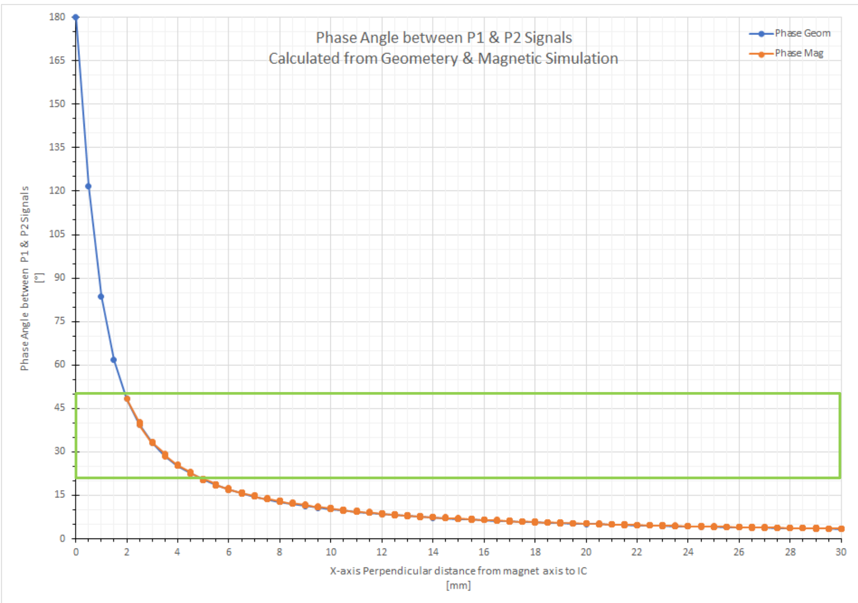


Figure 2-4: Phase Angle Consideration

From Figure 2-4 the optimal distance between the magnet axis and the IC is 2 mm to 5 mm. If the magnet axis is placed outside of this range the signal quality will not be optimal.

2.2.1 Example 1:

The geometry of the application have the following restrictions:

1. Outside Radius = 3 mm
2. Inside Radius = 2.5 mm
3. N40 magnet
4. D = ?

Use Figure 2-3 to locate these parameters. As seen on the graph the magnet should be placed ~4 mm away from the IC. This falls within the optimal phase angle range.

2.2.2 Example 2:

The geometry of the application have the following restrictions:

1. Inside Radius = 4 mm
2. D = 6 mm
3. N40 magnet
4. Outside Radius?

Use Figure 2-3 to determine what the outside radius should be. This point falls outside the optimal phase angle range. Move the IC 1 mm closer to the axis. On the N40 graph, the outside radius should be 4.5 mm.

2.2.3 FAQ's:

Which magnet should I use if I want the smallest possible assembly?

1. Inside Radius = 1 mm
2. Outside Radius = 1.5
3. D = 2.1 mm
4. N40 magnet

Which magnet should I use if I want the maximum distance between the IC and magnet axis?

1. Inside Radius = 1.5 mm
2. Outside Radius = 2.5
3. D = 5 mm
4. N40 magnet

2.3 Other magnet materials

Figure 2-5 compares two different strength ferrite magnets with a constant inner radius of 2 mm. It can be seen from this graph that because the magnets are a lot weaker than NdFeB magnets, the slope of this graph is greater than Figure 2-2.

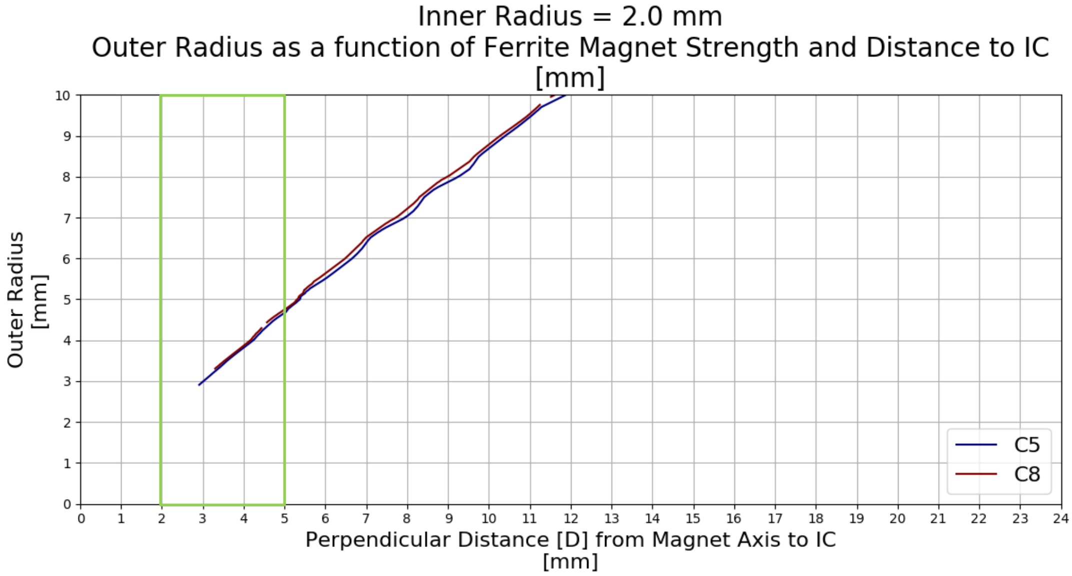


Figure 2-5: Comparison of Magnet strength (Ferrite)

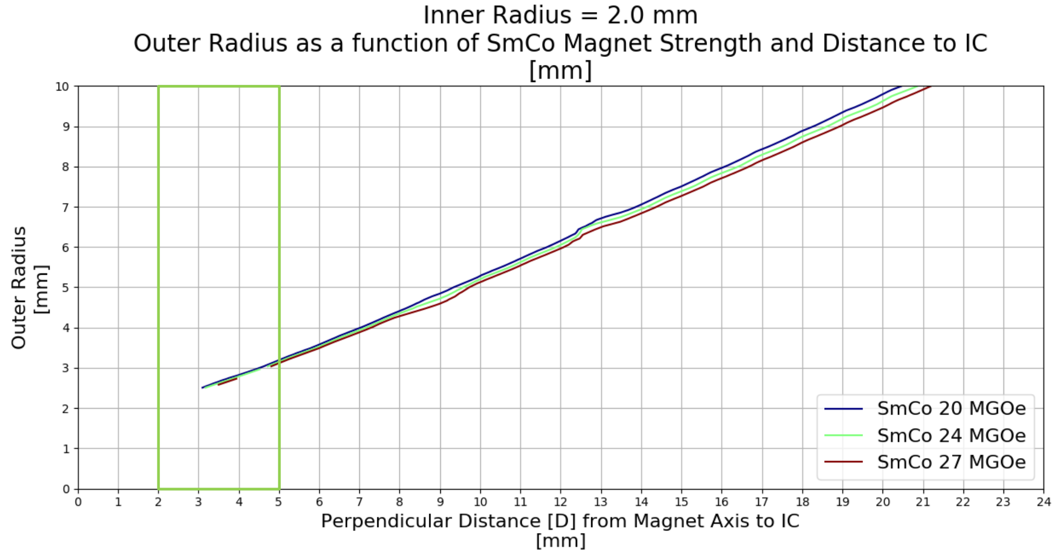


Figure 2-6: Comparison of Magnet strength (SmCo)

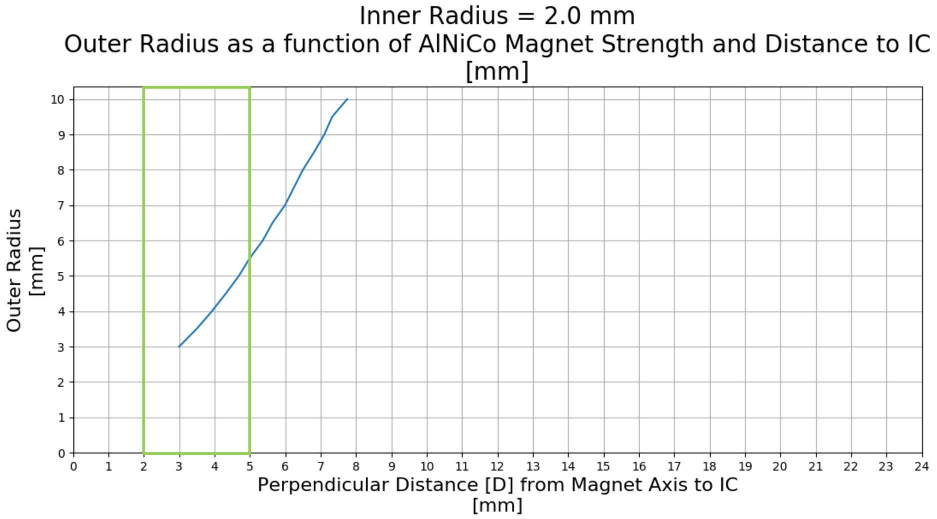


Figure 2-7: Comparison of Magnet strength (AlNiCo 8)

AlNiCo 5, 6 and 8 were simulated. AlNiCo 8 was the only one of these three that had a magnetic field strength strong enough for accurate calculations. It should also be noted that this peak magnetic energy occurs at the tip of the magnet.

3 MCU Processing

The IQS624 is an I2C device which can be connected to an MCU for further processing. A Variable Beta IIR filter can be applied to the degree output (0x80-0x81) to remove unwanted “jitter” on the rotation angle. The Variable Beta IIR filter can be implemented by using the equations below:

$$FiltValue = \beta \times FiltValue_{Prev} + (1 - \boldsymbol{\beta}) \times Degree_{Raw}$$

Where:

$$\beta = 1 - (Degree_{Current} - Degree_{Prev}) * Constant$$

Where the constant can be between 0 and 1. Figure 3-1 illustrates how the Beta term can be varied for bigger relative degree values.

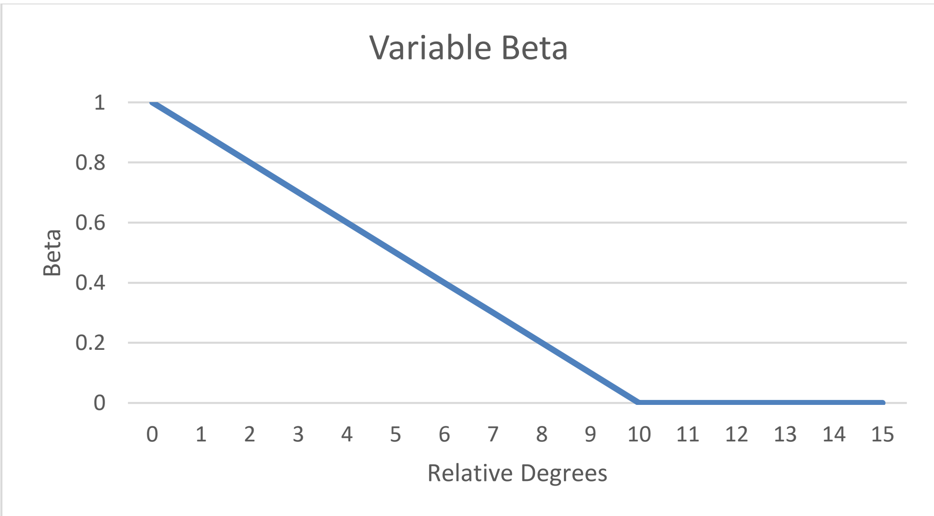


Figure 3-1: Variable Beta vs Relative Degrees

Figure 3-2 illustrates an example of where the variable Beta IRR filter was implemented on a noisy degree output.

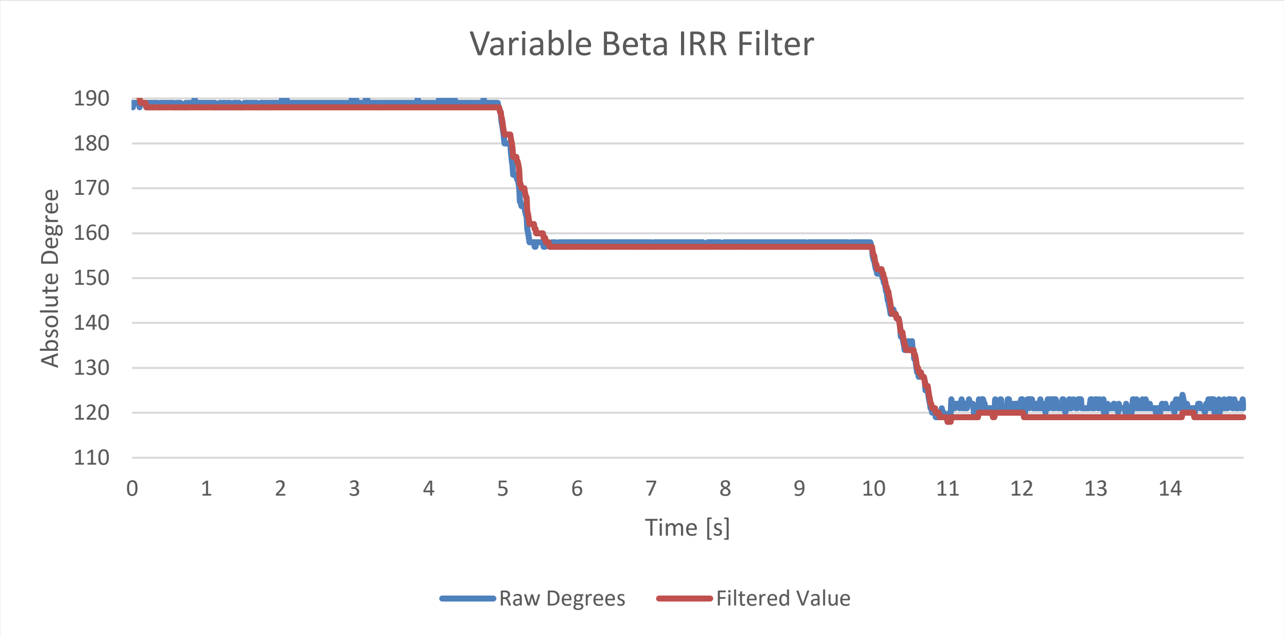


Figure 3-2: Variable Beta IIR Filter

4 Wheel Wakeup Sensor

The IQS624 has a wheel wakeup functionality. This functionality will decrease power consumption when the wheel is not active. The hall channels are activated by a touch on Channel 0. Below is a few guidelines for designing a wheel touch sensor.

The capacitive sensor consists of two parts: the wheel electrode and the stationary electrode. Figure 4-1 illustrates this concept.

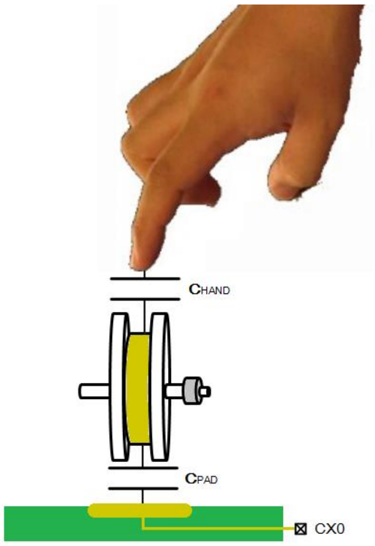


Figure 4-1: Wheel wakeup sensor concept

When the hand moves closer to the wheel the capacitance C_{HAND} increase and a touch can sensed on CX0. The wheel electrode should be an inductive material. This area can be covered with a rubber ring. The stationary electrode can have different designs. A larger stationary electrode will increase sensitivity. Figure 4-2 illustrates an example of a stationary electrode.

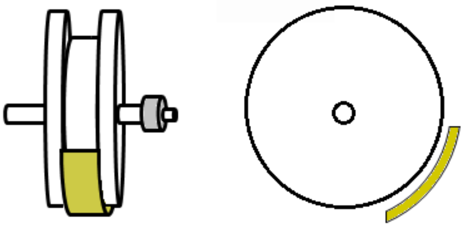


Figure 4-2: Stationary Electrode

A wheel touch sensor can provide more user interface functions while also decreasing current consumption when wheel wake-up is enabled. This function can be implemented using different designs and locations for the sensor connected to CX0. For example, if the application requires the user to hold the device, the sensor could be placed where the palm touches the device.

5 Event Mode for slow wheel movements

The IQS624 can be switched to event mode in the General System Settings Register (0xD0; bit 5). An internal counter is used to trigger events. On-chip calculations are done to determine whether the relative angle is big enough to trigger an event. If this is not the case the internal counter is cleared. If very slow movements of the magnet is required in event mode and wheel wakeup is not enabled, the following algorithm is suggested.

The IQS624 should start up in event mode. When the IQS624 switches to Normal Power mode the MCU disables event mode in the General System Settings Register (0xD0). The power mode can be read in the Power Mode Settings Register (0xD2; bit 4-3). If no events is detected, the IQS624 will go to Low-Power mode and then to Ultra-low Power mode (if enabled in the Power Mode Settings Register (0xD2; bit 6)). When the IQS624 is in either one of the low power modes the MCU should enable event mode again and when an event is triggered switch back to streaming mode.

The following report rates are suggested for this operation:

- Normal Power mode report rate: 10 ms
- Low Power mode report rate: 55 ms
- Ultra Low-power mode: 128 ms

Please note that the device will take a bit longer to respond but slow movements will also trigger events.

If wheel wakeup is enabled (described in this document) it is not necessary to switch between event and streaming mode on the MCU. When the device sees a touch on RX0, the hall sensors will be activated and stream data until the touch is released.

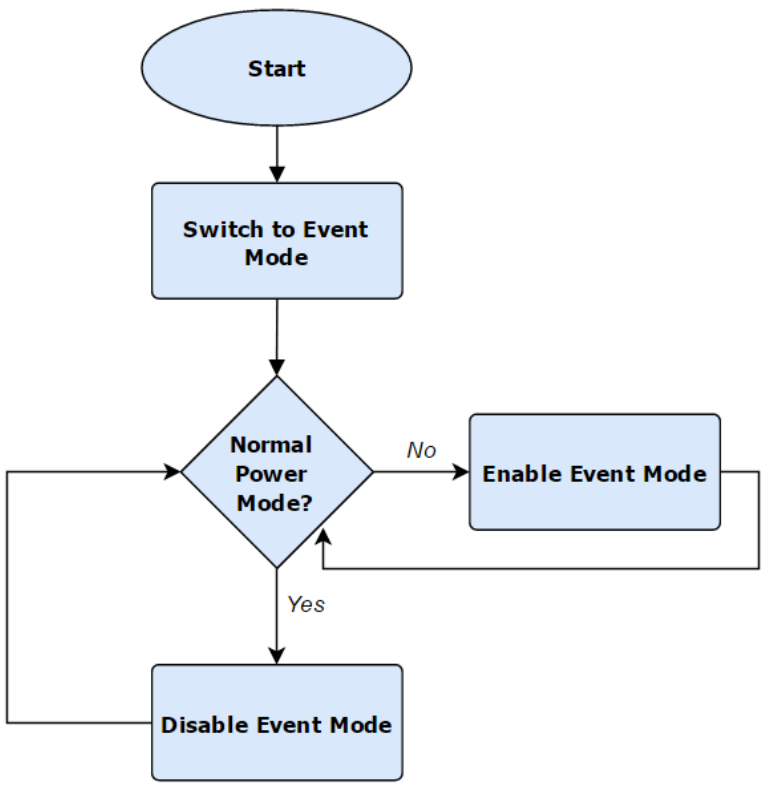


Figure 5-1 Diagram for slow movements in event mode

6 Appendix A:

6.1 NdFeB

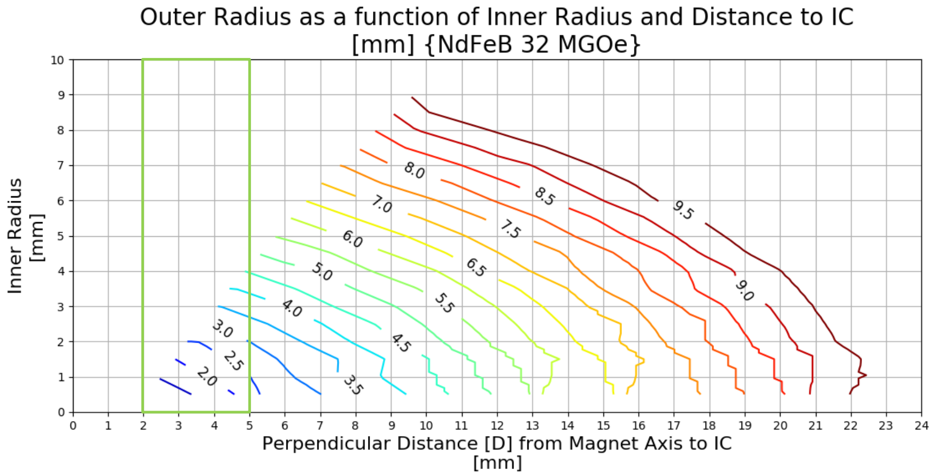


Figure 6-1: NdFeB 32 MGOe Magnet Simulation

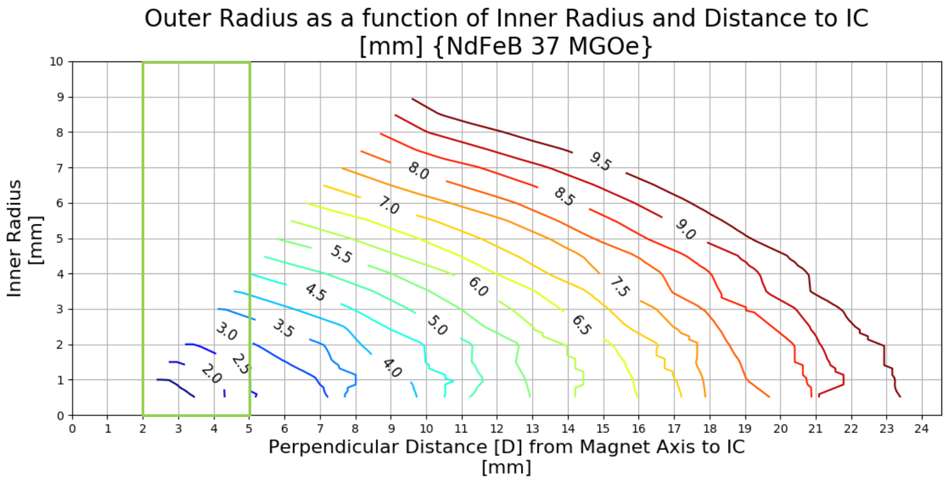


Figure 6-2: NdFeB 37 MGOe Magnet Simulation

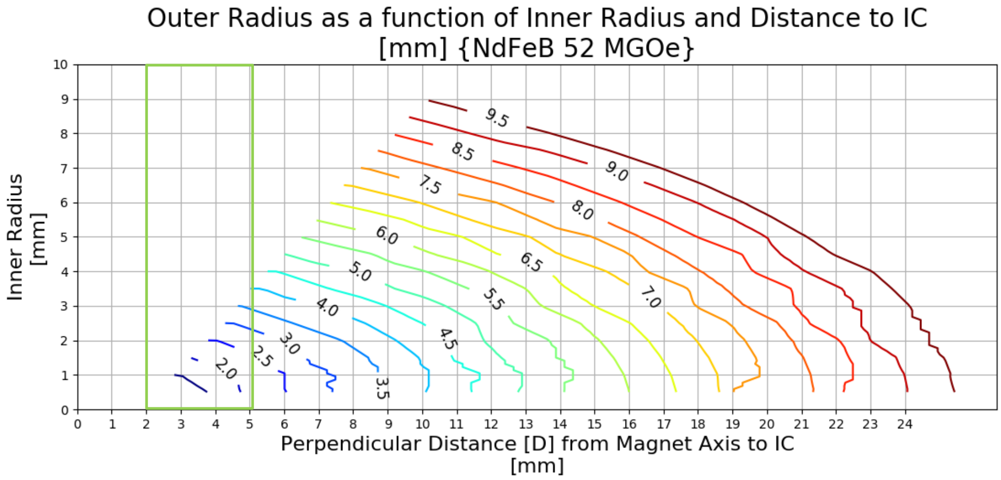


Figure 6-3: NdFeB 52 MGOe Magnet Simulation