Methods of Calculating B-Field at Hall Element in Open Loop Current Sensor

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Abstract. The demand for low-cost, accurate, small-size current sensor solutions has grown rapidly during the last decade, in industrial, automotive, commercial, and communications systems. As a low-cost sensor, C-core Hall sensor finds its application in wide area. The magnetic field strength at Hall element is the important parameter of interest in C-core current sensors. The main objective of this paper is to calculate B field at the centre of air gap. Open loop current sensor using FEA tool for mid range sensing applications with C-core using hall sensing technology is designed.

Keywords: C-core, Current sensor, Hall-Effect, 2D, Magnetic field.

1. Introduction

There are different magnetic sensing technologies are available nowadays. To name few technologies such as Hall Effect, Magneto Resistive (MR), Anisotropic Magneto Resistive (AMR), Giant Magneto Resistive (GMR) . The advantages of a Hall-effect magnetic detector are the inherent voltage isolation from the current path and the integration of the Hall element and interface electronics on a single silicon chip [1]. Magnetic field analysis is the key element which has to be done for sensing current. In such case C-type core is used mainly used along with the hall sensor. Various schemes adopted for field analysis are Magnetic circuit analysis,physics based modelling, FEM simulation and Lab experiments. This paper deals with the FEA based analysis of current sensor. The model designed contains a C-core surrounding a conductor. Hall sensor is placed at the air gap where current need to be sensed [2]. B- Field at the hall sensor is calculated by two methods line integral and point method.

Current sensing is accomplished by measuring the magnetic field surrounding a current-carrying conductor. The conductor is passed through the flux collector which concentrates the magnetic field at the sensing element. The magnetic field is directly proportional to the current passing through the conductor [3]. Thus, there is a direct relationship between the output voltage of the current sensor and the level of input current. The waveform of this output voltage will track the waveform of the measured current.

1.1. Hall Effect technology

The Hall voltage output signal is linearly proportional to the transverse component of the flux density passing through the sensing element [4].The Hall effect is created by Lorentz forces, which act on charges moving through a magnetic field.

$$F_L = q \cdot (V \times B) \tag{1}$$
$$V_{hall} \propto B \tag{2}$$

V_{hall}= Output Hall Effect Voltage
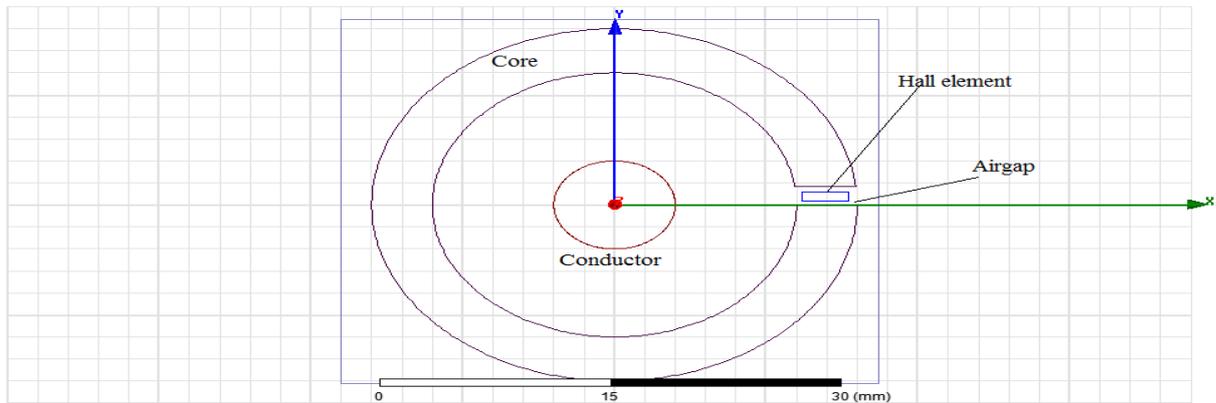B = Magnetic Field created by Magnet or Current-carrying Conductor

Fig 1: 2D of open loop current sensor

The Fig1 shows the 2D structure of open loop current sensor. The open loop current sensor is axis symmetry, hence the design in 2D is easy and results produced are also accurate. Therefore design is done in 2D. The Fig 2b shows the meshing used in FEA design. Number of elements in hall element is taken such that the output results obtained are accurate Hall sensor is placed exactly at the centre of the air gap.
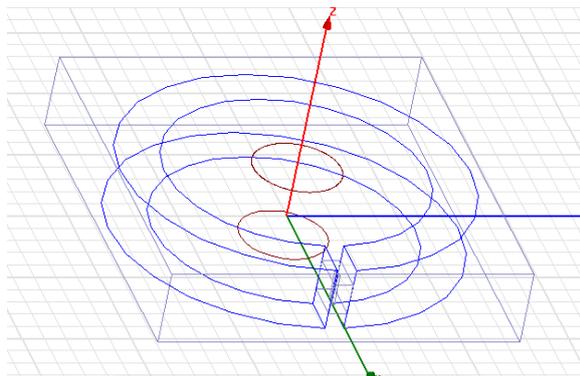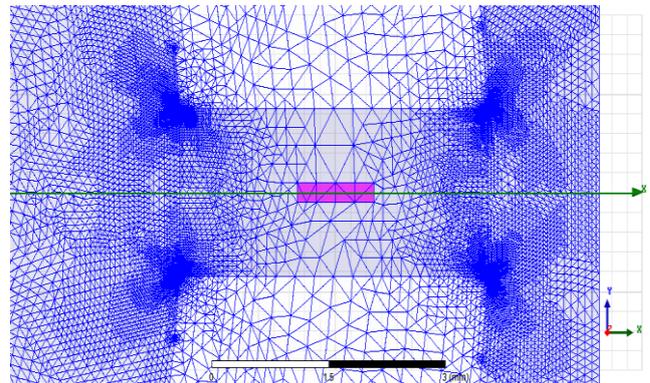

Fig2a: 3D design of open loop current sensor

Fig2b: Mesh plot near the hall element

1.2. Calculation of B-field

(i) B-field at the centre of Hall element is calculated by taking line integral using the following expression

$$B = Scl: *(Integrate \, (Line \, (Polyline1), ScalarY \, (< Bx, By, 0 >)), 10000) \qquad (3)$$

(ii) B-field at the centre of Hall element is calculated at a centre point using the following expression

$$B = Scl: *(PointValue \, (Point \, (Point1), ScalarY \, (< Bx, By, 0 \,)), 10000) \qquad (4)$$
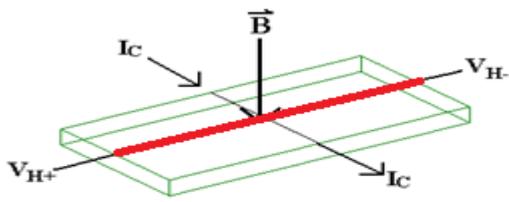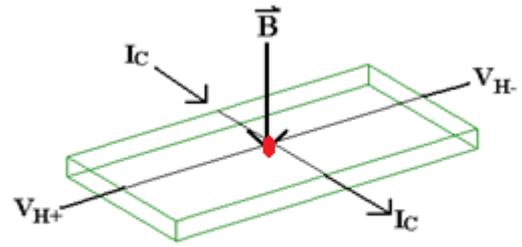
Fig3a: Line integral calculation of B Field　　　　Fig3b: Point calculation of B Field

In general the concentric magnetic field lines are generated around a current carrying conductor which can be calculated with the expression [5].

$$B = \mu_0 I / 2\pi r \qquad (5)$$

Where μ_0 is the permeability of free space,

　　　I is the current and,

　　　r is the distance from the centre of the current conductor.

2. Simulation results

2.1. Shaded Plot

The shaded plot displays the outline of the model, or the outline of a slice through the model, and a field. The field values are represented by a range of colours. The field point at the least vicinity of North Pole yields a Positive B value. Similarly, the field point at the least vicinity of South Pole yields a negative B value. The magnitude of B Field at the centre of the Hall sensor is analysed.
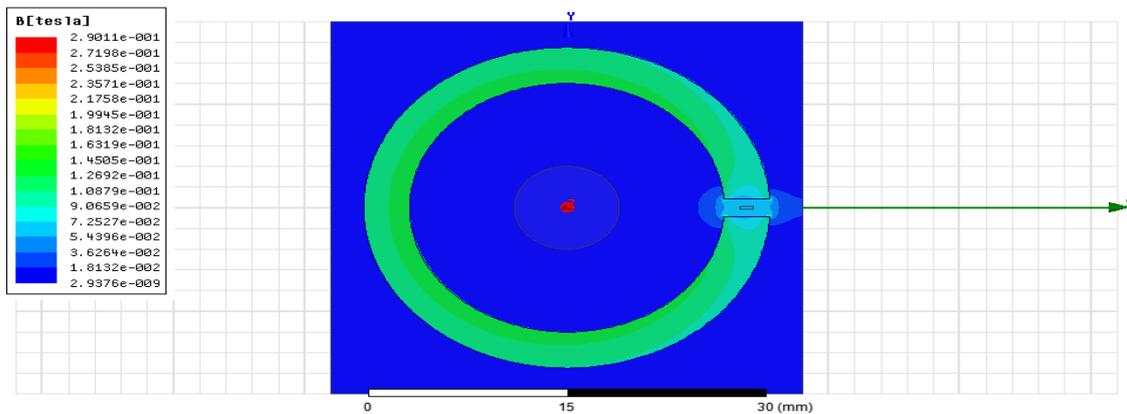

Fig 4: Mag-B plot of Open loop current sensor

2.2. Arrow Plot

The arrow plot displays the surface of the model, or the outline of a slice through the model, and a grid of arrows. The direction and length of the arrows represent the direction and magnitude of the field plotted. The Fig 5 shows the direction of magnetic field over the hall sensor which indicates the presence of perpendicular field.
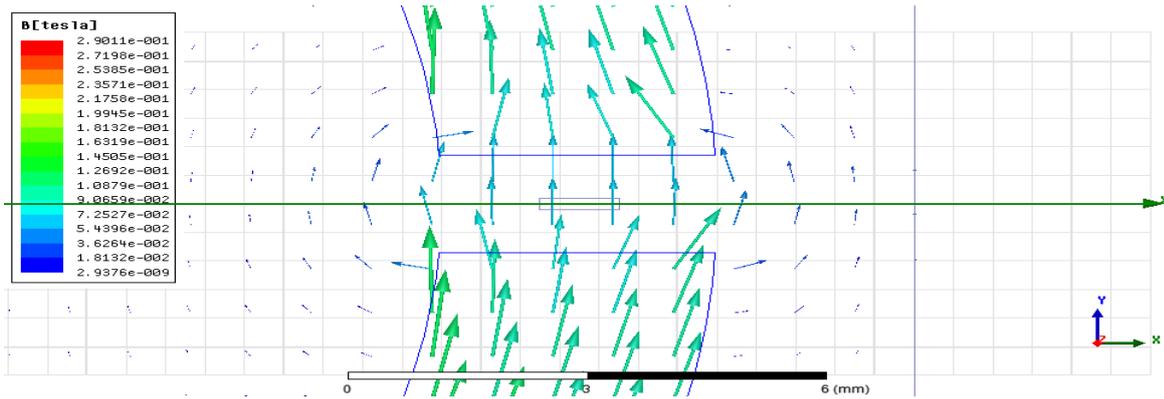
Fig 5: Arrow plot near Hall sensor

2.3. Flux Plot

The field results will be shown in the 2D plane. This helps to obtain the flux path in the single plane known as flux plot. The inner region of core near to conductor has high intense flux lines compared to the outer region.
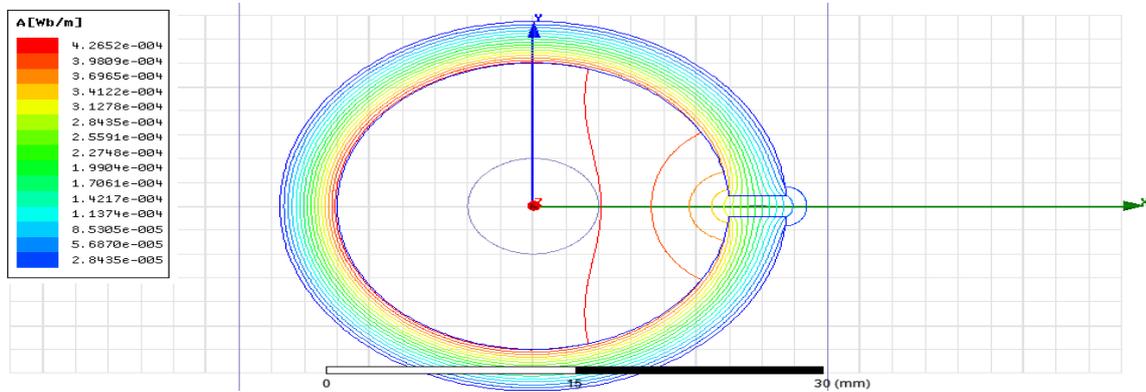

Fig6: Flux plot of open loop current sensor

Table shows the perpendicular B field at the centre of the Hall sensor. The perpendicular B field calculated for various current values at a point and on a line at the centre of the hall. The results show that both methods have same values with difference in decimals.

Current (Amps)	B-Field (Gauss)
0	0
10	65.60987
20	131.2285
30	196.8617
40	262.5175
50	328.2036
60	393.9275
70	459.6971
80	525.5201
90	591.4043
100	657.3580

Table2a: B Field at the point Vs Current

Current (Amps)	B-Field (Gauss)
0	0
10	65.62565
20	131.2606
30	196.9014
40	262.5911
50	328.2819
60	394.0077
70	459.78
80	525.6385
90	591.5388
100	657.5184

Table 2b: B-Field in a line Vs current

3. Conclusion

The values of By calculated at the centre point and in a centre line are same. Thus the two different methods used to calculate B field in FEA tool determines that both the methods produce same output. The applications for linear Hall-effect sensor in open-loop current sensing continue to evolve and expand. Presently, the devices available are far superior to any earlier linear, and advancements in design, processing, packaging, testing, etc. are incessant and relentless.

4. Acknowledgement

5. References

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