EE236: Electronic Devices Lab Lab No.-12

Hall Effect Sensor

Mohammad Samiuddin Shafi, 22b3912 October 5, 2024

# Aim of the Experiment

* To study the Hall Effect and observe the output voltage of a Hall Effect sensor with varying distance for different magnetic strengths.
* To determine the strength of the given bar magnet.
* To calculate the doping concentration of the Hall element within the sen- sor.

# Components Used

* 3-terminal Hall sensor
* 3 bar magnets
* 2 Multimeters
* 15cm scale
* 2 breadboards
* Connecting wires

# Theory

The Hall Effect suggests that the voltage generated in a conductor is directly proportional to the applied magnetic field and the current passing through the conductor. A Hall Effect sensor uses this phenomenon to generate an output voltage in response to an applied magnetic flux.

# Experimental Setup

1. A DC voltage input of 8V was provided between VCC and GND terminals of the Hall sensor.
2. A multimeter was connected across the output and GND terminals to measure the output voltage.
3. Two breadboards were placed with a 15cm scale between them. The Hall sensor was mounted on one breadboard, and the magnets were placed on the other.
4. The curved surface of the Hall sensor was positioned to face the magnet.

# Procedure

1. One bar magnet was placed 15cm away from the Hall sensor.
2. The distance between the magnet and the sensor was reduced in steps of 2mm until the distance was approximately 0. The output voltage was recorded at each step.
3. After reaching minimum distance, the pole of the magnet facing the sensor was reversed, and the magnet was moved back to the 15cm position.
4. Step 2 was repeated for the reversed polarity.
5. The entire process was repeated for 2 bar magnets and 3 bar magnets.
6. The current flowing between the VCC and GND terminals (Iin) was mea- sured when no magnetic field was applied.

# Observations

## Single Magnet

Table 1: Observed Data for Single Magnet

### Reverse Polarity Normal Polarity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Distance (cm) | Vout (V) |  | Distance (cm) | Vout (V) |  |
|  | 15.0 | 1.008 |  | 15.0 | 0.99 |  |
|  | 14.8 | 1.008 |  | 14.5 | 0.98 |  |
|  | 14.6 | 1.009 |  | 14.0 | 0.98 |  |
|  | 14.4 | 1.009 |  | 13.5 | 0.98 |  |
|  | 14.2 | 1.009 |  | 13.0 | 0.98 |  |
|  | 14.0 | 1.009 |  | 12.5 | 0.98 |  |
|  | 13.8 | 1.010 |  | 12.0 | 0.98 |  |
|  | 13.6 | 1.010 |  | 11.5 | 0.97 |  |
|  | 13.4 | 1.010 |  | 11.0 | 0.97 |  |
|  | 13.2 | 1.010 |  | 10.5 | 0.97 |  |
|  | 13.0 | 1.010 |  | 10.0 | 0.96 |  |
|  | 12.8 | 1.011 |  | 9.5 | 0.96 |  |
|  | 12.6 | 1.011 |  | 9.0 | 0.96 |  |
|  | 12.4 | 1.011 |  | 8.5 | 0.96 |  |
|  | 12.2 | 1.012 |  | 8.0 | 0.95 |  |
|  | 12.0 | 1.012 |  | 7.5 | 0.95 |  |
|  | 11.8 | 1.012 |  | 7.0 | 0.95 |  |
|  | 11.6 | 1.012 |  | 6.5 | 0.94 |  |
|  | 11.4 | 1.013 |  | 6.0 | 0.92 |  |
|  | 11.2 | 1.013 |  | 5.5 | 0.91 |  |
|  | 11.0 | 1.013 |  | 5.0 | 0.89 |  |
|  | 10.8 | 1.013 |  | 4.8 | 0.89 |  |
|  | 10.6 | 1.013 |  | 4.6 | 0.88 |  |
|  | 10.4 | 1.014 |  | 4.4 | 0.87 |  |
|  | 10.2 | 1.014 |  | 4.2 | 0.84 |  |
|  | 10.0 | 1.015 |  | 4.0 | 0.83 |  |
|  | 9.8 | 1.016 |  | 3.8 | 0.82 |  |
|  | 9.6 | 1.016 |  | 3.6 | 0.80 |  |
|  | 9.4 | 1.017 |  | 3.4 | 0.77 |  |
|  | 9.2 | 1.017 |  | 3.2 | 0.75 |  |
|  | 9.0 | 1.018 |  | 3.0 | 0.72 |  |
|  | 8.8 | 1.018 |  | 2.8 | 0.69 |  |
|  | 8.6 | 1.019 |  | 2.6 | 0.66 |  |
|  | 8.4 | 1.020 |  | 2.4 | 0.60 |  |
|  | 8.2 | 1.021 |  | 2.2 | 0.54 |  |
|  | 8.0 | 1.022 |  | 2.0 | 0.47 |  |
|  | 7.8 | 1.023 |  | 1.8 | 0.40 |  |
|  | 7.6 | 1.024 |  | 1.6 | 0.30 |  |

7.4 1.025 3

|  |  |  |  |
| --- | --- | --- | --- |
| 7.2 | 1.0266 | 1.2 | 0.05 |
| 7.0 | 1.028 | 1.0 | 0.04 |
| 6.8 | 1.030 | 0.8 | 0.03 |
| 6.6 | 1.032 | 0.6 | 0.03 |
| 6.4 | 1.035 | 0.4 | 0.03 |
| 6.2 | 1.036 | 0.2 | 0.03 |
| 6.0 | 1.040 | 0.0 | 0.02 |

1.4 0.18

## Double Magnet

Table 2: Observed Data for Double Magnet

### Reverse Polarity Normal Polarity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Distance (cm) | Vout (V) |  | Distance (cm) | Vout (V) |  |
|  | 15.0 | 1.010 |  | 15.0 | 0.99 |  |
|  | 14.5 | 1.011 |  | 14.5 | 0.99 |  |
|  | 14.5 | 1.011 |  | 14.5 | 0.99 |  |
|  | 14.0 | 1.012 |  | 14.0 | 0.98 |  |
|  | 14.0 | 1.012 |  | 14.0 | 0.98 |  |
|  | 13.5 | 1.013 |  | 13.5 | 0.98 |  |
|  | 13.5 | 1.013 |  | 13.5 | 0.98 |  |
|  | 13.0 | 1.013 |  | 13.0 | 0.98 |  |
|  | 13.0 | 1.013 |  | 13.0 | 0.98 |  |
|  | 12.5 | 1.014 |  | 12.5 | 0.98 |  |
|  | 12.5 | 1.014 |  | 12.5 | 0.98 |  |
|  | 12.0 | 1.014 |  | 12.0 | 0.98 |  |
|  | 12.0 | 1.014 |  | 12.0 | 0.98 |  |
|  | 11.5 | 1.016 |  | 11.5 | 0.98 |  |
|  | 11.5 | 1.016 |  | 11.5 | 0.98 |  |
|  | 11.0 | 1.017 |  | 11.0 | 0.98 |  |
|  | 11.0 | 1.017 |  | 11.0 | 0.98 |  |
|  | 10.5 | 1.018 |  | 10.5 | 0.98 |  |
|  | 10.5 | 1.018 |  | 10.5 | 0.98 |  |
|  | 10.0 | 1.020 |  | 10.0 | 0.97 |  |
|  | 10.0 | 1.020 |  | 10.0 | 0.97 |  |
|  | 9.5 | 1.022 |  | 9.5 | 0.97 |  |
|  | 9.5 | 1.022 |  | 9.5 | 0.97 |  |
|  | 9.0 | 1.024 |  | 9.0 | 0.97 |  |
|  | 9.0 | 1.024 |  | 9.0 | 0.97 |  |
|  | 8.8 | 1.025 |  | 8.8 | 0.97 |  |
|  | 8.5 | 1.026 |  | 8.5 | 0.97 |  |
|  | 8.6 | 1.026 |  | 8.6 | 0.97 |  |
|  | 8.0 | 1.027 |  | 8.0 | 0.96 |  |
|  | 8.4 | 1.027 |  | 8.4 | 0.96 |  |
|  | 7.5 | 1.028 |  | 7.5 | 0.96 |  |
|  | 8.2 | 1.029 |  | 7.5 | 0.96 |  |
|  | 7.0 | 1.030 |  | 7.0 | 0.96 |  |
|  | 8.0 | 1.030 |  | 7.0 | 0.96 |  |
|  | 6.5 | 1.032 |  | 6.5 | 0.95 |  |
|  | 7.8 | 1.032 |  | 6.5 | 0.95 |  |
|  | 6.0 | 1.034 |  | 6.0 | 0.94 |  |
|  | 7.6 | 1.034 |  | 6.0 | 0.94 |  |
|  | 5.5 | 1.033 |  | 5.5 | 0.93 |  |
|  | 7.4 | 1.036 |  | 5.5 | 0.93 |  |

5.0 1.038 4

|  |  |  |  |
| --- | --- | --- | --- |
| 7.2 | 1.038 | 5.0 | 0.92 |
| 4.8 | 1.040 | 4.8 | 0.91 |
| 7.0 | 1.040 | 4.8 | 0.91 |
| 4.6 | 1.042 | 4.6 | 0.90 |
| 6.8 | 1.042 | 4.6 | 0.90 |
| 4.4 | 1.047 | 4.4 | 0.89 |
| 6.6 | 1.047 | 4.4 | 0.89 |
| 4.2 | 1.049 | 4.2 | 0.87 |

5.0 0.92

## Triple Magnet

Table 3: Observed Data for Triple Magnet

### Reverse Polarity Normal Polarity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Distance (cm) | Vout (V) |  | Distance (cm) | Vout (V) |  |
|  | 15.0 | 1.013 |  | 15.0 | 0.99 |  |
|  | 14.5 | 1.014 |  | 14.5 | 0.99 |  |
|  | 14.5 | 1.014 |  | 14.5 | 0.99 |  |
|  | 14.0 | 1.015 |  | 14.0 | 0.99 |  |
|  | 14.0 | 1.015 |  | 14.0 | 0.99 |  |
|  | 13.5 | 1.015 |  | 13.5 | 0.98 |  |
|  | 13.5 | 1.015 |  | 13.5 | 0.98 |  |
|  | 13.0 | 1.016 |  | 13.0 | 0.98 |  |
|  | 13.0 | 1.016 |  | 13.0 | 0.98 |  |
|  | 12.5 | 1.017 |  | 12.5 | 0.98 |  |
|  | 12.5 | 1.017 |  | 12.5 | 0.98 |  |
|  | 12.0 | 1.018 |  | 12.0 | 0.98 |  |
|  | 12.0 | 1.018 |  | 12.0 | 0.98 |  |
|  | 11.5 | 1.020 |  | 11.5 | 0.98 |  |
|  | 11.5 | 1.020 |  | 11.5 | 0.98 |  |
|  | 11.0 | 1.022 |  | 11.0 | 0.98 |  |
|  | 11.0 | 1.022 |  | 11.0 | 0.98 |  |
|  | 10.5 | 1.023 |  | 10.5 | 0.98 |  |
|  | 10.5 | 1.023 |  | 10.5 | 0.98 |  |
|  | 10.0 | 1.025 |  | 10.0 | 0.98 |  |
|  | 10.0 | 1.025 |  | 10.0 | 0.98 |  |
|  | 9.5 | 1.028 |  | 9.5 | 0.98 |  |
|  | 9.5 | 1.028 |  | 9.5 | 0.98 |  |
|  | 9.0 | 1.031 |  | 9.0 | 0.98 |  |
|  | 9.0 | 1.031 |  | 9.0 | 0.98 |  |
|  | 8.8 | 1.033 |  | 8.8 | 0.97 |  |
|  | 8.5 | 1.034 |  | 8.5 | 0.97 |  |
|  | 8.6 | 1.034 |  | 8.6 | 0.97 |  |
|  | 8.0 | 1.035 |  | 8.0 | 0.97 |  |
|  | 8.4 | 1.035 |  | 8.4 | 0.97 |  |
|  | 7.5 | 1.037 |  | 7.5 | 0.97 |  |
|  | 8.2 | 1.037 |  | 7.5 | 0.97 |  |
|  | 7.0 | 1.039 |  | 7.0 | 0.97 |  |
|  | 8.0 | 1.039 |  | 7.0 | 0.97 |  |
|  | 6.5 | 1.041 |  | 6.5 | 0.96 |  |
|  | 7.8 | 1.041 |  | 6.5 | 0.96 |  |
|  | 6.0 | 1.044 |  | 6.0 | 0.96 |  |
|  | 7.6 | 1.044 |  | 6.0 | 0.96 |  |
|  | 5.5 | 1.046 |  | 5.5 | 0.95 |  |
|  | 7.4 | 1.046 |  | 5.5 | 0.95 |  |

5.0 1.049 5

|  |  |  |  |
| --- | --- | --- | --- |
| 7.2 | 1.049 | 5.0 | 0.94 |
| 4.8 | 1.052 | 4.8 | 0.94 |
| 7.0 | 1.052 | 4.8 | 0.94 |
| 4.6 | 1.055 | 4.6 | 0.94 |
| 6.8 | 1.055 | 4.6 | 0.94 |
| 4.4 | 1.058 | 4.4 | 0.93 |
| 6.6 | 1.058 | 4.4 | 0.93 |
| 4.2 | 1.062 | 4.2 | 0.92 |

5.0 0.94

# Results and Analysis

## Graph

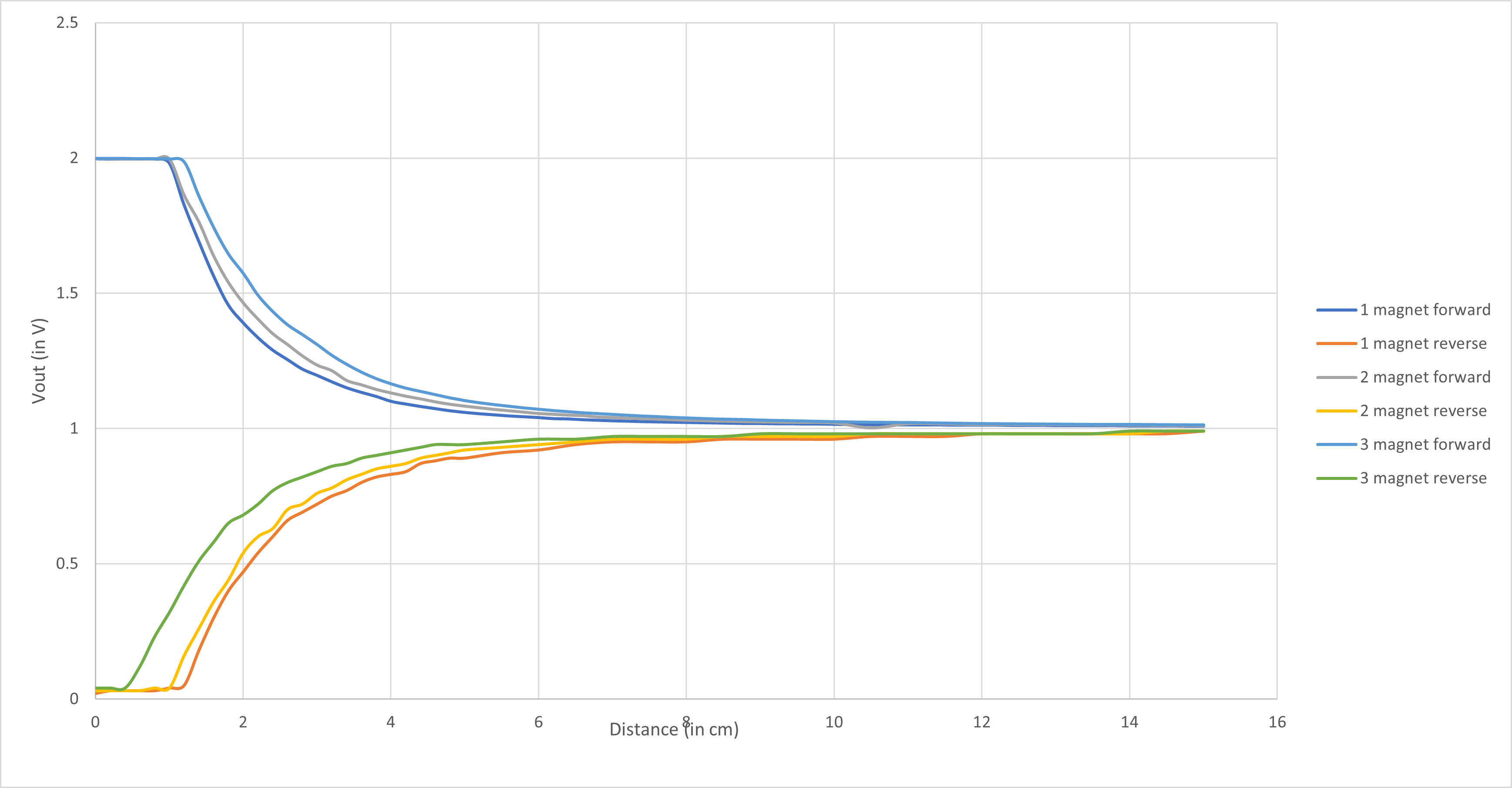


Figure 1: Output Voltage vs. Distance for Different Magnet Configurations

## Calculations

Given parameters:

* Hall element side length, *a* = 0*.*53 mm
* Input voltage, *V*in = 8 V
* Mobility, *µ* = 0*.*8 m2 V*−*1 s*−*1
* Hall element thickness, *t* = 0*.*053 mm
* Elementary charge, *e* = 1*.*6 *×* 10*−*19 C Measured values:
* *V*out*,*0 = 1*.*005 V
* *V*out,max = 2 V
* *I*in = 2*.*62 mA

### Calculating the Strength of the Bar Magnet

Longitudinal electric field:

*E* = *V*in = 8

= 15 094*.*34 V m*−*1 (1)

long *a*

0*.*53 *×* 10*−*3

Lateral electric field due to Hall effect:

*E* = *|V*out*,*0 *− V*out,max*|* = *|*1*.*005 *−* 2*|*

= 1877*.*36 V m*−*1 (2)

lat *a*

0*.*53 *×* 10*−*3

Magnetic field strength of one bar magnet:

*E*lat 1877*.*36

*B* = =

= 0*.*0518 T (3)

3*µE*long

3 *×* 0*.*8 *×* 15094*.*34

### Determining Doping Concentration

Hall coefficient:

*V*out,max *· t*

2 *×* 0*.*053 *×* 10*−*3

3 *−*1

*RH* =

*I*in

*· B* = 2*.*62 *×* 10*−*3 *×* 0*.*0518 = 0*.*7807 m C

(4)

Doping concentration:

1

*N* =

*RH · e*

1

= 0*.*7807 *×* 1*.*6 *×* 10*−*19

= 8*.*0057 *×* 1018 cm*−*3 (5)

# Conclusion

Based on the experimental results and analysis, we can conclude:

* The output voltage of the Hall Effect sensor varies inversely with the distance between the sensor and the magnet.
* The strength of the magnetic field influences the rate of change of the output voltage with distance.
* Reversing the polarity of the magnet results in an inverted response curve.
* The calculated strength of a single bar magnet is approximately 0*.*0518 T.
* The estimated doping concentration of the Hall element in the sensor is 8*.*0057 *×* 1018 cm*−*3.

This experiment demonstrates the practical application of the Hall Effect in sensing magnetic fields and highlights the relationship between magnetic field strength, sensor output, and material properties of the Hall element.