Characterizing the Sensitivity of a Hall Sensor

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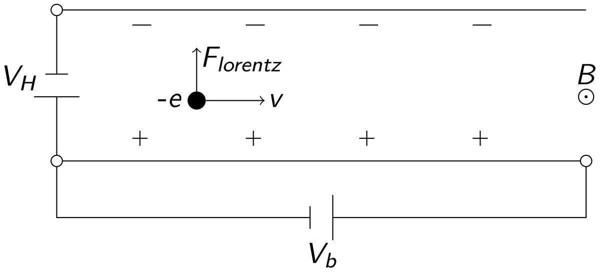
What are Hall Sensors?

- Hall Sensors are devices that utilize the Hall Effect to measure magnetic fields
- Made from semiconductors
- Uses for Hall Sensors include:
  - Navigation
  - Detection of metallic objects
  - Non-destructive location of cracks in metallic objects
- Design Considerations
  - Material with large electron mobility
  - Small
  - Reduce internal magnetic fields

Project Goals

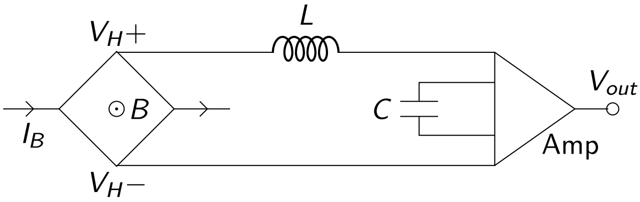
- Development of Hall Sensor with both High Spatial and High Magnetic field resolution
  - Develop materials with high electron mobility and low carrier densities
  - Create array of small sensors
- These sensors can be used to image metallic objects through the use of eddy current analysis
- Measure the sensitivity of a specific Hall Sensor made of 2.1 μm n-doped InSb material
  - Characterize how sensitivity changes with frequency and time constant

Hall Effect



- When applying a bias voltage in the presence of a magnetic field, a Hall Voltage will develop due to the Lorentz force
- $V_H \propto \dfrac{I_B B}{n_{2D}}$

Device Model



$$V_{out} = \left(V_H - iL\frac{dB}{dt} \right) G(C,\omega)$$

Experimental Setup

- Apply magnet field with known current loop driven by Lock-In Amplifier
  - Measure current through loop to calculate applied field
- Apply bias current of 30 mA with Current Source
- Measure V_{out} with Lock-In Amplifier
  - Lock-In isolates the frequency of the magnetic field
  - Lock-In also allows us to look at the phase difference between field and output
- Measure V_{out} 5 times and take 3 times the standard deviation as error
- Measure how V_{out} and error change with
  - Frequency of Magnetic Field
  - Amplitude of Magnetic Field
  - Time Constant on Lock-In

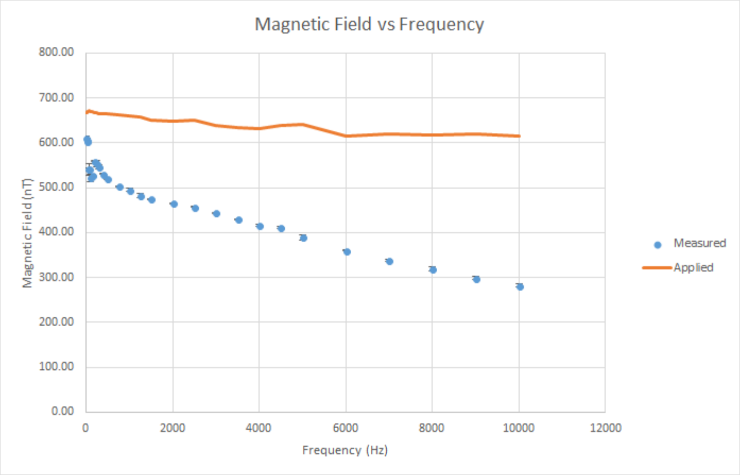
Using Current Reversal to Remove Inductance

- Determination of inductance is a large problem
- Inductive term does not depend on Bias Current, while Hall term does
- Take measurement with positive and negative biases. Subtract the two to cancel out inductive term.

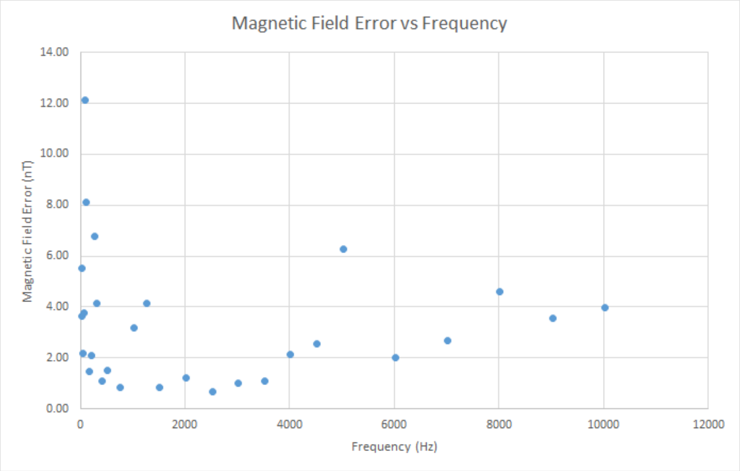
$$V_{out} = \left(V_H - iL\frac{dB}{dt}\right) G(C, \omega)$$

$$\Delta V_{out} = V_{out}(I_B) - V_{out}(-I_B)$$

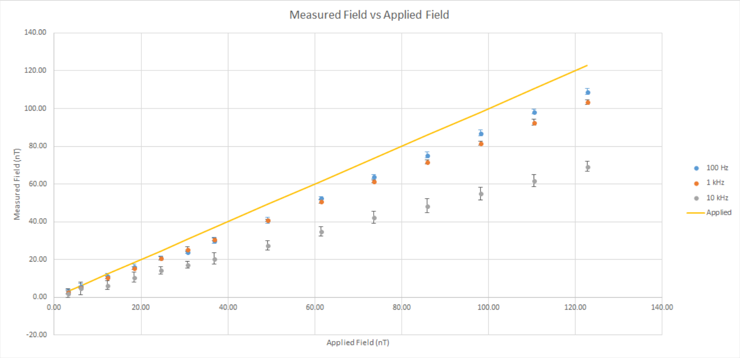
$$= 2 V_H G(C, \omega)$$



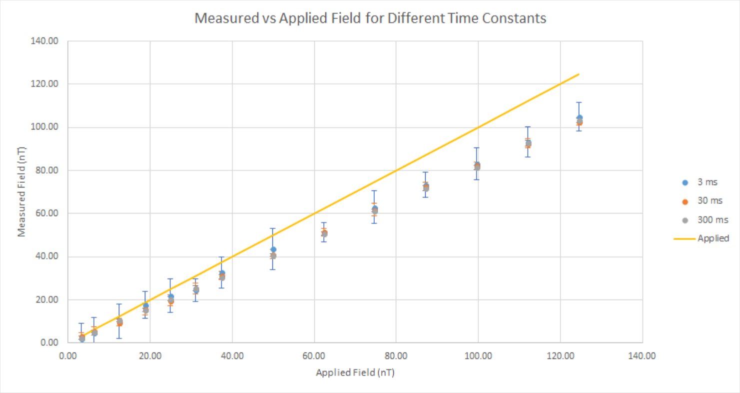
- Measured field is on the same order of magnitude as applied field
- Measured field decreases with frequency



- Expect 1/f dependence in error



- For 100 Hz, error $2nT$
- For 1 kHz, error $1nT$
- for 10 kHz, error $3nT$



- For 3 ms, error $7nT$
- For 30 ms, error $2nT$
- for 300 ms, error $1nT$

Future Work

- Determine why measured field decreases with frequency
- Determine the main source of error in the system
- Characterize the sensitivity of a Hall sensor made from an InSb Quantum Well material
  - 2D carrier density of Quantum Well is 20 times lower so expect better sensitivity
- Perform tests on larger array of smaller sensors
  - Smaller sensors will give better spatial resolution, but worse field resolution

Conclusion

- Current sensors seem to have the sensitivity on the order of several nT; however, practical sensors may not do as well
- System still appears to have some component, which is not included in model
- It may be possible to improve sensitivity by using Quantum Well material

Sources

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- Pavel Ripka 2013 J. Phys.: Conf. Ser. 450 012001