THE HALL EFFECT

OUTLINE

What Is The Hall Effect?

- How does it affect you?
- Scientific Principles
- Applications

Previous Setup

- Shortcomings

New Setup

- How it works
- Possible Improvements

Results

Conclusion

HALL EFFECT: THE DISCOVERY

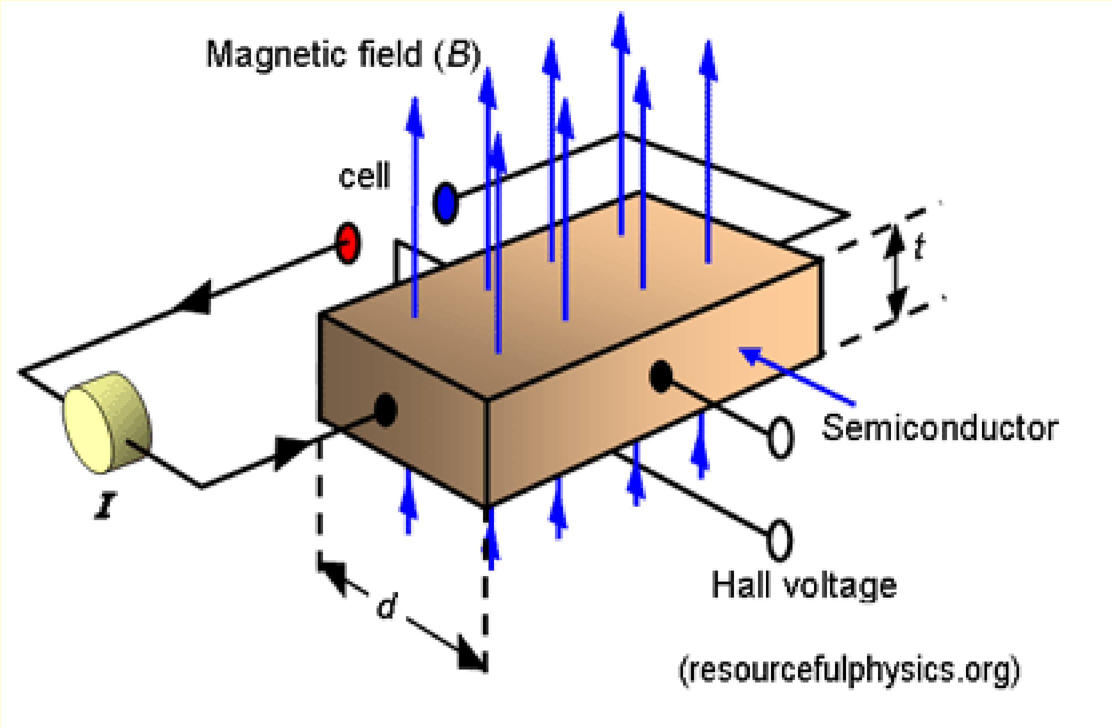
Discovered by Edwin Hall in 1879.

Quantum Hall Effect discovered in 1975

THE HALL EFFECT

Lorentz Force:

F = q[E + (v x B)]



- Hall voltage is produced by charge accumulation on sidewalls
- Charge accumulation balances Lorentz Force
- Charge accumulation increases resistance

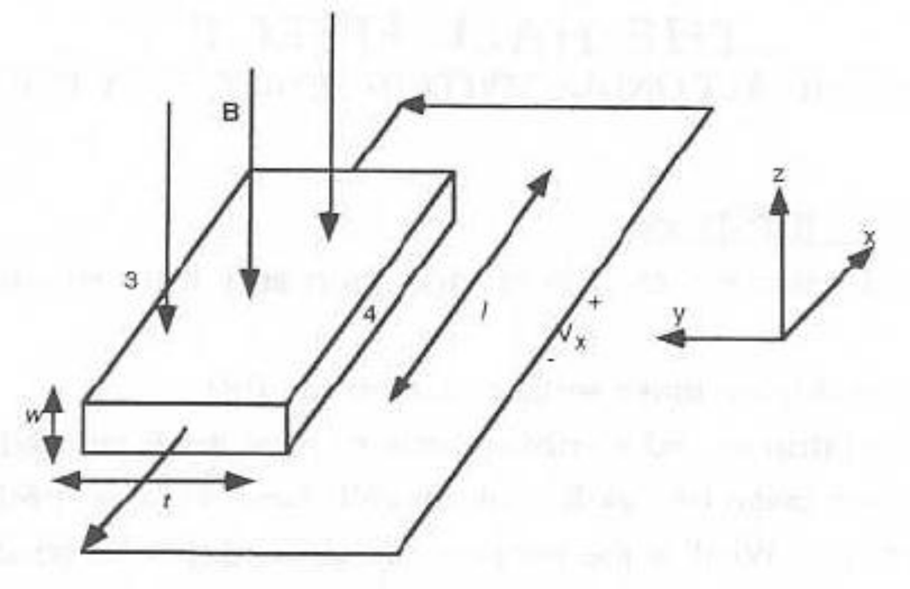
THE HALL EFFECT: SEMICONDUCTORS

Why Semiconductors?

- Ideal number of charge carriers
- Charge carriers increase with temperature

What we can learn

- Sign of charge carrier
- Charge carrier density
- Charge carrier mobility
- Energy gap



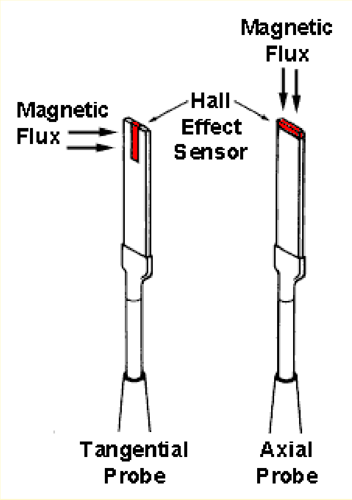
HALL VOLTAGE

For simple conductors

$$V_H = \frac{-IB}{ned} = R_H \frac{IB}{d}$$

Where n = carrier density, d = conductor length

- R_H is known as the Hall coefficient
- V_H α B ➔ Useful for measuring B-Fields



Gaussmeter Probe uses a hall sensor

HALL COEFFICIENT

Semiconductors have two charge carriers

$$R_H = \frac{-n\mu_e^2 + p\mu_h^2}{e(n\mu_e^2 + p\mu_h^2)^2}$$

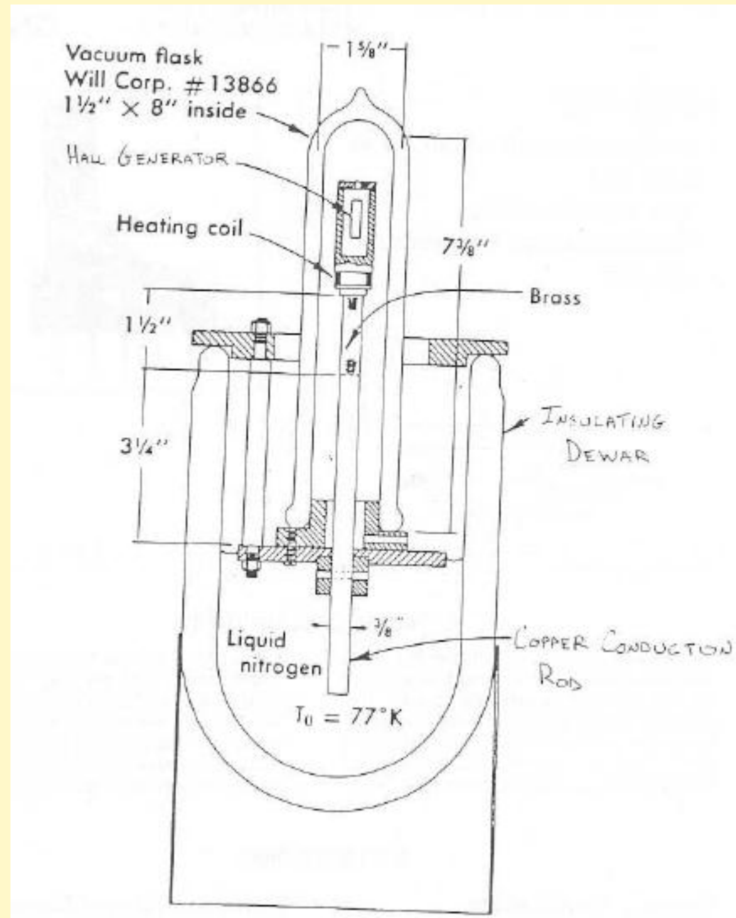
However, for large magnetic fields

$$R_H = \frac{1}{(p-n)e}$$

Enables us to determine the carrier density

EXPERIMENTAL SETUP

Liquid N_2 & Heaters are used for temperature control



NEW EXPERIMENTAL SETUP

Motivation

Old automated system inadequate

- Previous groups frustrated with results

Goal

Create new DAQ+LabVIEW system

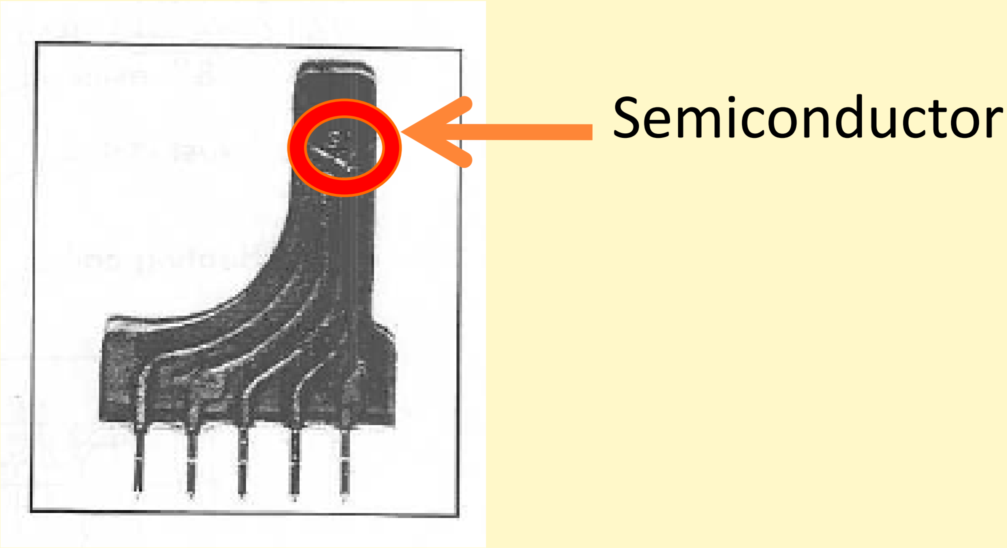
- More reliable measurements
- Easy user interface
- Easy data collection

Measure

- Hall Voltage
- Current through Semiconductor
- Temperature
- Magnetic Field

MEASUREMENT OF HALL VOLTAGE

Our hall generator is a fully integrated device

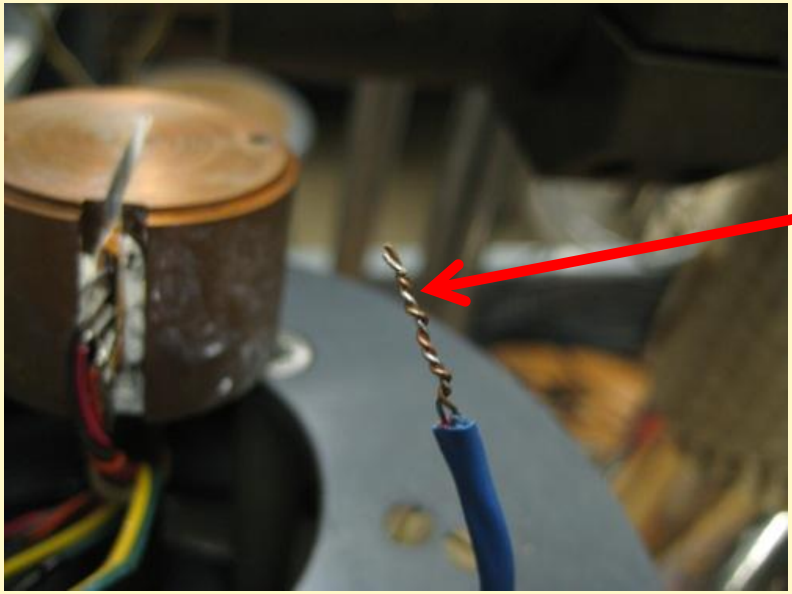


- Easy measurement of Hall Voltage
- Indirect but easy measurement of current

TEMPERATURE MEASUREMENT

Constantan-Copper Thermocouple

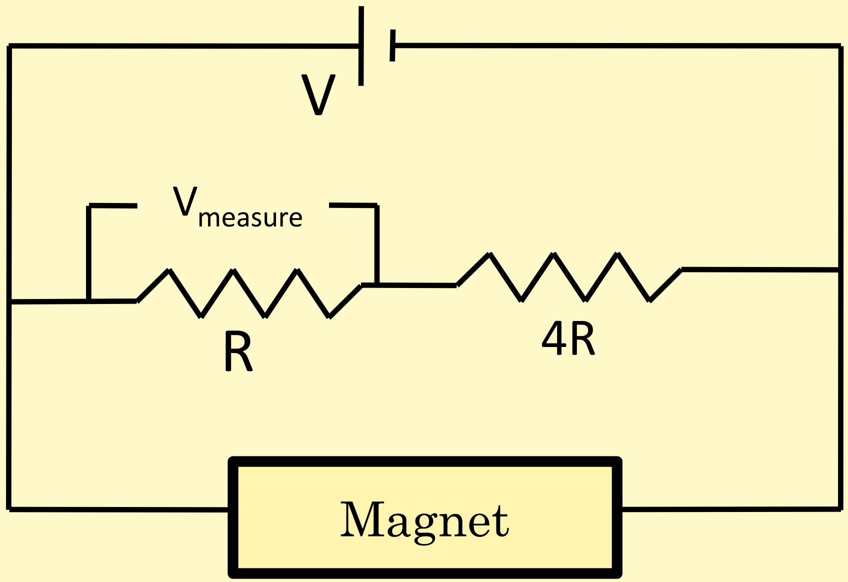
- Seebeck effect converts temperature gradient to voltage
- Non-Linear
- Original thermocouple didn't work!



Where is it?

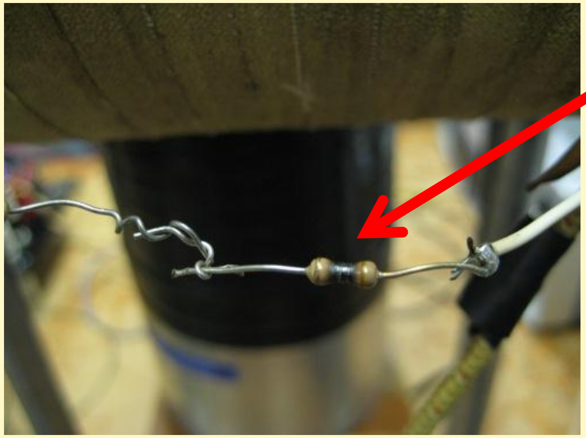
It is this junction between metals!

MAGNETIC FIELD MEASUREMENT



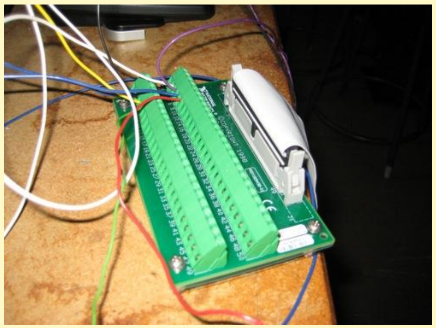
Burned Resistor

Disaster!

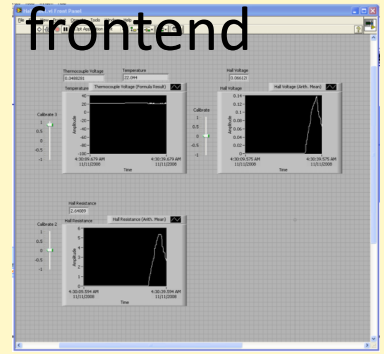


DAQ, LABVIEW INTERFACING

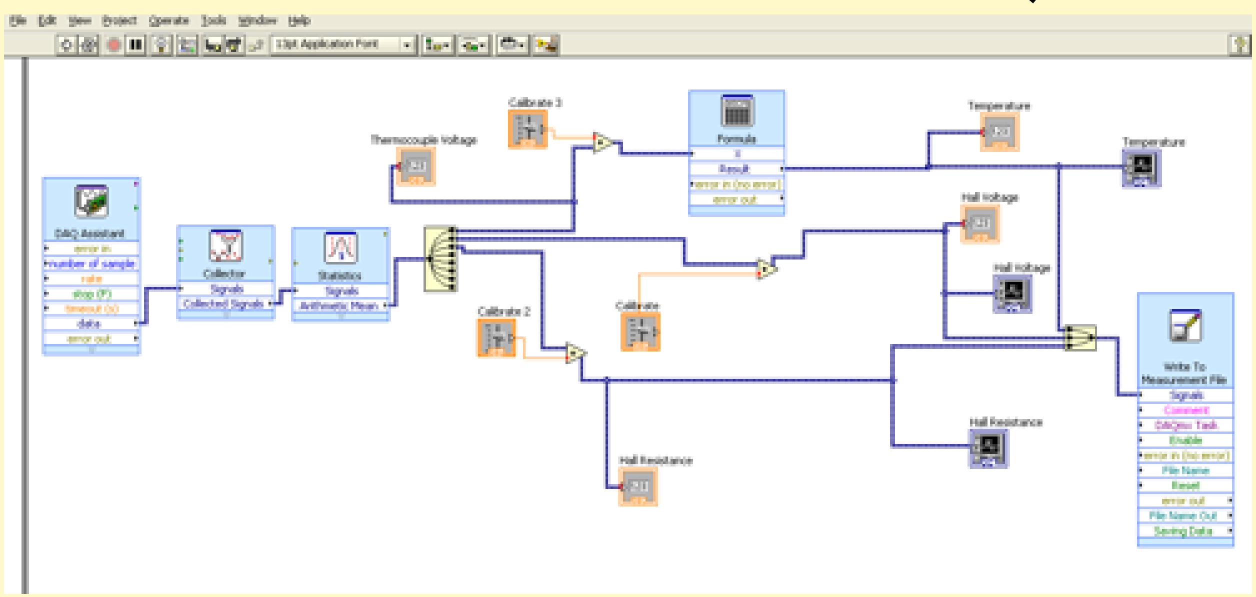
DAQ



LabVIEW frontend



LabVIEW backend



NEW EXPERIMENTAL SETUP

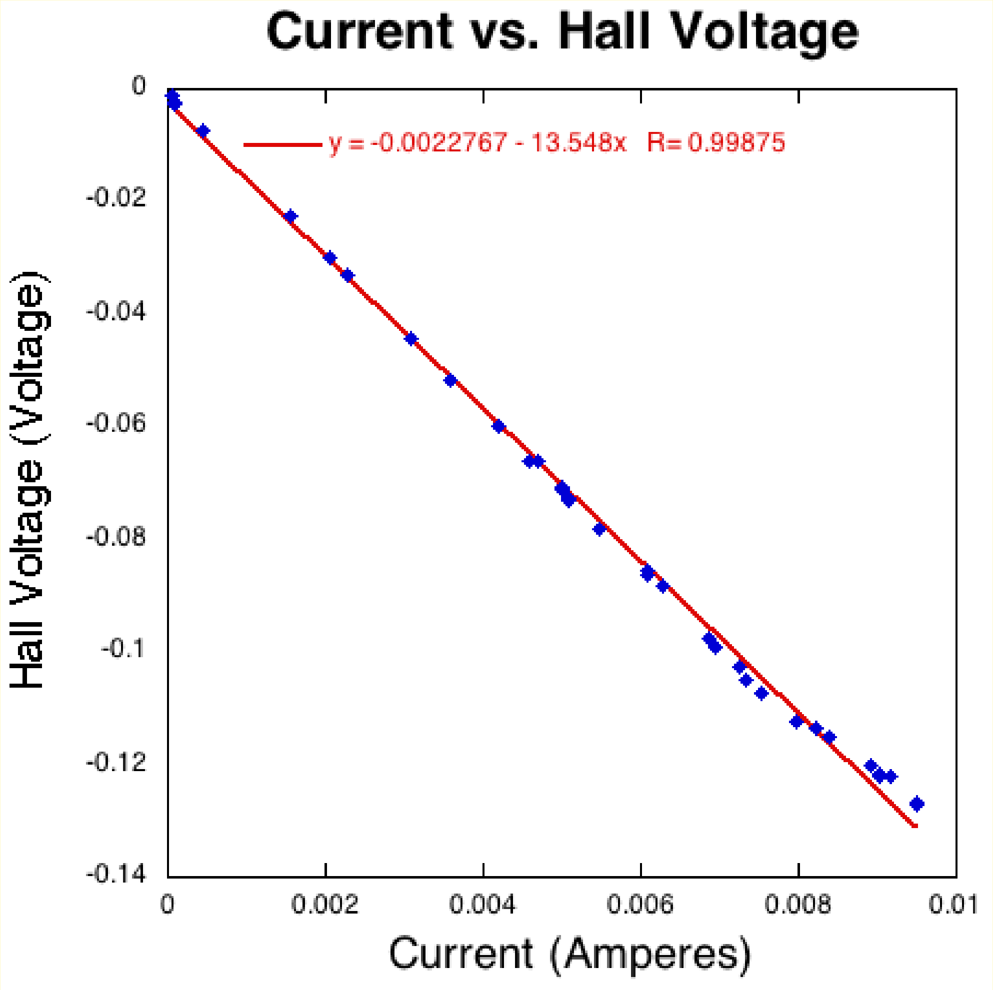
Success

- Integrated DAQ w/ Labview
- Automated measurements of temperature, hall voltage, semiconductor current

Setup Shortcomings

- Not able to measure magnetic field
- Accuracy of hall voltage and temperature measurements
- Heaters are too small
- Unshielded magnetic field

RESULTS



$$V_H = \frac{-IB}{ned} = R_H \frac{IB}{d}$$

$$R_H = \frac{1}{(p-n)e} \approx \frac{1}{-ne}$$

(-) slope

➔ (-) charge carriers

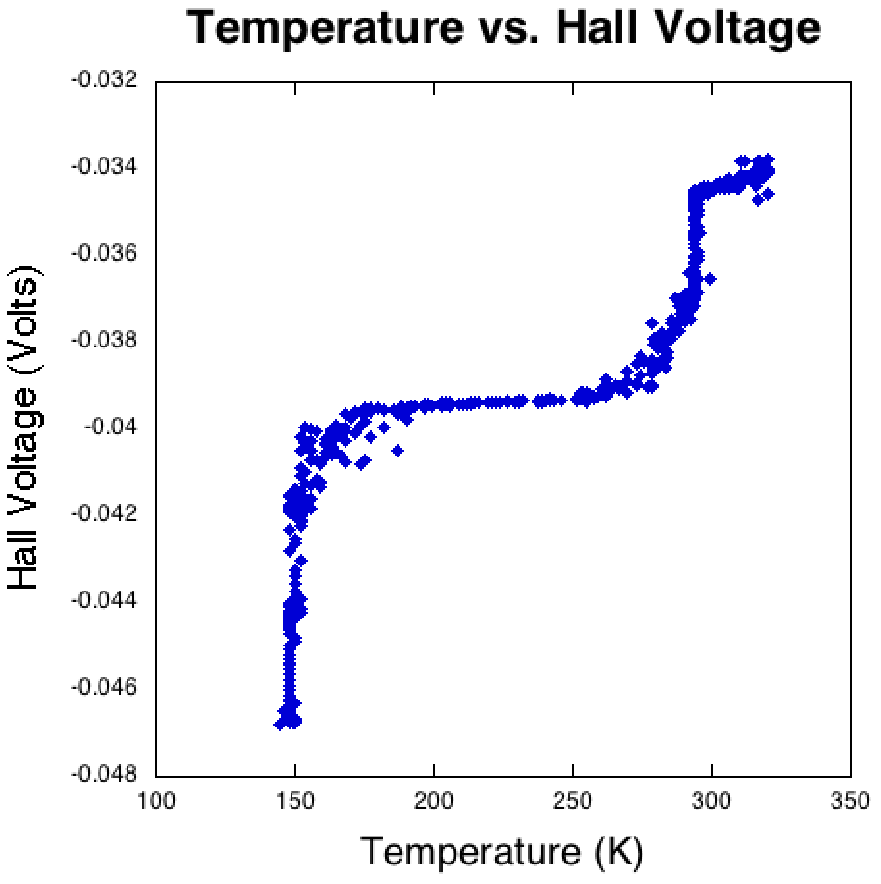
n = 1.38E12 cm^{-3}

n_{Si} = 1.5E10 cm^{-3}

RESULTS

Increase Temperature ➔ Increased Resistance

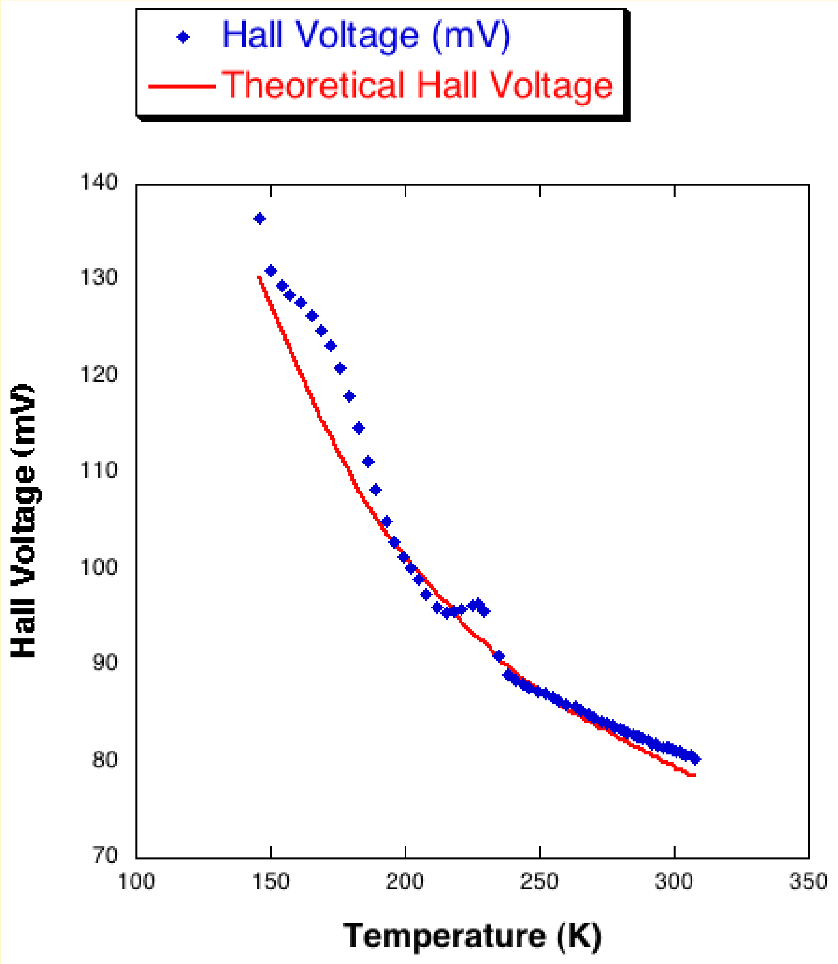
$V_H \propto T^{-3/2}$



These results are displeasing

RESULTS

Prior results when experiment was conducted manually



Note: sign was flipped on purpose

CONCLUSIONS

What we learned about

- The Hall Effect
- Labview/DAQ integration
- Common problems in experimental setup
- Safety (Liquid N_2)
- Maintaining team motivation

Who we learned from

- Steve Bloch
- Professor Howell