Demonstration of the Hall Effect in Semiconductors

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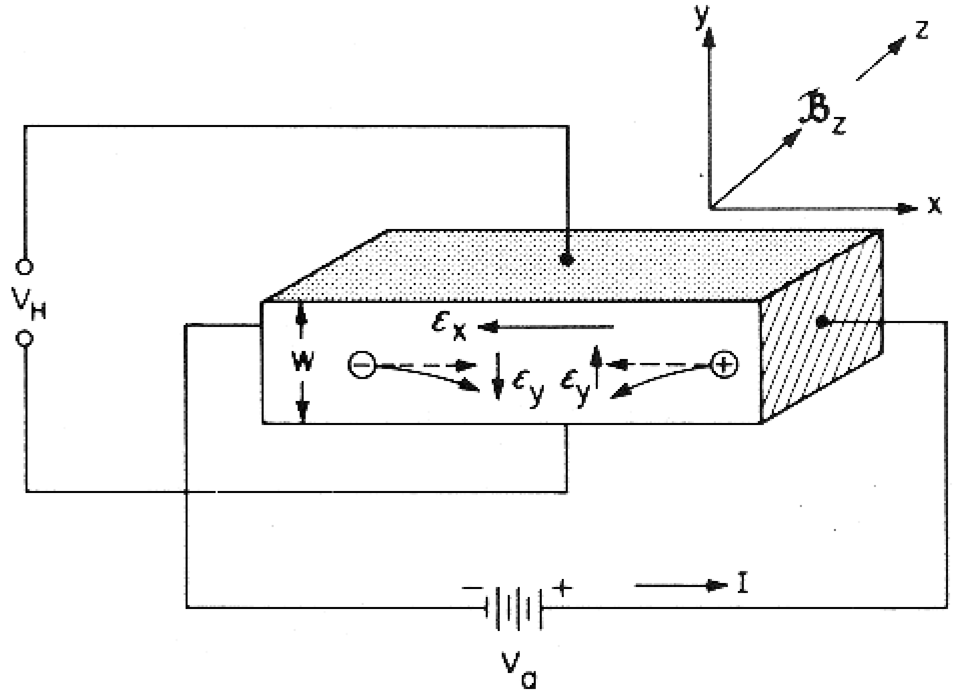
The Hall Effect

- Discovered in 1879 by Edwin Hall
- It is the development of a potential difference in a conductor transverse to the current passing through the conductor and the magnetic field perpendicular to the current
- $F=q(E+v \times B)$

Hall Effect in semiconductors

- Holes and electrons



- $V_H = \frac{R_H B I}{w}$

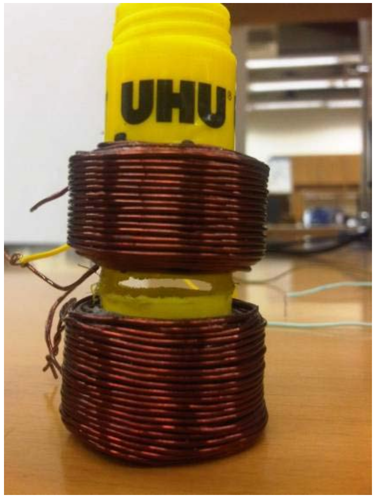
- $R_H = \frac{(p\mu_h^2 - n\mu_e^2)}{e(n\mu_e + p\mu_h)^2}$

- This can be derived from definition of R_H

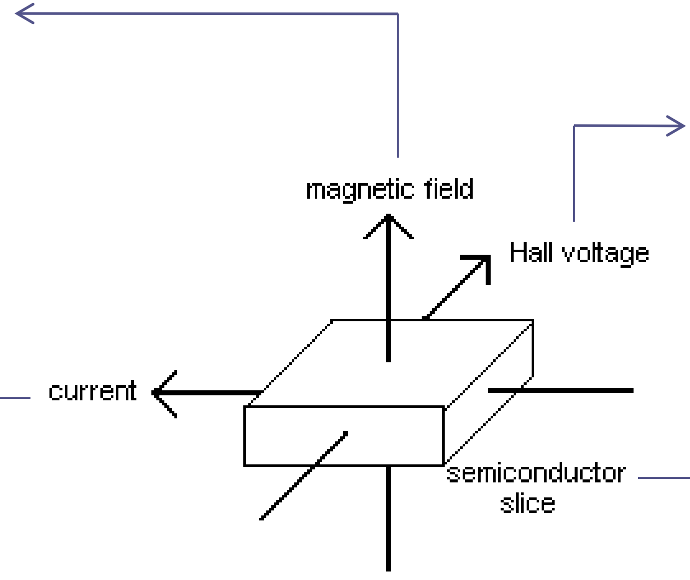
  $R_H = E_y/(j_x B)$

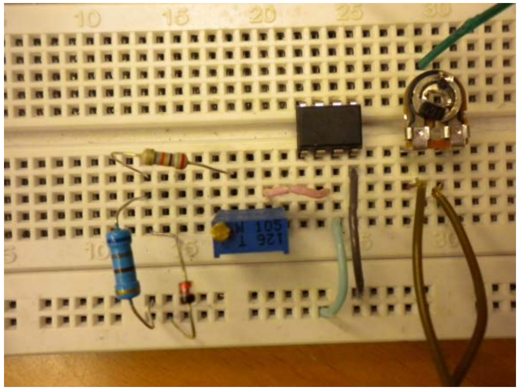
μ_e = electron mobility   n = electron density

μ_h = hole mobility   p = hole density


UHU


KEITHLEY
2182A NANOVOLTMETER
CHANNEL 1
CHANNEL 2
POWER

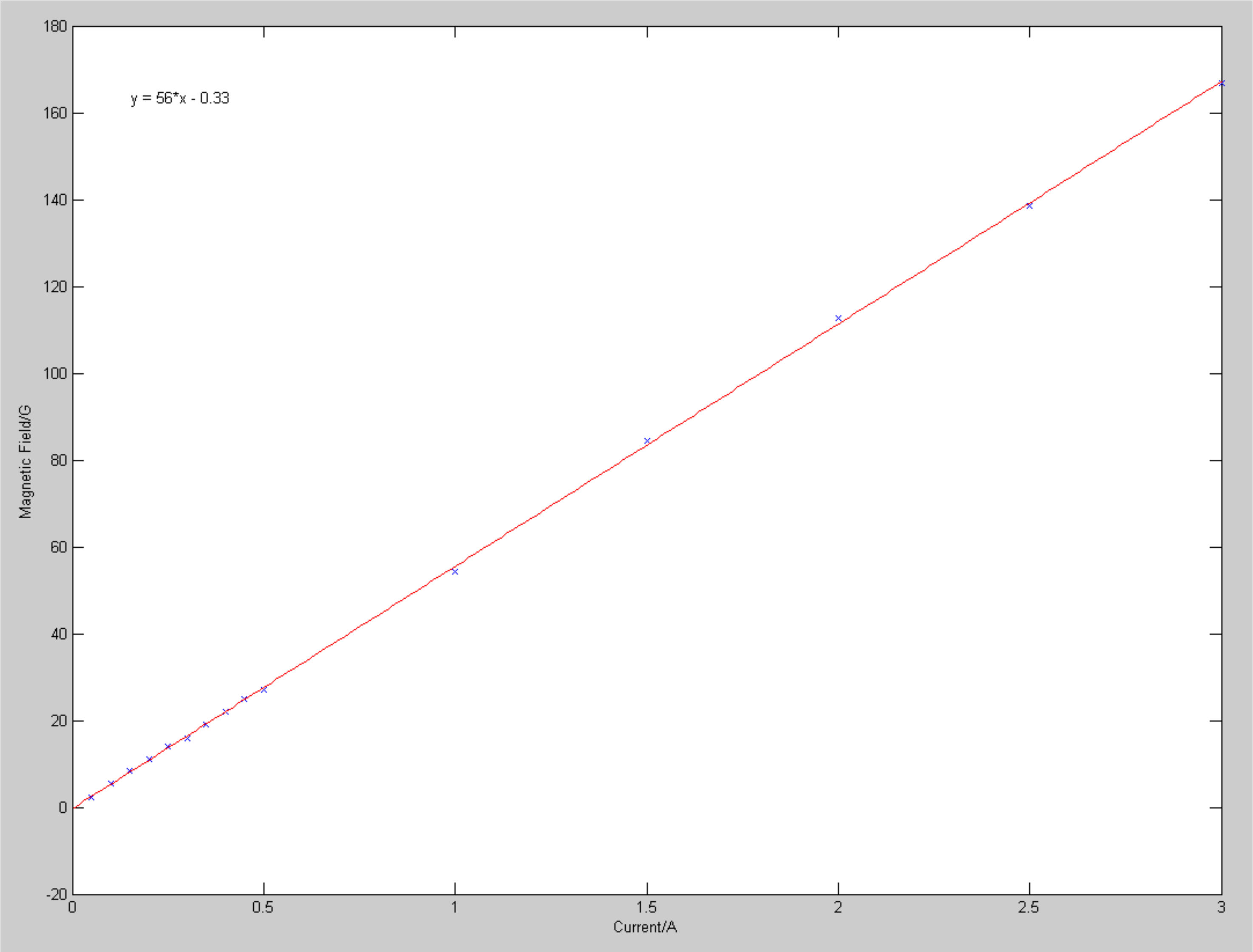

magnetic field
Hall voltage
current
semiconductor
slice



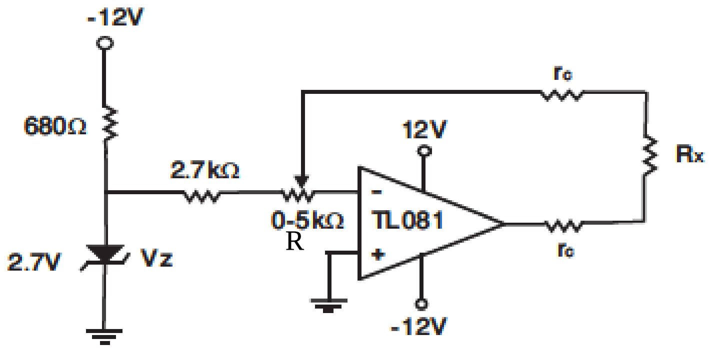
Magnetic Field

- Helm holtz coil
- Current provided using simple DC power supply
- Able to produce fields of upto 170G/0.017T
- Slide on which semiconductor rests is inserted into the coil
- Average deviation of B from maximum value = 5.4%
- Measured using Gaussmeter (axial probe)

Current through coil vs. Magnetic field



Constant Current Source



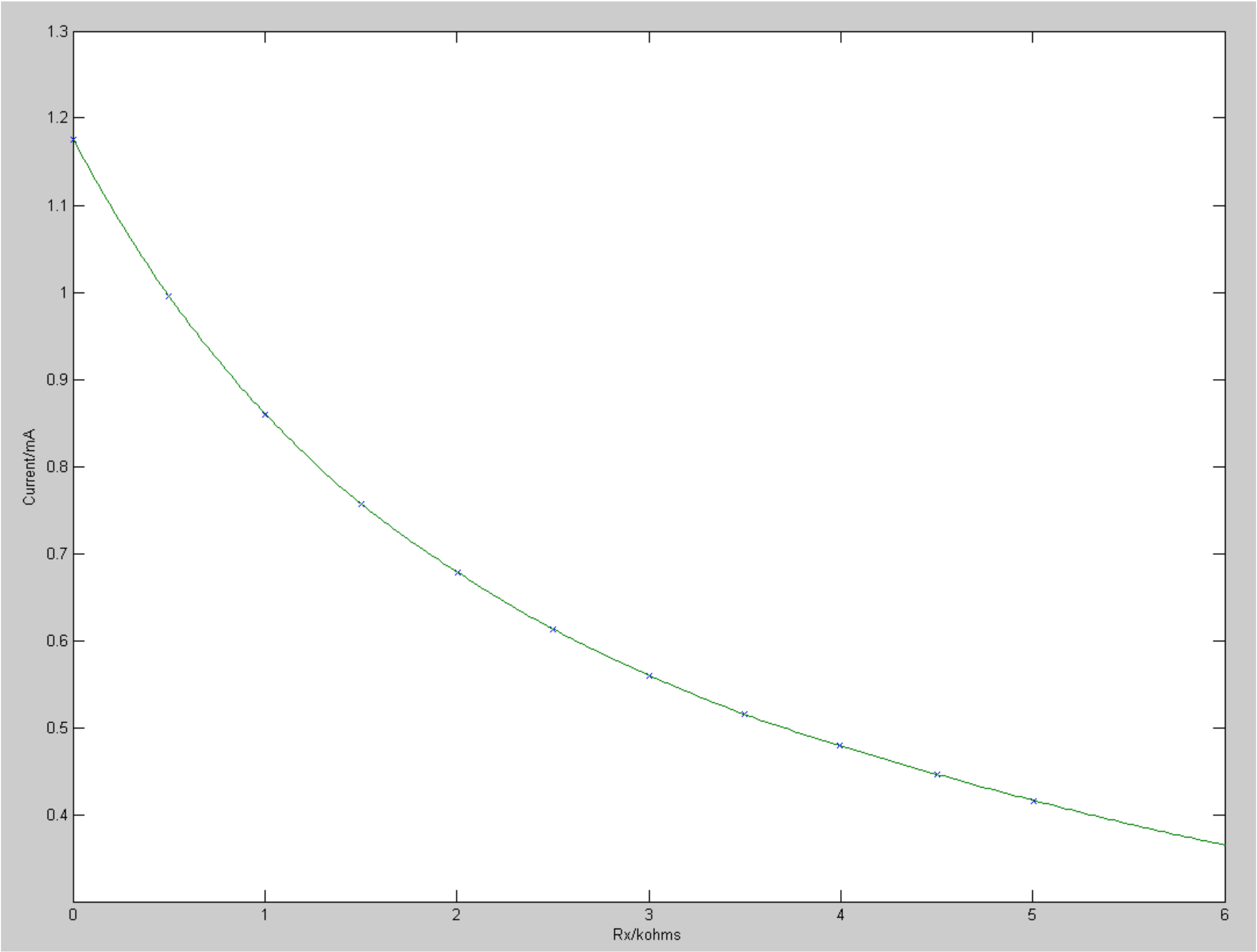
Stable for up to 0.1μA

TL081 Opamp

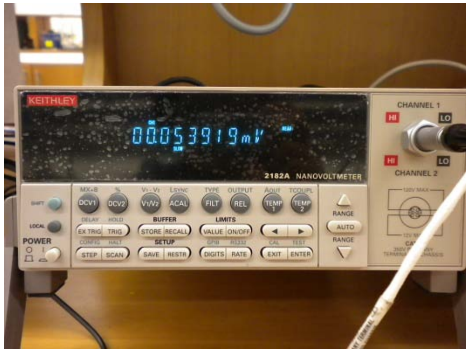
R_x Load

$I_x = 3.2/(2.7k+R)$

R_x vs. I_x



Voltmeter and Ammeter



Keithley nanovoltmeter

A microvoltmeter can replace this

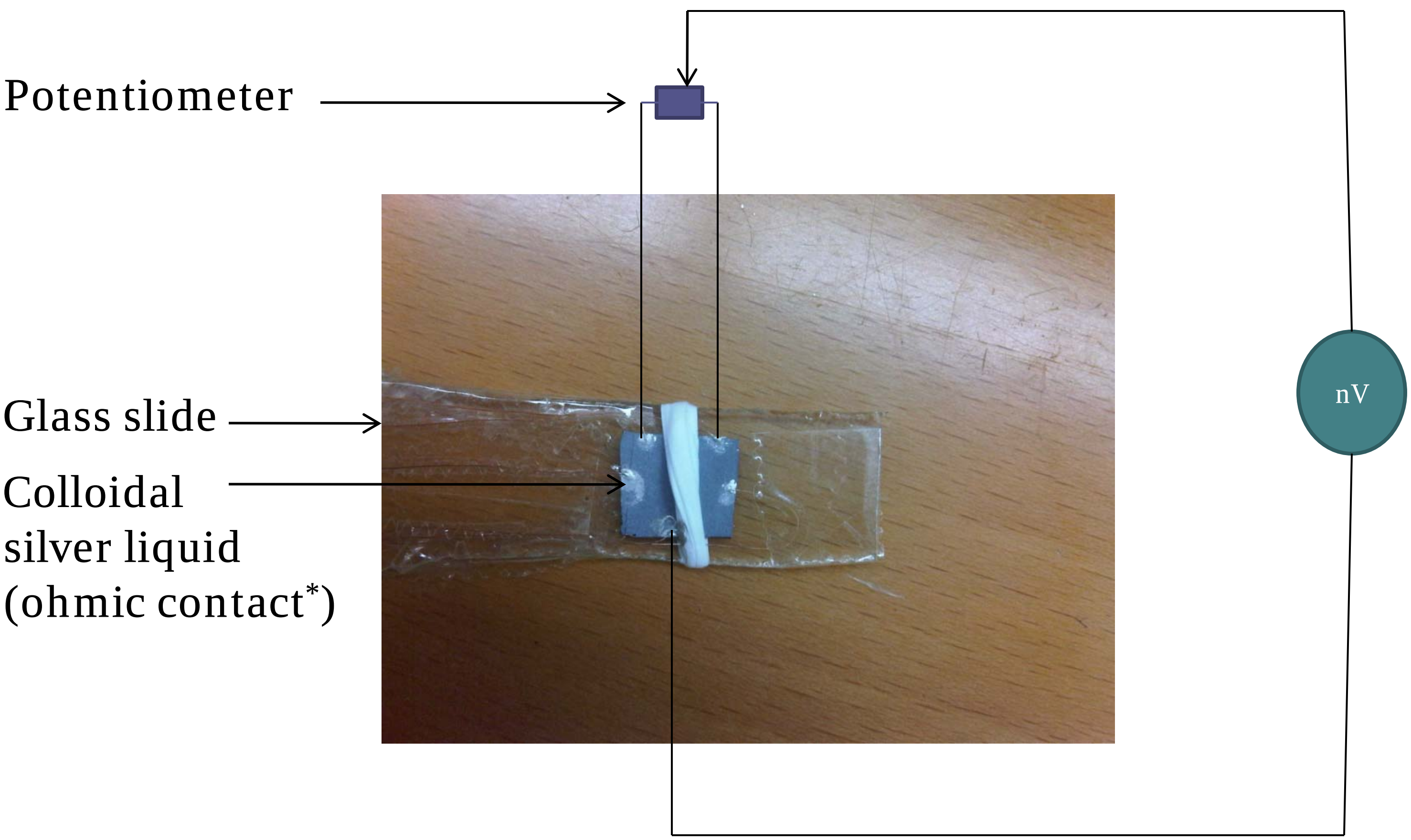
Keithley picoammeter

Can be replaced with a microammeter

Keithley DC & AC current source

Used in delta mode; no ammeter needed when this is used

Silicon Samples



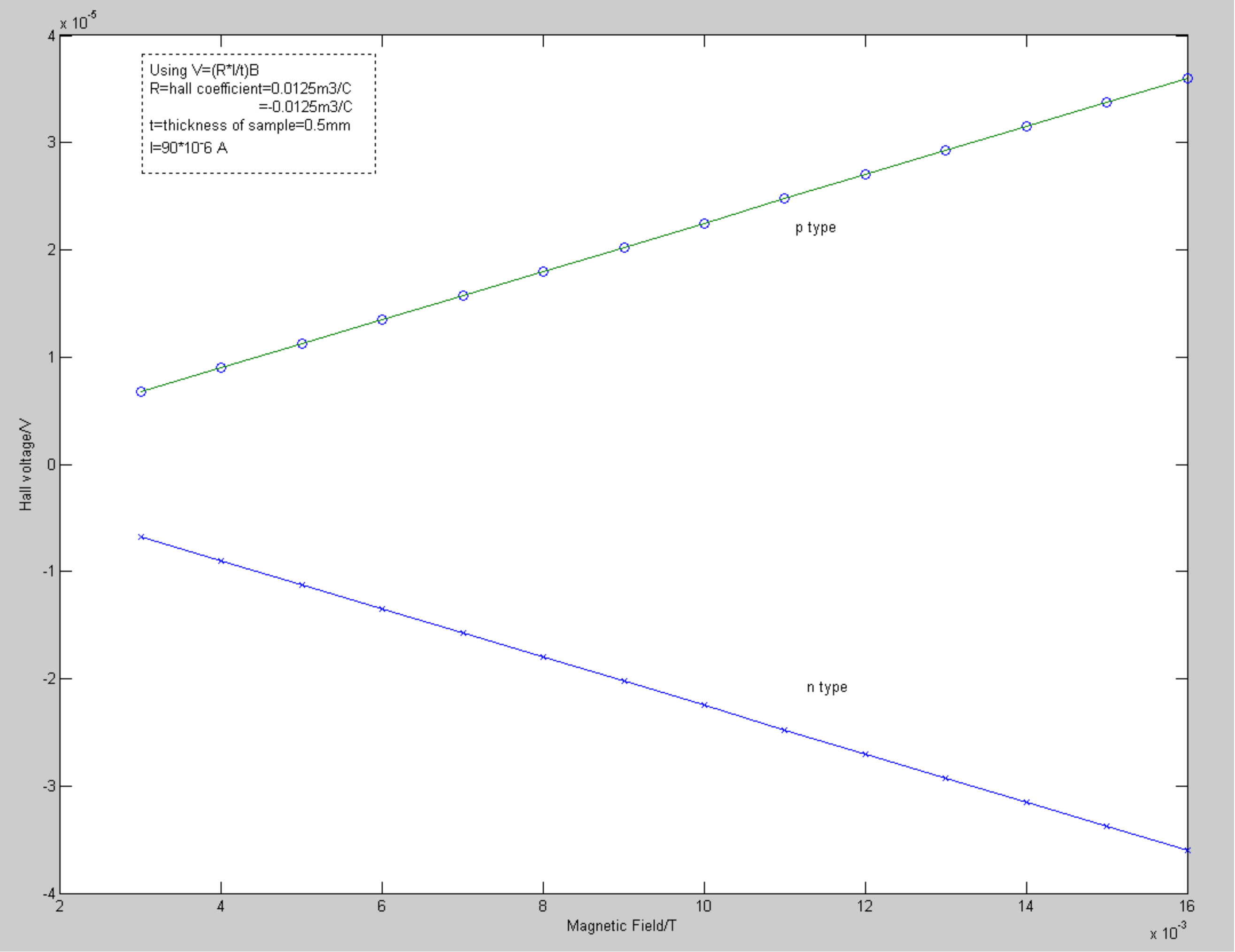
*Region of a semiconductor with linear I-V characteristics

- Glass slide is cut to fit into the slot in the helm holtz coil
- Potentiometer used to correct zero error in zero magnetic field with constant current flowing
- The metal-semiconductor contact is made using colloidal silver liquid. This contact must be ohmic for the readings to be accurate

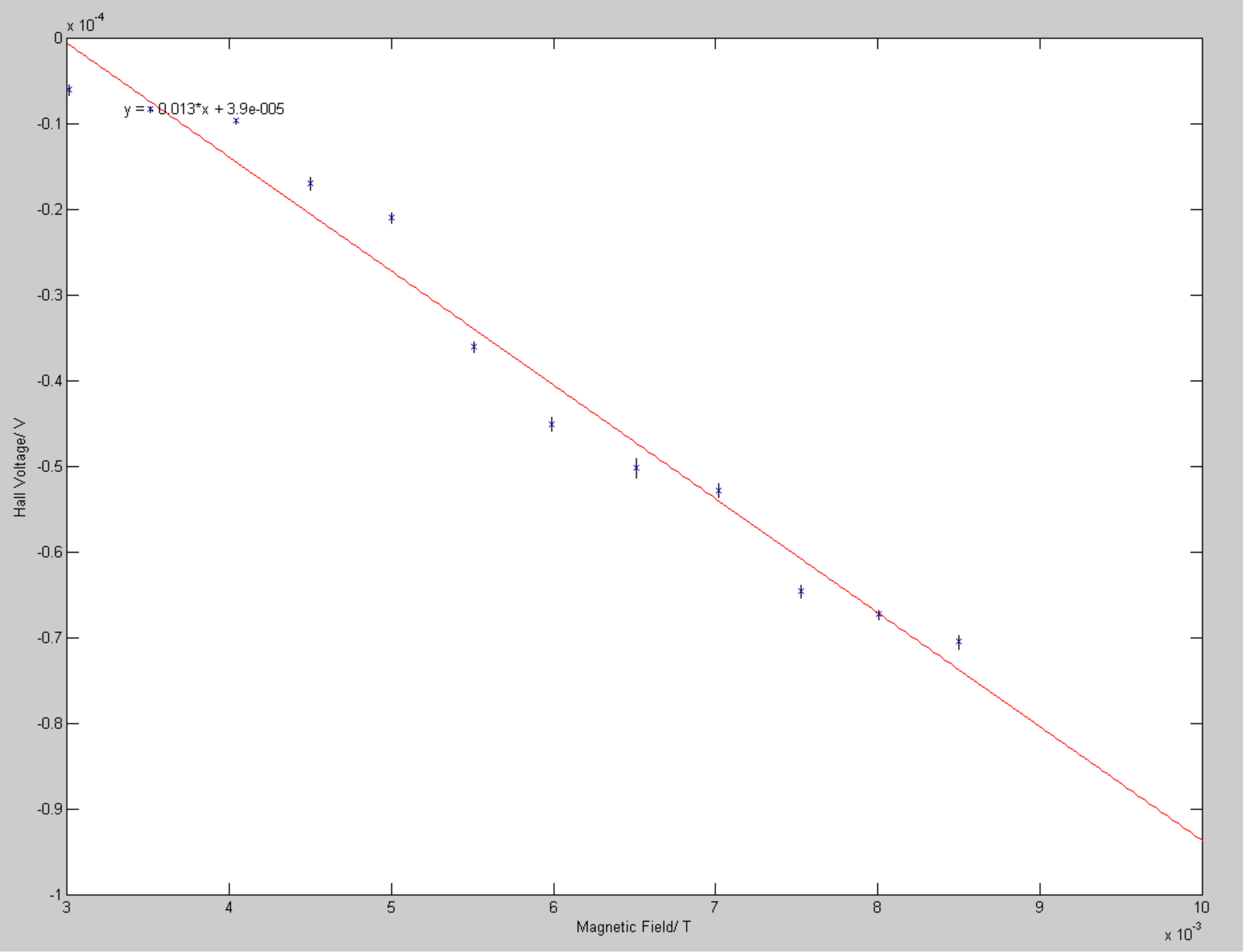
The Experiment & Results

- Experiment was first conducted using n-type sample, with constant current source made with circuit
- Potentiometer not used in this experiment

Simulated Result for B vs. V_H



Measured Results for B vs. V_H (n type)



- Simulated results gradient = -0.0027 m^3C^{-1}
- Measured results gradient = -0.013 m^3C^{-1}
- Discrepancy could be due to a number of reasons:

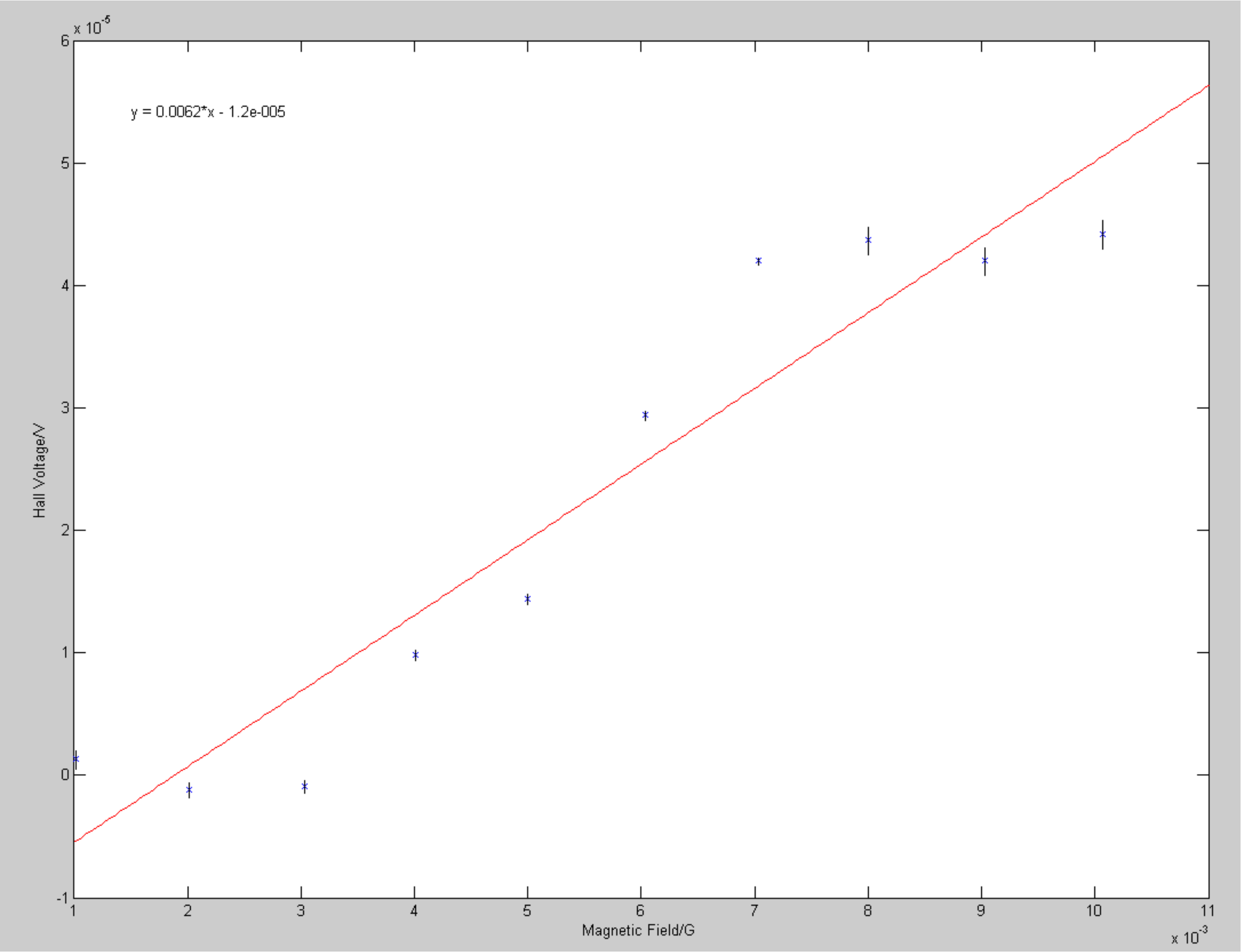
  Noise

  Approximations used in calculation of simulated results

  Exact ratio of doping unknown (10^6-10^8)

- Same procedure followed for p-type silicon
- The direction of current, magnetic field and voltmeter connections must be kept the same

Measured Results for B vs. V_H



- Simulated results gradient = 0.0043 m^3C^{-1}
- Measured results gradient = 0.0062 m^3C^{-1}

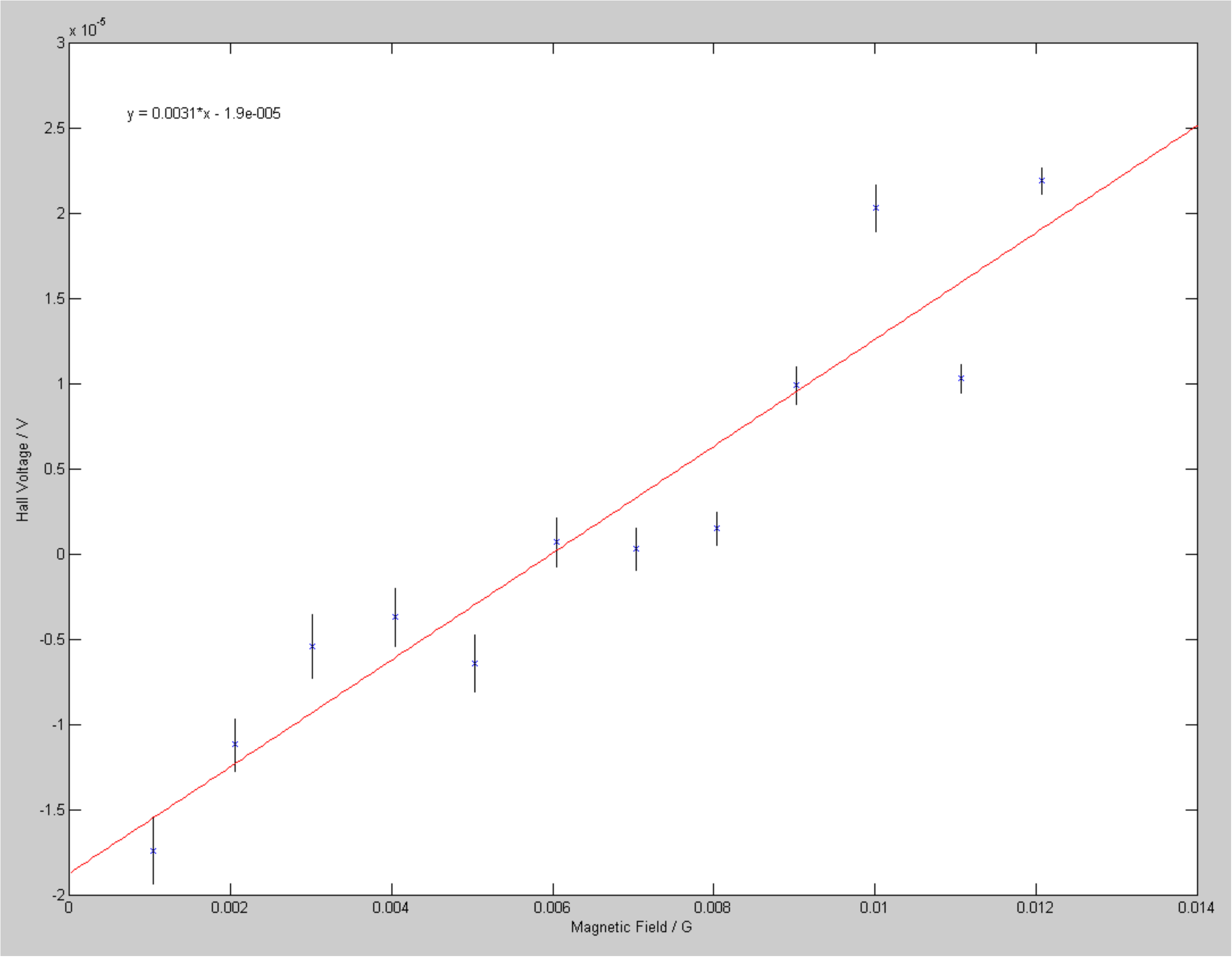
- This experiment repeated using delta mode to cancel noise

  $I(t_1) = +I \qquad V(t_1) = V_H + V_{noise}$

  $I(t_2) = -I \qquad V(t_2) = -V_H + V_{noise}$

  $V_H = (V(t_1) - V(t_2))/2$

B vs. V_H in Delta Mode



- Simulated results gradient = 0.0043 m^3C^{-1}
- Measured results gradient = 0.0031 m^3C^{-1}
- Assuming initial value taken for doping ratio was wrong, we can approximate the values of μ_e and μ_h and get new doping ratio using this measured value of gradient

  Doping Ratio = 7.3×10^7 (initially assumed to be 1×10^8)

- Any inaccuracy in the measurement may be caused by

  A contact being non-ohmic

  The delay between delta measurements being larger than the time constant for the noise

Further improvements

- Van der Pauw technique can be used
- A more accurate helm holtz coil with a constant current
- Conduct experiment at lower temperatures to reduce thermal noise
- Make sure circuit is of uniform temperature to reduce thermal gradients

Questions?