8

2.Lab Report

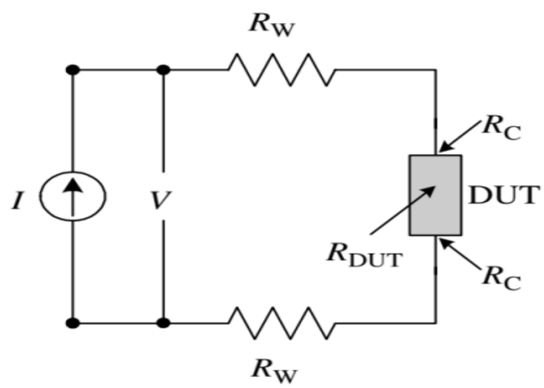
Resistivity Measurements, Mobility Measurements

H Nareshkumar
EE21M005

Resistivity measurements:

Theory:

1. Two terminal measurements



Objective

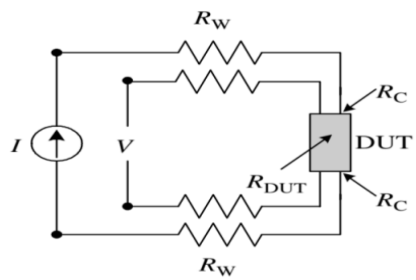
Rw: voltmeter internal resistance

Rc: contact resistance

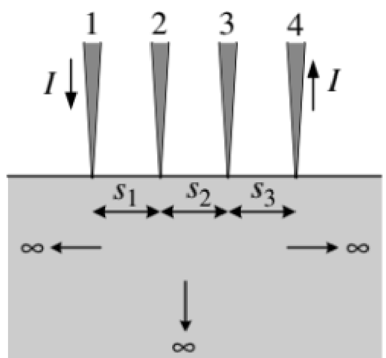
Rdut: resistance of device under test

$$R_T = V/I = 2R_W + 2R_C + R_{DUT}$$

2. four terminal measurements

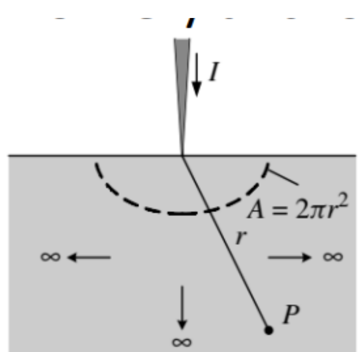


➔ Pass the current from 1 and 4 probes and measure the voltage across the 2 and 3 terminals



s1,s2,s3 spacing between probes, for simplicity let us take spacing between them is equal

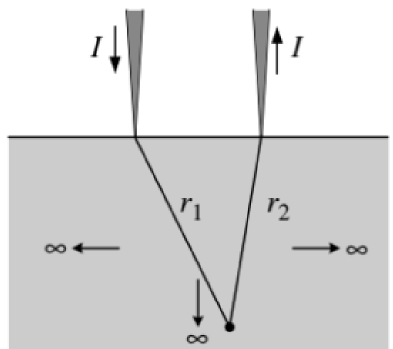
➔ Let us take a simple case



Here r is the radius until p point

$$\mathscr{E} = J\rho = -\frac{dV}{dr};\ \ J = \frac{I}{2\pi r^2}$$

$$\int_0^V dV = -\frac{I\rho}{2\pi}\int_0^r \frac{dr}{r^2} \Rightarrow V = \frac{I\rho}{2\pi r}$$



Apply superposition

$$V = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2} = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

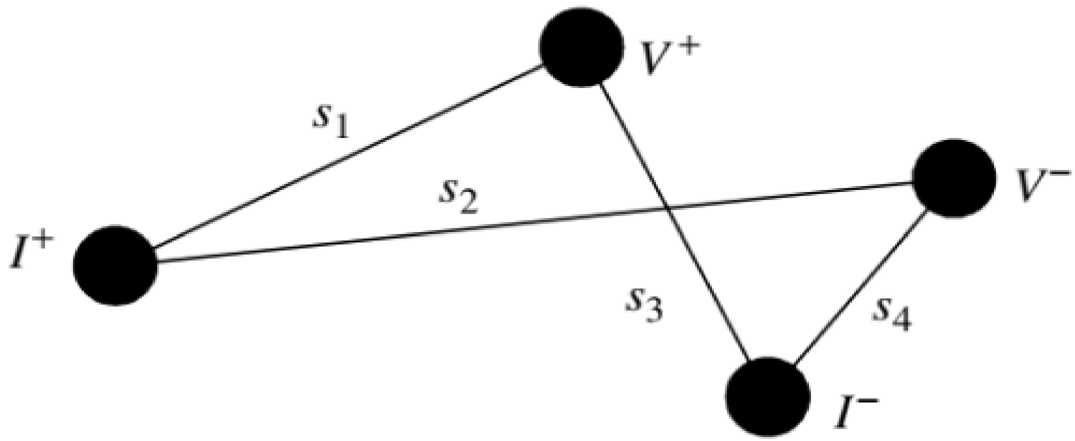
$$V_2 = \frac{I\rho}{2\pi}\left(\frac{1}{s_1} - \frac{1}{s_2 + s_3}\right)$$

$$V_3 = \frac{I\rho}{2\pi}\left(\frac{1}{s_1 + s_2} - \frac{1}{s_3}\right)$$

V = V2-V3

$$\rho = \frac{2\pi}{(1/s_1 - 1/(s_1 + s_2) - 1/(s_1 + s_2) + 1/s_3)}\frac{V}{I} = 2\pi s\frac{V}{I}$$

For a sample with finite thickness t



$$\mathscr{E} = J\rho = \frac{I\rho}{2\pi r t} = -\frac{dV}{dr}$$

$$\int_{V_{s1}}^{V_{s2}} dV = -\frac{I\rho}{2\pi t}\int_{s_1}^{s_2} \frac{dr}{r} \Rightarrow V_{s1} - V_{s2} = V_{12} = \frac{I\rho}{2\pi t}\ln\left(\frac{s_2}{s_1}\right)$$

$$V_{34} = -\frac{I\rho}{2\pi t}\ln\left(\frac{s_3}{s_4}\right) \qquad V = V_{12} - V_{34} = \frac{I\rho}{2\pi t}\ln\left(\frac{s_2 s_3}{s_1 s_4}\right)$$

- For colinear arrangement $s_1 = s_4 = s$ and $s_2 = s_3 = 2s$

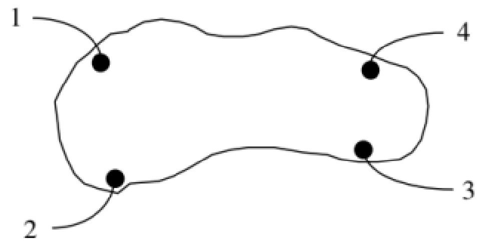
$$\rho = \frac{\pi t}{\ln(2)}\frac{V}{I} = 4.532t\frac{V}{I}$$

Van der pauw method:

- ➔ If the samples are in arbitary shaped

  Pass current from 1,2, and measure voltage between 3,4

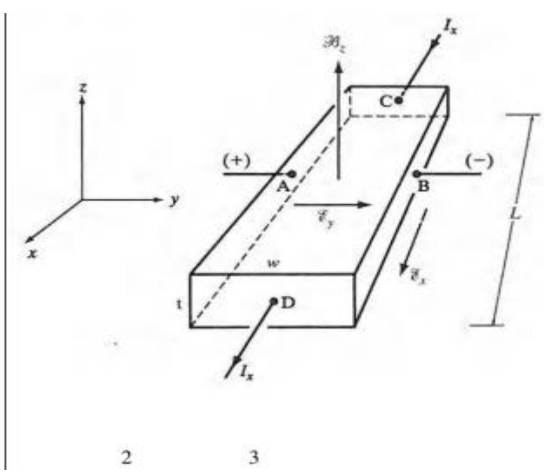
  Pass current from 2,3 and measure voltage between 1,4



$$R_{12,34} = \frac{V_{34}}{I_{12}} \qquad \rho = \frac{\pi}{\ln(2)} t \frac{(R_{12,34} + R_{23,41})}{2} F$$

$$e^{-\frac{\pi t R_{12,34}}{\rho}} + e^{-\frac{\pi t R_{23,41}}{\rho}} = 1$$

<u>Hall effect</u>

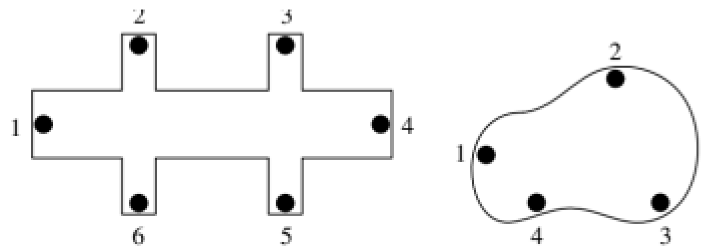


$$\mathbf{F} = q(\mathscr{E} + \mathrm{v} \times \mathscr{B}) \qquad F_y = q(\mathscr{E}_y - \mathrm{v}_x \mathscr{B}_z)$$

$$\mathscr{E}_y = \mathrm{v}_x \mathscr{B}_z = \frac{J_x}{qp_0} \mathscr{B}_z = R_H J_x \mathscr{B}_z, \quad R_H \equiv \frac{1}{qp_0}$$

$$p_0 = \frac{1}{qR_H} = \frac{J_x \mathscr{B}_z}{q\mathscr{E}_y} = \frac{(I_x/wt)\mathscr{B}_z}{q(V_{AB}/w)} = \frac{I_x \mathscr{B}_z}{qtV_{AB}}$$

$$\mu_p = \frac{\sigma}{qp_0} = \frac{1/\rho}{q(1/qR_H)} = \frac{R_H}{\rho}$$



Pass current from I and 4 terminals and measure the voltage between 2,6 or 3,5.

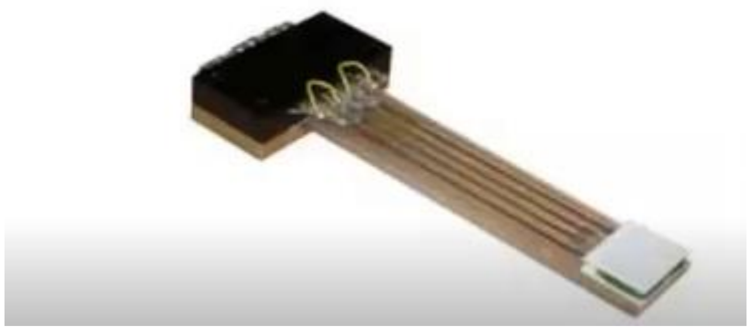
$$R_H = \frac{tV_{AB}}{I_x \mathfrak{B}_z} = \frac{tR}{\mathfrak{B}_z} \qquad \mu_p = \frac{tR}{\rho \mathfrak{B}_z} = \frac{t\Delta R_{24,13}}{\rho \mathfrak{B}_z}$$

Experiment

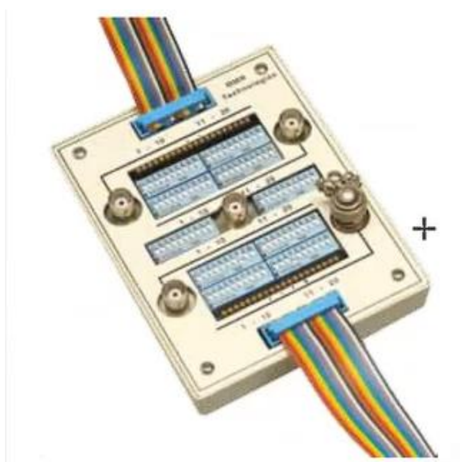
Hall measurements system: used to measuring the carrier mobility, carrier concentration and resistivity.

Here mobility, carrier concentration and resistivity are a function of temperature

Joule thomson refrigerator: this used for cooling and heating sample. Sample is placed on the heating plate operating range is from 80k to 580k.



Circuit breakout box: used to give power supply to joule thomson refrigerator, this circuit breakout interfaced with the temperature controller.



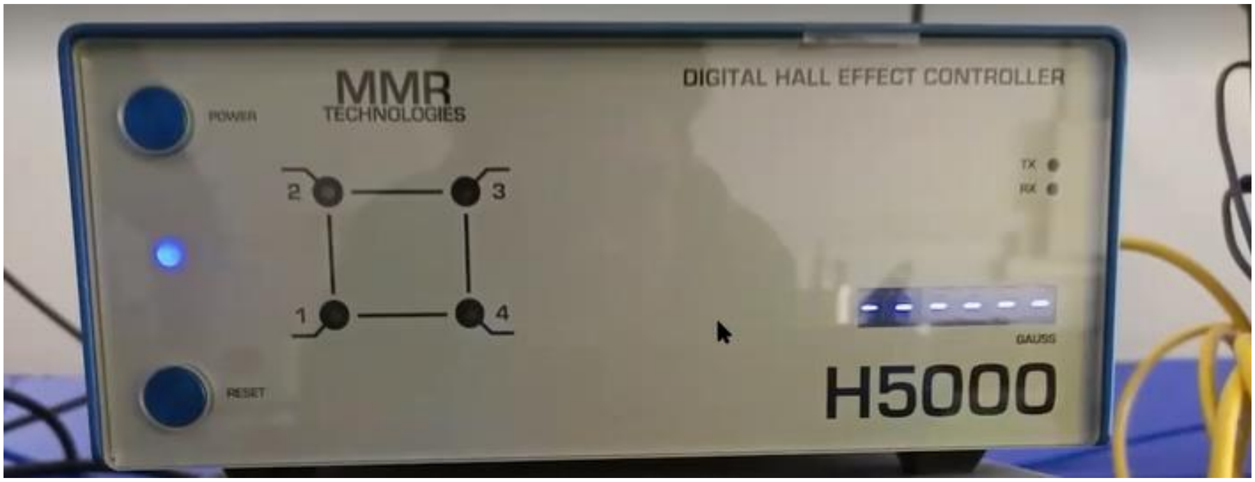
The filter/dryer setup : in order to reduce the temperature below the room temperature, Nitrogen

Flows to the chamber form the metal wire.

Dryer is connected to chamber. The complete chamber show below

Permanent magnet : in our lab we have 7500 gauss magnet.

Digital hall effect multiplier: this Digital hall effect multiplier is controlled with the help of software.

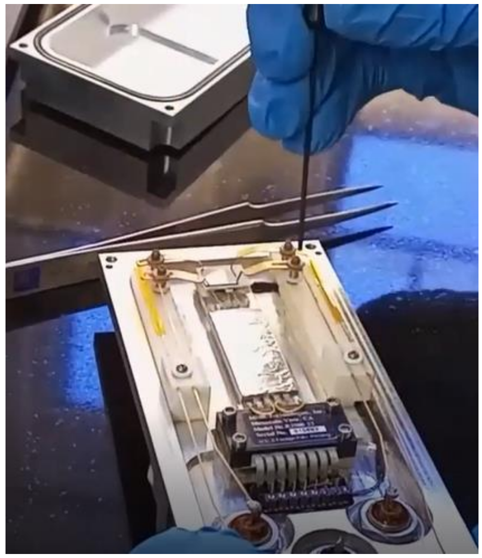


Here 4 point configuration given, we can supply current to any two probes and we have to measure the voltage between remaining two nodes.

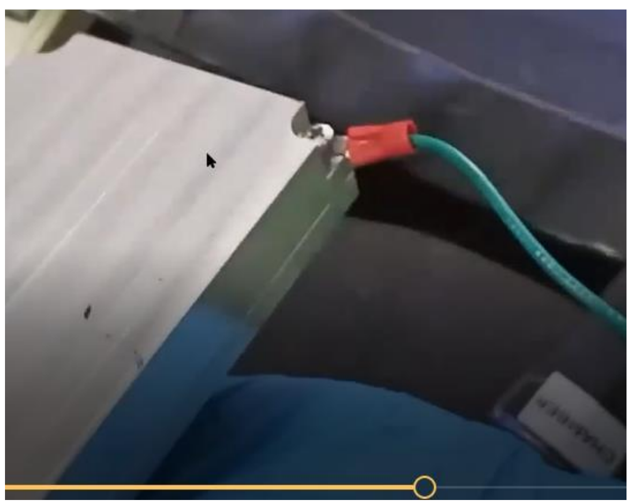
Digital temperature controller(k2000):

➔ Take si sample, thickness is 380 micrometer. 1 cm X 1 cm .this sample have to place in the cheark in the chamber.

➔ After placing the sample, we have to see the electrical connections to four probes. Fix the sample with help of screw



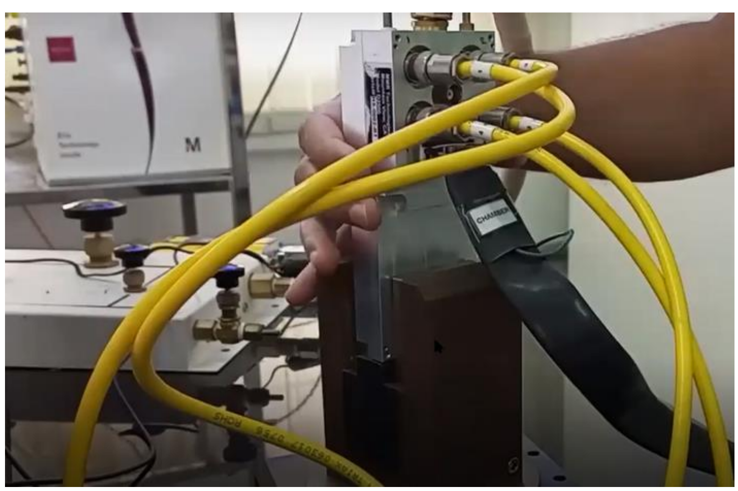
➔ close the chamber, joule thomson refrigerator ground connection have to connect with any one of four screw which was used to close the chamber.



➔ From the Digital temperature controller(k2000) take 4 cables and connect as shown below. This cables number must be matched.

- ➔ Switch on the Digital temperature controller, Digital hall effect controller.
- ➔ Turn on the vacume pump, which creates the vacume in chamber to remove the gases and dust particles in chamber. We reduce the vacume below 40 m tor.

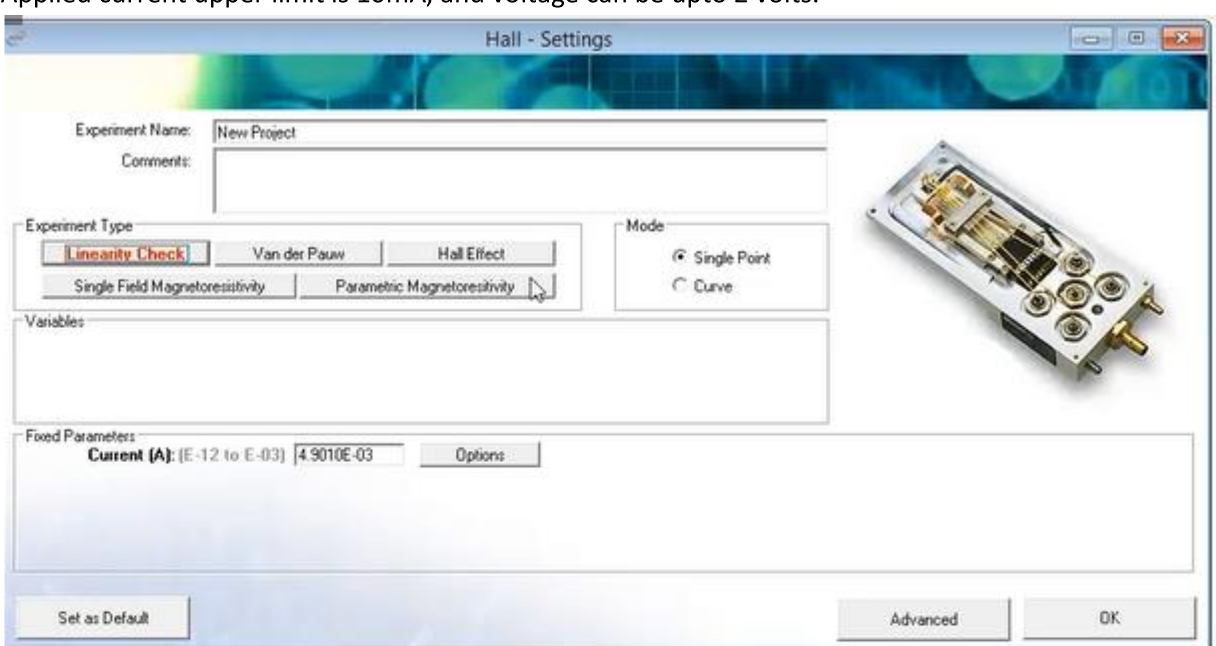
- ➔ Place the chamber in between the permanent magnet



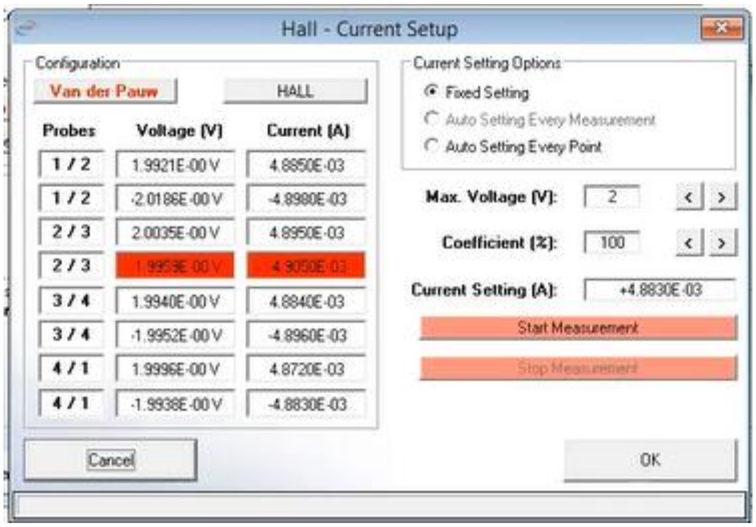
- ➔ Open the software Mmr technology
- ➔ We are using comm4 and comm5 for communications.

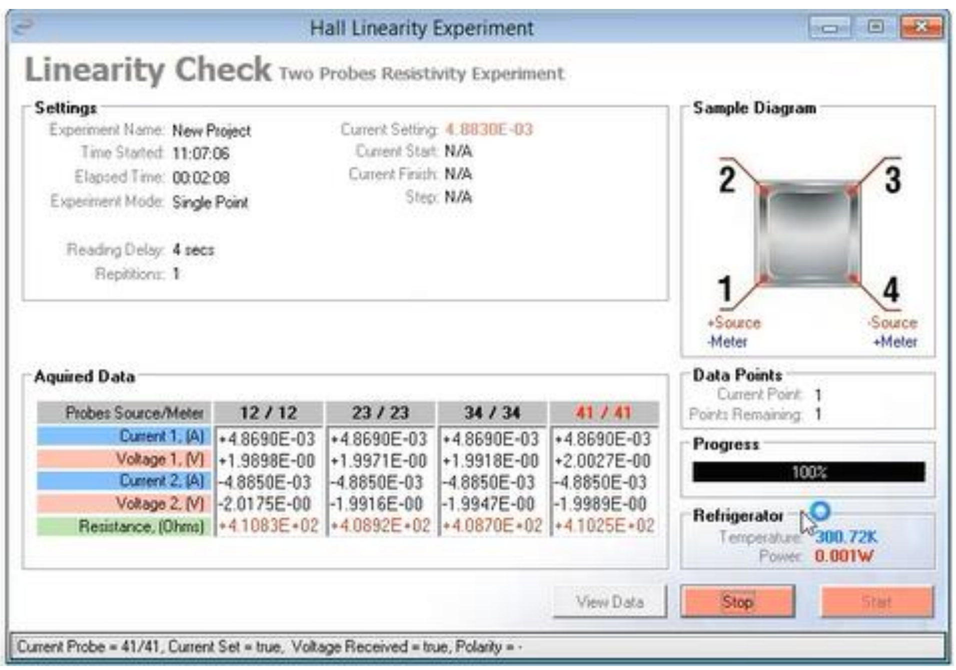
- ➔ First linearity check

Applied current upper limit is 10mA, and voltage can be upto 2 volts.



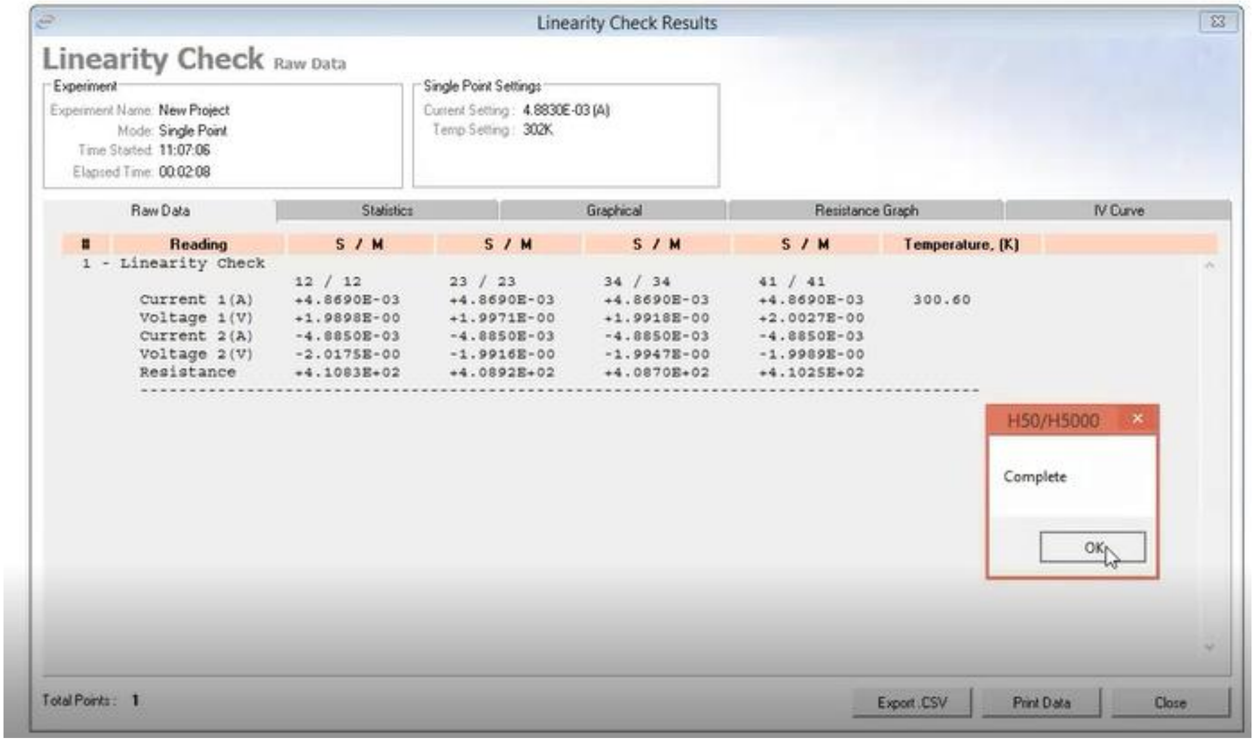
➔ For single point current



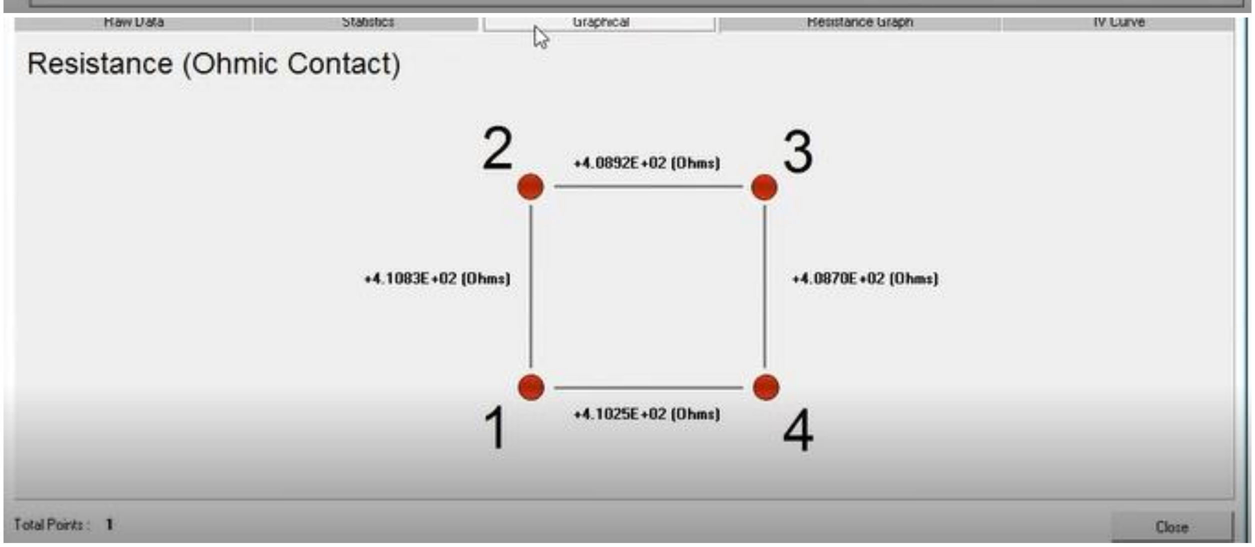


Compare values obtained analytically from equations

Results:

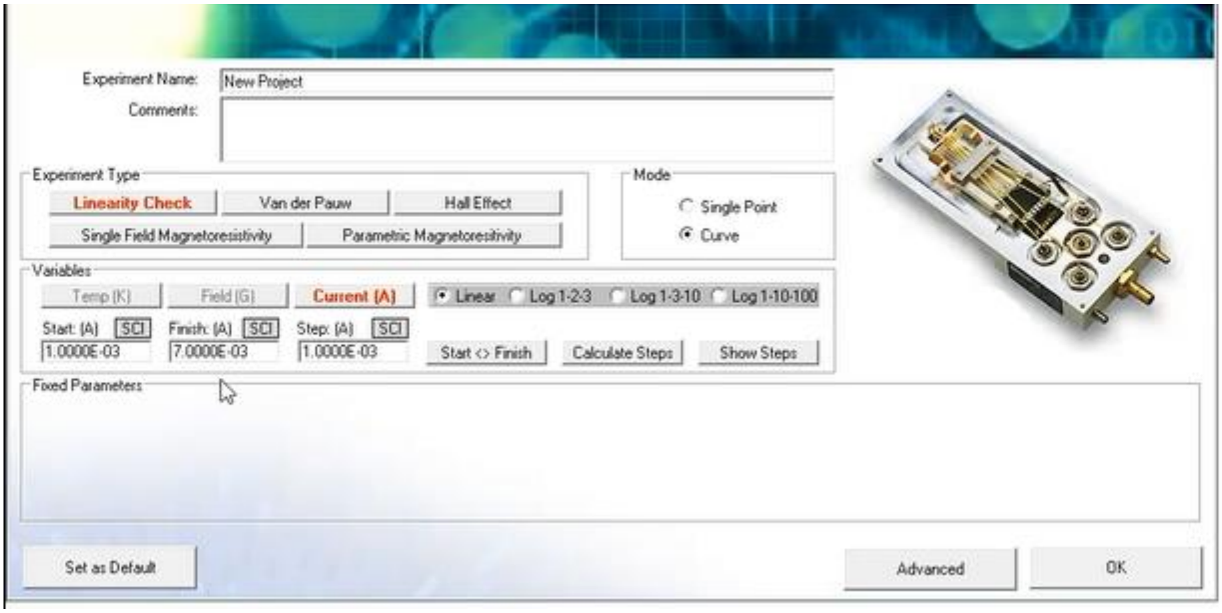


Linearity Check Results
Linearity Check Raw Data
Experiment
Experiment Name: New Project
Mode: Single Point
Time Started: 11:07:06
Elapsed Time: 00:02:08
Single Point Settings
Current Setting: 4.8830E-03 (A)
Temp Setting: 302K
Raw Data
Statistics
Graphical
Resistance Graph
IV Curve
Reading S / M S / M S / M S / M Temperature, (K)
1 - Linearity Check
12 / 12 23 / 23 34 / 34 41 / 41
Current 1(A) +4.8690E-03 +4.8690E-03 +4.8690E-03 +4.8690E-03 300.60
Voltage 1(V) +1.9898E-00 +1.9971E-00 +1.9918E-00 +2.0027E-00
Current 2(A) -4.8850E-03 -4.8850E-03 -4.8850E-03 -4.8850E-03
Voltage 2(V) -2.0175E-00 -1.9916E-00 -1.9947E-00 -1.9989E-00
Resistance +4.1083E+02 +4.0892E+02 +4.0870E+02 +4.1025E+02
H50/H5000
Complete
OK
Total Points: 1
Export .CSV
Print Data
Close

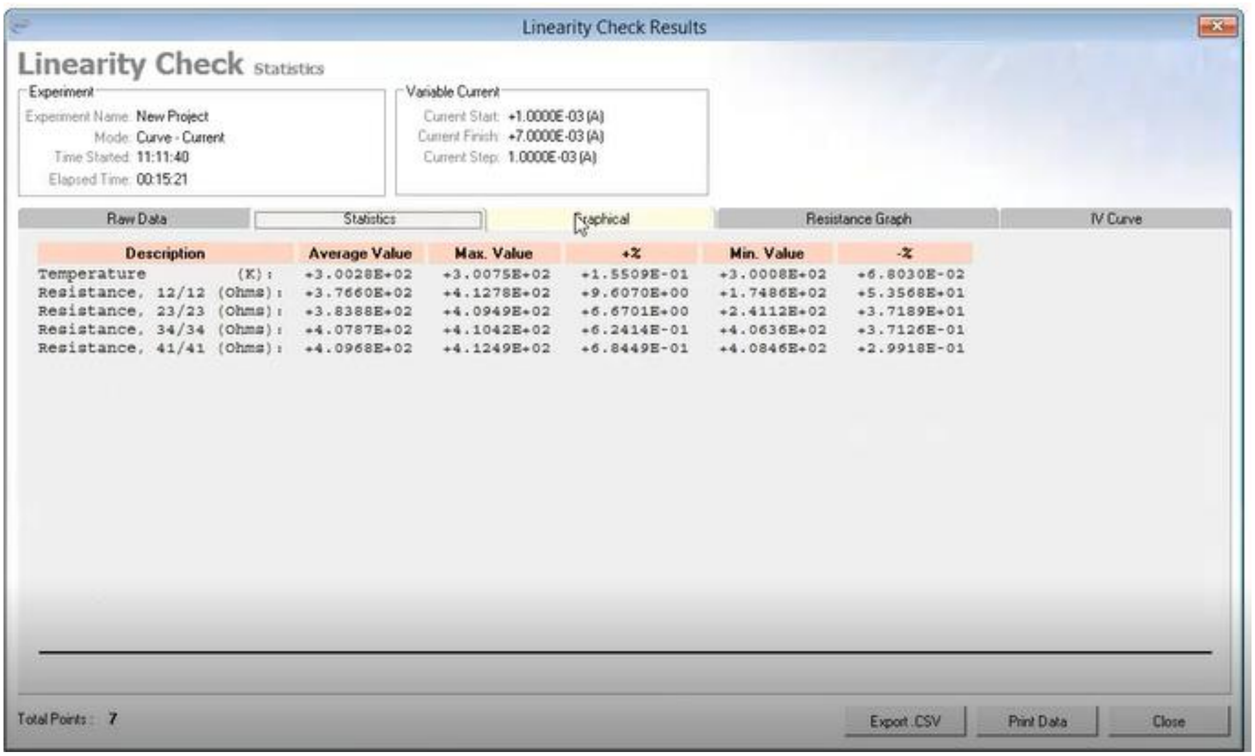


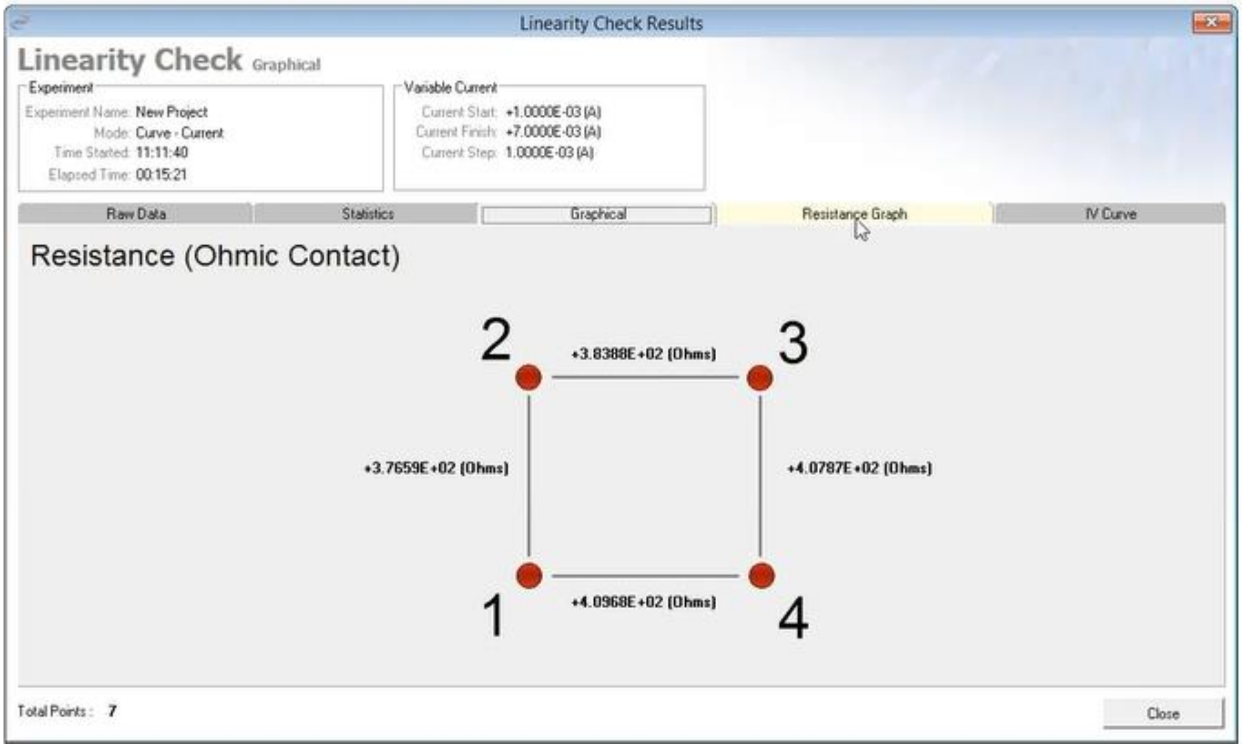
Raw Data
Statistics
Graphical
Resistance Graph
IV Curve
Resistance (Ohmic Contact)
2
3
+4.0892E+02 (Ohms)
+4.1083E+02 (Ohms)
+4.0870E+02 (Ohms)
1
4
+4.1025E+02 (Ohms)
Total Points: 1
Close

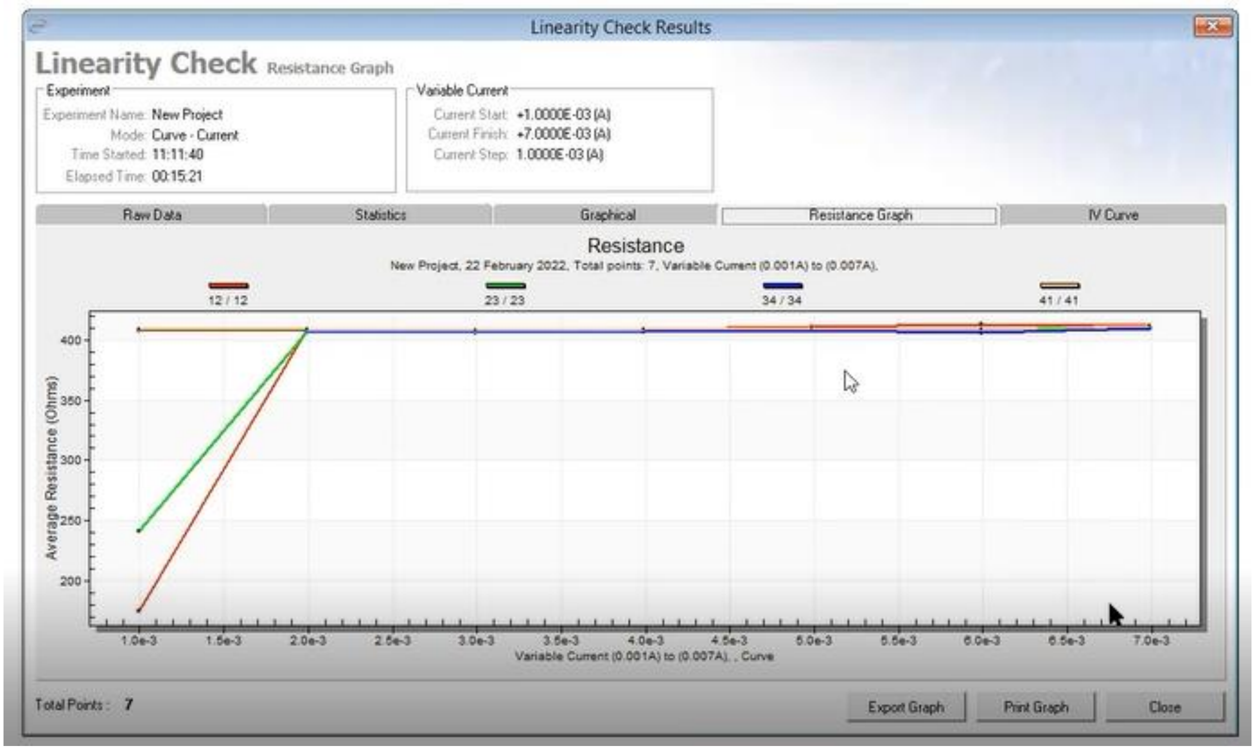
→ Now let us go for curved point current

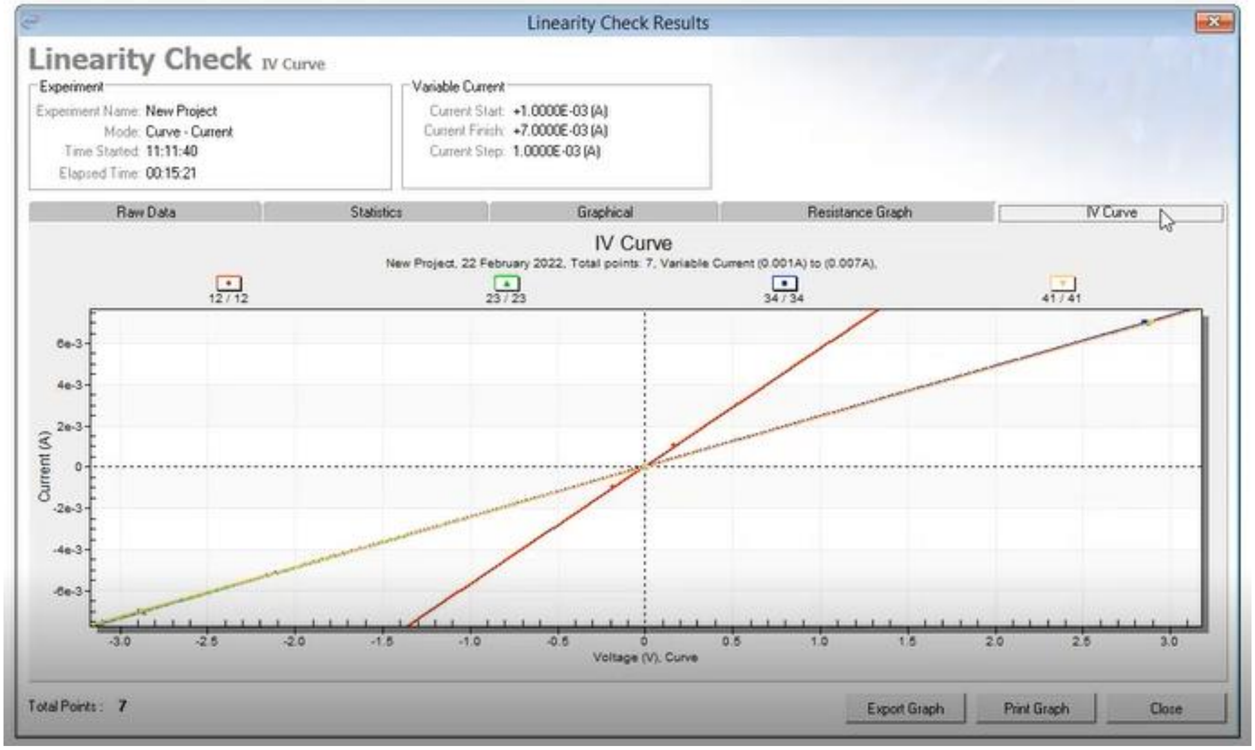


→

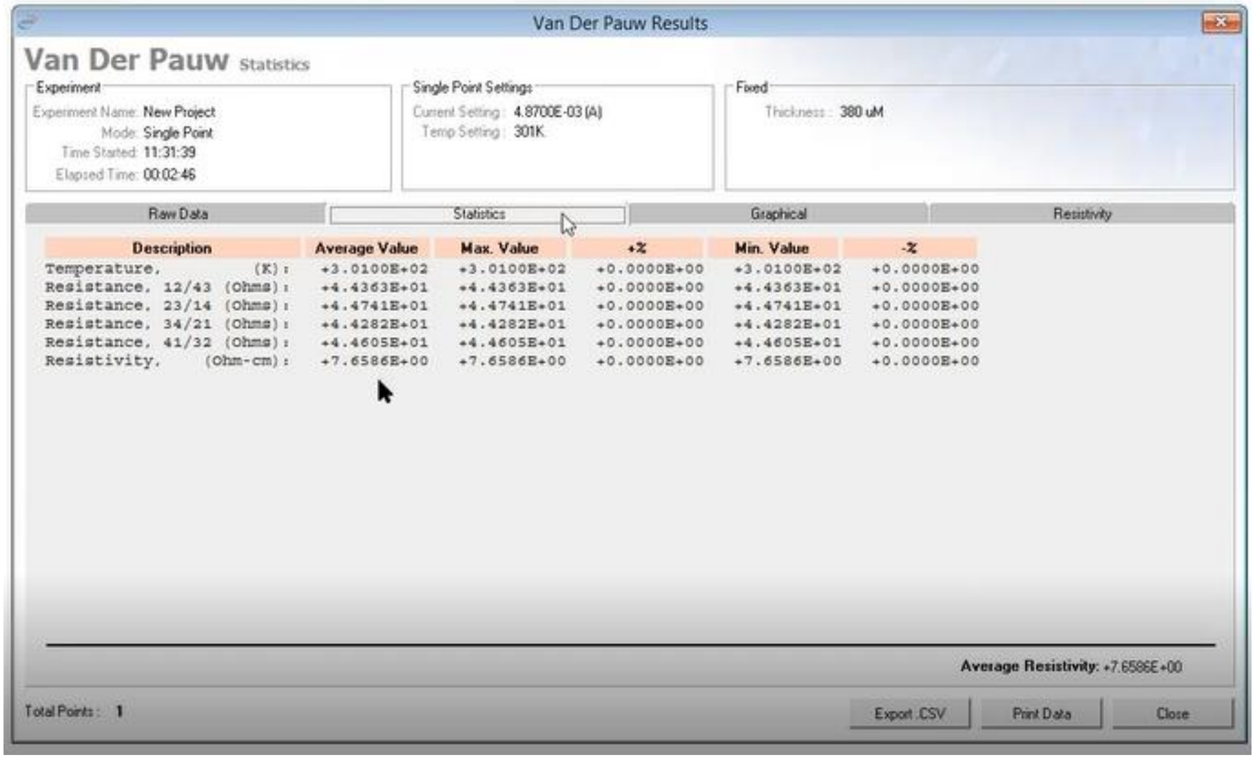


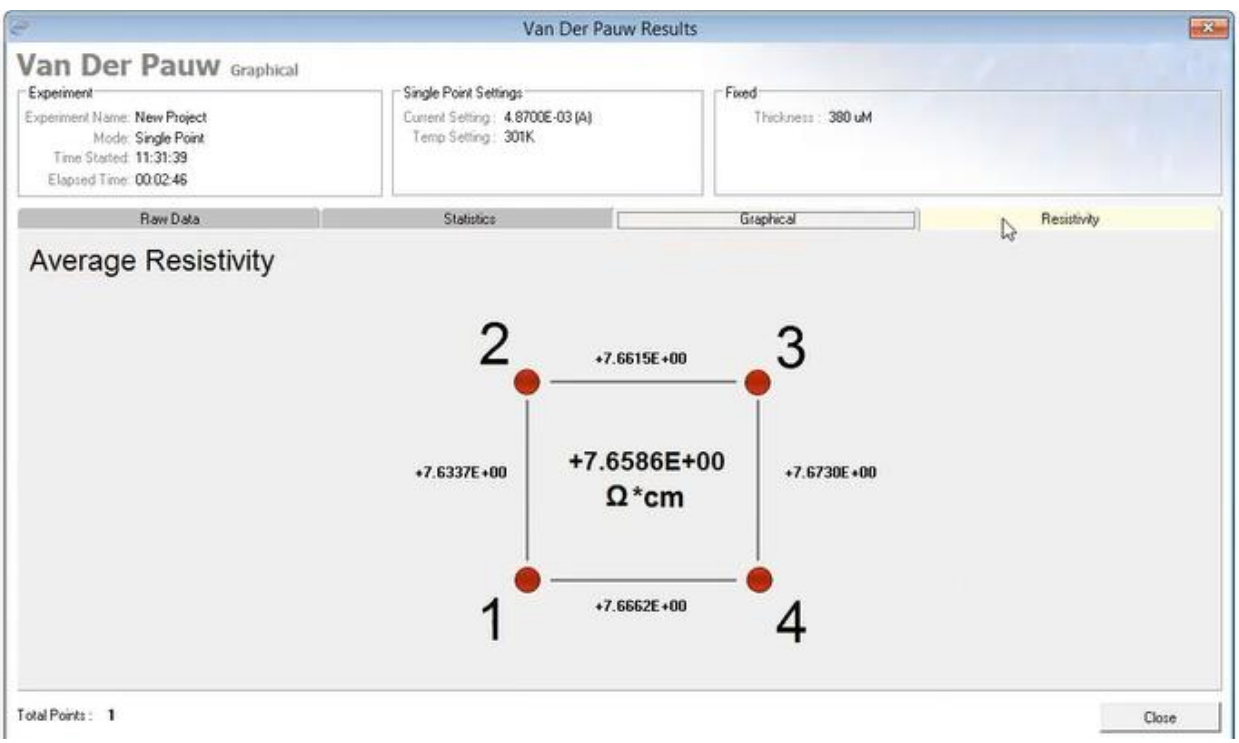

Linearity Check Results
Linearity Check Graphical
Experiment
Experiment Name: New Project
Mode: Curve - Current
Time Started: 11:11:40
Elapsed Time: 00:15:21
Variable Current
Current Start: +1.0000E-03 (A)
Current Finish: +7.0000E-03 (A)
Current Step: 1.0000E-03 (A)
Raw Data
Statistics
Graphical
Resistance Graph
IV Curve
Resistance (Ohmic Contact)
2
3
1
4
+3.8388E+02 (Ohms)
+3.7659E+02 (Ohms)
+4.0787E+02 (Ohms)
+4.0968E+02 (Ohms)
Total Points : 7
Close


Linearity Check Results
Linearity Check Resistance Graph
Experiment
Experiment Name: New Project
Mode: Curve - Current
Time Started: 11:11:40
Elapsed Time: 00:15:21
Variable Current
Current Start: +1.0000E-03 (A)
Current Finish: +7.0000E-03 (A)
Current Step: 1.0000E-03 (A)
Raw Data
Statistics
Graphical
Resistance Graph
IV Curve
Resistance
New Project, 22 February 2022, Total points: 7, Variable Current (0.001A) to (0.007A).
12 / 12
23 / 23
34 / 34
41 / 41
Average Resistance (Ohms)
Variable Current (0.001A) to (0.007A), , Curve
Total Points : 7
Export Graph
Print Graph
Close


Linearity Check Results
Linearity Check IV Curve
Experiment
Experiment Name: New Project
Mode: Curve - Current
Time Started: 11:11:40
Elapsed Time: 00:15:21
Variable Current
Current Start: +1.0000E-03 (A)
Current Finish: +7.0000E-03 (A)
Current Step: 1.0000E-03 (A)
Raw Data
Statistics
Graphical
Resistance Graph
IV Curve
IV Curve
New Project, 22 February 2022, Total points: 7, Variable Current (0.001A) to (0.007A),
12 / 12
23 / 23
34 / 34
41 / 41
Current (A)
Voltage (V), Curve
Total Points : 7
Export Graph
Print Graph
Close

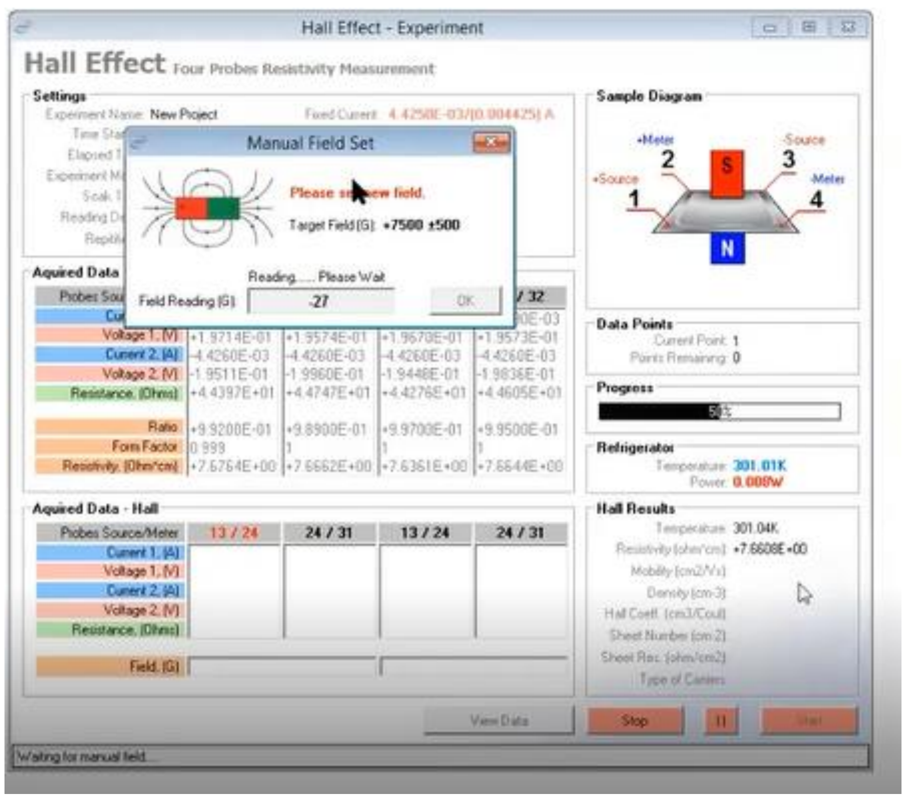
Now temperature changed from 300 k to 301 k



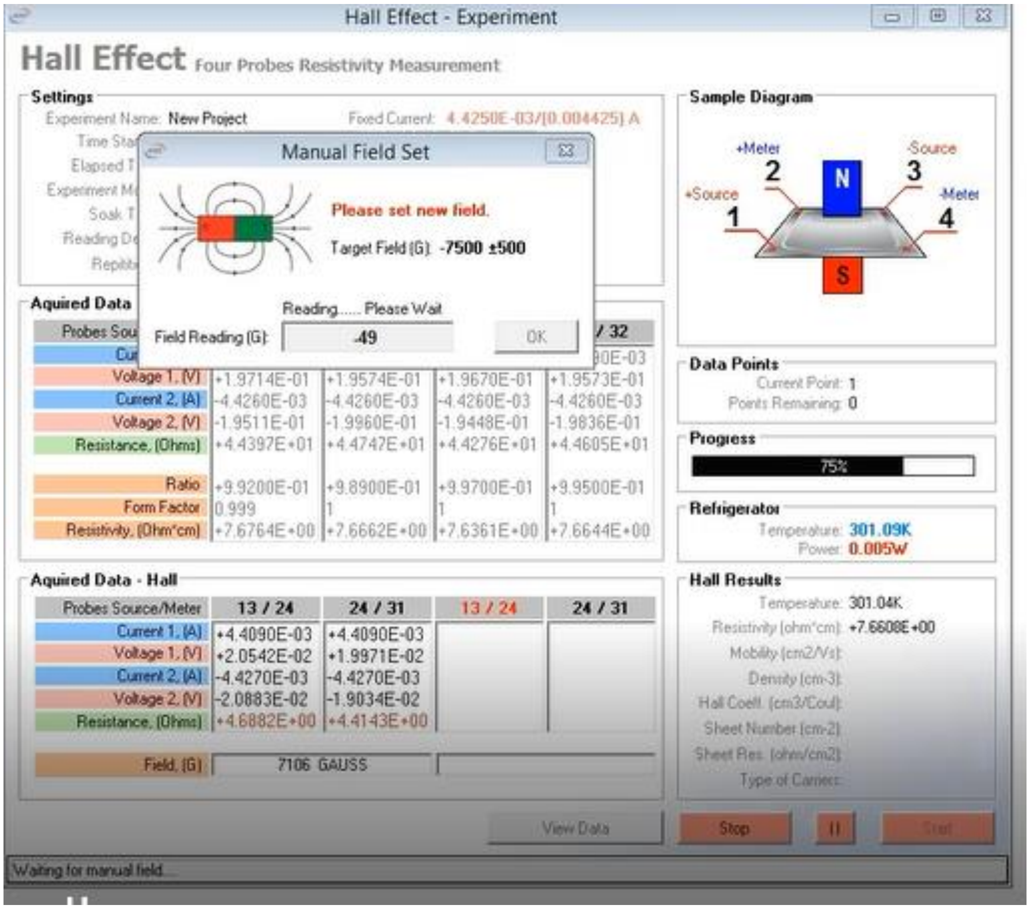


Hall effect

When the above message pops up , need to apply magnetic field.



When the above message pops up , we need to reverse the magnetic field direction



Hall effect results: