H50/H5000 Hall Effect Controller

Installation & Operators Guide DRAFT

Rev C – March 2016

CE

This document outlines the installation and setup of the MMR H50/H5000 Hall Effect Controller.

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CONTENTS

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Specifications

The H5000 Hall Effect controller is built on and intended to replace the proven H50 Hall Effect controller previously offered by MMR Technologies. See Page 9 for the Theory of Operation. This device provides accurate Hall Effect, Van Der Pauw and Magnetoresistivity measurements when used with a MMR Hall Chamber and Refrigerator assembly. *These devices are intended for use with MMR Refrigerators only*.

Voltage:	115VAC - 220VAC 50/60Hz (Not user selectable)
Power Consumption:	50W
Communications:	RS232 or USB1.0 *(USB with H5000 only)*
K2000 Needed:	No
Weight:	10Lbs
Dimensions:	8.5"(W) x 4.5"(H) x 14.25"(D)
Environmental:	Indoor use only, 5C - 40C Temperature, 5000M Max Altitude, 80% Humidity for temperatures up to 31 °C decreasing linearly to 50 % Rel humidity at 40 °C.

System Requirements

The H5000 Hall Effect Controller is designed for use with 'MMR Technologies Software Suite' which must be installed prior to using this device. For custom control of this device see page 19, please note MMR may not support custom configurations and in some cases the warranty may be void.

Operating System:	Windows 2000, Windows XP, Windows 7, Windows 8
Hardware:	32BIT / 64BIT INTEL or AMD Processor
Memory RAM:	2GB
Memory Hard Disk:	1GB
Peripheral Interface:	1x RS232 Serial or USB1.0.
Mac OS:	Not Supported
Linux / Unix:	Not Supported

Environmental and Safety

The H5000 Hall Effect Controller is built on and intended to replace the proven H50 Hall Effect Controller previously offered by MMR Technologies. Please observe the following safety warnings. Do not open the enclosure, do not operate on any voltage other than specified, do not attempt to service or modify the equipment, do not operate in wet/damp locations. Warning, electrical shock, injury or death may occur if the device is opened or the earth modified. Use only the cables supplied with the device and ensure a proper Ground is present. The H5000 should only be used as intended and should not be used for any other purpose. Any non-intended use could cause fire, loss of life, loss of equipment, and bodily harm. User assumes all risk should the equipment be misused, modified, or use in an unintended manner. Contact MMR for service requirements.

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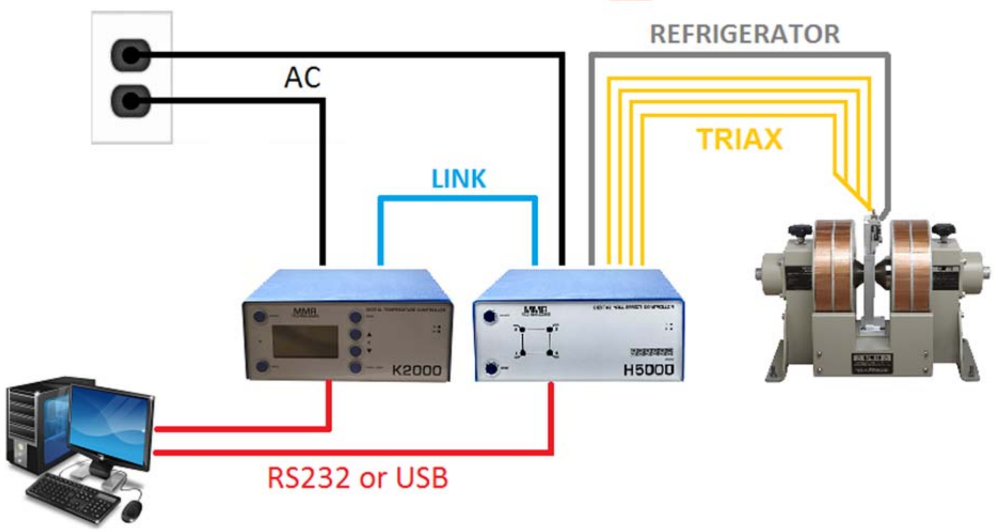
Installation

Before proceeding please ensure the MMR Technologies Software Suite is installed and the following items are present:

- 1x H5000 Hall Effect Controller
- 1x K2000 Temperature Controller *(If Temperature control is required)*
- 1x AC Power Cable
- 1x RS232 DB9 Serial Cable
- 1x USB 3FT Cable
- 1x User Manual and Software / Driver Installation CD
- 1x 4FT Refrigerator Ribbon Cable
- 1x BNC Probe5 Magnet Control Cable
- 4x Triax Cables
- 1x H5000 - K2000 Link Cable

Please connect the H5000 as shown below. Do not connect both the RS232 Serial cable and USB cable simultaneously, these are provided as an option should ports be unavailable.



Once connected and with the PC running you may now power up the H5000 device. Please first ensure the AC Power switch at the rear of the unit is 'ON' *(see page 6 for further information).* Press the front button labeled 'Power' to activate the unit. If the USB cable was used Windows will automatically assign a Comm port. This must be identified and if necessary changed to be in the range of 1-16. *(See page 5 or contact your system administrator)* Please note down the assigned Comm Port Number as this will be required to communicate with the device.

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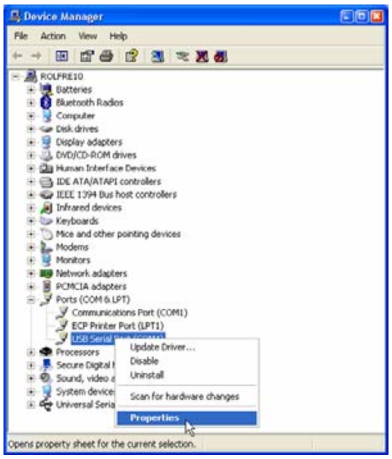
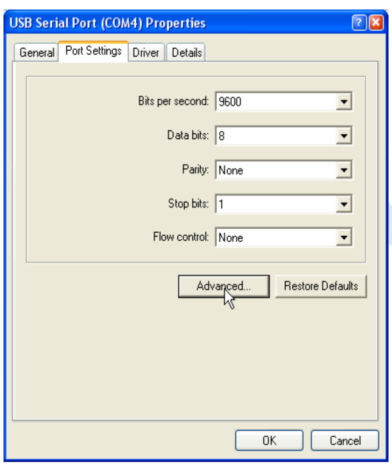
Changing Port Numbers in Windows

(Note: Administrator access maybe needed, contact your IT department)



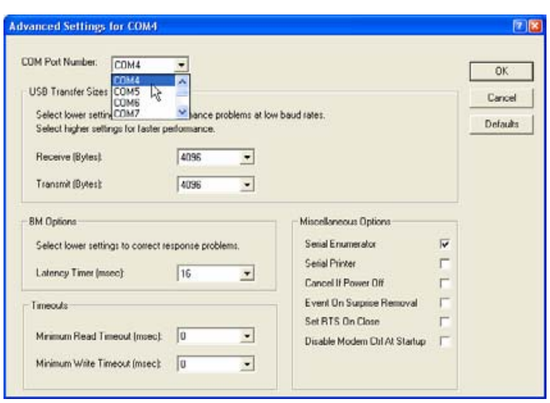
1/. Open Device Manager.
(Control Panel -> Device Manager)

2/. Select the corresponding Serial Converter Device.
(Right Click -> Left Click Properties)



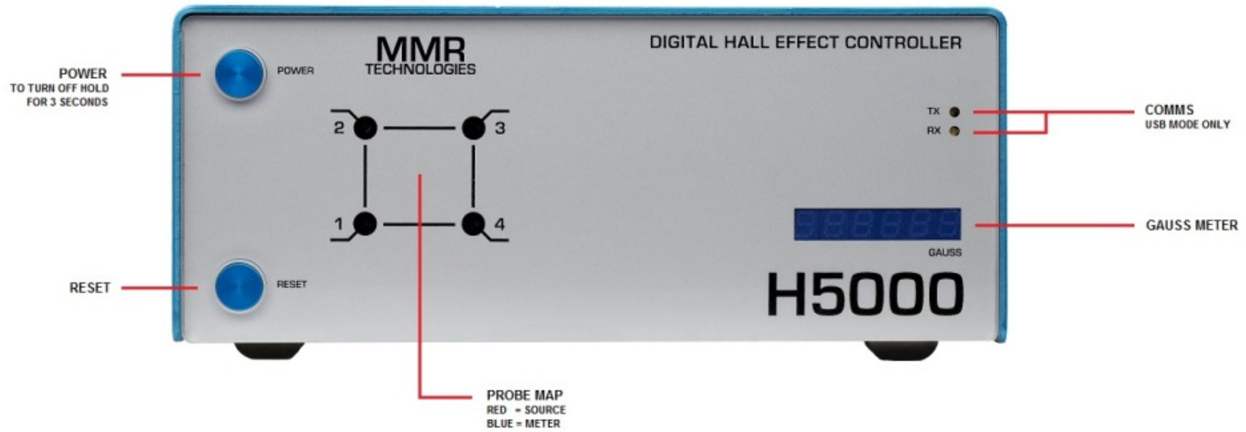
3/. Click on the 'Port Settings' Tab.

4/. Click Advanced.

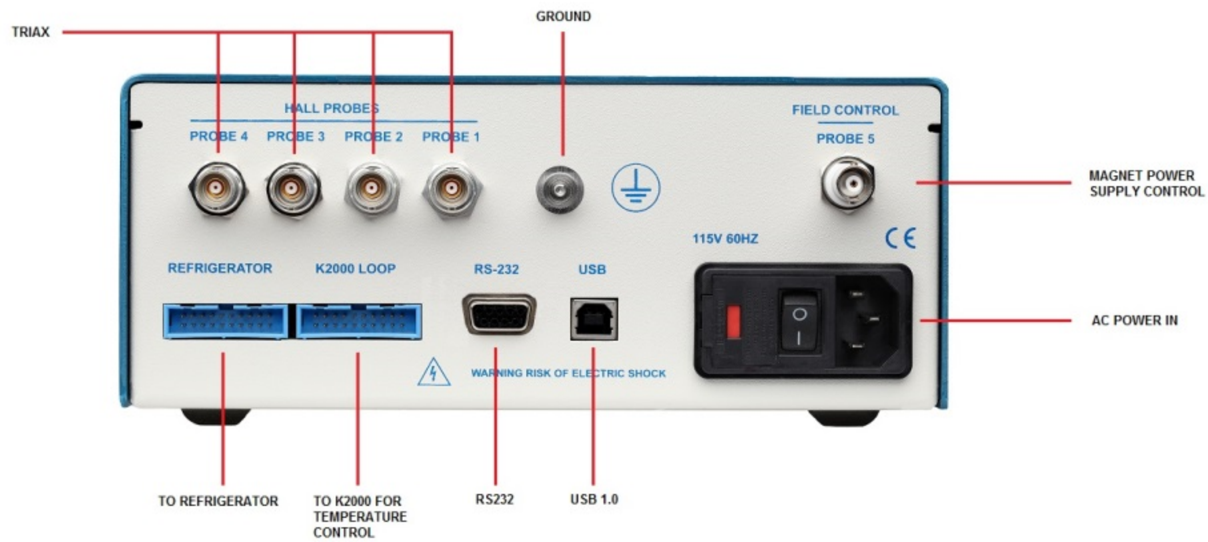


5/. Select a Comm Port between 1 - 16 that is not in-use by other hardware then click OK. *(Note: On some computers you may need to disconnect (unplug) and reconnect the device to make the changes permanent.)*

Front / Rear Panel Interface



NOTE: TO POWER DOWN THE UNIT, PRESS AND HOLD THE POWER BUTTON FOR 3 SECONDS.



*Replace fuse with 3.15A Slow Blow (IEC 127-2 or similar) ONLY.

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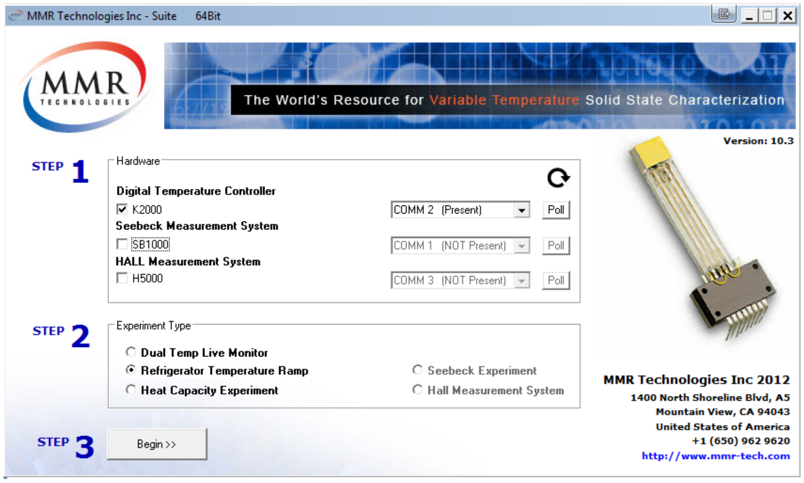
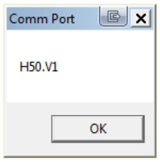
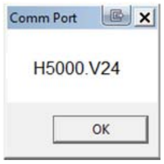
Getting Started



Step 1 - Device ports are easily verified through the welcome screen above, select the port number the H50/H5000 Hall Effect Controller is connected to *(shown as present next to the H5000)* and press 'Poll'. If the H50/H5000 is connected to that port and powered on it will respond with a device name and version number.





If the port number is not visible try refreshing the port list by clicking the refresh icon above the 'Poll' buttons. If this does not resolve the issue try restarting the computer. For further assistance contact your system administrator and finally the MMR Helpdesk (See contact information on Page 27)

Refreshes the available port list and starts Device Auto Detect.

Step 2 - Select 'Hall Measurement System' this will load the Hall experiment module, if there is no K2000 present deselect 'K2000' under hardware. This will disable temperature control for all experiments. Errors will occur if the K2000 remains selected when not present.

Step3 - Press 'Begin

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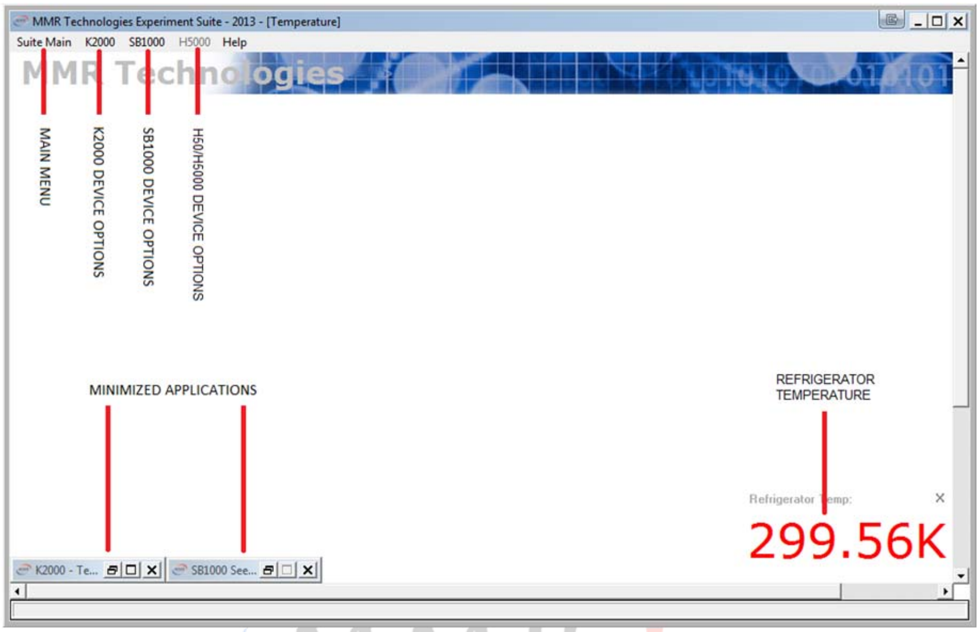
Main Interface

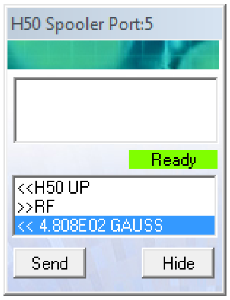


The main interface of the MMR Technologies Suite is shown above; this is the primary container for all MMR applications. The Applicable items for the H50/H5000 Hall Effect Controller are show above.

H50/H5000 Spooler

[Main Suite -> H50/H5000 - > Show Spooler]

This window shows the communications queue and response from the associated device, in this case the H5000 Hall Effect Controller. Troubleshooting is the primary use for this window. However clicking "Send" is a short cut to the' Main Communications Console' outlined in the Software Installation Guide.



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Theory of Operation

MMR Technologies has designed the H5000 to allow the user to make completely automatic measurements of the resistivity and Hall coefficient of thin uniform conductive samples of arbitrary shape, over a wide range of temperatures. The system uses the Van der Pauw method to measure the resistivity and the Hall coefficient. Four probes are attached to the sample and current can be forced to flow between any two while the potential between the other two is sensed.

The sample is mounted in an evacuated enclosure on a cold stage which can be cooled from ambient temperature to as low as 70K by a MMR Technologies' micro miniature refrigerator. A PT100 RTD temperature sensor and resistance heater, incorporated in the cold stage of the refrigerator, allows the temperature of the sample to be set at any value in a range as wide as 70K to 730K, depending on the model. This temperature control is provided by connecting the refrigerator and Hall Dewar system to the MMR K2000 Digital Temperature Controller.

To add to the versatility of the H50/H5000 and to MMR's refrigeration systems, several features have been incorporated into the H50/H5000. These allow it to control and sense the magnetic field or to be used for thermo power measurements.

A ± 2.0V programmable voltage is available at Probe 5 on the rear panel to control a magnet power supply. The software sets and adjusts this voltage automatically to produce a field for Hall and Magnetoresistivity experiments.

A Hall probe located in the base of the Hall vacuum chamber is present to sense the magnetic field immediately below the sample. The H50/H5000 provides the current source for the probe and A-to-D conversion of the sensor voltage. This gives the user a direct measurement of the field at the cold stage.

AUTO CURRENT

An Auto Current feature has been added to automatically find the maximum current a sample will take before the resulting potential (V) exceeds the measurement capabilities of the H50/H5000 (approx. ± 2.5V). The Hall and Van der Pauw measurement system sources the current through a pair of probes connected to the sample and measures the voltage across another pair of probes. It is obvious that a larger measurement current produces a larger voltage. In order to get the best signal to noise one should apply the biggest possible current. The Built in Auto Current feature (see current options) varies the voltage to the sample up to a desired level (just below the maximum measurement capabilities of the H50/H5000) and reads back the resulting current. The maximum current measured will be used for future experiments if desired to ensure no over range errors occur during the experiment. This approach however is limited by several factors. First, the maximum voltage value that can be read by the system is ±2.5 Volts, so increasing of the current will at some point bring the measurement channel to overflow. Second, there is a limit to the maximum current or voltage that can be applied to the sample. A request for values of current (voltage) that exceed the maximum may produce an undesirable nonlinear response. Third, for the low-impedance samples the maximum output current is usually limited by the system current source.

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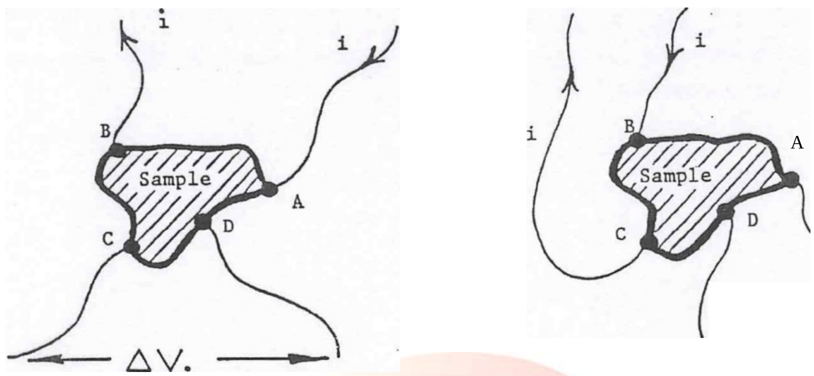
RESISTIVITY MEASUREMENTS

The H50/H5000 uses the Van der Pauw method to determine the resistivity and Hall coefficient of samples on the cold stage. Consider the sample illustrated in Figure 1.

Current enters the sample at A and leaves at B and the potential between D and C is measured.



A B

Figure 1. Current and voltage connections for determining resistivity:

(a) Connection for R_A defined in text; (b) connections for R_B.

We define the resistance R_A as $\frac{V_D - V_C}{i}$. In (b), the leads are rearranged so current enters the sample at B and leaves at C and the potential between A and D is measured.

We define the resistance R_B in this case as $\frac{V_A - V_D}{i}$.

Van der Pauw showed, by the use of conformal mapping, that for flat conductive samples of arbitrary shape the resistivity ρ of the material is determined by the expression:

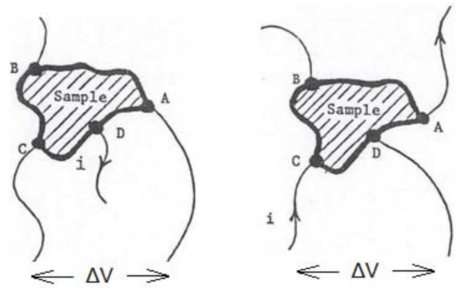
$$\exp(+\pi R_A\, d/\rho) + \exp(-\pi R_B\, d/\rho) = 1 \quad \textit{Note: } R = V/I$$

Where *d* is the sample thickness, provided that:

(a) The contacts are on the circumference of the sample;
(b) The contacts are sufficiently small;
(c) The sample is homogeneous in thickness;
(d) The sample does not have isolated holes.

HALL MEASUREMENTS

The Hall coefficient may be measured by the Van der Pauw method.See Figure 2.



A B

Figure 2. Current and voltage connections for determining Hall mobility:
(a) Connections for R_C, defined in text; (b) connections for RD .

In case (a) the current enters at B and leaves at D and the voltage between C and A is measured. The resistance Rc is defined as (V_C-V_A) *I i* . In case (b) current enters at C, leaves at A and the voltage between D and B is measured. We define R_D as (V_D-V_B) *I i.* These measurements are repeated in a known magnetic field applied perpendicular to the plane of the sample. The Hall mobility is then given by:

$$\mu = \frac{(\Delta RC + \Delta RD)}{2} \cdot \frac{d}{\rho B}$$

Where ΔR_C and ΔR_D are the changes in R_C and R_D respectively, with applied field B.

PRECAUTIONS

Spurious results can be obtained through the interfering effects of several factors.
These include:

(a) Photoconductive and photovoltaic effects. Measurements should be done in a dark chamber.
(b) Non-ohmic contacts on the sample. Check linearity of resistances with current.
(c) Heating effects. Use minimum current and check for changes of properties with time after application of current.
(d) Surface leakage on sample and leakage path between conductors. Clean sample and keep leads free of moisture.
(e) Thermal EMF's. Measurable voltages p without current applied.
(f) Magnetic field not oriented perpendicular to the surface of the specimen.
(g) Specimen is not homogeneous, is not of uniform thickness, has voids in it, or is anisotropic.
(h) Contacts are large and not located on circumference of sample.

These various factors can be minimized by utilizing the flexible connection arrangements made possible by the H50/H5000, by making a rapid series of measurements at various current settings and by averaging over many measurements.

References: Van Der Pauw, L.J. (1958). "A method of measuring specific resistivity and Hall effect of discs of arbitrary shape"

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MAGNETORESISTIVITY MEASUREMENTS

Magnetoresistivity allows the study of a sample's resistivity as a function of magnetic field. Two types of measurement capability are available: "Magnetoresistivity 1" and "Magnetoresistivity 2". Both provide automatic four probe measurements of the resistivity (similar to a Van der Pauw measurement) in the presence of a magnetic field. "Magnetoresistivity 1" allows measurement of the resistivity as a function of field, or as a function of either current or temperature in the presence of a fixed magnetic field. "Magnetoresistivity 2" allows measurement of the resistivity versus temperature or current, but readings are taken for two values of magnetic field at each setting of current or temperature. This experiment generates two measurement curves on the same domain, with magnetic field as the measurement parameter. Based on the measurements, the program can calculate other functions characterizing the field dependence of the resistivity at a given temperature or current.

With "Magnetoresistivity 2" the magnetic field is a fixed experimental parameter and not an experimental variable. Field #1 and Field #2 are the fixed parameters and need to be set accordingly.
The system will do the measurements first with Field #1 and then with Field #2. This procedure can be explained by the following example:

Consider the system is to collect data for the temperature range 300K to 500K with steps of 50K,
Field #1 = 1000G, Field #2 = 5000G, and "Number of Repetitions"= 3.

e.g. At 300K the program will set the field to the value of 1000G (Field#1). The system will take 3 ('number of repetitions') resistivity measurements. After this the program will set the field to the value of 5000G (Field#2) and take another 3 resistivity measurements. Then the program will average results for each set of measurements and calculate the Magnetoresistivity Coefficient and Relative Resistivity Deviation at 300K. After this, the system will set the next temperature value (350K) and will repeat the cycle for all temperature settings. One should notice that the actual number of measurements at each variable value is twice the 'Number of repetitions' setting.

The graph of the experimental results will contain two curves: one for Field #1 and the other for Field #2. These curves will differ by the color and shape of the curve symbols.

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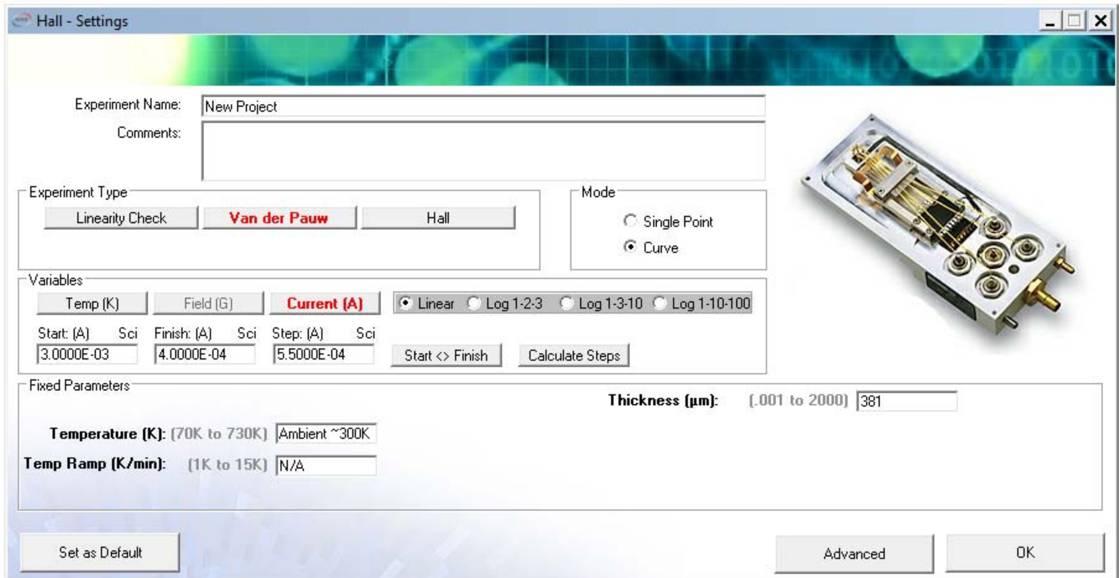
Settings and Experiment Setup



All H50/H5000 related experiments are configured through the above window. Note: Only options applicable to the current experiment are visible. For instance a Fixed Temperature variable will not be available when the user has selected Variable Temperature. Quick Definitions to the above window are listed below:

EXPERIMENT TYPES

Linearity Check: The Linearity Check is useful for ensuring good ohmic contact between the probes and the sample being studied. It is recommended that this check be done after each sample mounting. An IV curve is included in the results along with the individual resistance values between probes. Temperature or Field Setting is not needed and therefore disabled in this mode.

Van der Pauw: The Van der Pauw experiment enables resistivity measurements between probes, the results are graphed and individual resistivity's displayed. Temperature setting is possible if a K2000 Temperature controller is connected. The experiment can be customized with variable Temperature or Current depending on the individual study.

Hall: The Hall Effect enables discovery of the Hall Coefficient, Hall Mobility, Sheet Carrier, Density and Carry type by first calculating the Resistivity and then applying a magnetic field. All results are plotted and displayed at the end of the run. The experiment can be customized with variable Temperature, Field or Current depending on the individual study.

Magnetoresistivity: Similar to Van Der Pauw in that resistivity measurements can be made but as a function of field.

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EXPERIMENT MODES

Single Point: A single point takes one reading only at a given fixed setting. The Current, Temperature or Field cannot be varied in this mode. For averaging purposes multiple repetitions can be set under 'Advanced Settings'.

Curve: Multi points can be taken with varying Temperature, Current or Field depending on the experiment. For averaging purposes multiple repetitions can be set under 'Advanced Settings'. For instance if the Variable is Temperature starting at 320K and ending at 340K with a step of 10K, there will be 3 readings. If more than 1 repetition is specified under 'Advanced' the readings will be multiplied.

Example: *Repetitions = 2. Total Readings = 6*

- *Reading #1 = 320K (Variable Point)*
- *Reading #2 = 320K (Point)*
- *Reading #3 = 330K (Variable Point)*
- *Reading #4 = 330K (Point)*
- *Reading #5= 340K (Variable Point)*
- *Reading #6 = 340K (Point)*

VARIABLE STEP MODE

Linear: Variables are incremented by adding or subtracting a step value.
Log 1-2-3: Variables are logarithmically incremented eg. 1-2-3...9-10-20-30...90-100-200 etc
Log 1–3- 10: Variables are logarithmically incremented eg. 1-3-10-30-100-300-etc
Log 1-10-100: Variables are logarithmically incremented by order of magnitude steps.
Note: Logarithmic steps are only available in 'Variable Current' mode.

VARIABLES

Variable Temp: The Temperature is varied each reading specified by the Start, Finish and Step parameters, this is only available in Van der Pauw or Hall modes, if Curve is selected and if a K2000 Temperature Controller is connected and configured in the Startup Screen.

Variable Current: The Current is varied each reading specified by the Start, Finish and Step parameters, this is available in all modes, if Curve is selected and if a K2000 Temperature Controller is connected and configured in the Startup Screen. The Start/Stop/Step values can be entered as either decimal or scientific format, converting between formats is possible by clicking the 'Sci' or 'Dec' label above the value.

Variable Field: The Field is varied each reading specified by the Start, Finish and Step parameters, this is only available in Hall mode, if Curve is selected and if a Magnet and power supply are connected to Probe 5 of the H50/H5000. When using manual permanent magnets it isn't recommended to use Variable Field. *(See 'Field Accuracy')*

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VARIABLE VALUES

Variable Start: Enter the initial or starting value setting. Note in Variable current mode the values can be entered as either decimal or scientific format, converting between formats is possible by clicking the 'Sci' or 'Dec' label above the value.

Variable Finish: Enter the final value setting. Note in Variable current mode the values can be entered as either decimal or scientific format, converting between formats is possible by clicking the 'Sci' or 'Dec' label above the value.

Step: Available in Linear Step Mode only. Click Calculate Steps to get the number of total resulting readings.

Start <> Finish: Swaps the Start and Finish values to invert the slope of the variable curve.

Calculate Steps: Useful for calculating the number of readings based on the total steps between start and finish multiplied by the total number of repetitions set under 'Advanced'

FIXED PARAMETERS

Options: Only available when a Fixed Current is being used. This opens a program that determines the maximum current the experiment can apply to the sample within the readable range of the H50/H5000 AD Converter. There are three current setting options associated with this:

- **Fixed Setting:** The maximum current is determined once and used in the Hall Settings, Click 'Use Value' after the process completes.
- **Auto Setting Every Measurement:** The maximum current is re measured and set at each new Variable Point.
- **Auto Setting Every Point:** The maximum current is re measured and set at every point. *(Note: Experiment Run time will increase)*

Advanced: For setting the following Experiment Parameters.

- **Number of Repetitions:** Setting for repeating each Variable Point.
- **Soak Time:** A delay that runs each time the Variable (Temperature, Field or Current) changes.
- **Reading Delay:** A delay between applying current to the probes and reading back the voltage.
- **Standby Temp:** Specify if the system should return the sample to a given temperature at the end of the experiment. (Note: Only if a K2000 Temperature Controller is present).

Fixed Current: When varying the temperature or field a fixed current must be specified in scientific format. The range is 1.0E-03 – 1.0E-12

Fixed Temperature: When varying the current or field and Temperature control is present a desired fixed temperature should be entered.

Temp Ramp (K/Min): The suggested Temperature Ramp rate is 15K/Min for all MMR refrigerators. This can be lowered if required.

Thickness: For Van der Pauw and Hall Experiments a sample thickness value in µm is necessary to calculate resistivity.

Field: When varying the Temperature or Current a fixed field value is required. Note: If an error is generated see 'Max Field Value' under Field Settings.

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Field Ramp Const: This is the Field Setting field feedback loop multiplier. The default value is 100 and shouldn't be changed unless the user desires to make very small field changes.

Sensitivity V/kG: This coefficient should match the calibration value of the Gauss sensor in the Hall Chamber. If it does not the Gauss readings taken from the H50/H5000 will be inaccurate. This value is uploaded to the controller at the beginning of each experiment. For the H5000 if now gauss reading is shown on the front panel the sensitivity constant needs to be set. See commands page XX for more information or rerun the experiment with the correct setting.

FIELD CONTROL MODE

H50/H5000: Automatic Field setting mode, this controls the field and polarity by a magnet power supply connected to Probe5.

Manual: Manual Field Setting mode, the user will be responsible to set the field and polarity at each measurement point. If the measured field is outside of the experiment range then an error will be produced.

Field Settings: In order to control the external power supply a maximum field value which corresponds to the maximum control voltage (2.0V) of the H50/H5000 probe 5 must be specified, the time delay needed to set Magnet current and field setting accuracy. The **maximum field value** is needed for the software to calculate the first control voltage setting to provide the required Field value. After the system has measured the actual field the control voltage will be adjusted. This feedback loop will function until the required field value has been obtained. It takes time to change the current through the inductive load, so a time delay between the action which forces the current and the measurement of the field value is necessary. The system decides that the required field value has been reached when the difference between the actual and target values of the field is within the specified accuracy**.** You can set the Field Control Setup parameters using the same technique as for the Fixed Parameters.

Note: There is one limitation to the system field control which is true for all of the field control options. The field measurements are taken by a Hall Sensor inside the sample chamber. The Maximum voltage which can be read at this input is 50 mV. So, the maximum field value, which can be measured (and therefore controlled) by the system, can be defined as 50 mV divided by the Hall sensor sensitivity. For example, if the sensitivity is 10mV/kG, then the maximum field which is readable is 5kG. If you have specified a field value which exceeds the maximum an error message will occur. If larger fields are required, Hall sensor with lower sensitivity will be needed.

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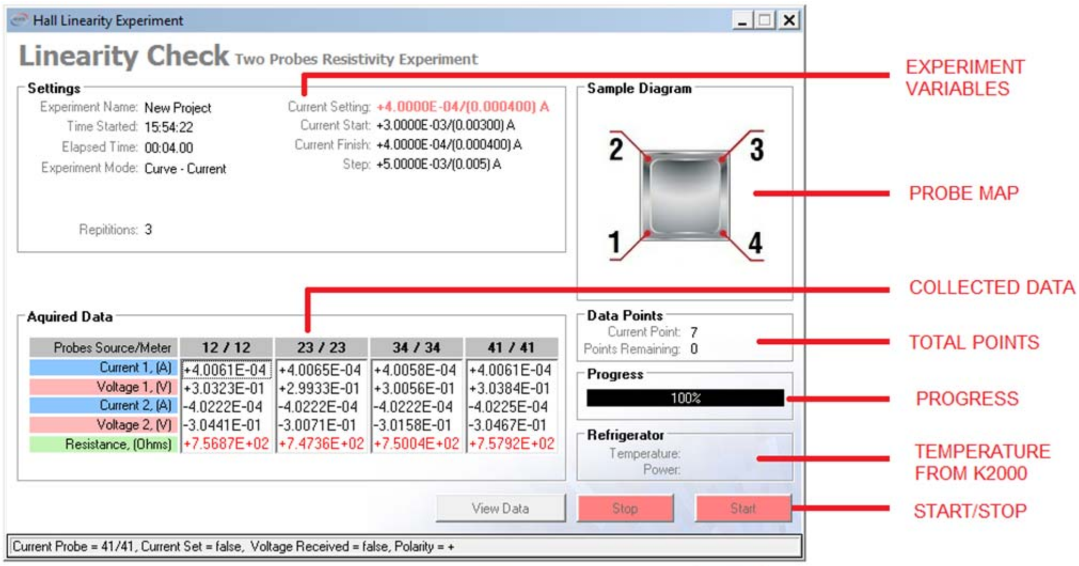
LINEARITY



LINEARITY RESULTS

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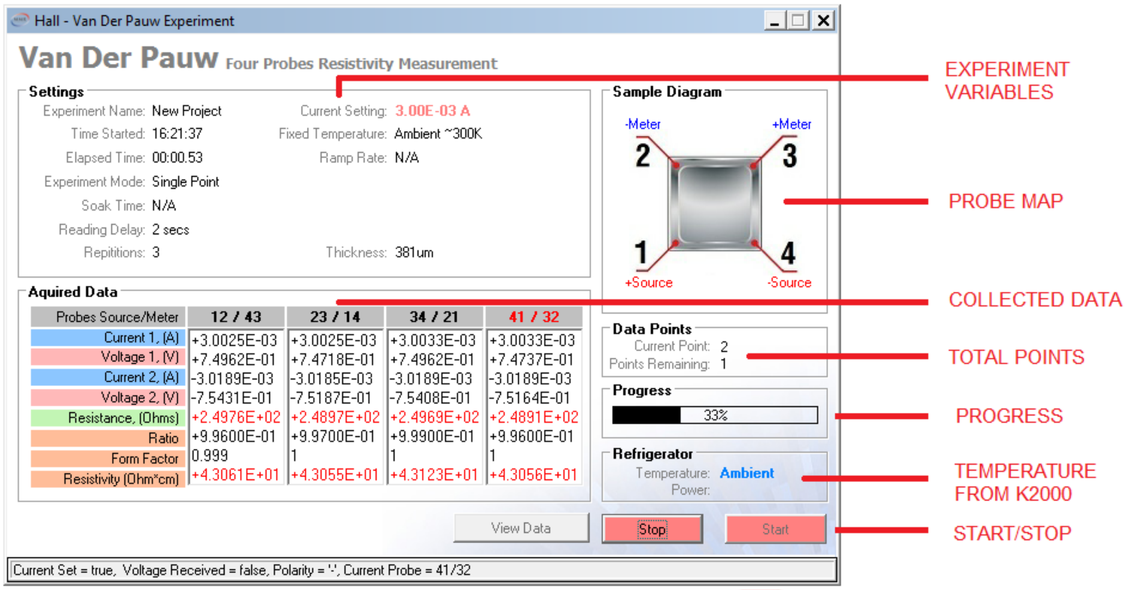
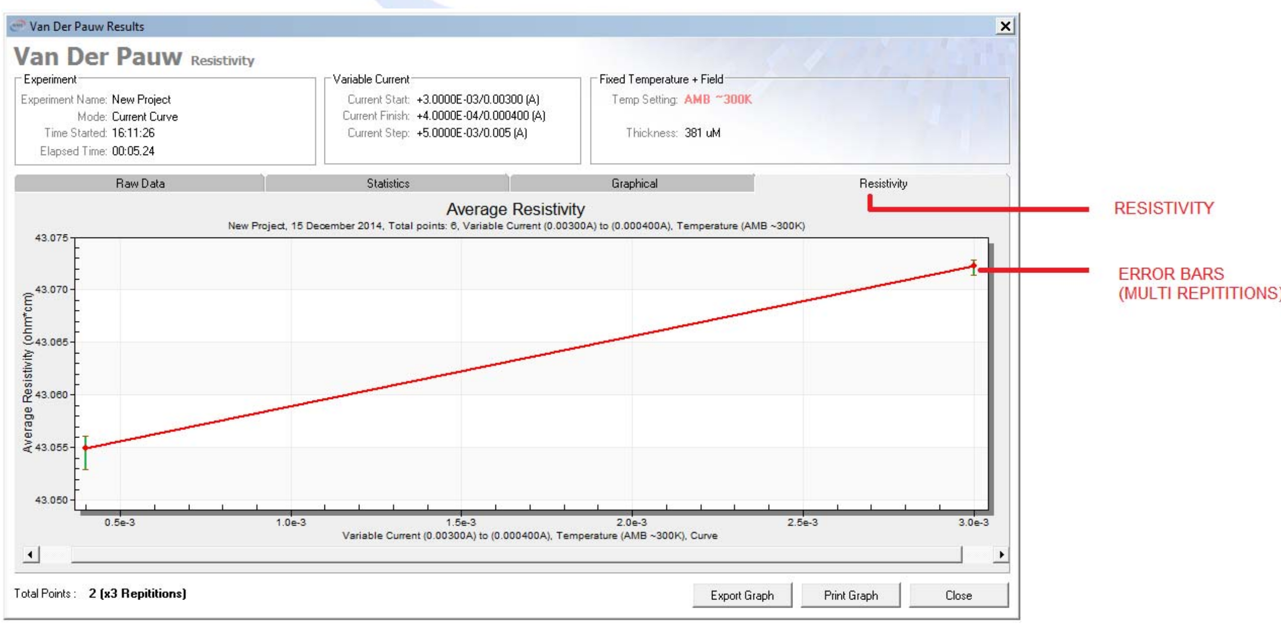
VAN DER PAUW



VAN DER PAUW RESULTS



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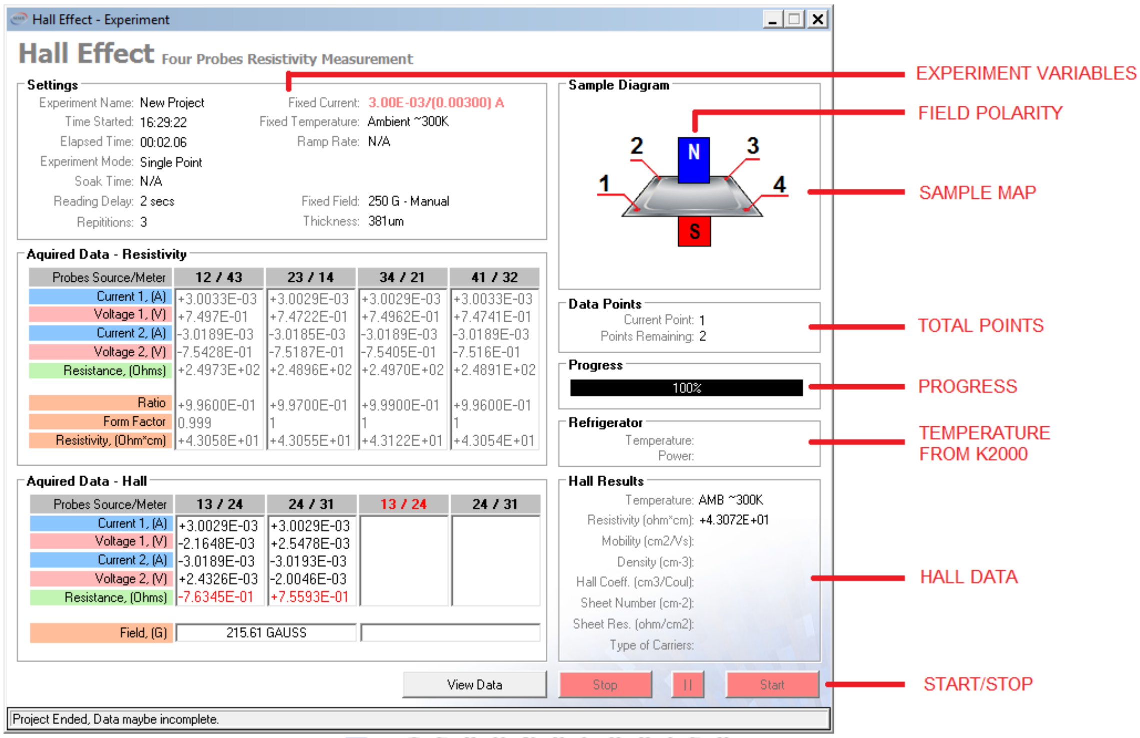
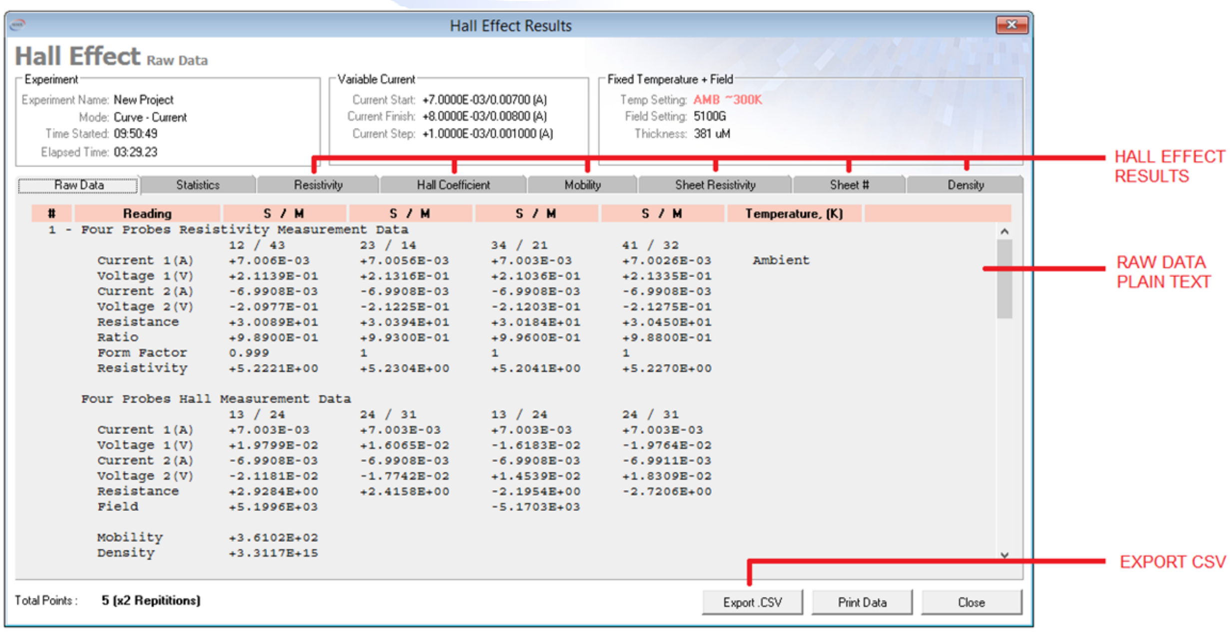
HALL EFFECT



HALL EFFECT RESULTS



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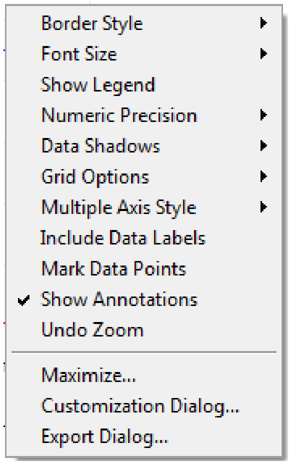
GRAPH - ZOOMING

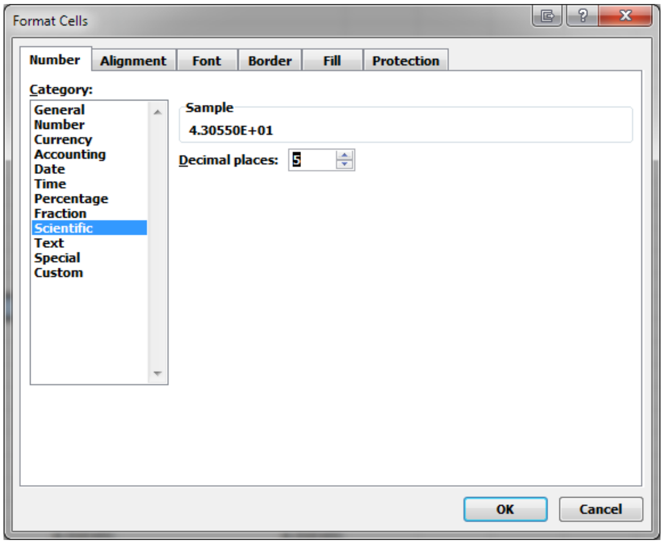


Zooming In – Left click and drag a box over the area of interest. On release of the mouse the graph will be enlarged. Note: When printing only the current view will be printed.

Zooming Out – Right click the graph and select 'Undo Zoom'

EXPORTING DATA

Exporting data is done via CSV (Comma Separated Values) and can be easily opened in EXCEL or similar.
Please note that EXCEL sometimes reduces the decimal places shown. In order to maintain resolution change the decimal place value to at least 5 in the Format section of EXCEL, *see below*.



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Command List

Communications between the H50/H5000 are made via Plain Text serial. There are slight differences between the H50 and H5000 communications protocols outlined below.

	H50	H5000
Communication Ports:	IEEE GPIB, RS232	USB, RS232
Baud Rate:	4800bps	9600bps
Handshaking:	None	RTS/CTS
Serial Data Type:	Plain Text	Plain Text

COMMAND	ACTION	FORMAT H50	FORMAT H5000
DE	Set Defaults	"DE"	"DE"
RF	Read Field	"RF"	"RF"
SC?	Read Gauss Sensor Constant	"SC?"	"SC?"
SC	Set Gauss Sensor Constant	"SC0.0025"	"SC=0.0025"
RI	Read Current	"RI"	"RI"
FI	Force Current to probes *(SCI FORMAT)*	"FI34=3.00E-04"	"FI34=3.00E-04"
RV	Read Voltage across probes	"RV12"	"RV12"
FV	Force Voltage to probes *(DEC FORMAT)*	"FV14=1.82"	"FV14=1.82"

Measurement Accuracy

Output:	Triax output leads for 4 probe measurements. (All probes are equivalent, each programmable for current injection or voltage sensing.)
Accuracy:	Measurement accuracy ±2% mid-range, ± 5% end-range.
Resolution:	15 ppm.
Resistance Range:	10^{2} to 10^{10} Ohms.
Field Measurement:	Integrated Gauss meter included in chamber.
Interface:	USB and RS-232C for computer control, recommended for use with MMR Technologies Software Suite only.
Voltage Range:	±2.5VDC
Current Range:	$\pm 1.0E^{-3} - 1.0E^{-12}$ A
Probe5 Range:	±2.0VDC
Digital Resolution:	16 Bit with PGA

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Help Desk and MMR Contact Information

Help Desk Email Address:	support@mmr-tech.com
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Help Desk:	+1 650 962 9620
Office Hours:	7:30am - 5:00pm (Pacific Time) Monday - Friday
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Declaration of Conformity

CE

Manufacturer: **MMR Technologies**
Model Name: **H5000**
Date: **July 2014**
Expires: **July 2018**

UL / IEC 61010

Application of Council Directives:

Low Voltage Directive (LVD) 2006/95/EC
Standards to which Conformity is Declared: IEC EN 61010-1 3rd Edition
Electrical equipment for measurement, control, and laboratory use
Pressure Equipment Directive (97/23/EC)
Conformity is declared to Annex I Essential Requirements of the Directive

Application of Council Directives:

Electromagnetic Compatibility Directive (EMC) 2004/108/EC
Conformity is declared to Annex I and II (EMC) 2004/108/EC

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