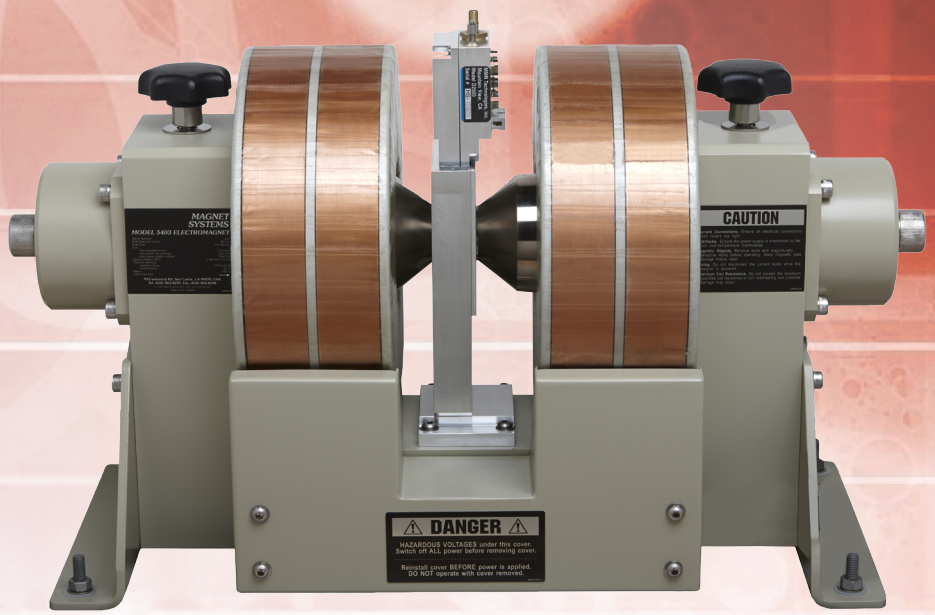
# Hall Measurement Systems




THE WORLDS RESOURCE FOR

VARIABLE TEMPERATURE

SOLID STATE CHARACTERIZATION

# THE VARIABLE TEMPERATURE HALL EFFECT MEASUREMENT SYSTEMS

The variable temperature Hall Effect Measurement System is designed to provide totally automatic measurements of the electrical properties of semiconductor and high temperature semiconductor materials using the van der Pauw measurement technique.

## A TYPICAL VARIABLE TEMPERATURE HALL EFFECT MEASUREMENT SYSTEM

A typical variable temperature Hall Effect Measurement system includes:

- High-purity high-pressure gas (typically nitrogen or argon)
- A filter/dryer apparatus (cooling stages only) with high-pressure gas lines
- Thermal stage for heating and/or cooling
- MMR's Programmable Temperature Controller and Hall Effect Measurement Controller
- Vacuum Chamber Equipped with Triax Cables for Data Acquisition
- Magnet setup (may be a permanent magnet or an electromagnet and the required power supplies for operation)
- Vacuum Pump Setup
- Spring Loaded Probes or a Kapton Harness for taking 4-point van der Pauw Measurements
- Computer

The Hall Effect and Seebeck Effect Measurement systems have many common components. It is possible to add on a Seebeck Measurement Option to any Hall Measurement System to broaden the experimental information available from samples of interest.

## AVAILABLE TEMPERATURE RANGES ON THERMAL STAGES

When the vacuum chamber system is held under a vacuum pressure of at least 8 milliTorr, the following temperature ranges are available on the MMR Technologies instruments:

- Room Temperature
- 70K to 580K*
- 80K to 580K
- 70K to 730K*
- 80K to 730K
- Room temperature to 730K*


* Vacuum assist Joule-Thomson thermal stages require an auxiliary vacuum pump at the thermal stage gas exhaust. These thermal stages are not available on ultra high vacuum or scanning electron microscope systems. Hot stages do not require a filter/dryer setup or high pressure Nitrogen.

When a thermal stage is used within an ambient pressure setup and a well controlled atmosphere, the following temperature ranges are available using the appropriate thermal stage setup:

- -10 °C to 200 °C (using Nitrogen gas) or -30 °C to 200 °C (using Argon gas)
- -10 °C to 350 °C (using Nitrogen gas) or -30 °C to 350 °C (using Argon gas)
- Room temperature to 350 °C

## MMR TECHNOLOGIES UNIQUE TEMPERATURE CONTROLLER

MMR Technologies offers a unique Programmable Temperature Controller that is exclusively intended for use with our patented cryogenic cooling and thermal stage systems. This controller provides accurate temperature measurement, precise and very stable temperature control and easy-to-use data acquisition functions over the temperature range from 70K to 730K. Controlled cycling, temperature ramping and changing temperature operation under software control gives the user a valuable tool for solid state characterization studies.




## HALL AND VAN DER PAUW MEASUREMENT CONTROLLER

MMR Technologies offer a turnkey solution with their Programmable Temperature Controller and their Hall Measurement Controller. The two controllers work together, operated by the Hall Measurement software to provide an integrated temperature control both of the overall sample area and the small required temperature gradient.


## THE VACUUM CHAMBER AND CONNECTIONS FOR FOUR-POINT MEASUREMENTS

The Hall System Dewar or vacuum chamber has been designed to facilitate rapid and simple measurements of resistivities, carrier densities, and mobilities of semiconductor materials over a range of temperatures. The sample is mounted in an evacuated dewar or vacuum chamber on a thermal stage which is cooled by a microminiature Joule-Thomson thermal stage and heated by a computer controlled heater. When used with MMR Technologies' programmable temperature controller, the thermal stage will provide controlled cycling and temperature measurements over the range of 70K to 730K.

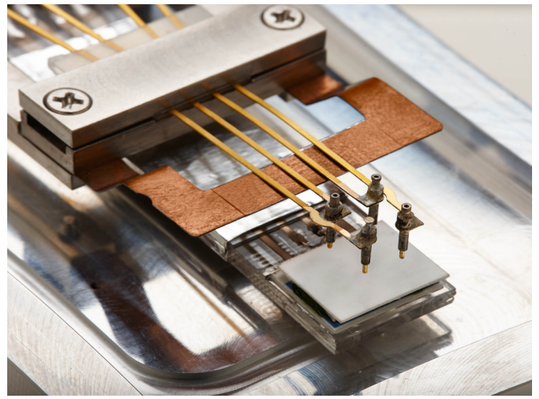
There are two ways of making connections with the sample surface:

- Spring Loaded Probes (image to the left)
- Wire Bonding to a Kapton Harness (image on the next page)

The spring loaded probe assemblies provide the electrical access to the sample under study without the use of wire bonding or soldered connections. This is particularly useful when the sample is to be studied at temperatures that are above the melting point of many common solders. The spring loaded probe assemblies additionally enable faster sample exchange.

The Kapton harness method of making electrical contacts using wire bond or solder is advantageous when the sample surface is sensitive to scratching, or when very low resistivities and electrical contact through touch (like with the spring loaded probes) are challenging to obtain. Use of the Kapton harness is also particularly useful when non-square geometry is desired in the sample measurements.

The Hall vacuum chamber has a built in Hall sensor, located directly under the sample that is being measured. This enables the measurement of the magnetic field experienced by the sample to be measured through the MMR electronics, and to be taken into account during calculations. This also allows the Hall Measurement Controller, when coupled with an electromagnet, to control both the magnetic field strength and direction automatically during experiments.

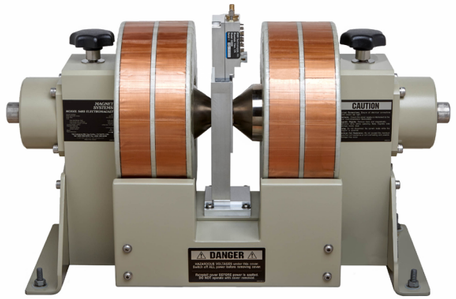


## MAGNETS AND ELECTROMAGNETS

There are three magnet systems offered by MMR Technologies. All three models will work as a part of a turnkey solution with the MMR Technologies Hall controller and software. These magnets provide both low field and high field options, and offer solutions for a range of budget needs and sample measurement needs. To increase the mobility of carriers within a sample, moving to a stronger magnetic field can increase successful measurements and reproducibility, while reducing noise.

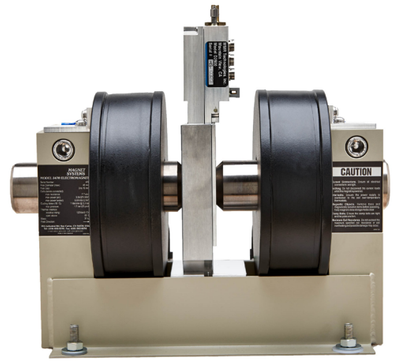
### 5000 Gauss (0.5 Tesla) Permanent Magnet

The M25 Permanent Magnet is a low cost, low field magnet system. This compact bench top magnet provides a 5000 Gauss field between flat 2.5 inch by 1.66 inch pole pieces with a 0.78 inch gap. The Hall vacuum chamber slides into the pole gap of the magnet, and a measurement can be taken in one field direction. The MMR Technologies Hall Measurement software prompts the user to remove the chamber and to insert it in the opposite direction when a reversed direction field measurement is required.




### 5000 Gauss (0.5 Tesla) Electromagnet and Power Supplies

The MK50 Electromagnet is our variable low field magnet system. This compact, air or water cooled, bipolar bench top system provides a reversible field of 5000 Gauss with a 20 mm face diameter pole pair and 0.75 inch gap. The size of the gap can be adjusted if necessary to accommodate other chambers or devices.




The MK50 electromagnet is coupled with the MPSK-50 bipolar power supply. This power supply is capable of providing 12 Amps of current at 36 volts (400 Watts). It is continuously controllable over both the current and voltage range windows, and is controlled by the MMR Technologies Hall Measurement software and the Hall Measurement Controller.

With the MPSK-50, field reversal of the electromagnet is automatic and measurements can be done with either sign or at zero field.

This electromagnet is air cooled but has water cooling ports as an option for temperature stability over long experimental setups.

### 14,000 Gauss (1.4 Tesla) C-Frame Electromagnet and Power Suppliers

This high field electromagnet is supplied with a 38 mm face diameter pole pair to provide the highest possible field versus current values. It may be operated with currents up to 40 amps at 20 volts (800 Watts) when coupled with the MPS150 Magnetic Power supplies from MMR Technologies. Higher current operation is possible, but this requires power supplies from alternate vendors.[1] For high current operation, or lengthy experiments, the M150 electromagnet must be operated with a recirculating chiller.

The MPS-150 power supplies are high powered operational amplifiers with full 4-quadrant, bipolar operation. The voltage and current outputs can be made to vary smoothly and linearly through the entire plus and minus ranges, passing smoothly through zero with no polarity switching.

The MPS-150 power supplies enable easy software controlled field reversal, and measurements can be done with either sign or at zero field.

[1] Alternate power supplies may not be compatible to be operated as a turnkey system with the MMR Technologies' Hall Controller and software.



## SPECIFICATIONS FOR THE VARIABLE TEMPERATURE HALL SYSTEM

| | |
|---|---|
| Operating Temperature Range: | Available between 70K and 730K (Joule-Thomson Thermal Stage |
| Dimensions of Vacuum Chamber: | 2.5 in wide x 6.0 in long x 0.75 in high (at sample end) |
| Weight of the Vacuum Chamber: | 16 oz (454 grams) with thermal stage mounted |
| Sample Mounting Surface Size: | 10 mm x 12 mm |
| Standard Window Material: | Fused Silica |
| Maximum Sample Weight Allowed: | No more than 5 grams |
| Working Distance: | 12 mm |
| Dimension Configurations: | Spring Loaded Probe Spacing: 0.1 in, 0.2 in, 0.3 in (2.25 mm, 5 mm, 10.5 mm)<br>Kapton Harness Space: not applicable |
| Electrical Connections: | Triax connectors. |
| Current source range : | $1^{-12}$ to 0.01 Amps |
| Voltage measurement range: | $1^{-6}$ to 2.4 Volts |
| Resistance (or resistivity) range:** | Typical range is $10^{-4}$ Ohm*cm to $10^{13}$ Ohm*cm (dependent on sample thickness) |
| Carrier concentration range:** | Approximate range is $10^{3}$ $cm^{-3}$ to $10^{19}$ $cm^{-3}$ (dependent on sample thickness ) |
| Mobility range:** | Approximate range is 1 $cm^2$/volt*sec to $10^{7}$ $cm^2$/volt*sec<br>(Dependent on magnetic field strength) |
| Sample Thickness: | 0.001-2000 micrometer |
| Temperature Controller Requirements: | MMR's Programmable Temperature Controller |
| Temperature Accuracy: | < 0.5K at 80K; +/- 0.5K between 80K and 400K; < 1.5K from 400K to 730K |
| Temperature Stability: | +/- 0.05K |
| Temperature Resolution: | 0.01 K |

* For more information, please refer to the product data sheets for the Joule-Thomson thermal stages.
** For more information, please refer to the Measurement Range of the MMR Technologies Hall System Application note. Measurement ranges can be increased one to two orders of magnitude by varying the sample geometry (length to width ratio), sample thickness, and magnetic field strength.

## FEATURES AND BENEFITS

The variable temperature Hall and van der Pauw Measurement systems are noted for their unique benefits and features, making these systems easy to use and valuable additions to research facilities:

- Modular - you can build the systems up over time to meet your budget and experimental needs.
- Two Sizes of Systems Available:
  - -Bench-top Configuration: small and compact in size.
  - -Large High Field Magnets: powerful measurement systems with the largest range of samples possible.
- Excellent temperature setting, stability, and reproducibility.
- Absence of mechanical, acoustic, or electrical noise.
- Fast cool down and warm up times, with frost free operation.
- Wide range of operation: 70K to 730K.
- Non-magnetic electrical feedthroughs facilitate electrical connections directly to samples on the thermal stage.
- Low cost of operation: $0.50/hour.
- On the Joule-Thomson stages there are no liquid cryogens to handle.
- Very low power consumption - less than 12 watts on any stage.
- Seebeck Add-On Option Available to expand your measurement capabilities.
- Three Magnet Options Available - Low and High Field Systems.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