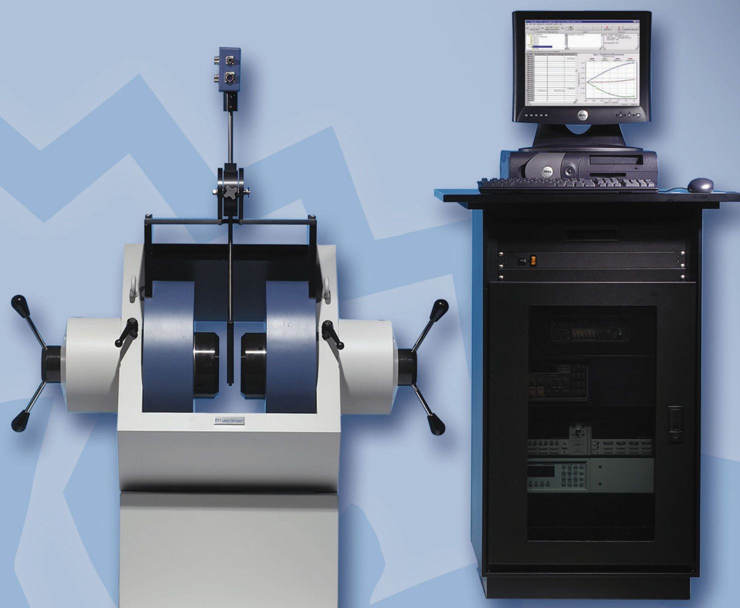
LakeShore

Hall Effect Measurement Systems



Backed and supported by nearly two decades of expertise in materials characterization systems, Lake Shore's fully integrated Hall effect measurement systems (HMS) are used to characterize physical properties in semiconductors, as well as other electronic materials including magnetoresistors, multilayer magnetic films, dilute magnetic semiconductors, superconductors, and spintronics devices. Available in a variety of electromagnet-based configurations ranging in field up to 2 T or a powerful 9 T superconducting magnet-based configuration, Lake Shore HMS are ideally suited for the most demanding materials research applications, product development, and quality control. An assortment of options expands the functionality of Lake Shore HMS.

Modern materials ranging from compound semiconductors to nanomaterials are pushing the limits of transport measurements. Lake Shore combines precision electronics, flexible software, variable magnetic field and temperature, and a wide resistance range into the most advanced HMS. When used in combination with data taken from the variable field Hall measurement, our proprietary Quantitative Mobility Spectrum Analysis (QMSA®) software resolves individual carrier mobilities and densities in multi-carrier devices such as quantum wells and high electron mobility transistors (HEMTs).

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Fully integrated Lake Shore HMS are backed and supported by nearly two decades of expertise in materials characterization systems

Easy Sample Access — for ease of sample exchange, the sample holder module swings forward and out of the magnet

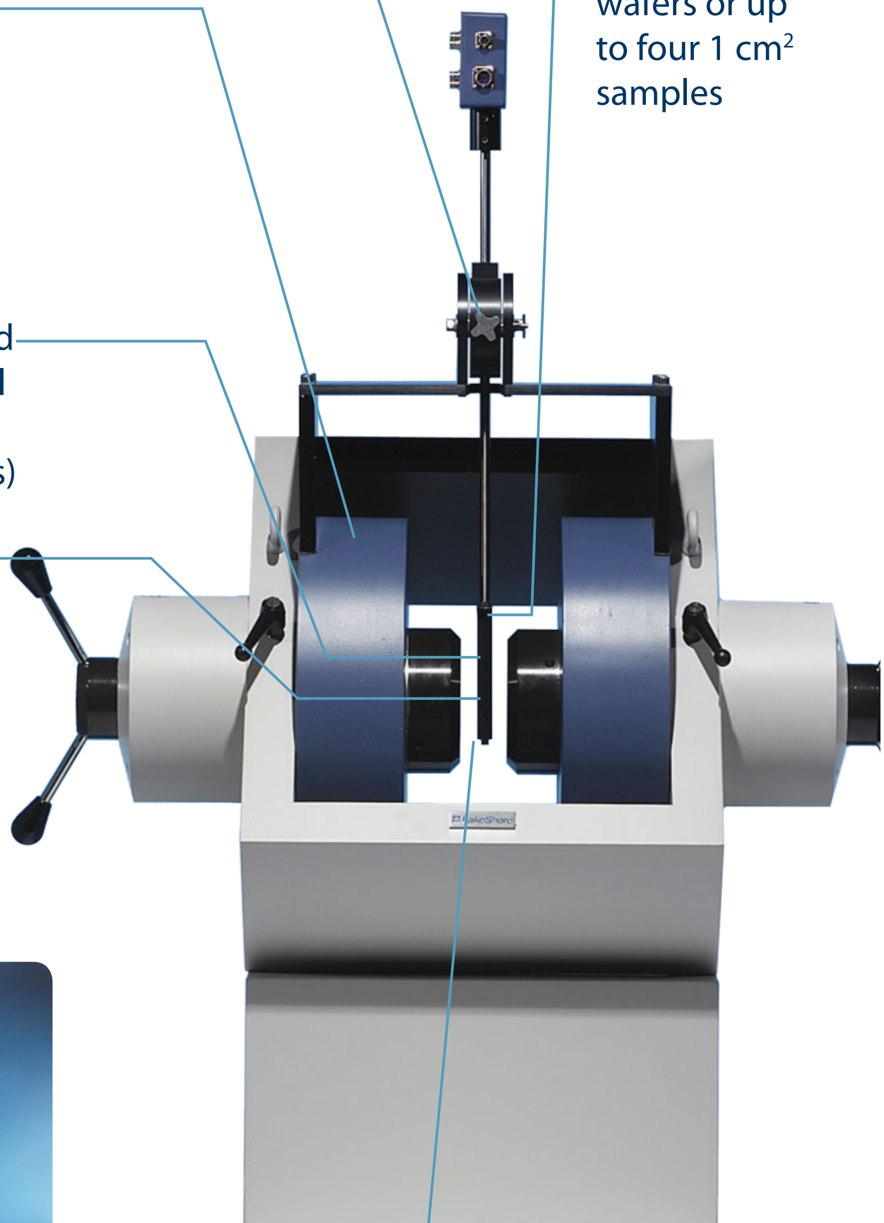
Multiple Magnet Configurations — 4-, 7-, and 10-inch electromagnet-based configurations provide fields to 2 T; fields to 9 T available in our superconducting magnet-based configuration

LN_2 Pour-Fill Bucket Dewar — included with electromagnet-based systems; cool samples to 77 K to reduce the electron scattering by lattice vibrations (phonons)

Variable Temperature — measure samples from 15 K to 800 K with an optional closed cycle refrigerator and high temperature oven

Superconducting Magnet — the 9709A 9 T magnet is ideal for measuring samples with low mobilities

Sample Holders — accommodate up to 6-inch wafers or up to four 1 cm^2 samples



Contact blasting — simplify the tedious process of forming low resistance ohmic contacts

Integrated Software — define samples and create measurement profiles from the Windows® menu-driven interface

Detailed Post Processing — our optional QMSA® software package determines the mobility spectrum for each carrier species in a multi-carrier material

Ergonomic Workstation — in addition to housing all of the integrated electronics, the workstation acts as a convenient tabletop

AC current Hall Effect Option — extend the low-end resistance down to 10 μΩ for materials requiring the measurement of very low voltages

Wide Resistance Range — 10 μΩ to 200 GΩ

Precision components designed to deliver quality measurements

Our knowledgeable technical staff is available to answer your questions

Fields of Study/Research Areas

A Lake Shore HMS is an ideal tool for characterizing the electronic transport properties of materials in a multitude of research areas.

Strained Semiconductors

Strained semiconductors with step-graded buffers have different scattering rates in each of the step buffers. The mobility and density in each layer can be determined using data from the variable field Hall measurements along with our optional QMSA software package.

Organic LEDs (OLEDs), Molecular Electronics, Organic Semiconductors, and Transparent Oxides

The Lake Shore HMS are standard equipped with a voltage-tracking mode that allows for the synchronous measurement of the Hall voltage while the magnetic field changes. Temperature drifts are asynchronous with the field change and appear as a slow drift on the voltage offset.

Solid State

Variable field and temperature magnetotransport measurements provide a tool for the researcher to understand fundamental processes in solid state physics and materials science. Precision Lake Shore HMS provide a means for understanding scattering mechanisms, impurities, strain, band gap energy, and other material parameters.

Semiconductor

By post-processing data with our QMSA software, high electron mobility transistor (HEMT) structures and multi-quantum wells can be characterized with a Lake Shore HMS. The high mobility and density 2-dimensional electron gas (2DEG) carrier in the quantum well channel layer can be clearly distinguished and separated from the doped cap layer carrier.

HTC Superconductivity and Quantum Hall Effect

With variable temperature capabilities from 2 K to 400 K and variable fields to 9 T, the Lake Shore Model 9709A HMS is well suited for studying superconducting materials as well as Quantum Hall effect and other quantum conductance systems.

Anomalous Hall Effect (AHE)

The AHE is a tool for measuring the magnetic properties of low moment materials, ferromagnetic/semiconductor heterostructures (spintronic devices), and dilute magnetic semiconductors. Our AC current options provides a means to conduct AHE measurements.

Metal-Insulator Transitions

Lake Shore variable field HMS can easily and quickly measure the magnetoresistance used to study the weak localization and interaction effect at the metal-insulator transition.

Dilute Magnetic Semiconductors (DMS)

DMS materials can be characterized to determine the spin-dependent scattering in metallic ferromagnetic/nonmagnetic multilayers by examining giant magnetoresistance (GMR) effect. The coercivity of the layers can be compared by examining sheet resistance when the ferromagnetic layers are antiparallel.

Materials

III-V Semiconductors

GaAs based devices:
- HEMTs (High Electron Mobility Transistors)
- pHEMTs (pseudomorphic High Electron Mobility Transistors)
- HBTs (Heterojunction Bipolar Transistors)
- FETs (Field Effect Transistors)
- MESFETs (Metal-Semiconductor Field Effect Transistors)

InP, InAs, GaN, and AlN based devices

Semiconductors

a-Si, Si, Ge, SiC, Si on insulator (SOI) devices, HgCdTd, ZnO

SiGe based devices: HBTs and FETs

Dilute Magnetic Semiconductors

MnGaAs and ZnO

Multi Quantum Well Structures

IR applications (LEDs, laser diodes, and detectors)

Other Conducting Materials

Metal oxide

Organic and inorganic conductors

Magnetoresistors (MR)

MR, Giant-MR, Tunneling-MR, and Colossal-MR devices

High Temperature Superconductors

Ferrites

Direct and Derived Measurements as a Function of Field and Temperature

Hall Voltage

IV Curve

Resistance

Magnetoresistance

Anomalous Hall Effect (AHE)

Hall Coefficient

Carrier Concentration/Density

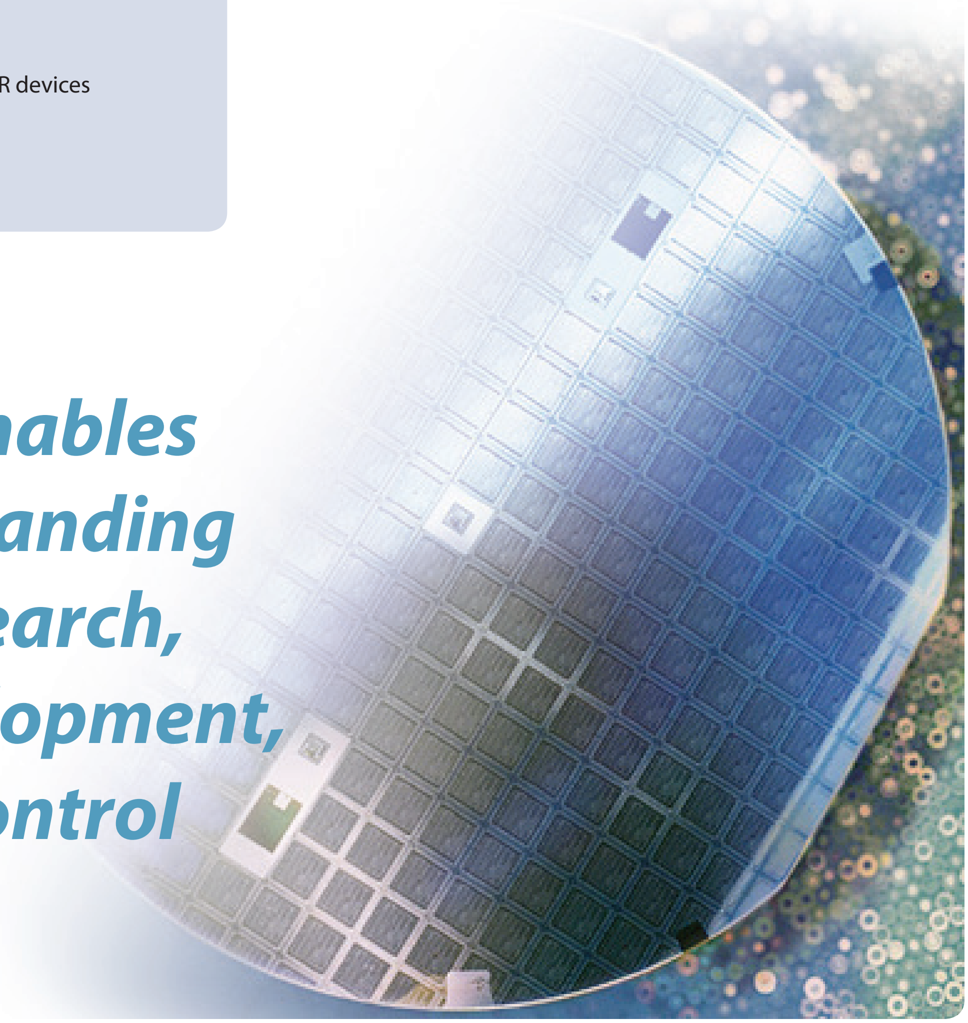
Hall Mobility

Quantum Hall Effect

4-Lead Resistance

Magnetotransport

Shubnikov-de Haas Oscillations (SdH)



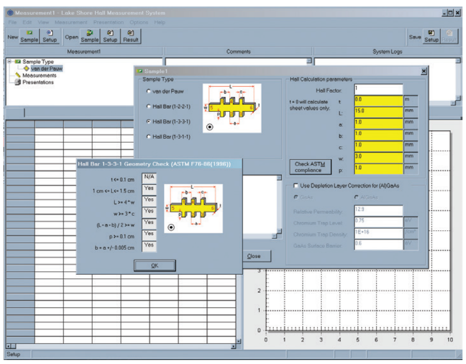
Our unique integration enables the most demanding materials research, product development, and quality control

System Application Software

The fully integrated HMS software is Windows® XP color graphic menu-driven using a Windows® Explorer® interface for system operation, data acquisition, and analysis. It controls magnetic field, temperature, and sample excitation during measurements allowing for the most comprehensive collection of measurement capabilities.

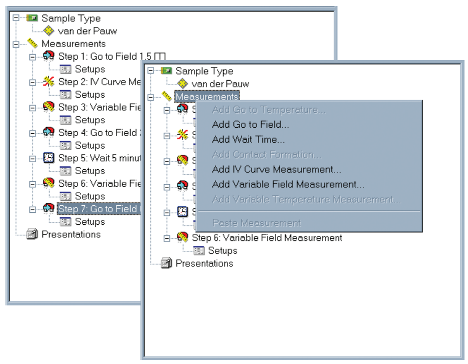
The software enables the user to define and save specifications and experimental configurations, as well as record and display data in laboratory and SI units for further analysis. Real-time feedback of processed data can be displayed in graphical and tabular format. The software automatically records data on single or multi-sample experiments for additional processing and analysis.

Our proprietary QMSA® package enhances the functionality of our IDEAS™ HMS application software



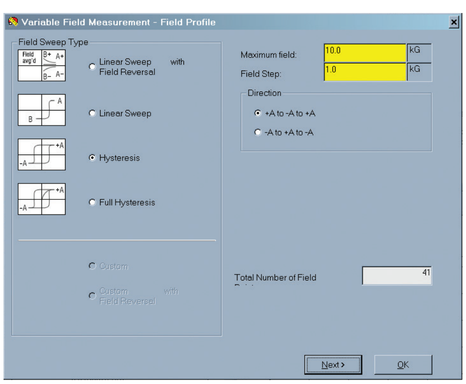
Define a Sample

Select from several standard sample geometries and contact arrangements. Sample definition parameters include thickness, width, length, as well as contact pad width, length, and distance between contacts. An ASTM compliance check can also be performed. The 7600 series allows users to define up to four samples for consecutive measurement in one sample experiment without a hardware change.



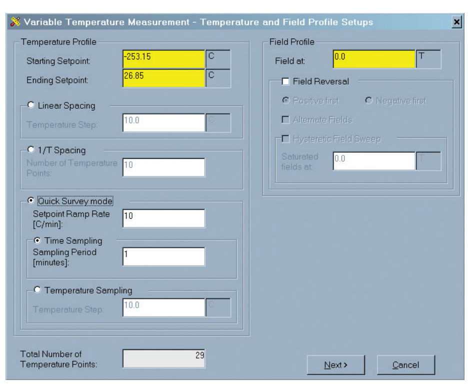
Create a Measurement Profile

Define custom experiment profiles and measurement steps — you can include just a single step parameter (e.g., Go to Temperature, Go to Field, Wait a Specific Time), or you can set up multiple step parameters in one profile for the software to automatically execute.



Field Measurement Setup

Various field sweep (with field reversal to eliminate material resistivity errors) methods can be used to determine magnetoresistance, resistivity, Hall coefficient, mobility, four wire resistance, or hysteresis loops.



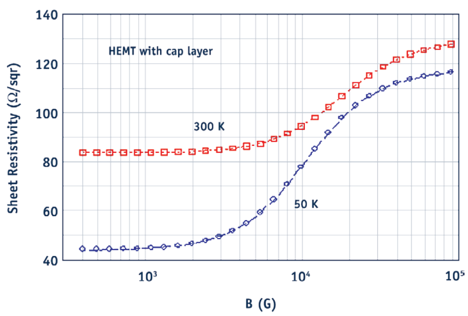
Temperature Measurement Setup

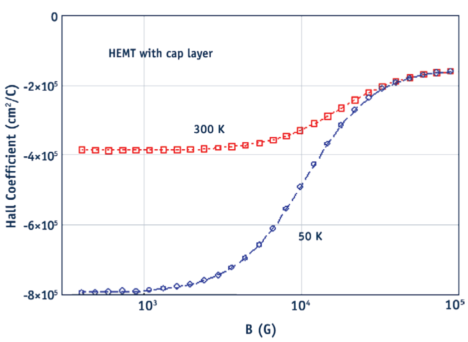
Various temperature sweeps (with temperature options) use a minimum and maximum temperature. Temperature profiles can incorporate linear spacing, definable numbers of points, or definable ramp rates.

Post Processing and Analysis with QMSA®

Lake Shore's Quantitative Mobility Spectrum Analysis (QMSA) software package represents that most advanced multi-carrier analysis capability available. This exclusive Lake Shore software automatically segregates the mobility spectrum for each carrier species (electrons and holes) that comprise a multilayer or multi-carrier material, including heterostructures, quantum wells, and multiply doped materials. Input for the software analysis includes Hall coefficient, resistivity, and magnetic field. Output parameters include conductivity spectra as a function of mobility, number of carriers (peaks in the mobility graph), density, mobility, and sign of each carrier.

Hall Coefficient and Conductivity

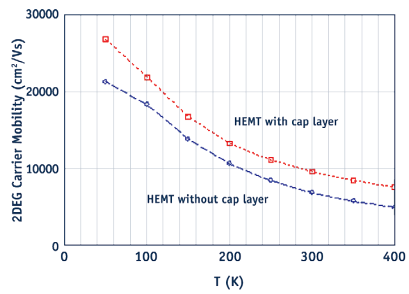


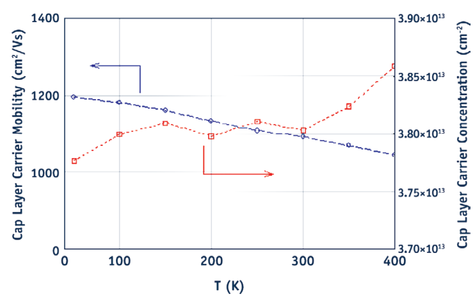


The ability to vary both magnetic field and temperature give the researcher complete flexibility to extract the maximum information from the material of interest. These figures show the field and temperature dependence of an InP pseudomorphic high electron mobility transistor (pHEMT) sample at two different temperatures. The field dependence of the Hall coefficient and resistivity implies that there is parallel conduction in the sample. The temperature dependence of the Hall coefficient and resistivity relate to changes in the scattering mechanism with temperature.

Analyzing the field dependence of this data along with similar data at different temperatures allows mobility vs. temperature and density vs. temperature plots to be obtained.

Mobility and Density





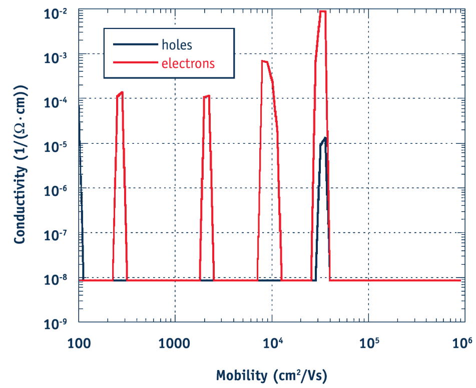
Analyzing the variable field and temperature data from a pHEMT sample, 2 electron carriers were identified at each temperature from 50 K to 400 K. The pHEMT sample was measured on the Model 9709A HMS.

Application notes

Download free from www.lakeshore.com or request at 614-891-2244.

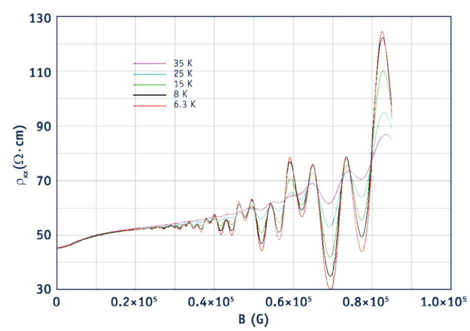
Full listing on page 18.

Mobility Spectrum



This is the resulting QMSA spectrum for a pseudomorphic high mobility transistor (pHEMT) structure. There are 4 distinct electron carriers and a single hole that populate this heterostructure device. The multi-carrier mixed conduction of this sample is clearly shown.

The Shubnikov-de Haas (SdH) Effect



The SdH effect, mostly seen at low temperatures, is an oscillation of the magnetoresistance. Shown are SdH data for an InP pHEMT that was acquired with a Model 9709A HMS.

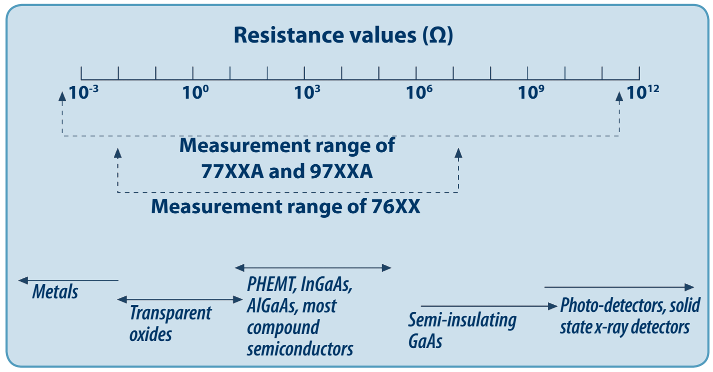
Select a system to fit your applications

Parameters to consider when selecting an HMS:

1 Resistance Range

Electronic transport measurements require the calculation of resistance by measuring the voltage output and dividing by the current input. The resistance range of the sample materials to be studied determines the measurement system specifications.

The Model 7700A and 9700A series HMS offer the widest possible resistance range. These systems take great care in controlling low currents and small voltages present in electron transport systems. Our AC current option extends the low-end resistance down to 10 μΩ when used with any system configuration. The wide resistance range offered by Lake Shore HMS enables the study of the widest possible range of materials.



2 Magnet Configuration

Variable Magnetic Field (DC)

The magnet is a key components of a Hall effect measurement system. Since it determines, in part, what kind of measurements you will be able to perform, it is important to identify current as well as anticipate future measurement needs. In addition, multi-carrier conduction of materials can only be determined with variable field Hall measurements. Lake Shore variable field Hall systems are available in electromagnet-based configurations providing fields to 2 T at room temperature, or in a 9 T superconducting magnet-based configuration.

Electromagnet Range

The 7700A and 7600 series systems are available in 4-, 7-, and 12-inch electromagnet designs providing fields to 1.3 T, 2 T, and 2 T, respectively, at room temperature. With variable temperature options installed, the 4-inch system provides fields to 0.87 T and the 7-inch system to 1 T (oven and closed cycle refrigerator [CCR] are not available with the 12-inch magnet). In addition to higher field strengths, the 12-inch electromagnets provide higher field uniformity and the capability to measure samples up to 6 inches in diameter.

Superconducting Magnet Range

Our Model 9709A HMS has a powerful 9 T superconducting magnet. The Model 9709A is ideal for measuring samples with extremely low mobilities that require constant temperature at high fields, such as some forms of ZnO, GaN, and quantum well structures.

3 Temperature Range

When configured with the optional CCR, the temperature range of our electromagnet-based HMS provides variable temperatures from 15 K to 350 K. The optional high temperature oven permits temperatures from 350 K to 800 K. Our Model 9709A superconducting magnet-based HMS comes standard with a temperature range from 2 K to 400 K.

Variable temperature measurement of resistivity and Hall coefficients are valuable for all materials. While measurements at room temperature are sufficient in many cases, transport properties can change significantly as the temperature varies. Measuring the sample material at variable temperatures allows carriers to be identified by their excitation energies and provides clues to the dominating scattering mechanism in materials. High temperature measurements also help to identify low mobility carriers in high resistance samples such as ZnO and GaN. By warming to 800 K with an optional high temperature oven, the impurities and defects of wide band gap materials can be observed. At temperatures of less than 10 K, measurement of Shubnikov-de Haas oscillations and the quantum Hall effect can yield additional information. For materials intended for applications requiring variable temperature ranges, testing the material at these temperatures can determine if it is suitable for such an application. Lake Shore HMS are designed to control temperature and magnetic flux to produce accurate, reliable Hall effect and electronic transport measurements.

	76XX	77XXA	9709A
Current ±50 nA to ±1 A	✔		
Current ±1 pA to ±100 mA		✔	✔
Voltage 0 V to 200 V	✔		
Voltage 0 V to 100 V		✔	✔
Magnetic Field to 2 T	✔	✔	
Magnetic Field to 9 T			✔
Resistance Range 0.04 mΩ to 200 GΩ		✔	✔
Resistance Range 10 mΩ to 10 MΩ	✔		
10 µΩ lower limit with AC current option	✔	✔	✔
Room temp/77 K	✔	✔	
2 K to 400 K			✔
CCR for measurements from 15 K to 350 K*	✔	✔	
High temp oven for measurements from 350 K to 800 K*	✔	✔	
Contact blasting†	standard	optional	
Up to 4 samples	optional		
Up to a 152 mm^2 (6 in^2) sample size	✔	✔	
Wide mobility range: 10 to 1×10^6 cm^2/Vs	✔	✔	✔

*Not available with Model 7612 or 7712A

†This option is not CE-certified

Size/Number of Samples

Our versatile HMS can measure samples from 10 mm^2 (0.4 in^2) up to 152 mm^2 (6 in^2). Our standard 7600 series can measure up to 2 samples at a time, or can be configured to measure up to 4 samples at a time.

Mobility Range

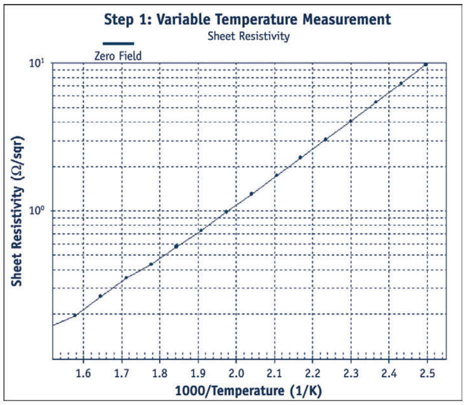
The wide standard mobility range of our HMS enables you to measure the widest possible range of materials. When combined with the HMS voltage tracking mode, low mobility materials typically used in organic semiconductors, molecular electronics, organic LEDs, and transparent oxides can be measured.

Use us as a resource!

Our experts can advise you on the optimal system for your applications. To demonstrate the performance of our HMS and to insure the proper configuration is selected, we can measure one of your actual samples at no charge to you. Get us involved early and benefit from our many years of experience.

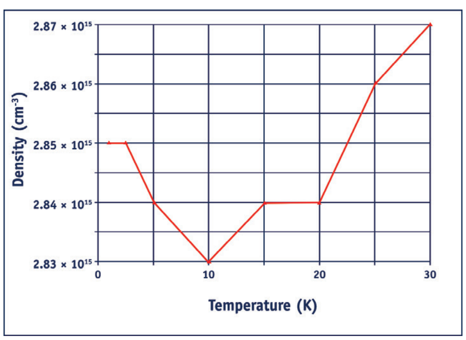
Classical Measurements

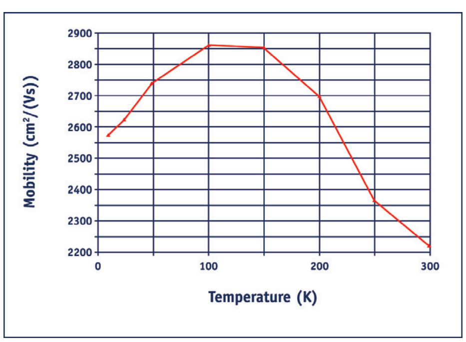
Intrinsic Conduction of Ge



This figure shows the resistivity of germanium vs. temperature. The sample temperature varied from 400 K to 650 K. As expected, a log plot of resistivity vs. magnetic field to 1 T is a straight line.

Temperature Coefficient of Si (4 K – 350 K)

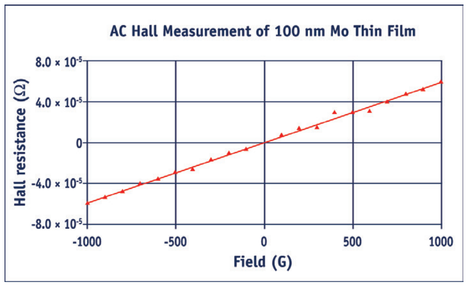




These figures demonstrate the mobility and density of Si as a function of temperature. The density is nearly independent of temperature and the mobility shows a typical electron-phonon scattering behavior.

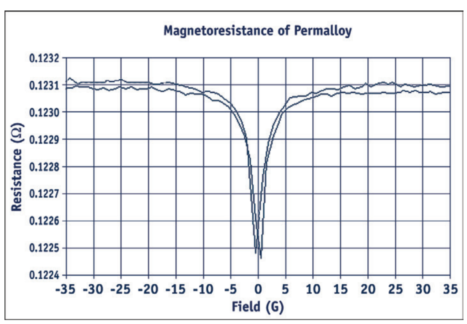
Hall effect in metals

Measuring the Hall effect in metals requires some care. The resistivity of a metal is very low and the carrier density is very high. For these measurements, the AC current option provides superior performance.



This measurement of Hall resistance vs. field for a 100 nm thick molybdenum thin film was taken while the sample was at a temperature of 50 K. The triangles are the measured data points and the line is the best-fit straight line. A change of resistance of 10 μΩ can easily be resolved. The measurement time is 20 s per point.

Magnetoresistance of NiFe

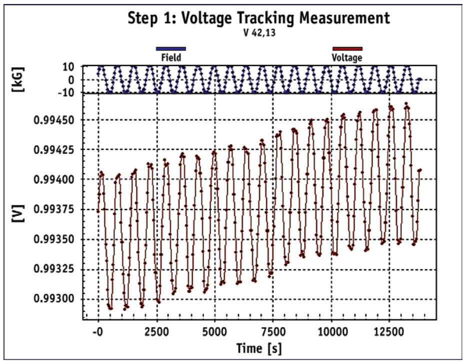


Lake Shore HMS can be used to characterize magnet-transport in magnetic materials. If the sample mount in an electromagnet system is rotated 90° so the field lies in the plane of the sample, classical MR measurements can be made. These MR measurements on a thin film Permalloy sample were taken on a Model 7704A system. Note that the small MR effect ($\Delta R/R$=0.5%) is easily seen. The small coercivity (~1 G) of the sample is also resolved.

Our versatile HMS are capable of both classical and state of the art measurements

State of the Art Measurements

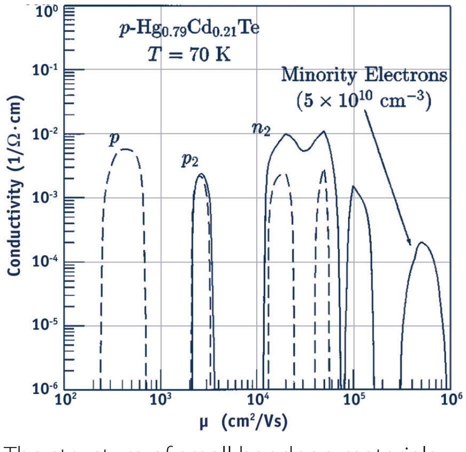
Transparent Oxides (ZnO)



The Hall voltage of a ZnO sample was taken in voltage tracking mode. This mode is very useful for low mobility materials, as it allows Hall voltage measurements during magnetic field change. The data shows the Hall voltage and field for 10 cycles of ±10 kG field sweeps. Here, the amplitude of the Hall voltage oscillations is the true Hall signal — approximately 1.25 mV. The Hall voltage offset is almost 1 V, therefore, the true signal is 0.1% of the measured signal. The sample was measured at constant temperature in a cryostat. In this case, the drift in the offset over the 4-hour measurement was about 0.5 mV.

Multi-Quantum Well Structures

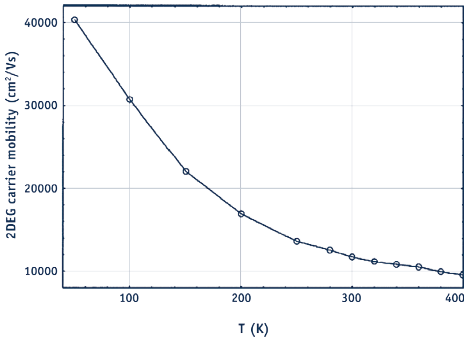
IR Applications (LEDs, Laser Diodes, and Detectors)



The structure of small bandgap materials like HgCdTe (used for near IR detectors) is very complicated, requiring high fields and variable temperatures to characterize. Using QMSA, this conductivity vs. mobility for a HgCdTe sample was taken with a Model 9709A HMS, which offers variable field capabilities to 9 T and a temperature range of 2 K to 400 K.

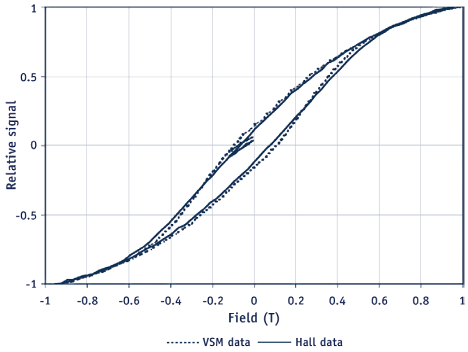
III-V Semiconductors

pHEMT Mobility vs. Temp for Channel Carrier



A typical pHEMT structure has a 2DEG high mobility carrier. A low mobility carrier associated with the cap layer is also often present. The mobility of high mobility carriers increases as temperature decreases. Using a variable field and temperature HMS along with QMSA®, the mobility of the 2DEG carriers can be distinguished from the cap layer carrier. This figure shows the temperature dependence of the 2DEG carrier mobility.

Anomalous Hall effect (AHE)



The AHE is an alternative method for measuring magnetic hysteresis M(H) loops and/or magnetotransport properties of perpendicular magnetic recording media (PMRM), ferromagnetic semiconductors, dilute magnetic semiconductors, spintronics devices, and other magnetic materials. Lake Shore HMS, when used in combination with the AC current measurement option, are capable of measuring the AHE of low moment recording media. This figure shows the hysteresis loop with minor loop for a CrCo sample. Both VSM data and AHE data are shown.

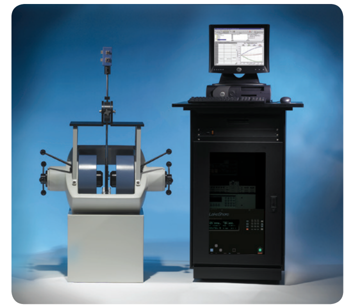
Application notes

Download free from www.lakeshore.com or request at 614-891-2244.

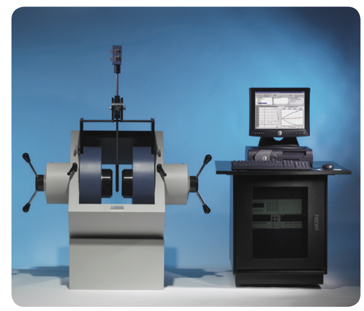
Full listing on page 18.

7600 Series Specifications

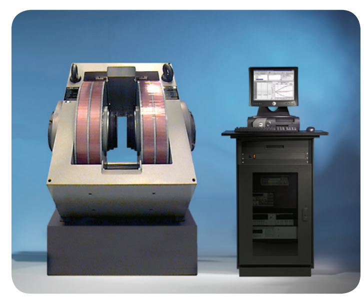
	7604	7607		7610
Magnetic field (room temp)	±1.3 T	±2 T		Please consult Lake Shore for 10 inch magnet system information
(variable temp)	±0.87 T	±1.2 T		
Temperature Standard	77 K or room temperature			
CCR	15 K to 350 K			
Oven	350 K to 800 K			
Carrier concentration density	1×10^{6} to 1×10^{19} cm^{-3}			
Mobility	1 to 1×10^{5} cm^2/Vs			
Current (A)	±10 nA to ±1 A			
Voltage (V)	0 V to 200 V			
Resistance range (standard)	2% accuracy— VdP minimum: 40 mΩ, HB minimum: 10 mΩ, maximum: 10 MΩ			
Resistance range (AC current)	2% accuracy— VdP minimum: 10 μΩ, HB minimum: 10 μΩ, maximum: 10 MΩ			
System equipment Sample holder module	75011 room temperature/77 K; 2-sided sample cards			
Sample holder kit (included with sample holder module)	(50) 671-209s, (10) 671-202s, (1) 671-205, (1) 671-260, (1) 671-250, and (10) 1-inch sheets of Indium foil			
Sample size	Up to 10 × 14 mm (0.4 × 0.6 in) on a 25 × 75 mm (1 × 3 in) card; up to 60 mm (2.4 in) square on an 82 × 93 mm (3.2 × 3.7 in) card	Up to 76 mm (3 in) in diameter		
Number of samples	Up to 4 (2 standard)			
Model 475 gaussmeter	1			
Keithley equipment				
2400 SourceMeter	1			
2700 Multimeter	1			
7709 6 × 8 Matrix Card	1 (2 included with 4-sample configuration)			
Magnet	EM4-HVA	EM7-HV		
Pole diameter	102 mm (4 in)	178 mm (7 in)		
Pole face diameter	102 mm (4 in)	152 mm (6 in)	76.2 mm (3 in)	
Max magnetic field at room temperature	1.3 T (13 kG) at 25 mm (1 in) air gap	1.6 T (16 kG) at 25 mm (1 in) air gap	2.17 T (21.7 kG) at 25 mm (1 in) air gap	
Max magnetic field at variable temperature	0.87 T (8.7 kG) at 51 mm (2 in) air gap	1.18 T (11.8 kG) at 51 mm (2 in) air gap	1.47 T (14.7 kG) at 51 mm (2 in) air gap	
Field homogeneity	±0.1% over 10 mm^3 (0.4 in^3)	±0.1% over centered 51 mm (2 in) diameter circle		
Cooling water requirements	Tap water or closed cycle cooling system (optional chiller available)			
Inlet temperature	25 °C (77 °F) maximum	32 °C (90 °F) maximum		
Pressure drop	200 kPa (30 psi)	220 kPa (32 psi)		
Flow rate	7.6 L (2 gal)/min	11.4 L (3 gal)/min		
Water chiller cooling capacity	2.5 kW (8,530 BTU)/h	5 kW (17,060 BTU)/h		
Bipolar magnet power supply	643	648		
Mode	DC			
Maximum output	±35 V ±70 A (2450 W)	±75 V/±135 A (9.1 kW nominal)		
AC line input	204/208 VAC ±10%, 13 A/phase; 220/230 VAC ±10%, 12 A/phase; 380 VAC ±10%, 7 A/phase; 400/415 VAC ±10%, 6.5 A/phase at 50/60 Hz	200 VAC ±10%, 41 A/phase; 208 VAC ±10%, 40 A/phase; 220 VAC ±10%, 38 A/phase; 230 VAC ±10%, 37 A/phase; 380 VAC ±10%, 23 A/phase; 400 VAC ±10%, 21 A/phase; 415 VAC ±10%, 21 A/phase		
Flow rate	5.7 L (1.5 gal)/min minimum	7.6 L (2 gal)/min		
Cooling water requirements	Tap water or closed cooling system (optional chiller available) +15 °C to +30 °C	Tap water or closed cooling system (optional chiller available) +15 °C to +30 °C		
Computer	Dell® computer with HDD, CD-ROM, 19-inch SVGA flat screen monitor, Windows® XP, Hall software, and National Instruments IEEE-488 USB adaptor			



Model 7604



Model 7607



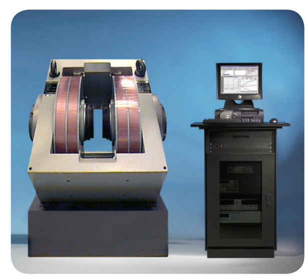
Model 7610

7700 Series/9709A Specifications

	7704A	7707A		7710A	9709A
Magnetic field (room temp)	±1.3 T	±2 T		Please consult Lake Shore for 10 inch magnet system information	±9 T
(variable temp)	±0.87 T	±1.2 T			±9 T
Temperature Standard	77 K or room temperature				2 K to 400 K
CCR	15 K to 350 K				NA
Oven	350 K to 800 K				NA
Carrier concentration density	8×10^{2} to 8×10^{23} cm^{-3}				8×10^{2} to 8×10^{23} cm^{-3}
Mobility	1 to 1×10^{6} cm^{2}/V s				1 to 1×10^{6} cm^{2}/V s
Current (A)	±1 pA to ±100 mA				±1 pA to ±100 mA
Voltage (V)	0 V to 100 V				0 V to 100 V
Resistance range (standard)	2% accuracy— VdP minimum: 0.5 mΩ, HB minimum: 0.8 mΩ, Maximum: 100 GΩ 5% accuracy— VdP minimum: 0.1 mΩ, HB minimum: 0.04 mΩ, Maximum: 200 GΩ				2% accuracy— VdP minimum: 0.5 mΩ, HB minimum: 0.8 mΩ, Maximum: 100 GΩ 5% accuracy— VdP minimum: 0.1 mΩ, HB minimum: 0.04 mΩ, Maximum: 200 GΩ
Resistance range (AC current)	2% accuracy— VdP minimum: 10 µΩ, HB minimum: 10 µΩ, Maximum: 100 GΩ 5% accuracy— VdP minimum: 10 µΩ, HB minimum: 10 µΩ, Maximum: 200 GΩ				2% accuracy— VdP minimum: 10 µΩ, HB minimum: 10 µΩ, Maximum: 100 GΩ 5% accuracy— VdP minimum: 10 µΩ, HB minimum: 10 µΩ, Maximum: 200 GΩ
System equipment Sample holder module	75013 room temperature/77 K; 1-sided sample cards				9500-SI; 1-sided sample cards
Sample holder kit (included with sample holder module)	(1) 750SC10-50, (1) 750SC50-10, (1) 671-205, (1) 671-260, (1) 671-250, and (10) 1-inch sheets of Indium foil				Integrated into 9500-SI
Sample size	Up to 10 × 14 mm (0.4 × 0.6 in) on a 25 × 75 mm (1 × 3 in) card; up to 60 mm (2.4 in) square on an 82 × 93 mm (3.2 × 3.7 in) card	Up to 76 mm (3 in) diameter			12 × 14 mm (0.5 × 0.6 in) in a 25.4 mm (1 in) bore
Number of samples	1				1
Model 475 gaussmeter	1				NA
Model 776 matrix	1				1
Other equipment					
6220 Current Source	1				1
6485 Autoranging Digital Picoammeter	1				1
2182A Digital Voltmeter	1				1
Magnet	EM4-HVA	EM7-HV			Superconducting
Pole diameter	102 mm (4 in)	178 mm (7 in)			NA
Pole face diameter	102 mm (4 in)	152 mm (6 in)	76 mm (3 in)		NA
Max magnetic field at room temperature	1.3 T (13 kG) at 25 mm (1 in) air gap	1.6 T (16 kG) at 25 mm (1 in) air gap	2.17 T (21.7 kG) at 25 mm (1 in) air gap		9 T
Max magnetic field at variable temperature	0.87 T (8.7 kG) at 51 mm (2 in) air gap	1.18 T (11.8 kG) at 51 mm (2 in) air gap	1.47 T (14.7 kG) at 51 mm (2 in) air gap		9 T
Field homogeneity	±0.1% over 10 mm^{3} (0.4 in^{3})	±0.1% over centered 51 mm (2 in) diameter circle			±0.1% over 60 mm (2.3 in) on axis
Cooling water requirements	Tap water or closed cycle cooling system (optional chiller available)				Liquid helium
Inlet temperature	25 °C (77 °F) maximum	32 °C (90 °F) maximum			NA
Pressure drop	200 kPa (30 psi)	220 kPa (32 psi)			NA
Flow rate	7.6 L (2 gal)/min	11.4 L (3 gal)/min			NA
Water chiller cooling capacity	2.5 kW (8,530 BTU)/h	5 kW (17,060 BTU)/h			NA
Bipolar magnet power supply	643	648			625
Mode	DC				DC
Maximum output	±35 V ±70 A (2450 W)	±75 V/±135 A (9.1 kW nominal)			±5 V/±60 A (300 W)
AC line input	204/208 VAC ±10%, 13 A/phase; 220/230 VAC ±10%, 12 A/phase; 380 VAC ±10%, 7 A/phase; 400/415 VAC ±10%, 6.5 A/phase at 50/60 Hz	200 VAC ±10%, 41 A/phase; 208 VAC ±10%, 40 A/phase; 220 VAC ±10%, 38 A/phase; 230 VAC ±10%, 37 A/phase; 380 VAC ±10%, 23 A/phase; 400 VAC ±10%, 21 A/phase; 415 VAC ±10%, 21 A/phase			Single phase 100, 120, 220, 240 VAC +6% -10%, 50 or 60 Hz, 850 VA
Flow rate	5.7 L (1.5 gal)/min minimum	7.6 L (2 gal)/min			NA
Cooling requirements	Tap water or closed cooling system (optional chiller available) +15 °C to +30 °C	Tap water or closed cooling system (optional chiller available) +15 °C to +30 °C			Air cooled
Computer	Dell® computer with HDD, CD-ROM, 19-inch SVGA flat screen monitor, Windows®, Hall software, and National Instruments IEEE-488 USB adaptor				


Model 7704A


Model 7707A


Model 7610


Model 9709A

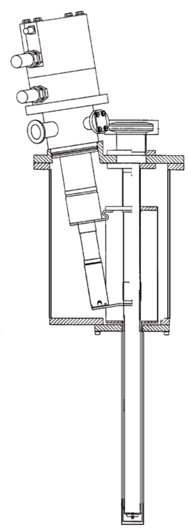
Options and accessories to customize your system

QMSA® Software

Our exclusive Quantitative Mobility Spectrum Analysis (QMSA®) software pairs with variable field Hall measurements to characterize the mobility spectrum for individual carrier species (electrons and holes) that comprise multilayer or multi-carrier materials (e.g., heterostructures, quantum wells, multiply doped materials).

Input parameters for the software analysis include Hall coefficient, resistivity, and magnetic field. Output parameters include conductivity spectra as a function of mobility, number of carriers (peaks in the mobility graph), density, mobility, and sign of each carrier.

Model 75014A and 76014A Closed Cycle Refrigerators (CCRs)



CCRs provide a variable temperature environment by cooling helium exchange gas. No liquid cryogens are required, therefore, ongoing operating costs are minimal. The sample probe, rotation stage, and hose accessories are provided. The sample is surrounded by helium gas at a pressure slightly above atmospheric, so samples can be changed without breaking vacuum or warming up the CCR. Pump out of the vacuum jacket to 100 Pa (0.1 torr) is required before cooldown.

The Model 750TC temperature controller is required and must be ordered separately. Continuous operation for more than one week or at temperatures greater than room temperature requires a dedicated turbomolecular pump (Lake Shore Model TPS-FRG or equivalent), which also must be ordered separately.

Cryostat: ARS Omniplex with 204SL closed cycle refrigerator and compressor, water cooled (3 L [0.8 gal] per min)
Temperature range: 15 K to 350 K
Sample geometry: One 12 mm (0.47 in) diameter maximum; van der Pauw or Hall bar geometry
Contacts: 6 solder posts provided; 6 additional, unguarded feedthrough pins available

Model 750TC Temperature Controller

The autotuning cryogenic temperature controller is used to measure and control either the closed cycle refrigerator or oven. The Model 750TC includes a Model 340 temperature controller, connectors, and accessories.

Model 75016 and 76016 High Temperature Ovens

The Hall system oven sample module features a heating unit oven body, sample insert, and sample chamber flush/fill unit. The oven body is rigidly mounted to the electromagnet frame and positioned between the electromagnet pole faces. The sample insert attaches through the top of the oven body via a turn locking mechanism. The sample insert makes no contact with the oven body. Because the oven body and sample insert form a vacuum-tight enclosure, the sample heating can be done under an inert gas atmosphere—argon is recommended. The insert has a temperature sensor mounted near the sample location. Electrical contact to the sensor is made through a connector at the top of the sample insert.

The Model 750TC temperature controller and a mechanical fore vacuum pump (such as the Lake Shore Model E2M) are required and must be ordered separately.

Temperature range: 350 K to 800 K
Accuracy: 0.4 K to 3 K over temperature range
Sample geometry: 14 mm × 17 mm × 1 mm maximum; Hall bar or van der Pauw geometry

— exactly the way you need it

Model TPS-FRG Compact Turbo Pumping System

Versatile vacuum pumping station used to pump out the vacuum jacket and transfer line vacuum spaces. Pump station includes V-81 turbo pump (NW 40) with oil free dry scroll backing pump, FRG-700 full range gauge, controller, and interface cable to USB port; full range gauge allows measurement of pressure from atmosphere to 10^{-8} Torr; included interface cable allows connection to standard USB computer port for vacuum pressure logging; includes Agilent 24 month warranty. *Note: requires SYS-TP-KIT*

AC Current Hall Effect Measurement

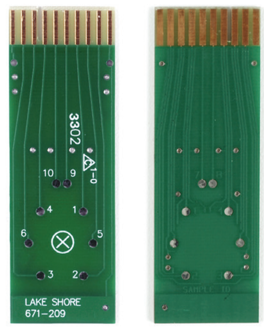
The AC current Hall option is used for the measurement of Hall effect and resistivity in materials with high conductivity (metals) or low mobility (transparent oxides), requiring the measurement of very low voltages. AC measurements are more sensitive than DC measurements.

The AC Hall option, designed for precise, low noise AC resistance measurements on van der Pauw samples with resistances as small as 10 μΩ, incorporates a Lake Shore Model 370 AC resistance bridge. The fully integrated Model 370 uses 4-lead AC measurement for the best possible accuracy with the lowest possible excitation current. AC coupling at each amplifier stage reduces offsets for higher gain and greater sensitivity than DC techniques allow. Phase sensitive detection, an AC filtering technique used in lock-in amplifiers, reclaims small measurement signals from environmental noise.

Contact Blasting

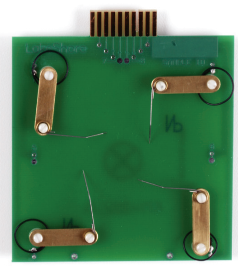
Contact blasting delivers high voltage blasting to the probe and semiconductor surfaces, allowing low-resistance ohmic contacts to be made on high performance, high resistance semiconductor devices. *Note: this option is not CE-certified.*

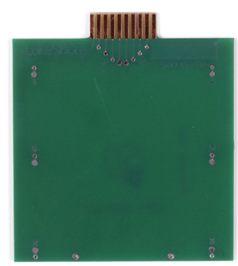
Room Temperature/77 K 4-Sample Card Module



The 4-sample probe with two 2-sided plug-in sample cards facilitates consecutive multi-sample measurements without hardware exchange.

Sample size: 2-sided sample plug-in cards – permits up to four 12 mm (0.47 in) diameter maximum samples on a 25 × 75 mm (1 × 3 in) card
Sample geometry: Hall bar or van der Pauw
Number of contacts: 4 or 6
Temperature: Room temperature or 77 K (liquid nitrogen required for 77 K)

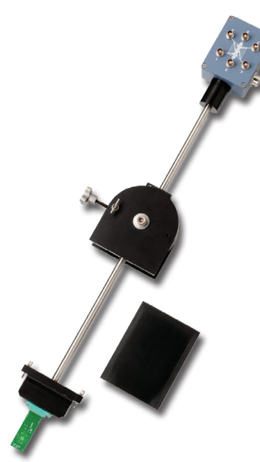




Sample Holders

A variety of sample holders are available to facilitate sample mounting and storage as well as expedite sample exchange. Standard plug-in sample cards allow mounting for one or two samples up to 12 mm (0.47 in) in diameter. Optional cards permit 76, 102, and 152 mm (3, 4, and 6 in) wafer samples, while a contact pin-pressure probe card permits sample mounting without requiring contact pad soldering. Some of the available sample holders include*:

760SC10-50: 2-sided Hall sample card, 12 mm (0.47 in) diameter sample, pack of 50, including one with InAs sample
750SC10-50: Hall sample card, 12 mm (0.47 in) diameter sample, pack of 50
671-205: Hall sample card with 4 pressure probes, 50 mm (2 in) diameter sample
671-202: Hall sample card, 60 mm (2.36 in) diameter sample
**See ordering information for a complete list with descriptions of available sample holders*



Application Notes

- Extraction of Low Mobility, Low Conductivity Carriers from Field Dependent Hall Data
- Anomalous Hall Effect Magnetometry Studies of Magnetization Processes of Thin Films
- Compound Semiconductors: Electronic Transport Characterization of HEMT Structures
- Characterizing Multi-Carrier Devices with Quantitative Mobility Spectrum Analysis and Variable Field Hall Measurements
- Measurement of the Magnetic Properties of Double Layered Perpendicular Magnetic Recording Media Using an Anomalous Hall Effect Magnetometer
- Characterization of Multi-Carrier Heterostructure Devices with Quantitative Mobility Spectrum Analysis and Variable Field Hall Measurements
- Evaluation of Transport Properties Using Quantitative Mobility Spectrum Analysis

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Shipping Dimensions and Weight (w × d × h)

	Model 7604	Model 7607	Model 7704	Model 7707	Model 9709
Instrument Console	1.17 m × 1.10 m × 1.75 m (46.1 in × 43.3 in × 68.9 in) 392 kG (864 lb)	1.17 m × 1.10 m × 1.75 m (46.1 in × 43.3 in × 68.9 in) 318 kG (700 lb)	1.17 m × 1.10 m × 1.75 m (46.1 in × 43.3 in × 68.9 in) 392 kG (864 lb)	1.17 m × 1.10 m × 1.75 m (46.1 in × 43.3 in × 68.9 in) 318 kG (700 lb)	0.89 m × 1.10 m × 1.75 m (35.0 in × 43.3 in × 68.9 in) 139 kG (305 lb)
Electromagnet	0.92 m × 0.87 m × 1.10 m (36.2 in × 34.3 in × 43.3 in) 275 kG (605 lb)	1.30 m × 1.22 m × 1.20 m (51.2 in × 48.0 in × 47.2 in) 705 kG (1550 lb)	0.92 m × 0.87 m × 1.10 m (36.2 in × 34.3 in × 43.3 in) 275 kG (605 lb)	1.30 m × 1.22 m × 1.20 m (51.2 in × 48.0 in × 47.2 in) 705 kG (1550 lb)	
Electromagnet Stand					
Power Supply	0.64 m × 0.74 m × 0.56 m (25.0 in × 29.0 in × 22.0 in) 79 kG (175 lb)	0.76 m × 0.84 m × 1.53 m (29.9 in × 33.1 in × 60.2 in) 295 kG (650 lb)	0.64 m × 0.74 m × 0.56 m (25.0 in × 29.0 in × 22.0 in) 79 kG (175 lb)	0.76 m × 0.84 m × 1.53 m (29.9 in × 33.1 in × 60.2 in) 295 kG (650 lb)	0.69 m × 0.69 m × 0.46 m (27 in × 27 in × 18 in) 36 kG (80 lb)
Dewar and Cryostat					0.97 m × 0.90 m × 1.27 m (38.2 in × 35.4 in × 50.0 in) 80 kG (175 lb)

Installation Dimensions and Weight (w × d × h)

	Model 7604	Model 7607	Model 7704	Model 7707	Model 9709
Instrument Console	0.79 m × 0.77 m × 1.60 m (31.1 in × 30 in × 63.0 in) 131 kG (288 lb)	0.79 m × 0.77 m × 1.60 m (31.1 in × 30 in × 63.0 in) 70 kG (155 lb)	0.79 m × 0.77 m × 1.60 m (31.1 in × 30 in × 63.0 in) 131 kG (288 lb)	0.79 m × 0.77 m × 1.60 m (31.1 in × 30 in × 63.0 in) 70 kG (155 lb)	0.79 m × 0.77 m × 1.60 m (31.1 in × 30 in × 63.0 in) 125 kG (275 lb)
Electromagnet and Insert	0.84 m × 0.54 m × 1.65 m (33.1 in × 21.3 in × 65.0 in) 295 kG (650 lb)	1.20 m × 0.71 m × 1.65 m (47.2 in × 28.0 in × 65.0 in) 739 kG (1625 lb)	0.84 m × 0.54 m × 1.65 m (33.1 in × 21.3 in × 65.0 in) 295 kG (650 lb)	1.20 m × 0.71 m × 1.65 m (47.2 in × 28.0 in × 65.0 in) 739 kG (1625 lb)	
Power Supply	Installed in instrument console	0.60 m × 0.70 m × 1.35 m (23.6 in × 27.6 in × 53.1 in) 250 kG (550 lb)	Installed in instrument console	0.60 m × 0.70 m × 1.35 m (23.6 in × 27.6 in × 53.1 in) 250 kG (550 lb)	0.48 m × 0.52 m × 0.18 m (18.9 in × 20.5 in × 7.1 in) 27 kG (60 lb)
Dewar and Cryostat					0.89 m × 0.81 m × 1.19 m (35.0 in × 31.9 in × 46.9 in) 69 kG (150 lb)

Site Requirements

Power

Instrumentation, computer, and optional vacuum pump require two standard single-phase electrical outlets (20 A maximum). Magnet power supply and optional recirculation chiller requires 3-phase electrical outlets (21 A maximum).

Water

Electromagnet requires one supply and one return line for cooling with up to 23 L/min and 45 to 75 psi. Magnet power supply requires up to 8 L/min with 45 to 75 psi and +15 °C to +24 °C water temperature.

Floor

The floor must support the weight of the magnet and the supply (see Installation Dimensions and Weight table).

Environment

The Hall system requires an environment between 18 °C and 28 °C that is relatively free of airborne dust and debris. Also, there should be no equipment placed next to the Hall system that would emit or be susceptible to high levels of magnetic interference (distribution boxes, vibration equipment, x-ray machines, etc.)

LHe (Model 9709A)

The 9709A requires < 6 to 7 L per day of LHe (static operation at 4.2 K).

Ordering Information

Hall Effect Systems

7604	Hall system, 102 mm (4 in) electromagnet, 643 magnet power supply, 2 sample, 10 MΩ limit
7604-4	Hall system, 102 mm (4 in) electromagnet, 643 magnet power supply, 4 sample, 10 MΩ limit
7607	Hall system, 178 mm (7 in) electromagnet, 648 magnet power supply, 2 sample, 10 MΩ limit
7607-4	Hall system, 178 mm (7 in) electromagnet, 648 magnet power supply, 4 sample, 10 MΩ limit
7610	Hall system, 305 mm (10 in) electromagnet, 648 magnet power supply, 2 sample or wafer capability, 10 MΩ limit*
7610-4	Hall system, 305 mm (10 in) electromagnet, 648 magnet power supply, 4 sample or wafer capability, 10 MΩ limit*
7704A	Hall system, 102 mm (4 in) electromagnet, 643 magnet power supply, 100 V, 200 GΩ, autoswitching
7707A	Hall system, 178 mm (7 in) electromagnet, 648 magnet power supply, 100 V, 200 GΩ, autoswitching
7710A	Hall system, 305 mm (10 in) electromagnet, 648 magnet power supply, 100 V, 200 GΩ, autoswitching*
9709A	Hall system, 9 T magnet, 100 V, 200 GΩ, autoswitching

**Temperature options not available with these systems*

7600 Series Options

75011	Sample holder module, room temp/77 K nitrogen pour-fill bucket
76014A	Closed cycle refrigerator (CCR) with sample module
76014-SI	Sample insert for 76014A CCR
76016	Oven sample module for 7600, 350 K to 800 K
750QMSA	QMSA® software option (for 7600, 7700A, and 9700A systems)
76020	AC current measurement option, 2-sample configuration
76020-4	AC current measurement option, 4-sample configuration
750TC	Temperature controller option with cabling and rack mount
3464	Thermocouple input card
750SC-3	Hall sample card and enclosure with 4-point contacts for 76 mm (3 in) wafer
750SC-4	Hall sample card and enclosure with 4-point contacts for 102 mm (4 in) wafer
750SC-6	Hall sample card and enclosure with 4-point contacts for 152 mm (6 in) wafer
750SC-3-RK	Hal sample card replacement kit (board, ring, and screws) for 76 mm (3 in) wafer
750SC-4-RK	Hal sample card replacement kit (board, ring, and screws) for 102 mm (4 in) wafer
750SC-6-RK	Hal sample card replacement kit (board, ring, and screws) for 152 mm (6 in) wafer
750EN-3	Hall sample enclosure for 76 mm (3 in) wafer
750EN-4	Hall sample enclosure for 102 mm (4 in) wafer
750EN-6	Hall sample enclosure for 152 mm (6 in) wafer
671-209	Hall sample card, 2 sided, 10 × 14 mm (0.4 × 0.6 in) square or 12 mm (0.5 in) diameter sample
760SC10-50	Hall sample card, 2 sided, 10 × 14 mm (0.4 × 0.6 in) square or 12 mm (0.5 in) diameter sample, box of 50 including one with an InAs sample
671-202	Hall sample card, 60 mm (2.36 in) square or 60 mm (2.36 in) diameter sample
671-205	Hall sample card, 50 mm (2 in), with four pressure probes
671-260	Wire for sample contacts

9700A Series Options

9500-SI	Sample insert for 9700A system
9700-SI-IP	Sample insert, in plane, vertical sample mount for 9700A system
750QMSA	QMSA® software option (for 7600, 7700A, and 9700A systems)
77020	AC current measurement option

Accessories

700TLF	LHe flexible transfer line
PA-40-25	NW 40 to NW 25 reducer
PA-SHOSE	Stainless flex hose 25 mm (1 in) with NW 25 fittings
PA-ST255	Foreline sorption trap
PS-R2010	Rotary oil-sealed vacuum pump
TPS-FRG-100/120V	Compact turbo pumping system with gauge; 100 to 120 V/60 Hz; requires SYS-TP-KIT
TPS-FRG-220/240V-CE	Compact turbo pumping system with gauge; 220 to 240 V/50 Hz; requires SYS-TP-KIT
SYS-TP-KIT	Includes all components necessary to connect NW 40 turbo pumping system to the vacuum port of any Lake Shore system (except probe stations)
RC-EM4	Recirculating chiller for 7604 and 7704A
RC-EM7	Recirculating chiller for 7607 and 7707A
RC-EM10	Recirculating chiller for 7612 and 7712A

7700A Series Options

75013	Sample holder module, room temp/77 K nitrogen pour-fill bucket
75014A	Closed cycle refrigerator with sample module
75016	Oven sample module, 350 K to 800 K
750QMSA	QMSA® software option (for 7600, 7700, and 9700 systems)
77020	AC current measurement option
77021	Contact blasting option (Note: this option is not CE-certified)
750TC	Temperature controller option with cabling and rack mount
3464	Thermocouple input card
750SC-3	Hall sample card and enclosure with 4-point contacts for 76 mm (3 in) wafer
750SC-4	Hall sample card and enclosure with 4-point contacts for 102 mm (4 in) wafer
750SC-6	Hall sample card and enclosure with 4-point contacts for 152 mm (6 in) wafer
750SC-3-RK	Hal sample card replacement kit (board, ring, and screws) for 76 mm (3 in) wafer
750SC-4-RK	Hal sample card replacement kit (board, ring, and screws) for 102 mm (4 in) wafer
750SC-6-RK	Hal sample card replacement kit (board, ring, and screws) for 152 mm (6 in) wafer
750EN-3	Hall sample enclosure for 76 mm (3 in) wafer
750EN-4	Hall sample enclosure for 102 mm (4 in) wafer
750EN-6	Hall sample enclosure for 152 mm (6 in) wafer
750SC10-10	Hall sample card, 10 × 14 mm (0.4 × 0.6 in) square or 12 mm (0.5 in) diameter sample, pack of 10
750SC10-50	Hall sample card, 10 × 14 mm (0.4 × 0.6 in) square or 12 mm (0.5 in) diameter sample, pack of 50
750SC50-10	Hall sample card, 60 mm (2.36 in) square or 60 mm (2.36 in) diameter sample, box of 10
671-201	Hall sample card, 10 × 14 mm (0.4 × 0.6 in) square or 12 mm (0.5 in) diameter
671-202	Hall sample card, 60 mm (2.36 in) square or 60 mm (2.36 in) diameter sample
671-204	Hall sample card, 19 mm (0.75 in), in-plane operation
671-205	Hall sample card, 50 mm (2 in), with four pressure probes
671-211	Spare sample probe for 75014A CCR sample module
671-260	Wire for sample contacts, box
671-250	Box for 25 × 25 mm (1 × 1 in) sample cards (for 10 mm [0.4 in] samples)

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www.lakeshore.com

Established in 1968, Lake Shore Cryotronics, Inc. is an international leader in developing innovative measurement and control solutions. Founded by Dr. John M. Swartz, a former professor of electrical engineering at the Ohio State University, and his brother David, Lake Shore produces equipment for the measurement of cryogenic temperatures, magnetic fields, and the characterization of the physical properties of materials in temperature and magnetic environments.

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