Magnetic Measurement and Control Catalog

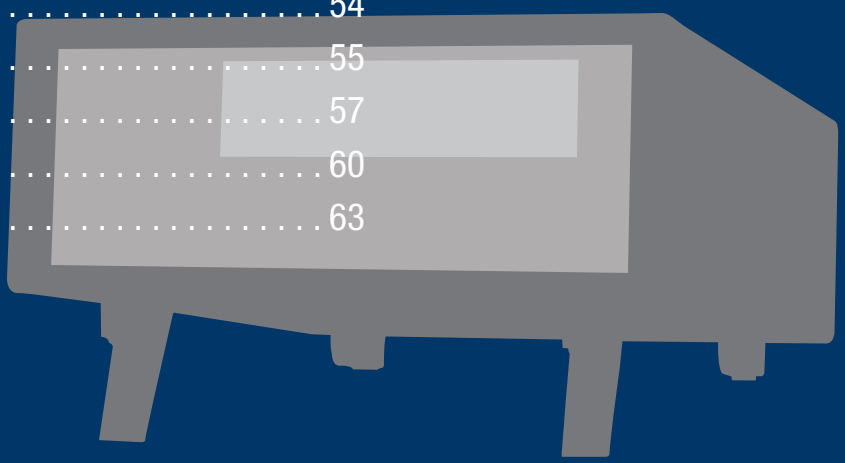
Lake Shore
CRYOTRONICS

3-year warranty and technical support

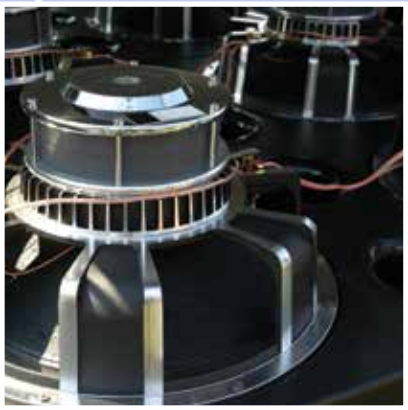
Lake Shore products are supported by a 3-year standard warranty, our confirmation of quality and commitment for the long term. Our scientists understand your applications and measurements and provide support throughout your decision making process and beyond the sale.

Magnetics

Contents



Applications for Hall gaussmeters and probes



University and commercial research
Any lab application where researchers need magnetic measurement capabilities

Automotive manufacturing
In-process verification of motors, valves, and other vehicle components

Speaker manufacturing
Field verification of speaker assemblies

Magnetic shielding assembly
For testing enclosures designed to isolate electronics from magnetic fields

Machine and fabrication shops
To inspect parts for residual magnetic particles after machining

Magnet manufacturing
To assess magnet field strength, uniformity, and shape

Transportation, particularly overseas shipping containers
To inspect for magnetic field leakage in order to meet IATA regulations

Measuring magnetic fields is required in many research and development fields today. In the university lab, gaussmeters and Hall effect probes enable scientists to detect and compare the magnetic fields for various materials studied, and to explore magnetic phenomena. These experiments can lead to the development of improved magnetic materials and devices for the medical, geology, energy, and computing fields.

But the need to measure magnetic fields extends far beyond the university lab. Magnetics have become increasingly common in modern technical products, appliances, automotive, and industrial products and systems. Factors such as the continuing emphasis on energy efficiency and the drive to reduce cost and parts count have prompted a revived interest in using magnets.

What's more, a number of products such as motors, speakers, interlock switches, and magnetic separators benefit from magnetic components due to their ability to transmit force across a space without physical connection. Then there's the increasing use of rare earth materials. The use of rare earths has increased the efficiency of magnetic products by producing high magnetic fields, often in very compact spaces, such as in lightweight electronics, toys, and handheld telecommunications devices.

With this rise in the use of magnets, there's a greater need for the right testing tools. Some of the instrumentation conventionally used in various phases of inspection may test magnets and magnetic assemblies indirectly, but this type of testing can often provide questionable results or disclose critical flaws too late in the process. Indirect testing might, for instance, fail to detect a faulty or under-performing magnet in a multiple-magnet assembly, or it might fail to identify a magnet that is only marginally defective before it is integrated into a product.

> "With this rise in the use of magnets, there's a greater need for the right testing tools."

This is why direct testing of magnetic components using gaussmeters, probes, and other sophisticated testing instrumentation is often necessary. If your goal is to determine magnetic field strength at a point or in a gap, field uniformity, or field shape, then a Lake Shore gaussmeter is the instrument of choice.

Types of Hall testing for manufacturing QC

Use the results of magnetic field measurement for:

- **Sorting sub-assemblies**
- **Confirming magnetic field characteristics vs. applied current**
- **Mapping magnetic field shape for a component**
- **Measuring fringe fields or residual fields**
- **Diagnosing detrimental effects of an external field**
- **Measuring operator exposure to magnetic fields**

At various points in the manufacturing process, from incoming inspection to final assembly and performance testing, quality control engineers must ensure that magnetic components, and the products using them, meet specifications. This process often involves test and measurement activities that confirm the accuracy, location, shape, and stability of the magnetic fields that are generated.

Hall gaussmeters and probes offer real value to manufacturing QC. But, suprisingly, the instrumentation and methods used in these tests may be unfamiliar to the average product engineer or technician. And, until recently, magnetics knowledge and expertise were not high on the list of QC skill priorities. Furthermore, the relatively high level of technical knowledge required for thorough magnetic analysis and testing has also been a deterrent.

> “Quality control is key to a manufacturer’s customer satisfaction and profits.”

But this is all beginning to change. Lake Shore provides the technical guidance necessary for manufacturers to correctly apply magnetic measurement tools and processes. With minimal investment, design and quality control managers can accurately perform magnetic testing for modern products and equipment, avoiding costly assembly rework in later stages of production.

Failure to detect and correct design or production problems at an early stage can lead to later problems, including final inspection rejections and field failures that require costly revisions or rework. In the worst case, inability to quickly identify problems related to magnet performance can lead to product recalls and even raise safety concerns.

Quality control is key to a manufacturer’s customer satisfaction and profits. Lake Shore’s magnetic and measurement solutions help ensure your product will perform as the designer intended.

Choosing an InAs or GaAs Hall Probe: General Guidelines

Proper selection of a Hall probe is probably the most difficult and important decision to make after choosing a gaussmeter. Using the improper probe could lead to less than optimal accuracy or, even worse, costly damage.

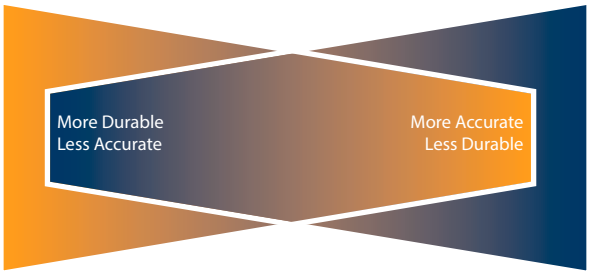
The next few pages will help you make an informed probe choice. If you have additional questions, contact Lake Shore. Our experts can guide you through the selection process. Lake Shore can even custom design a Hall probe to meet your specific application requirements.

Use these guidelines to help choose a probe:

- Choose a probe to match the application. Do not buy more accuracy, field range, or thinness than is actually needed.
- The thinner a probe, the more fragile it is. Try to avoid selecting an easy-to-damage probe based on a possible, but not required, future application. For instance, avoid using an exposed-device probe such as a model HMFT-3E03-type for general field measurements. (Also, once you have a thin probe in use, be sure to use proper fixtures that hold it in a non-stressed manner and eliminate physical contact with measured items. Once a stem or sensor has been damaged, the probe is not repairable.)
- Metal-enclosed probes, such as the HMMT-6J04 and HMMA-2504 types, offer good protection to the Hall sensor. Brass stem transverse probes are even more rugged than the aluminum type probes and offer the greatest amount of protection.
- Be cautious about using aluminum-stemmed transverse probes, such as the HMMT-6J04-type, where AC magnetic fields are to be measured. Eddy currents in the stem material can affect reading accuracy. A superior choice for AC measurements would be the HMNT-4E04-type fiberglass-epoxy stem probes. Consult the probe's frequency range specifications when selecting a suitable probe.
- Several stem lengths are offered for each probe type. User preference or test set-up dimensions usually determine the final selection. Longer stems are more susceptible to accidental bending (in many cases not catastrophic, but bothersome). Typically, stem length does not affect performance.
- Be aware of the differences in the probe "active areas" shown on the data sheet. A Hall effect probe will indicate the average field value sensed over that total active area. Thus, when measuring magnetic fields with a high gradient across the sensor width, choose the smallest active area practical. Keep in mind the fragility rule (see the second bullet above).
- Lake Shore gaussmeter probes exhibit different ranges of magnetic fields over which they will provide valid readings. Check the specification sheet and the tables at the right for these usable ranges.
- Be aware that when operating a high-sensitivity (HSE) probe below 100 G, the temperature coefficient of offset becomes more significant during low-field readings and that these changes can contribute to field error. So be sure to keep this in mind when evaluating sensitivity of a probe when ordering. For more information, please call us.

NOTE: If none of the probe configurations listed in this catalog fit your needs, Lake Shore can provide custom probes to meet your physical, temperature, and accuracy requirements. Please contact us with your special requirement details.

Durability versus Versatility



Handle Hall probes with care

All Hall probes are fragile. The sensor, normally located at the tip of the probe stem, must not be bent, physically shocked, or abraded. Also, it may be tempting to choose a probe with the thinnest transverse stem or smallest diameter axial stem; however, it is always best to choose the most robust probe that fits the immediate application. For example, the HMMT-6J04-VR (aluminum stem) is less prone to damage than the HMFT-3E03-VR (flexible stem), and the HMMA-2502-VR (¼ in diameter aluminum) is more durable than the HMNA-1904-VR (3⁄16 in diameter fiberglass) with its exposed Hall sensor.

NOTE: Never fasten a probe stem to another object. If a probe is clamped, always apply the clamp to the handle.

Usable full-scale ranges vs. probe type for Model 425, 455, and 475

HST-3	HST-4	HSE
—	—	3.5 G
35 G	35 G	35 G
350 G	350 G	350 G
3.5 kG	3.5 kG	3.5 kG
35 kG	35 kG	35 kG
350 kG	—	—

Usable full-scale ranges vs. probe type for Models 460, 450, and 421

HST-1	HST-2	HSE-1
—	—	30 G
300 G	300 G	300 G
3 kG	3 kG	3 kG
30 kG	30 kG	30 kG
300 kG	—	—

Magnitude

Typical Hall probes cover an operating range of 3 to 5 orders of magnitude. Operation beyond this field range requires some compromise in performance, often including higher noise or loss of resolution. Choosing the correct probe type ensures optimal performance in the desired measurement range.

High stability (HST-1, HST-2, HST-3, HST-4):

With a high field range of up to 350 kG[1] (35 T), high stability probes are used when fields exceed the limit of other probe types. Their low field performance is slightly degraded with a minimum sensitivity of 50 mG (5 µT). HST probes are also inherently more temperature stable than other probes, and should be used when large temperature fluctuations are expected. They are offered in a variety of stem geometries.

High sensitivity (HSE and HSE-1):

High sensitivity probes are the most common for general-purpose field measurement. They operate effectively in fields up to 35 kG[2] (3.5 T) with excellent sensitivity. At low fields, their sensitivity can be as low as 5 mG (0.5 µT). Convenient for many applications because of their relatively small active area, HSE probes are offered in the same geometries as HST probes.

Radiation effects on Hall probes

The HST and HSE probes use a highly doped indium arsenide active material. The HST material is the more highly doped of the two and therefore will be less affected by radiation. Some general information relating to highly doped indium arsenide Hall sensors is as follows.

- Gamma radiation seems to have little effect on the Hall sensors
- Proton radiation up to 10 Mrad causes sensitivity changes less than 0.5%
- Neutron cumulative radiation (>0.1 MeV, 10^{15} per cm^2) can cause a 3% to 5% decrease in sensitivity

In all cases, the radiation effects seem to saturate and diminish with length of time exposed

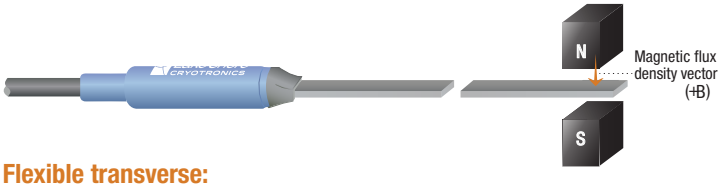
Orientation

Getting to the field is part of the challenge in selecting a probe. Field orientation dictates the most basic probe geometry choice of transverse versus axial. Other variations are also available for less common, more challenging applications. Listed below are the standard configurations for HSE and HST probes.

Common geometries

Transverse:

Transverse probes, most often rectangular in shape, measure fields normal to their stem width. They are useful for most general-purpose field measurements and are essential for work in magnet gaps. Several stem lengths and thicknesses are available as standard probes. To identify the polarity of a transverse probe, the output will be positive when the direction of the flux density vector is into the Lake Shore logo (i.e., the logo is toward the north pole).



Flexible transverse:

Flexible probes have a flexible portion in the middle of their stem, while the active area at the tip remains rigid and somewhat exposed. This unique feature makes them significantly more fragile than other transverse probes. Flexible probes should only be selected for narrow-gap measurement applications.

Axial:

Axial probes, usually round, measure fields normal to their end. They can also be used for general-purpose measurements, but are most commonly used to measure fields produced by solenoids. Several stem lengths and diameters are available as standard probes. To identify the polarity of an axial probe: (except in rare, special cases) the output will be positive when the field vector is into the tip of the probe.

[1] 350 kG with Models 475 and 455, 300 kG range with Models 460, 450, and 421

[2] 35 kG with Models 475 and 455, 30 kG range with Models 460, 450, and 421

Advanced geometries

Tangential:

Tangential probes are transverse probes designed to measure fields parallel to and near a surface. The active area is very close to the stem tip. They are intended for this specific application and should not be selected for general transverse measurements.

Multi-axis:

These probes measure two or three vectors of field simultaneously, important in directional applications such as field mapping.

Cryogenic:

Cryogenic Hall probes come in axial and transverse configurations and are specially designed to withstand extreme thermal contraction of probe materials while measuring at ultra-low temperatures. The probe construction helps prevent shifts in operating points when measuring fields in cryogenic applications. In addition, cryogenic probes are cold-cycled in liquid nitrogen during the manufacturing process to verify stable performance before shipment to the customer.

Frequency

Gaussmeters are equally well suited for measuring either static DC or periodic AC fields, but proper probe selection is required to achieve optimal performance.

Metal stem:

Metal stem probes are best for DC and low-frequency AC measurements. Non-ferrous metals are used for the stems because they provide the best protection for the delicate Hall sensor without altering the measured field. Aluminum is the most common stem material, but brass can also be used. Metal stems do have one drawback: eddy currents are generated in them when they're placed in AC fields. These currents oppose the field and cause measurement error. The error magnitude is proportional to frequency and is most noticeable above 800 Hz.

Non-metal stem:

Non-metal stems are required for higher-frequency AC fields and for measuring pulse fields. Fiberglass/epoxy is a common non-metal material. Alternatively, the sensor can be left exposed on its ceramic substrate, which provides less protection for the sensor. Eddy currents do not limit the frequency range of these non-conductive materials, but other factors may.

NOTE: No gaussmeter probe type is suitable for direct exposure to high voltage.

Gradient

Probe selection would be easier if all fields were large and uniform, but most fields are limited in volume and contain gradients (changes in magnitude). Hall probes measure an average magnitude over their active area, so be sure to understand the relationship between active area and field gradients. Severe field gradients are always experienced as the active sense element is moved away from a permanent magnet pole, making it important to know the distance between the active area and probe tip. The distance between probe tip and active area is specified for axial probes, but is less easily defined for transverse probes.

Nominal active area:

HSE and HST probes have a nominal active area on the order of 1 mm diameter, which is useful for all but the most stringent applications. The measured field is the average of the active area but without severe gradients. Therefore, the measured value accurately represents the true field. Field mapping with standard probes is also practical if a mapping resolution of 1 mm or greater is acceptable.

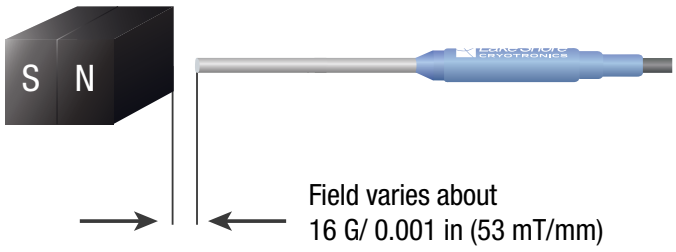
Small active area:

HSE and HST probes with a smaller active area are also available as custom products for measurements in severe gradients, or for high-resolution mapping applications.

Other considerations

Minor differences in probe position or angle can drastically change a reading; therefore you need to be precise when positioning it for some types of components. With magnet pole surface testing, for instance, be aware of the extreme falloff of the field strength near the surface. Only a few thousandths of an inch difference in distance between the sensor active area and the magnet surface can change the gaussmeter reading by more than the tolerance allowed by the test engineer. Similarly, another factor to consider is the change in reading with magnetic field vector angle. Be sure to ensure that the field is perpendicular to the probe sensor active area in order to achieve the most accurate reading. An even better option is to maximize the field reading by slightly rotating a transverse probe during test. Accurately aligning the longitudinal axis of an axial probe in a test fixture is also suggested.

Pole field gradient



NOTE: One of the greatest sources of repeatability errors is variable distance to the probe's active area.

Calibration and NIST traceable standards

All Lake Shore probes and instruments ship to you factory calibrated for accuracy and interchangeability. Because the Hall probes feature a programmable read-only memory (PROM) in the probe connector, calibration data can be read automatically by the instrument. This way, you're assured that the probe you receive is ready to use out of the box.

But our calibration capabilities don't end there. Lake Shore also offers a full-service recalibration lab for probes, gaussmeters, and gaussmeter/probe combinations returned for calibration on a regular (typically annual) basis. This way, manufacturers and engineers who use our instruments for quality control can be sure of accurate measurements in product performance testing.

Point-by-point calibration on probes

Technicians at our on-site recalibration stations ensure that the instrument or probe you ship back to us is calibrated to the same performance specifications as our new products. With probes, this process involves performing a point-by-point calibration, placing the devices into a magnetic field with a preset reference standard. If required, we will perform a field sweep to create a curve that incorporates measurements taken. Typically, a Hall probe calibration involves 28 points, but can be more depending on the instrument type. Gaussmeters are adjusted electrically or electronically to ensure they meet published specifications.

And to ensure that you're not without your Hall probe or gaussmeter for long, we offer quick turnaround. With most devices, we target between 7 and 10 business days.

Recalibrated to ISO 9001-2008 standards

With every recalibrated device returned to you, you get a certificate of calibration, indicating that the instrument and/or probe has been recalibrated to a standard that's traceable to an original NIST standard. For our own certification, Lake Shore has an independent, accredited calibration company inspect and verify our recalibration systems and tools.

All Lake Shore probes and instruments are provided with certification indicating ISO 9001-2008 compliance, documentation required by many international manufacturers whose metrology instruments or labs play a key role in their overall quality management systems. If required, we can also provide traceability trees for specific models.

Pre- and post-calibration data available for many models

Depending on the instrument, we can also provide reports relating to pre- and post-calibration data, as well as technical data relating to measurement uncertainties, errors we encountered, and other metrology factors, as well as a list of every type of equipment used to perform the calibration.

This level of certification is required by many aerospace and government lab customers who require before and after data in order to meet standards of other national and international accrediting bodies. For details about our calibration data services, please contact us at **service@lakeshore.com**.

Gaussmeters

Gaussmeters come in various sizes and capabilities and are easy to use. You can use them to measure both AC and DC magnetic fields, but if you have a permanent magnet application, only DC magnetic field capability is required. All Lake Shore gaussmeters are supported by industry-leading experts in magnet measurement instrumentation, sensor, and Hall probe technology.

For most manufacturing operations, the affordable Model 425 benchtop instrument may be all that you need. For advanced research measurements using filtering with fast pulse applications, order the odel 475. For questions about which model will work best for you, contact Lake Shore today.

Model 475 DSP gaussmeter

Intended for use in demanding applications, the Model 475 features superior field-measurement performance and DSP technology. It is also offers field control and high-performance filtering with high-speed pulses. Please see page 12 for more information regarding the Model 475.

Model 425 gaussmeter

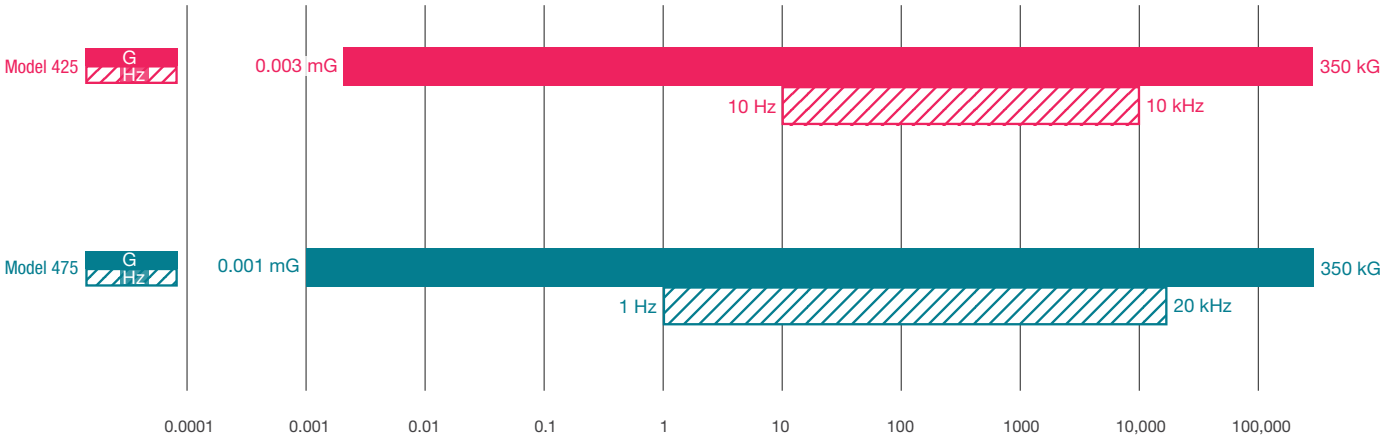
Designed to meet the demanding needs of the permanent magnet industry, the Model 425 gaussmeter (featured on page 23) provides high-end functionality and performance in an affordable desktop instrument.

Need to measure flux? See our Model 480 fluxmeter

An advanced tool designed primarily for use in industrial and measurement systems settings, the Model 480 fluxmeter (featured on page 52) measures total flux from which B, flux density, and/or H, magnetic field strength, can be determined. It's valuable for magnetizing, manual and automated magnet testing and sorting, and as the main component in BH loop or hysteresis measurement system applications. Use it, for instance, if you need to sort magnets in accordance with field strength and uniformity or test an assembly after the magnets have been installed. The Model 480 fluxmeter is compatible with most sensing coils and fixtures.

A comparison of Lake Shore gaussmeters

Field ranges and frequency ranges by model



Applications and product recommendations

Primary task:	Model 425	Model 475
Magnetizing	■	■
Magnet sorting (manual)	■	■
Magnet sorting (automated)	■	■
Magnet testing (manual)	■	■
Magnet testing (automated)	■	■
Magnetic sensing/switching		■
Fringe field and safety	■	■
Hall electromagnet*		■
Hall superconducting	■	■
B/H looper		■
Field mapping		■
Magnetic levitation testing	■	■
Testing shielding effectiveness		■
Portable testing (manual)		
Field control of magnet		■
Filtering with high-speed pulses		■

*For measuring Hall electromagnetic flux, see our Model 480 fluxmeter.

Model 475 DSP Gaussmeter RoHS

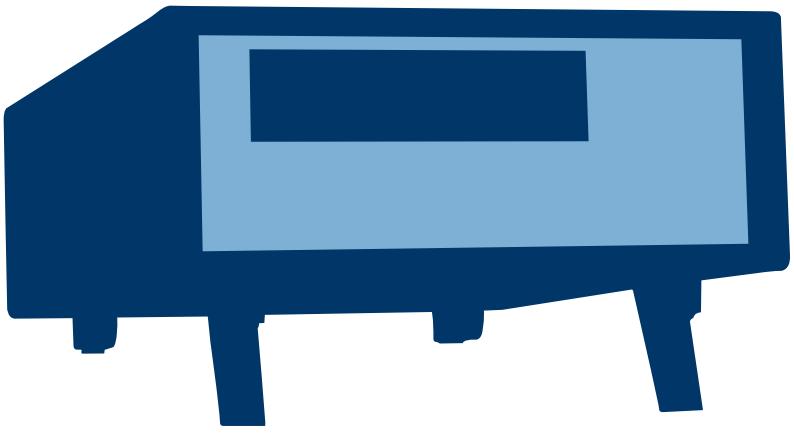
Model 475 features

- Full-scale ranges from 35 mG to 350 kG
- DC measurement resolution to 0.02 mG
- Basic DC accuracy of ±0.05%
- DC to 50 kHz frequency range (probe-dependent)
- 15 band-pass and 3 low-pass AC filters
- Peak capture to 20 µs pulse widths
- Data buffer sampling rates to 1000 readings per s
- Computer interface sampling rates to 100 new readings per s
- Integrated electromagnet field control algorithm
- Specialized and custom probes available
- CE mark certification

For the most demanding DC and AC applications

Lake Shore combined the technical advantages of digital signal processing with over a decade of experience in precision magnetic field measurements to produce the first commercial digital signal processor (DSP) based Hall effect gaussmeter, the Model 475. DSP technology creates a solid foundation for accurate, stable, and repeatable field measurement while simultaneously enabling the gaussmeter to offer an unequaled set of useful measurement features. The Model 475 is intended for the most demanding DC and AC applications. In many cases, it provides the functionality of two or more instruments in a field measurement system.

The power of DSP technology is demonstrated in the superior performance of the Model 475 in DC, RMS, and Peak measurement modes.



Advanced features

The Model 475 combines hardware and firmware elements to create advanced features that facilitate automation and materials analysis.

Field control

A built-in PI control algorithm turns the Model 475 into an essential building block for magnetic field control in electromagnet systems. It, along with a voltage-programmable magnet power supply, is all that is needed to control stable magnetic fields in an electromagnet at the user-specified setpoint. One of the built-in analog voltage outputs drives the program input of the power supply for either bipolar or unipolar operation. See page 60 for more information.

High-speed data transfer

The IEEE-488 interface can be set to send readings in binary format rather than the more common ASCII format. This reduces interface overhead, enabling real-time reading rates up to 100 new readings per second. Temperature compensation is not available at the highest interface rate.

Data buffer

Internal memory provides storage for 1024 field readings in a data buffer. The buffer can be filled at high speed, up to 1000 readings per second, which is as much as ten times faster than the computer interface. Stored readings can then be retrieved over interface at slower speed and processed offline. A trigger input can be used to initiate the data log sequence. Slower sample rates can be programmed if desired.

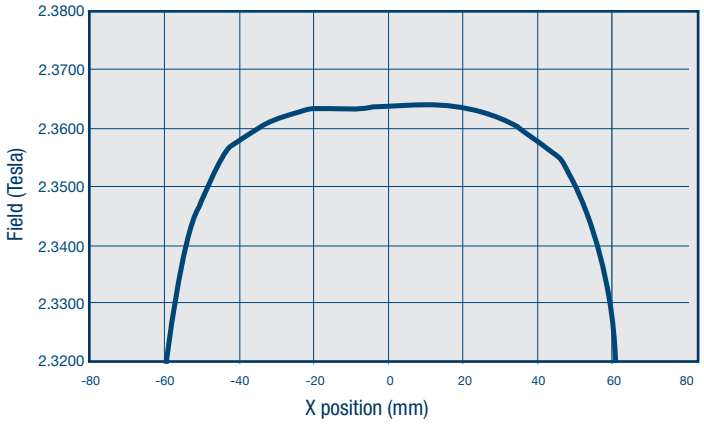
Trigger in and trigger out

A TTL-level hardware trigger into the instrument can be used to initiate the data log sequence. A TTL-level hardware trigger out indicates when the instrument completes a reading, and can be used to synchronize other instruments in the system. An IEEE-488 software-based trigger can be used like the hardware trigger in.

DC measurement mode

Static or slowly changing fields are measured in DC mode, where the accuracy, resolution, and stability of the Model 475 are most evident. In this mode, the gaussmeter takes advantage of the internal auto zero function and probe linearity compensation to provide its best accuracy. Measurement resolution is enhanced by advanced signal processing capability, allowing users the choice of high reading rates to 100 readings per second or high resolution to 5¾ digits. The Model 475 also features front-end amplification specifically designed to complement DSP data acquisition, providing high stability and repeatability. That, along with probe temperature compensation, makes the Model 475 the most stable gaussmeter ever produced by Lake Shore, suiting it perfectly for demanding DC measurement applications such as field mapping and field control.

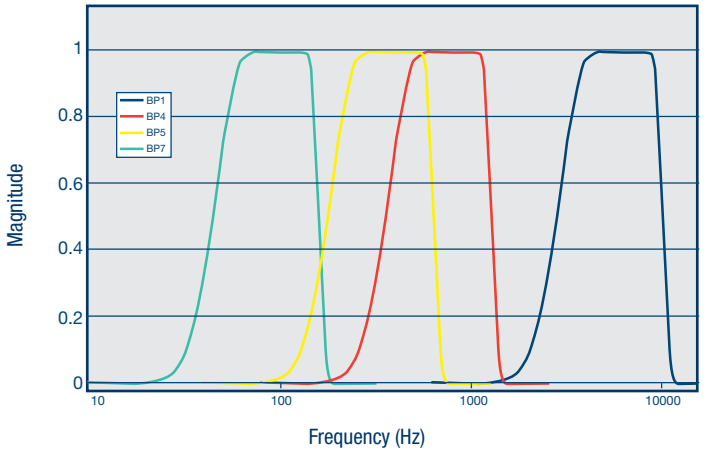
Field uniformity plot across an electromagnet pole face



RMS measurement mode

Periodic, AC fields are measured in RMS mode, which highlights the uniquely flexible filter functions of the Model 475. An overall frequency range of 1 Hz to 50 kHz is offered by the gaussmeter. Selectable band-pass and low-pass filters allow users to reject unwanted signals and improve measurement performance. The exclusive Lake Shore DSP algorithms also free the Model 475 from the limitations of conventional RMS conversion hardware and provide better dynamic range, resolution, and frequency response than ever before. These improvements permit meaningful RMS field measurements with broad frequency content or in noisy environments.

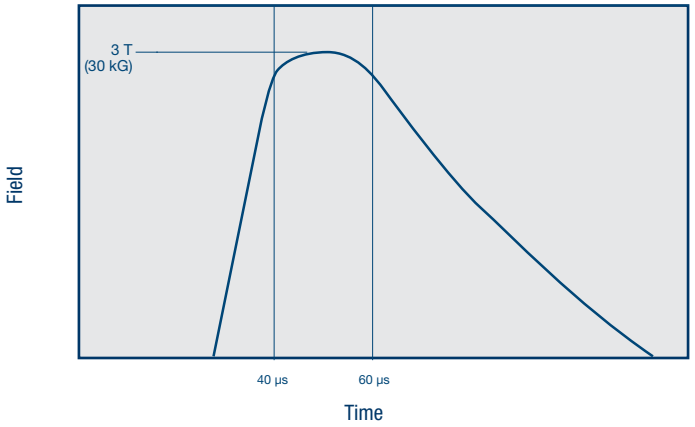
Selective bandpass filters (4 of a possible 15)



Peak measurement mode

Pulsed fields are measured in Peak mode, which is a natural extension of the high-speed data acquisition necessary for DSP operation. Fast instrument sample rates permit capture of positive and negative field pulses as narrow as 20 µs in width, which can be held for an unlimited length of time with no sag. This is ideal for most magnetizers and other fast pulse applications. For more moderate field changes, the Model 475 can process the captured data to create other features. The gaussmeter can be configured to follow the peak of a periodic waveform for evaluation of crest factor. The Model 475 can also be used to sample field changes at 1000 readings per second that can later be read over the interface to illustrate the shape of pulses or other waveforms.

Selective bandpass filters (4 of a possible 15)



The probe connection

The Model 475 is only half of the magnetic field measurement equation. For the complete solution, Lake Shore offers a full complement of Hall effect probes in a variety of sizes and sensitivities. See the table on page 18 for our stock probes recommended for use with this gaussmeter. We also offer other probes beginning on page 30. If you don't see the probe you need, give us a call.

Measurement features

The Model 475 offers a variety of features to enhance the usability and convenience of the gaussmeter.

Autorange: In addition to manual range selection, the instrument automatically chooses an appropriate range for the measured field. Autorange works in DC and AC measurement modes.

Auto probe zero: Allows the user to zero all ranges for the selected measurement mode with the push of a key.

Display units: Field magnitude can be displayed in units of G, T, Oe, and A/m.

Max/min hold: The instrument stores the fully processed maximum and minimum DC or RMS field value. This differs from the faster peak capture feature that operates on broadband, unprocessed field reading information.

Relative reading: Relative feature calculates the difference between a live reading and the relative setpoint to highlight deviation from a known field point. This feature can be used in DC, RMS, or Peak measurement mode.

Instrument calibration: Lake Shore recommends an annual recalibration schedule for all precision gaussmeters. Recalibrations are always available from Lake Shore, but the Model 475 allows users to field calibrate the instrument if necessary. Recalibration requires a computer interface and precision low resistance standards of known value.

Instrument probe features

The Model 475 has several capabilities that allow the best possible measurements with Lake Shore probes. These firmware-based features work in tandem with the probe's calibration and programming to ensure accurate, repeatable measurements and ease of setup. Many of the features require probe characteristics that are stored in the probe connector's non-volatile memory.

Probe field compensation: The Hall effect devices used in gaussmeter probes produce a near linear response in the presence of magnetic field. The small non-linearities present in each individual device can be measured and subtracted from the field reading. Model 475 probes are calibrated in this way to provide the most accurate DC readings.

Probe temperature compensation: Hall effect devices show a slight change in sensitivity and offset with temperature. Probe sensitivity temperature effects can be measured and subtracted out of field readings. A temperature sensor in the probe tip relays real time temperature to the gaussmeter, enabling compensation. Although temperature effects contribute only a small fraction of the overall probe measurement accuracy, temperature compensation will often improve measurement and control stability.

Probe temperature display: The gaussmeter can display the probe's temperature in °C along with a field reading when using a probe that includes a temperature sensor.

Frequency display: When operating in RMS mode, the gaussmeter can display the frequency of the measured AC field along with a field reading (up to 20 kHz).

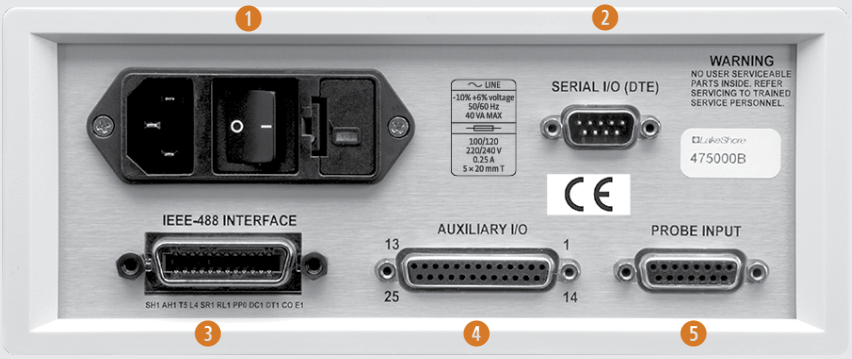
Probe information: The gaussmeter reads the probe information on power up or any time the probe is changed to allow hot swapping of probes. Critical probe information can be viewed on the front panel and read over the computer interface to ensure proper system configuration.

Extension cables: The complex nature of Hall effect measurements make it necessary to match extension cables to the probe when longer cables are needed. Keeping probes and their extensions from getting mixed up can become a problem when more than one probe is in use. The Model 475 alleviates most of the hassle by allowing users to match probes to extensions in the field. Stored information can be viewed on the front panel and read over the computer interface to ensure proper mating.

Hall effect sensors (magnetic field sensors): The Model 475 will operate with a discrete Hall effect sensor when a suitable probe is not available. Users can program nominal sensitivity and serial number into an optional HMCBL-6 blank connector to provide all gaussmeter functions except field and temperature compensation. If no sensitivity information is available, the Model 475 reverts to resistance measurement.

Model 475 rear panel

1. Line input assembly
2. Serial I/O interface
3. IEEE-488 interface
4. Auxillary I/O
5. Probe input



Display and interface features

Display

The Model 475 has a 2-line by 20-character vacuum fluorescent display. During normal operation, the display is used to report field readings and give results of other features such as max/min or relative. The display can also be configured to show probe temperature or frequency. When setting instrument parameters, the display gives the operator meaningful prompts and feedback to simplify operation. The operator can also control display brightness.

Following are four examples of the various display configurations:

Normal reading—the display configured to show the RMS field value and frequency, and the probe temperature

Max DC hold on—the display configured to show both the Maximum and Minimum DC field values

Max peak hold on—the display configured to both show the positive and negative Peak readings

Field control on—the display configured to show the field control setpoint and current field value, when field control is active

Keypad

The instrument has a 22-position keypad with individual keys assigned to frequently used features. Menus are reserved for less frequently used setup operations. The keypad can be locked out to prevent unintended changes of instrument setup.

Alarm and relay

High and low alarms are included in the instrument. Alarm actuators include display annunciator, audible beeper, and two relays. The relays can also be controlled manually for other system needs.

Voltage output 1

The first voltage output gives access to amplified voltage signal directly from the probe. This voltage is corrected for the nominal sensitivity of the probe and provides the widest bandwidth of the three voltage outputs. In wide band AC mode, the signal can be viewed on an oscilloscope to observe the shape of AC fields. In Peak mode, the output can be used to view a pulse shape or other characteristic of a momentary signal. Output 1 serves only as a diagnostic tool in DC and narrow band AC modes because modulation of the probe signal prevents a clear view of the field response.

Voltage output 2

The second voltage output provides a voltage proportional to measured field with the benefits of some signal processing. The output is produced by the DSP through a fast D/A converter. The output signal is updated at 40 kHz, giving good response for low to mid frequency fields. Signal quality degrades at high frequency because of the sampling rate. This voltage can be corrected for probe offset and for the nominal sensitivity of the probe.

Voltage output 3

The third voltage output provides a voltage proportional to measured field with the most signal processing of the three outputs. All probe compensation available to the display readings, including temperature compensation, can be performed on this output. The output is produced by the microprocessor through a high-resolution, 16-bit, D/A converter updated at 30 readings per second. This output can also be used for field control.

Computer interface

Two computer interfaces are included with the Model 475, serial RS-232C and parallel IEEE-488. Both allow setup of all instrument parameters and read-back of measured values. The reading rate over the interface is nominally 30 readings per second but settings from 10 to 100 readings per second are available. LabVIEW™ drivers are provided to instrument users — consult Lake Shore for availability.

Model 475 specifications

General measurement

(Does not include probe error, unless otherwise specified)
Input type: Single Hall effect sensor
Probe features: Linearity Compensation, Temperature Compensation, Auto Probe Zero, and Hot Swap
Measurement features: Autorange, Max/Min Hold, Relative Mode, and Frequency
Connector: 15-pin D style

DC measurement

Probe type ranges	5¾-digit resolution	4¾-digit resolution	3¾-digit resolution
HST Probe			
350 kG	000.001 kG	000.01 kG	000.1 kG
35 kG	00.0001 kG	00.001 kG	00.01 kG
3.5 kG	0.00001 kG	0.0001 kG	0.001 kG
350 G	000.003 G	000.02 G	000.1 G
35 G	00.0030 G	00.015 G	00.04 G
HSE Probe			
35 kG	00.0001 kG	00.001 kG	00.01 kG
3.5 kG	0.00001 kG	0.0001 kG	0.001 kG
350 G	000.001 G	000.01 G	000.1 G
35 G	00.0003 G	00.002 G	00.01 G
3.5 G	0.00030 G	0.0015 G	0.004 G
UHS Probe (discontinued)			
35 G	00.0001 G	00.001 G	00.01 G
3.5 G	0.00001 G	0.0001 G	0.001 G
350 mG	000.003 mG	000.02 mG	000.1 mG
35 mG	00.0030 mG	00.015 mG	00.04 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for shorted input (probe effects not included); value measured as peak-to-peak divided by 6.6
Display resolution: Indicated by number of digits in above table

	5¾-digit resolution	4¾-digit resolution	3¾-digit resolution
3 dB bandwidth:	1 Hz	10 Hz	100 Hz
Time constant:	1 s	0.1 s	0.01 s
Maximum reading rate:	10 rdg/s	30 rdg/s	100 to 1000 rdg/s*

*Limited feature set, interface dependent

DC accuracy: ±0.05% of rdg ±0.005% of range
DC temperature coefficient: ±0.01% of rdg ±0.003% of range/°C

AC RMS measurement

Probe type ranges	4¾-digit resolution
HST Probe	
350 kG	000.01 kG
35 kG	00.001 kG
3.5 kG	0.0002 kG
350 G	000.02 G
35 G	00.020 G
HSE Probe	
35 kG	00.001 kG
3.5 kG	0.0001 kG
350 G	000.02 G
35 G	00.002 G
3.5 G	0.0020 G
UHS Probe (discontinued)	
35 G	00.001 G
3.5 G	0.0002 G
350 mG	000.02 mG
35 mG	00.020 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for shorted input
Display resolution: Indicated by number of digits in above table
Max reading rate: 30 rdg/s (100 to 1000 rdg/s; limited feature set, interface dependent)
AC accuracy: ±1% of reading ≥ 1% of full-scale range
AC frequency range: 1 Hz to 1 kHz, narrow band mode; 100 Hz to 20 kHz, wide band mode
AC band limiting (filters): 18 user-selected frequencies of 3 low-pass or 15 band-pass

Peak measurement

Probe type ranges	4¾-digit resolution
HST Probe	
350 kG	000.01 kG
35 kG	00.001 kG
3.5 kG	0.0002 kG
350 G	000.02 G
35 G	00.020 G
HSE Probe	
35 kG	00.001 kG
3.5 kG	0.0001 kG
350 G	000.02 G
35 G	00.002 G
3.5 G	0.0020 G
UHS Probe (discontinued)	
35 G	00.001 G
3.5 G	0.0002 G
350 mG	000.02 mG
35 mG	00.020 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for periodic mode and shorted input
Display resolution: Indicated by number of digits in above table
Max reading rate (periodic mode): 30 rdg/s (100 to 1000 rdg/s; limited feature set, interface dependent)
Peak accuracy (5 Hz to 20 kHz): ±2% of rdg ≥ 1% of full-scale range (20 µs or longer pulse width)
Peak accuracy (20 kHz to 50 kHz): ±5% of rdg ≥ 1% of full-scale range (20 µs or longer pulse width)
Peak frequency range (periodic mode): 50 Hz to 5 kHz
Peak frequency range (pulse mode): 5 Hz to 50 kHz

Temperature measurement

Temperature range: Probe dependent (typically 0 °C to 75 °C)
Measurement resolution: 0.01 °C
Temperature display resolution: 0.01 °C
Electronic accuracy: ±0.7 °C

Front panel

Display type: 2-line × 20-character, vacuum fluorescent with 9 mm high characters
Display resolution: To ±5¾ digits
Display update rate: 5 rdg/s
Display units: gauss (G), tesla (T), oersted (Oe), and ampere per meter (A/m)
Units multipliers: µ, m, k, M
Display annunciators:
DC – DC measurement mode
RMS – AC RMS measurement mode
PK – Peak measurement mode
MX – Max hold value
MN – Min hold value
SP – Relative setpoint value
CSP – Field control setpoint value
LED annunciators:
Relative reading mode
Alarm active
Remote IEEE-488 operation
Keypad: 22 full-travel keys
Front panel features: Display prompts, front panel lockout, and brightness control Interfaces

RS-232C

Baud: 9600, 19200, 38400, and 57600
Update rate: 30 rdg/s (ASCII)
Software support: LabVIEW™ driver
Connector: 9-pin D-style, DTE configuration

IEEE-488.2

Capabilities: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT1, C0, and E1
Update rate: 30 rdg/s (ASCII), to 100 rdg/s (binary, no temperature compensation)
Software support: LabVIEW™ driver

Data buffer

Capacity: 1024 field readings
Reading rate: 1 to 1000 rdg/s
Data transfer: Through computer interface after data is logged
Trigger: Hardware trigger to begin data log sequence

Alarm

Settings: High/low setpoint, Inside/outside, Audible, and Sort
Actuators: LED annunciator, beeper, and relays

Relays

Number: 2
Contacts: Normally open (NO), normally closed (NC), and common (C)
Contact rating: 30 VDC at 2 A
Operation: Follows alarm or operated manually
Connector: In 25-pin I/O connector

Voltage output 1

Configuration: Real-time analog voltage output of wide-band AC signal
Range: ±3.5 V
Scale: ±3.5 V = ±full scale on selected range
Frequency response: 1 Hz to 40 kHz (wide-band AC)
Accuracy: Probe-dependent
Noise: ±1.0 mV
Minimum load resistance: 1 kΩ (short circuit protected)
Connector: In 25-pin I/O connector

Voltage output 2

Configuration: Voltage output of field value, generated by DAC
Range: ±5 V
Scale: ±3.5 V = ±full scale on selected range
Resolution: 16-bit, 0.15 mV
Update rate: 40,000 updates/s
Accuracy: ±10 mV
Noise: ±0.3 mV
Minimum load resistance: 1 kΩ (short circuit protected)
Connector: In 25-pin I/O connector

Voltage output 3

Configuration: Voltage output of compensated DC or RMS field value, generated by DAC (also used for field control)
Range: ±10 V
Scale: User-specified (defaults same as Voltage Output 2)
Resolution: 16-bit, 0.3 mV
Update rate: 30 updates/s
Accuracy: ±2.5 mV
Noise: ±0.3 mV
Minimum load resistance: 1 kΩ (short circuit protected)
Connector: In 25-pin I/O connector

General

Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C with reduced accuracy
Power requirement: 100, 120, 220, and 240 VAC (+6%, -10%), 50 Hz or 60 Hz, 20 VA
Size: 216 mm W × 89 mm H × 318 mm D (8.5 in × 3.5 in × 12.5 in), half rack
Weight: 3 kg (6.6 lb)
Approval: CE mark, RoHS

Probes and extensions

Probe compatibility: Full line of probes available—see page 18 for recommended stock probes available.
Hall sensor compatibility: Front panel programmable sensitivity and serial number for user-supplied Hall sensor.
Extension cable compatibility: Calibrated or uncalibrated probe extension cables with an EEPROM are available from 10 ft to 100 ft.

Lake Shore calibrated extension cables maintain the same accuracy as the Model 475 probe.

The uncalibrated version requires the operator to load the matching probe data file into the cable PROM directly from the Model 475 front panel. Additional errors caused by the uncalibrated extension cables are ±0.02% of field reading error and 1 °C temperature reading error.

Stock probes RoHS

The most commonly ordered probes for this gaussmeter. Others available starting on page 30.

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem length (in)	Probe part number
Model 475	Axial	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMA-2504-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNA-1904-VF
		DC to 10 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMA-2504-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNA-1904-VR
	Transverse	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMT-6J04-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNT-4E04-VF
			HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMT-6J04-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNT-4E04-VR

Ordering information

Part number	Description
475	Model 475 DSP gaussmeter

Please indicate your power/cord configuration:

1	100 V—U.S. cord (NEMA 5-15)
2	120 V—U.S. cord (NEMA 5-15)
3	220 V—Euro cord (CEE 717)
4	240 V—Euro cord (CEE 717)
5	240 V—U.K. cord (BS 1363)
6	240 V—Swiss cord (SEV 1011)
7	220 V—China cord (GB 1002)

Accessories included

106-253	I/O mating connector
106-264	I/O mating connector shell
4060	Small zero gauss chamber
119-036	Model 475 user manual

Accessories available

4005	1 m (3.3 ft) long IEEE-488 (GPIB) computer interface cable assembly—includes extender required for simultaneous use of IEEE cable and auxiliary I/O connector
4065	Large zero gauss chamber
HMCBL-6	User programmable cable with EEPROM (1.8 m [6 ft])
HMCBL-20	User programmable cable with EEPROM (6.1 m [20 ft])
HMPEC-10	Probe extension cable with EEPROM (3 m [10 ft]), calibrated
HMPEC-10-U	Probe extension cable with EEPROM (3 m [10 ft]), uncalibrated
HMPEC-25	Probe extension cable with EEPROM (7.6 m [25 ft]), calibrated
HMPEC-25-U	Probe extension cable with EEPROM (7.6 m [25 ft]), uncalibrated
HMPEC-50	Probe extension cable with EEPROM (15 m [50 ft]), calibrated
HMPEC-50-U	Probe extension cable with EEPROM (15 m [50 ft]), uncalibrated
HMPEC-100	Probe extension cable with EEPROM (30 m [100 ft]), calibrated
HMPEC-100-U	Probe extension cable with EEPROM (30 m [100 ft]), uncalibrated
RM-1/2	Rack mount kit for one ½-rack gaussmeter in 483 mm (19 in) rack
RM-2	Rack mount kit for two ½-rack gaussmeters in 483 mm (19 in) rack

Calibration services

CAL-NEW-DATA	New instrument calibration with certificate and data
CAL-475-CERT	Instrument recalibration with certificate
CAL-475-DATA	Instrument recalibration with certificate and data

All specifications are subject to change without notice

Other probes available — see page 30

Model 425 Gaussmeter RoHS

Model 425 features

- Field ranges from 350 mG to 350 kG
- DC measurement resolution to 4¾ digits (1 part of ±35,000)
- Basic DC accuracy of ±0.20%
- DC to 10 kHz AC frequency
- USB interface
- Large liquid crystal display
- Sort function (displays pass/fail message)
- Alarm with relay
- Standard and custom probes available
- CE mark certification

Introduction

Designed to meet the demanding needs of the permanent magnet industry, the Lake Shore Model 425 gaussmeter provides high-end functionality and performance in an affordable desktop instrument. Magnet testing and sorting have never been easier. When used in combination with the built-in relay and audible alarm features, the Model 425 takes the guesswork out of pass/fail criteria. Additional features including DC to 10 kHz AC frequency response, max hold and relative measurement make the Model 425 the ideal tool for your manufacturing, quality control and R&D flux density measurement applications. For added functionality and value, the Model 425 also includes a standard Lake Shore Hall probe. Put the Model 425 gaussmeter to use with confidence knowing it's supported by industry leading experts in magnet measurement instrument, sensor, and Hall probe technology.

Throughput

Throughput involves much more than just the update rate of an instrument. An intuitive menu navigation and keypad, along with overall ease of use are equally important. The Model 425 is designed with these qualities in mind. The operation is straightforward, with user display prompts to aid set-up. We understand that time is money! In addition to being user friendly, the automated magnet testing and sorting features of the Model 425 streamline sorting and testing operations. In addition, hot swapping of Hall probes allows you to switch probe types without powering the instrument off and back on. These features support increased productivity, allowing you to spend less time setting up your instrument and more time working on the task at hand.

DC measurement mode

Static or slowly changing fields are measured in DC mode. In this mode, the Model 425 uses probe field compensation to correct for probe nonlinearities, resulting in a DC accuracy to ±0.20%. Measurement resolution is enhanced with internal filtering, allowing resolution to 4¾ digits with reading rates to 30 readings per second over the USB interface.

AC measurement mode

In addition to the DC measurement mode, the Model 425 offers an AC measurement mode for measuring periodic AC fields. The instrument provides an overall frequency range of 10 Hz to 10 kHz and is equipped with both narrow and wide band frequency modes. While in narrow band mode, frequencies above 400 Hz are filtered out for improved measurement performance.

Measurement features

The Model 425 offers a variety of features to enhance the usability and convenience of the gaussmeter.

Autorange: In addition to manual range selection, the instrument automatically chooses an appropriate range for the measured field. Autorange works in DC and AC measurement modes.

Probe zero: Allows you to zero all ranges while in DC mode with the simple push of a key.

Display units: Field magnitude can be displayed in units of G, T, Oe, and A/m with resistance in Ω.

Max hold: The instrument stores and displays the captured maximum DC or AC field reading.

Relative reading: The relative mode calculates the difference between a live reading and the relative setpoint to highlight deviation from a known field point. This feature can be used in DC or AC measurement modes.

Instrument calibration: Lake Shore recommends an annual recalibration schedule for all precision gaussmeters. Recalibrations are always available from Lake Shore, but the Model 425 allows you to field calibrate the instrument if necessary. Recalibration requires a computer interface and precision low resistance standards of known value.

Instrument probe features

The Model 425 offers the best measurement performance when used along with Lake Shore Hall probes. Firmware-based features work in tandem with the probe's calibration and programming to ensure accurate, repeatable measurements and ease of setup. Many of the features require probe characteristics that are stored in the probe connector's non-volatile memory.

Probe field compensation: The Hall effect devices used in gaussmeter probes produce a near linear response in the presence of a magnetic field. The small nonlinearities present in each individual device can be measured and subtracted from the field reading. Model 425 probes are calibrated in a way to provide the most accurate DC readings.

Probe information: The gaussmeter reads the probe information on power up or any time the probe is changed to allow hot swapping of probes. Critical probe information can be viewed on the front panel and read over the computer interface to ensure proper system configuration.

Extension cable: The complex nature of Hall effect measurements makes it necessary to match extension cables to the probe when longer cables are needed. Keeping probes and their extensions from getting mixed up can become a problem when more than one probe is used. The Model 425 alleviates most of the hassle by allowing you to match probes to extension cables in the field. Stored information can be viewed on the front panel and read over the computer interface to ensure proper mating.

Hall effect sensors (magnetic field sensors): The Model 425 will operate with a discrete Lake Shore Hall effect sensor when a suitable probe is not available. You can program the nominal sensitivity and serial number into an optional HMCBL blank connector to provide all gaussmeter functions except field compensation. If no sensitivity information is available, the Model 425 reverts to resistance measurement.

Display and interface features

Keypad

The instrument keypad has 14 keys with individual keys assigned to frequently used features. Menus are reserved for less frequently used setup operations. The keypad can be locked out to prevent unintended changes of instrument setup.

Alarm, relay and sort

High and low alarm functions and one relay are included with the instrument, and can be used to automate repetitive magnet testing and sorting operations. Alarm actuators include display annunciator, audible beeper, and a relay. The alarm can be configured to display a pass or fail message and the relay can be configured to activate a mechanism to separate parts that meet pre-set fail criteria. The relay can also be controlled manually for other system needs.

Monitor output

The monitor output provides an analog representation of the reading that is corrected for probe offset and nominal sensitivity. This feature makes it possible to view the analog signal, which has not been digitally processed. The monitor output can be connected to an oscilloscope or data acquisition system.

Computer interface

The Model 425 is equipped with a universal serial bus (USB) interface. It emulates an RS-232C serial port at a fixed baud rate of 57,600, but with the physical connections of a USB. In addition to gathering data, nearly every function of the instrument can be controlled through the USB interface. The reading rate over the interface is nominally 30 readings per second. A LabVIEW™ driver is available from the downloads section of the Lake Shore website at www.lakeshore.com.

The Model 425 has a 2-line by 20-character liquid crystal display. During normal operation, the display is used to report field readings and give results of other features such as max or relative. When setting the instrument parameters, the display gives you meaningful prompts and feedback to simplify operation.

Display configuration examples

Normal reading—the default mode with the display of the live DC field reading.

Max DC hold on—the maximum value is shown in the lower display while the upper display contains the live DC field reading.

Alarm on—the alarm gives an audible and visual indication of when the field value is selectively outside or inside a user specified range. The relay can be associated with the alarm.

Sort on—the live reading is shown in the upper display while the lower display contains the pass/fail (repetitive sorting or testing) message. The relay facilitates pass/fail operation.

Model 425 specifications (Does not include probe error, unless otherwise specified)

General measurement

Input type: Single Hall effect sensor
Maximum update rate: 30 rdg/s
Probe features: Linearity compensation, probe zero, and hot swap
Measurement features: Autorange, max hold, relative mode, and filter
Probe connector: 15-pin D-sub

DC measurement

Probe type ranges	Filter on 4¾-digit resolution	Filter off 3¾-digit resolution
HST probe		
350 kG	000.01 kG	000.1 kG
35 kG	00.001 kG	00.01 kG
3.5 kG	0.0001 kG	0.001 kG
350 G	000.02 G	000.1 G
HSE probe		
35 kG	00.001 kG	00.01 kG
3.5 kG	0.0001 kG	0.001 kG
350 G	000.01 G	000.1 G
35 G	00.001 G	00.01 G
UHS probe (discontinued)		
35 G	00.001 G	00.01 G
3.5 G	0.0001 G	0.001 G
350 miG	000.02 mG	000.1 mG

Measurement resolution (RMS noise floor): Indicated by value in above table for shorted input
Display resolution: Indicated by number of digits in above table
DC accuracy: ±0.20% of reading ±0.05% of range
DC temperature coefficient: -0.01% of reading -0.003% of range/°C
DC filter: 16-point moving average

AC measurement

Probe type ranges	3¾-digit resolution
HST probe	
350 kG	000.1 kG
35 kG	00.01 kG
3.5 kG	0.001 kG
350 G	000.1 G
HSE probe	
35 kG	00.01 kG
3.5 kG	0.001 kG
350 G	000.1 G
35 G	00.01 G
UHS probe (discontinued)	
35 G	00.01 G
3.5 G	0.001 G
350 mG	000.1 mG

Measurement resolution (RMS noise floor): Indicated by value in above table, measured at mid-scale range
Display resolution: Indicated by number of digits in above table

	Narrow band mode	Wide band mode
AC accuracy	±2% of rdg, ±0.05% of rng (20 to 100 Hz); ±2.5% of rdg, ±0.05% of rng (10 to 400 Hz)	±2% of rdg, ±0.05% of rng (50 Hz to 10 kHz)
AC frequency response	10 Hz to 400 Hz	50 Hz to 10 kHz
Minimum input signal	>1% of rng	>1% of rng, except >2% of rng on lowest rng

AC specifications based on sine wave inputs or signals with crest factors <4.

AC temperature coefficient: ±0.01% of reading ±0.006% of range/°C

Front panel

Display: 2-line × 20-character LCD display module with 5.5 mm high characters and LED backlight
Display units: Gauss (G), tesla (T), oersted (Oe), and ampere per meter (A/m)
Display update rate: 3 rdg/s
Display resolution: To ±4¾ digits
Units multipliers: µ, m, k, M
Display annunciations: DC — DC measurement mode; RMS — AC RMS measurement mode; MAX — Max hold value; — Alarm on
Keypad: 14-key membrane
Front panel features: Display contrast control and keypad lock-out

Interfaces

USB

Function: Emulates a standard RS-232 serial port
Baud rate: 57,600
Connector: B-type USB connector
Reading rate: To 30 rdg/s
Software support: LabVIEW™ driver (consult Lake Shore for availability)

Alarm

Settings: High setpoint, low setpoint, deadband, inside or outside, algebraic or magnitude, audible on/off, and sort
Actuators: Display annunciator, sort message, beeper, and relay

Relays

Number: 1
Contacts: Normally open (NO), normally closed (NC), and common (C)
Contact rating: 30 VDC at 2 A
Operation: Follows alarm or operated manually
Connector: Shared 25-pin D-sub

Monitor output

Configuration: Real time analog voltage output proportional to measured field
Range: ±3.5 V
Scale: ±3.5 V = ± full scale on selected range
Frequency response: DC to 10 kHz
Accuracy: Offset and single point gain corrected to ±0.5% of reading ±0.1% of range, linearity is probe dependent
Minimum load resistance: 1 kΩ (short circuit protected)
Connector: Shared 25-pin D-sub

General

The Model 425 is the replacement for the Model 421 with a new software command set.
Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C with reduced accuracy
Power requirement: 100 VAC to 240 VAC, 50 Hz to 60 Hz, 40 VA
Size: 216 mm W × 89 mm H × 318 mm D (8.5 in × 3.5 in × 12.5 in), half rack
Weight: 2.1 kg (4.6 lb)
Approvals: CE mark, RoHS

Probes and extensions

Probe compatibility: Full line of probes available—see page 27 for recommended stock probes available.
Hall sensor compatibility: Front panel programmable sensitivity and serial number for user supplied Hall sensor using HMCBL cable
Extension cable compatibility: Calibrated or uncalibrated probe extension cables with an EEPROM are available from 10 ft to 100 ft

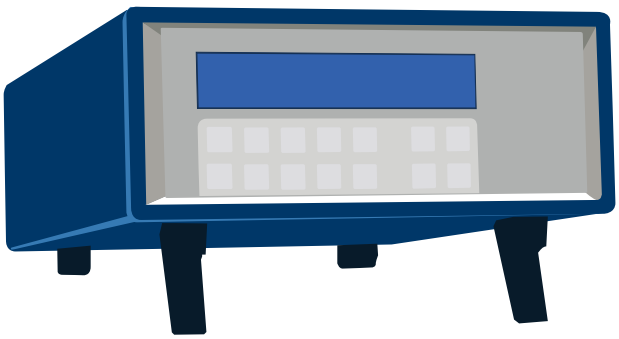
Model 425 rear panel

1. Line input assembly
2. USB
3. Auxiliary I/O
4. Probe input

Stock probes RoHS

The most commonly ordered probes for this gaussmeter. Others available starting on page 30.

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem length (in)	Probe part number
Model 425	Axial	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMA-2504-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNA-1904-VF
		DC to 10 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMA-2504-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNA-1904-VR
	Transverse	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMT-6J04-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNT-4E04-VF
			HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	HMMT-6J04-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass	4	HMNT-4E04-VR



Ordering information

Part number	Description
425	Model 425 gaussmeter

Please indicate your power/cord configuration:

1	100 V—U.S. cord (NEMA 5-15)
2	120 V—U.S. cord (NEMA 5-15)
3	220 V—Euro cord (CEE 717)
4	240 V—Euro cord (CEE 717)
5	240 V—U.K. cord (BS 1363)
6	240 V—Swiss cord (SEV 1011)
7	220 V—China cord (GB 1002)

Accessories included

G-106-253	I/O mating connector
G-106-264	I/O mating connector shell
4060	Small zero gauss chamber
119-053	Model 425 user manual

Accessories available

4065	Large zero gauss chamber
HMCBL-6	User programmable cable with EEPROM (6 ft)
HMCBL-20	User programmable cable with EEPROM (20 ft)
HMPEC-10-U	Probe extension cable with EEPROM (10 ft), uncalibrated
HMPEC-25-U	Probe extension cable with EEPROM (25 ft), uncalibrated
HMPEC-50-U	Probe extension cable with EEPROM (50 ft), uncalibrated
HMPEC-100-U	Probe extension cable with EEPROM (100 ft), uncalibrated
RM-1/2	Rack mount kit for one ½-rack gaussmeter in 483 mm (19 in) rack
RM-2	Rack mount kit for two ½-rack gaussmeter in 483 mm (19 in) rack

Calibration service

CAL-NEW-DATA	New instrument calibration with certificate and data
CAL-425-CERT	Instrument recalibration with certificate
CAL-425-DATA	Instrument recalibration with certificate and data

All specifications are subject to change without notice

Other probes available — see page 30

400 Series Hall Probes

Hall probe features

- Axial, transverse, multi-axis, and tangential Hall probes for measuring magnetic flux density
- Choose from a wide range of lengths and thicknesses
- Probes also available for cryogenic applications

Stock Probes—Ordering Information

Shown in the tables below are our recommended in-stock Hall probes for use with your gaussmeter. They are the ones most commonly ordered by our customers and require no special configuration. Because they are in stock, they offer shorter lead time when ordered.

For other probes, including versions for tangential, multi-axis, and cryogenic applications, see the specialized probes beginning on the next page. Also, for technical specifications and illustrations related to the probes listed (as well as others in this catalog), see the end of the Hall probes section.

Don't see the probe you need in this catalog? Please contact us. We also offer custom configured Hall probes.

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem length (in)	RoHS	Probe part number
Models 425, 455 and 475	Axial	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	Yes	HMMA-2504-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass			HMNA-1904-VF
		DC to 10 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum			HMMA-2504-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass			HMNA-1904-VR
	Transverse	DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	4	Yes	HMMT-6J04-VF
		DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass			HMNT-4E04-VF
			HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum			HMMT-6J04-VR
		DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass			HMNT-4E04-VR

NOTE: The Model 455 is a legacy gaussmeter no longer available from Lake Shore.

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem length (in)	RoHS	Probe part number
Models 421, 450 and 460	Axial	DC and 10 Hz to 400 Hz	HST-2: 300 G, 3 kG, 30 kG	Aluminum	4	No	MMA-2504-VG
			HSE-1: 30 G, 300 G, 3 kG, 30 kG	Fiberglass			MMA-2504-VH
	Transverse	DC	HST-2: 300 G, 3 kG, 30 kG	Aluminum	4	No	MMT-6J04-VG
		DC and 10 Hz to 100 Hz	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Aluminum			MMT-6J04-VH
		DC and 10 Hz to 400 Hz	HST-2: 300 G, 3 kG, 30 kG	Fiberglass			MNT-4E04-VG
			HSE-1: 30 G, 300 G, 3 kG, 30 kG	Fiberglass			MNT-4E04-VH
460 only	3-axis	DC and 10 Hz to 400 Hz	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Aluminum	8		MMZ-2508-UH

NOTE: The Model 421, 450, and 460 are legacy gaussmeters no longer available from Lake Shore.

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem length (in)	RoHS	Probe part number
Model 410	Axial	DC	200 G, 2 kG, 20 kG	Brass	2	No	MSA-2202-410
			200 G, 2 kG, 20 kG	Brass	4		MSA-2204-410
		DC to 10 kHz	200 G, 2 kG, 20 kG	Flexible plastic tubing	2.6		MSA-410
	Transverse	DC	200 G, 2 kG, 20 kG	Brass	2	No	MST-9P02-410
			200 G, 2 kG, 20 kG	Brass	4		MST-9P04-410
		DC to 10 kHz	200 G, 2 kG, 20 kG	Flexible plastic tubing	2.6		MST-410

For the specifications of each probe, please see the individual probe product spec sheets, starting on page 37.

Built-to-Order Probes—Ordering Information

Follow these steps to order the probe you need from the tables on the following pages:

Step 1:

Look for the table header identifying your Lake Shore gaussmeter model and your desired field orientation (axial, transverse) or specialized application (tangential, cryogenic, or multi-axis).

Built-to-Order Probes

Axial probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges		Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.08	02, 04, 08	MMA-08XX-UH	*Cable length can be changed. See below.
DC and 10 Hz to 400 Hz	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.06	02, 04, 08, 18	MMA-06XX-TH	
				0.18	02, 04, 08, 18	MMA-18XX-VG	
				0.25	02, 04, 08, 12	MMA-25XX-VG	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VG	
	HSE-1:	30 G, 300 G, 3 kG, 30 kG	Aluminum	0.18	02, 04, 08, 18	MMA-18XX-VH	
				0.25	02, 04, 08, 12	MMA-25XX-VH	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VH	

Step 2:

Within the table, choose the probe frequency range and field range.

Built-to-Order Probes

Axial probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges		Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.08	02, 04, 08	MMA-08XX-UH	*Cable length can be changed. See below.
DC and 10 Hz to 400 Hz	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.06	02, 04, 08, 18	MMA-06XX-TH	
				0.18	02, 04, 08, 18	MMA-18XX-VG	
				0.25	02, 04, 08, 12	MMA-25XX-VG	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VG	
	HSE-1:	30 G, 300 G, 3 kG, 30 kG	Aluminum	0.18	02, 04, 08, 18	MMA-18XX-VH	
				0.25	02, 04, 08, 12	MMA-25XX-VH	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VH	

Step 3:

Choose your stem material and diameter/thickness.

Built-to-Order Probes

Axial probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges		Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.08	02, 04, 08	MMA-08XX-UH	*Cable length can be changed. See below.
DC and 10 Hz to 400 Hz	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.06	02, 04, 08, 18	MMA-06XX-TH	
				0.18	02, 04, 08, 18	MMA-18XX-VG	
				0.25	02, 04, 08, 12	MMA-25XX-VG	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VG	
	HSE-1:	30 G, 300 G, 3 kG, 30 kG	Aluminum	0.18	02, 04, 08, 18	MMA-18XX-VH	
				0.25	02, 04, 08, 12	MMA-25XX-VH	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VH	

Step 4:

Specify stem length by filling in the "XX." This gives you the probe part number.

Built-to-Order Probes

Axial probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges		Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.08	02, 04, 08	MMA-08XX-UH	*Cable length can be changed. See below.
DC and 10 Hz to 400 Hz	HST-2:	300 G, 3 kG, 30 kG	Aluminum	0.06	02, 04, 08, 18	MMA-06XX-TH	
				0.18	02, 04, 08, 18	MMA-18XX-VG	
				0.25	02, 04, 08, 12	MMA-25XX-VG	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VG	
	HSE-1:	30 G, 300 G, 3 kG, 30 kG	Aluminum	0.18	02, 04, 08, 18	MMA-18XX-VH	
				0.25	02, 04, 08, 12	MMA-25XX-VH	
			Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VH	

Step 5 (optional): By default, most probes come with a 2 m cable. However, other cable lengths are available. For 6 m, 10 m, and 30 m probe cable lengths, add -06, -10, or -30 to end of the probe part number.

Built-to-Order Probes

Axial probes for Model 475, 455, and 425 gaussmeters

Frequency range	Full-scale field ranges	Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	0.08	02, 04, 08	HMMA-08XX-UH	* Cable length can be changed. See below.
DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	0.06	02, 04, 08, 18	HMMA-06XX-TH	
			0.18	02, 04, 08, 18	HMMA-18XX-VF	
			0.25	02, 04, 08, 12	HMMA-25XX-VF	
DC to 800 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass epoxy	0.187	02, 04, 08	HMNA-19XX-VF	
DC to 10 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	0.18	02, 04, 08, 18	HMMA-18XX-VR	
			0.25	02, 04, 08, 12	HMMA-25XX-VR	
DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass epoxy	0.187	02, 04, 08	HMNA-19XX-VR	
DC to 50 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass epoxy	0.25	18	HMNA-25XX-VR-HF	

Transverse probes for Model 475, 455, and 425 gaussmeters

Frequency range	Full-scale field ranges	Stem material	Stem thickness (in)	Stem lengths (in)	Probe part number	*
DC	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Brass	0.061	02, 04, 08	HMMTB-6JXX-VF	* Cable length can be changed. See below.
	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Brass	0.061	02, 04, 08	HMMTB-6JXX-VR	
DC to 400 Hz	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	0.061	02, 04, 08, 12, 18	HMMT-6JXX-VF	
DC to 800 Hz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Aluminum	0.061	02, 04, 08, 12, 18	HMMT-6JXX-VR	
	HST-4: 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass epoxy	0.045	02, 04	HMNT-4EXX-VF	
		Flexible plastic tubing	0.02	03	HMFT-29XX-VH	
			0.025	03	HMFT-3EXX-VF	
DC to 20 kHz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Fiberglass epoxy	0.045	02, 04	HMNT-4EXX-VR	
		Flexible plastic tubing	0.02	03	HMFT-29XX-VJ	
			0.025	03	HMFT-3EXX-VR	

04 Indicates probe characteristic and length that is offered as a stock probe. This item would not need to be "built-to-order." See page 31 for our stock probes.

* By default, most probes have a 2 m long cable. Also available: 6 m, 10 m, and 30 m lengths. To specify a length other than default length, add -06, -10, or -30 to end of the probe part number.

For the specifications of each probe, please see the individual probe product spec sheets, starting on page 37.

Built-to-Order Probes

Axial probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges	Stem material	Stem diameter (in)	Stem lengths (in)	Probe part number	*
DC	HST-2: 300 G, 3 kG, 30 kG	Aluminum	0.08	02, 04, 08	MMA-08XX-UH	* Cable length can be changed. See below.
DC and 10 Hz to 400 Hz	HST-2: 300 G, 3 kG, 30 kG	Aluminum	0.06	02, 04, 08, 18	MMA-06XX-TH	
			0.18	02, 04, 08, 18	MMA-18XX-VG	
			0.25	02, 04, 08, 12	MMA-25XX-VG	
		Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VG	
	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Aluminum	0.18	02, 04, 08, 18	MMA-18XX-VH	
			0.25	02, 04, 08, 12	MMA-25XX-VH	
		Fiberglass epoxy	0.187	02, 04, 08	MNA-19XX-VH	

Transverse probes for Model 460, 450, and 421 gaussmeters

Frequency range	Full-scale field ranges	Stem material	Stem thickness (in)	Stem lengths (in)	Probe part number	*
DC	HST-2: 300 G, 3 kG, 30 kG	Aluminum	0.061	02, 04, 08, 12, 18	MMT-6JXX-VG	* Cable length can be changed. See below.
		Brass	0.061	02, 04, 08	MMTB-6JXX-VG	
	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Brass	0.061	02, 04, 08	MMTB-6JXX-VH	
DC and 10 Hz to 100 Hz	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Aluminum	0.061	02, 04, 08, 12, 18	MMT-6JXX-VH	
DC and 10 Hz to 400 Hz	HST-2: 300 G, 3 kG, 30 kG	Fiberglass epoxy	0.045	02, 04	MNT-4EXX-VG	
		Flexible plastic tubing	0.02	03	MFT-29XX-VH	
			0.025	03	MFT-3EXX-VG	
	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Fiberglass epoxy	0.045	02, 04	MNT-4EXX-VH	
		Flexible plastic tubing	0.02	03	MFT-29XX-VJ	
			0.025	03	MFT-3EXX-VH	

Transverse and axial probes for Model 410 gaussmeters

Orientation	Frequency range	Full-scale field ranges	Stem material	Stem lengths (in)	Probe part number	
Axial	DC	200 G, 2 kG, 20 kG	Brass	02, 04	MSA-22XX-410	
	DC to 10 kHz	200 G, 2 kG, 20 kG	Flexible plastic tubing	2.6	MSA-410	
Transverse	DC	200 G, 2 kG, 20 kG	Brass	02, 04	MST-9PXX-410	
	DC to 10 kHz	200 G, 2 kG, 20 kG	Flexible plastic tubing	2.6	MST-410	

04 Indicates probe characteristic and length that is offered as a stock probe. This item would not need to be "built-to-order." See page 31 for our stock probes.

* By default, most probes have a 2 m long cable. Also available: 6 m, 10 m, and 30 m lengths. To specify a length other than default length, add -06, -10, or -30 to end of the probe part number. (NA for 410 probes)

For the specifications of each probe, please see the individual probe product spec sheets, starting on page 37.

Specialized Probes—Built-to-Order

Tangential probes for Model 475, 455, 425, 460, 460, and 421 gaussmeters

Probes to measure tangential fields, which are fields parallel to and near a surface

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem thickness (in)	Stem length (in)	Probe part number	*
475, 455, 425	N/A	DC to 400 Hz	HSE: 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	Plastic	0.11	1.5	HMNTAN-DQ02-TH	* Cable length can be changed. See below.
460, 450, 421	N/A	DC and 10 to 400 Hz	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Plastic	0.11	1.5	MNTAN-DQ02-TH	

Cryogenic probes for Model 475, 455, 425, 460, 450, and 421 gaussmeters

Probes designed to withstand thermal contraction of probe materials while measuring at ultra-low temperatures

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem diameter (in)	Stem length (in)	Probe part number	*
475, 455, 425	Axial	DC	HST-3: 35 G, 350 G, 3.5 kG, 35 kG, 350 kG	Stainless steel	0.25	60	HMCA-2560-WN	* Cryogenic probes have a standard 3 m cable; length can be changed. See below.
	Transverse	DC to 800 Hz	HST-3: 35 G, 350 G, 3.5 kG, 35 kG, 350 kG	Stainless steel	0.25	61	HMCT-3160-WN	
460, 450, 421	Axial	DC	HST-1: 300 G, 3 kG, 30 kG, 300 kG	Stainless steel	0.25	60	MCA-2560-WN	
	Transverse	DC and 10 Hz to 400 Hz	HST-1: 300 G, 3 kG, 30 kG, 300 kG	Stainless steel	0.25	61	MCT-3160-WN	

Multi-axis probes for Model 460 gaussmeter

Multi-sensor probes designed to measure three vectors of magnetic field simultaneously

Model	Orientation	Frequency range	Full-scale field ranges	Stem material	Stem diameter (in)	Approximate Stem lengths (in)	Probe part number	*
460	3-Axis	DC and 10 Hz to 400 Hz	HSE-1: 30 G, 300 G, 3 kG, 30 kG	Aluminum	0.25	02, 04, 08, 12, 18, 36, 60	MMZ-25XX-UH	* Cable length can be changed. See below.

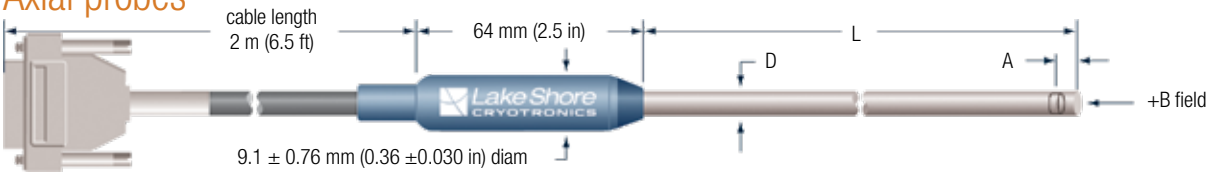
04 Indicates probe characteristic and length that is offered as a stock probe. This item would not need to be "built-to-order." See page 31 for our stock probes.

* By default, most probes have a 2 m long cable. Also available: 6 m, 10 m, and 30 m lengths. To specify a length other than default length, add -06, -10, or -30 to end of the probe part number. 30 m length not available for 3-axis probes.

For the specifications of each probe, please see the individual probe product spec sheets, starting on page 37.

Hall Probe Specifications

Axial probes

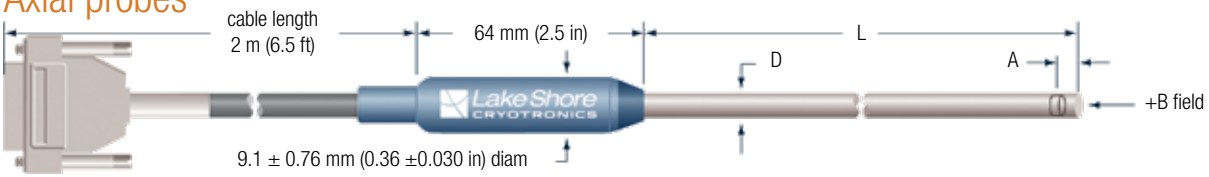


Operating temperature range: 0 °C to +75 °C

	RoHS	L mm (in)	D mm (in)	A mm (in)	Approx. active area dia. mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425												
HMMA-0602-TH	No	50.8 ±3.2 (2 ±0.125)	1.52 dia +0.03/-0.08 (0.060 dia +0.001/-0.003)	0.13 ±0.08 (0.005 ±0.003)	0.51 (0.020)	Aluminum	DC to 400 Hz	HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.25% to 10 kG	±0.13 G/°C	±0.01%/°C	No
HMMA-0604-TH	No	101.6 ±3.2 (4 ±0.125)										
HMMA-0608-TH	No	203.2 ±3.2 (8 ±0.125)										
HMMA-0618-TH	No	457 ±3.2 (18 ±0.25)										
HMMA-0802-UH	No	50.8 ±3.2 (2 ±0.125)	2.03 dia ±0.13 (0.080 dia ±0.005)	0.25 ±0.13 (0.010 ±0.005)			DC		±0.25% to 20 kG			
HMMA-0804-UH	No	101.6 ±3.2 (4 ±0.125)										
HMMA-0808-UH	No	203.2 ±3.2 (8 ±0.125)										
HMNA-1902-VR	No	50.8 ±3.2 (2 ±0.125)	4.75 dia ±0.13 (0.187 dia ±0.005)	0.13 ±0.08 (0.005 ±0.003)		Fiberglass epoxy	DC to 20 kHz	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.20% to 30 kG and ±0.25% 30 to 35 kG	±0.09 G/°C	455/475: ±0.015%/°C 425: -0.04%/°C	Yes
HMNA-1904-VR	Yes	101.6 ±3.2 (4 ±0.125)										
HMNA-1908-VR	No	203.2 ±3.2 (8 ±0.125)										
HMMA-1802-VR	No	50.8 ±1.6 (2 ±0.063)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)		Aluminum	DC to 10 kHz					
HMMA-1804-VR	No	101.6 ±3.2 (4 ±0.125)										
HMMA-1808-VR	No	203.2 ±3.2 (8 ±0.125)										
HMMA-1818-VR	No	457 ±6.4 (18 ±0.25)										
HMMA-1836-VR	No	914 ±6.4 (36 ±0.25)										
HMMA-2502-VR	No	50.8 ±1.6 (2 ±0.063)	6.35 dia ±0.15 (0.25 dia ±0.006)									
HMMA-2504-VR	Yes	101.6 ±3.2 (4 ±0.125)										
HMMA-2508-VR	No	203.2 ±3.2 (8 ±0.125)										
HMMA-2512-VR	No	305 ±6.4 (12 ±0.25)										
HMNA-2518-VR-HF	No	457 ±12.7 (18 ±0.5)	6.35 dia ±0.13 (0.25 dia ±0.005)	0.64 ±0.13 (0.025 ±0.005)	0.76 (0.030)		DC to 50 kHz					
HMNA-1902-VF	No	50.8 ±3.2 (2 ±0.125)	4.75 dia ±0.13 (0.187 dia ±0.005)	0.13 ±0.08 (0.005 ±0.003)		Fiberglass epoxy	DC to 800 Hz	HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.10% to 30 kG and ±0.15% 30 to 35 kG	±0.13 G/°C	–0.005%/°C	
HMNA-1904-VF	Yes	101.6 ±3.2 (4 ±0.125)										
HMNA-1908-VF	No	203.2 ±3.2 (8 ±0.125)										
HMMA-1802-VF	No	50.8 ±1.6 (2 ±0.063)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)		Aluminum	DC to 400 Hz					
HMMA-1804-VF	No	101.6 ±3.2 (4 ±0.125)										
HMMA-1808-VF	No	203.2 ±3.2 (8 ±0.125)										
HMMA-1818-VF	No	457 ±6.4 (18 ±0.25)										
HMMA-1836-VF	No	914 ±6.4 (36 ±0.25)										
HMMA-2502-VF	No	50.8 ±1.6 (2 ±0.063)	6.35 dia ±0.15 (0.25 dia ±0.006)									
HMMA-2504-VF	Yes	101.6 ±3.2 (4 ±0.125)										
HMMA-2508-VF	No	203.2 ±3.2 (8 ±0.125)										
HMMA-2512-VF	No	305 ±6.4 (12 ±0.25)										
-WL probes are temporarily unavailable												
HMMA-1804-WL	No	101.6 ±3.2 (4 ±0.125)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)	0.76 (0.030)	Aluminum	DC to 400 Hz	HST-3 35 G, 350 G, 3.5 kG, 35 kG, 350 kG	±1% to 100 kG	±0.13 G/°C	–0.005%/°C	Yes
HMMA-1808-WL	No	203.2 ±3.2 (8 ±0.125)										
HMMA-2504-WL	No	101.6 ±3.2 (4 ±0.125)	6.35 dia ±0.15 (0.25 dia ±0.006)				DC					
HMMA-2536-WL	No	914 ±6.4 (36 ±0.25)										

Note: 15 in flexible probes are no longer available. Please contact your local sales representative to discuss alternatives if you require a similar product for your application.

Axial probes



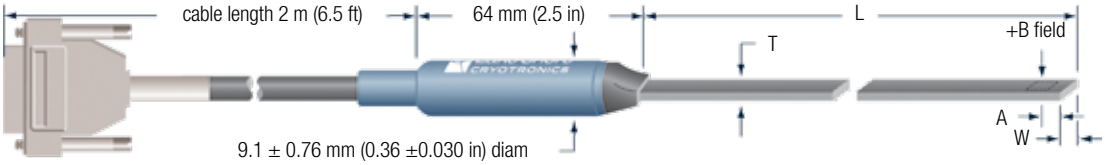
	L mm (in)	D mm (in)	A mm (in)	Approx. active area dia. mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Operating temp range (°C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 460, 450, and 421												
MMA-0602-TH	50.8 ±3.2 (2 ±0.125)	1.52 dia +0.03/-0.08 (0.060 dia +0.001/-0.003)	0.13 ±0.08 (0.005 ±0.003)	0.51 (0.020)	Aluminum	DC and 10 Hz to 400 Hz	HST-2 300 G, 3 kG, 30 kG	±0.25% to 10 kG	0 °C to +75 °C	±0.13 G/°C	±0.01%/°C	No
MMA-0604-TH	101.6 ±3.2 (4 ±0.125)											
MMA-0608-TH	203.2 ±3.2 (8 ±0.125)											
MMA-0618-TH	457 ±6.4 (18 ±0.25)											
MMA-0802-UH	50.8 ±3.2 (2 ±0.125)	2.03 dia ±0.13 (0.080 dia ±0.005)	0.25 ±0.13 (0.010 ±0.005)			DC		±0.25% to 20 kG				
MMA-0804-UH	101.6 ±3.2 (4 ±0.125)											
MMA-0808-UH	203.2 ±3.2 (8 ±0.125)											
MNA-1902-VH	50.8 ±3.2 (2 ±0.125)	4.75 dia ±0.13 (0.187 dia ±0.005)	0.13 ±0.08 (0.005 ±0.003)	0.76 (0.030)	Fiberglass epoxy	DC and 10 Hz to 400 Hz	HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.25% to 30 kG		±0.09 G/°C	450/460: ±0.015%/°C 421: -0.04%/°C	Yes
MNA-1904-VH	101.6 ±3.2 (4 ±0.125)											
MNA-1908-VH	203.2 ±3.2 (8 ±0.125)											
MMA-1802-VH	50.8 ±1.6 (2 ±0.063)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)		Aluminum							
MMA-1804-VH	101.6 ±3.2 (4 ±0.125)											
MMA-1808-VH	203.2 ±3.2 (8 ±0.125)											
MMA-1818-VH	457 ±6.4 (18 ±0.25)											
MMA-2502-VH	50.8 ±1.6 (2 ±0.063)	6.35 dia ±0.15 (0.25 dia ±0.006)										
MMA-2504-VH	101.6 ±3.2 (4 ±0.125)											
MMA-2508-VH	203.2 ±3.2 (8 ±0.125)											
MMA-2512-VH	305 ±6.4 (12 ±0.25)											
MNA-1902-VG	50.8 ±3.2 (2 ±0.125)	4.75 dia ±0.13 (0.187 dia ±0.005)	0.13 ±0.08 (0.005 ±0.003)		Fiberglass epoxy		HST-2 300 G, 3 kG, 30 kG	±0.15% to 30 kG		±0.13 G/°C	-0.005%/°C	No
MNA-1904-VG	101.6 ±3.2 (4 ±0.125)											
MNA-1908-VG	203.2 ±3.2 (8 ±0.125)											
MMA-1802-VG	50.8 ±1.6 (2 ±0.063)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)		Aluminum							
MMA-1804-VG	101.6 ±3.2 (4 ±0.125)											
MMA-1808-VG	203.2 ±3.2 (8 ±0.125)											
MMA-1818-VG	457 ±6.4 (18 ±0.25)											
MMA-2502-VG	50.8 ±1.6 (2 ±0.063)	6.35 dia ±0.15 (0.25 dia ±0.006)										
MMA-2504-VG	101.6 ±3.2 (4 ±0.125)											
MMA-2508-VG	203.2 ±3.2 (8 ±0.125)											
MMA-2512-VG	305 ±6.4 (12 ±0.25)											

-WL probes are temporarily unavailable

MMA-1804-WL	101.6 ±3.2 (4 ±0.125)	4.57 dia +0.05/-0.10 (0.180 dia +0.002/-0.004)	0.38 ±0.13 (0.015 ±0.005)	0.76 (0.030)	Aluminum	DC and 10 Hz to 400 Hz	HST-1 300 G, 3 kG, 30 kG, 300 kG	±1% to 100 kG	0 °C to +75 °C	±0.13 G/°C	-0.005%/°C	No
MMA-1808-WL	203.2 ±3.2 (8 ±0.125)											
MMA-2504-WL	101.6 ±3.2 (4 ±0.125)	6.35 dia ±0.15 (0.25 dia ±0.006)				DC						
MMA-2536-WL	914 ±6.4 (36 ±0.25)											

Note: 15 in flexible probes are no longer available. Please contact your local sales representative to discuss alternatives if you require a similar product for your application.

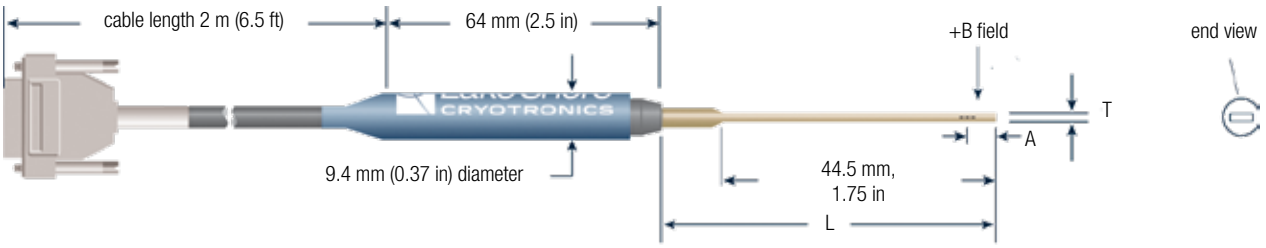
Transverse probes



Operating temperature range: 0 °C to +75 °C

	RoHS	L mm (in)	T mm (in)	W mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425													
HMMT-6J02-VR	No	50.8 ±3.2 (2 ±0.125)	1.55 (0.061) max	4.57 ±0.20 (0.180 ±0.008)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Aluminum	DC to 800 Hz	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.20% to 30 kG; ±0.25% 30 to 35 kG	±0.09 G/°C	455/475: ±0.015%/°C 425: -.04%/°C	Yes
HMMT-6J04-VR	Yes	101.6 ±3.2 (4 ±0.125)											
HMMT-6J08-VR	No	203.2 ±3.2 (8 ±0.125)											
HMMT-6J12-VR	No	305 ±6.4 (12 ±0.25)											
HMMT-6J18-VR	No	457 ±6.4 (18 ±0.25)											
HMNT-4E02-VR	No	50.8 ±3.2 (2 ±0.125)	1.14 (0.045) max	3.81 ±0.13 (0.150 ±0.005)			Fiberglass epoxy	DC to 20 kHz					
HMNT-4E04-VR	Yes	101.6 ±3.2 (4 ±0.125)											
HMMT-6J02-VF	No	50.8 ±3.2 (2 ±0.125)	1.55 (0.061) max	4.57 ±0.20 (0.180 ±0.008)			Aluminum	DC to 400 Hz	HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.10% to 30 kG; ±0.15% 30 to 35 kG	±0.13 G/°C	–0.005%/°C	
HMMT-6J04-VF	Yes	101.6 ±3.2 (4 ±0.125)											
HMMT-6J08-VF	No	203.2 ±3.2 (8 ±0.125)											
HMMT-6J12-VF	No	305 ±6.4 (12 ±0.25)											
HMMT-6J18-VF	No	457 ±6.4 (18 ±0.25)											
HMNT-4E02-VF	No	50.8 ±3.2 (2 ±0.125)	1.14 (0.045) max	3.81 ±0.13 (0.150 ±0.005)			Fiberglass epoxy	DC to 800 Hz					
HMNT-4E04-VF	Yes	101.6 ±3.2 (4 ±0.125)											
for Models 460, 450, and 421													
MMT-6J02-VH	No	50.8 ±3.2 (2 ±0.125)	1.55 (0.061) max	4.57 ±0.20 (0.180 ±0.008)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Aluminum	DC and 10 Hz to 100 Hz	HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.25% to 30 kG	±0.09 G/°C	450/460: ±0.015%/°C 421: -0.04%/°C	Yes
MMT-6J04-VH		101.6 ±3.2 (4 ±0.125)											
MMT-6J08-VH		203.2 ±3.2 (8 ±0.125)											
MMT-6J12-VH		305 ±6.4 (12 ±0.25)											
MMT-6J18-VH		457 ±6.4 (18 ±0.25)											
MNT-4E02-VH		50.8 ±3.2 (2 ±0.125)	1.14 (0.045) max	3.81 ±0.13 (0.150 ±0.005)			Fiberglass epoxy	DC and 10 Hz to 400 Hz					
MNT-4E04-VH		101.6 ±3.2 (4 ±0.125)											
MMT-6J02-VG		50.8 ±3.2 (2 ±0.125)	1.55 (0.061) max	4.57 ±0.20 (0.180 ±0.008)			Aluminum	DC	HST-2 300 G, 3 kG, 30 kG	±0.15% to 30 kG	±0.13 G/°C	-0.005%/°C	No
MMT-6J04-VG		101.6 ±3.2 (4 ±0.125)											
MMT-6J08-VG		203.2 ±3.2 (8 ±0.125)											
MMT-6J12-VG		305 ±6.4 (12 ±0.25)											
MMT-6J18-VG		457 ±6.4 (18 ±0.25)											
MNT-4E02-VG		50.8 ±3.2 (2 ±0.125)	1.14 (0.045) max	3.81 ±0.13 (0.150 ±0.005)			Fiberglass epoxy	DC and 10 Hz to 400 Hz					
MNT-4E04-VG		101.6±3.2 (4±0.125)											

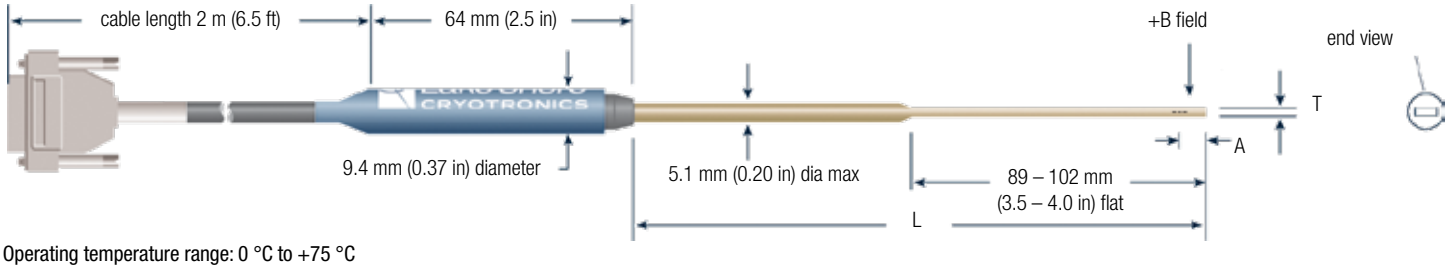
Brass stem transverse probes (short)



Operating temperature range: 0 °C to +75 °C

RoHS	L mm (in)	T mm (in)	Width mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425												
HMMTB-6J02-VR	No	50.8 ±3.2 (2 ±0.125)	1.78 (0.070) max	5.59 (0.22)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Brass	DC	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.20% to 30 kG and ±0.25% 30 to 35 kG	±0.09 G/°C	455/475: ±0.015%/°C 425: -0.04%/°C	Yes
HMMTB-6J02-VF								HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.10% to 30 kG and ±0.15% 30 to 35 kG	±0.13 G/°C	-0.005%/°C	
for Models 460, 450, and 421												
MMTB-6J02-VH	No	50.8 ±3.2 (2 ±0.125)	1.78 (0.070) max	5.59 (0.22)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Brass	DC	HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.25% to 30 kG	±0.09 G/°C	450/460: ±0.015%/°C 421:-0.04%/°C	Yes
MMTB-6J02-VG		50.8 ±3.2 (2 ±0.125)						HST-2 300 G, 3 kG, 30 kG	±0.15% to 30 kG	±0.13 G/°C	-0.005%/°C	No

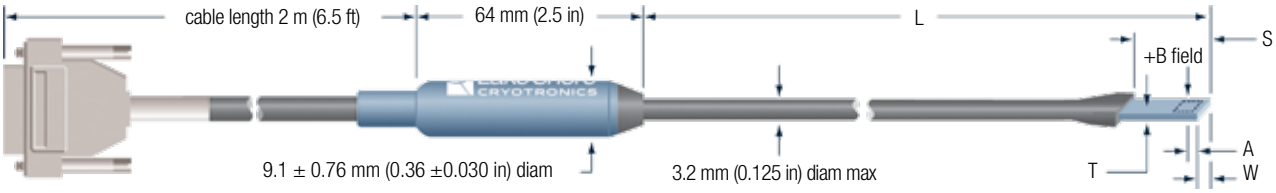
Brass stem transverse probes (long)



Operating temperature range: 0 °C to +75 °C

RoHS	L mm (in)	T mm (in)	Width mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425												
HMMTB-6J04-VR	No	101.6 ±3.2 (4 ±0.125)	1.78 (0.070) max	5.58 (0.22)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Brass	DC	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.20% to 30 kG and ±0.25% 30 to 35 kG	±0.09 G/°C	455/475: ±0.015%/°C 425: -0.04%/°C	Yes
HMMTB-6J08-VR		203.2 ±3.2 (8 ±0.125)										
HMMTB-6J04-VF		101.6 ±3.2 (4 ±0.125)						HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.10% to 30 kG and ±0.15% 30 to 35 kG	±0.13 G/°C	-0.005%/°C	
HMMTB-6J08-VF		203.2 ±3.2 (8 ±0.125)										
for Models 460, 450, and 421												
MMTB-6J04-VH	No	101.6 ±3.2 (4 ±0.125)	1.78 (0.070) max	5.58 (0.22)	3.81 ±1.27 (0.150 ±0.050)	Approx 1.02 dia (0.040 dia)	Brass	DC	HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.25% to 30 kG	±0.09 G/°C	450/460: ±0.015%/°C 421: -0.04%/°C	Yes
MMTB-6J08-VH		203.2 ±3.2 (8 ±0.125)										
MMTB-6J04-VG		101.6 ±3.2 (4 ±0.125)						HST-2 300 G, 3 kG, 30 kG	±0.15% to 30 kG	±0.13 G/°C	-0.005%/°C	No
MMTB-6J08-VG		203.2 ±3.2 (8 ±0.125)										

Flexible transverse probes

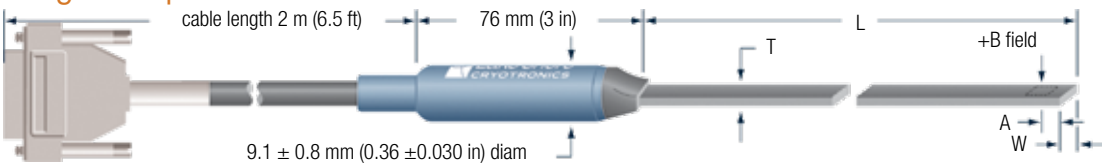


Operating temperature range: 0 °C to +75 °C

	RoHS	L mm (in)	W mm (in)	T mm (in)	A mm (in)	S mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425														
HMFT-3E03-VR	No	76.2 +12.7/-3.18 (3 +0.5/-0.125)	3.42 (0.135) max	0.64 (0.025) max	3.18 ±0.13 (0.125 ±0.005)	9.52 (0.375)	Approx 1.02 dia (0.040 dia)	Flexible plastic tubing	DC to 20 kHz	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.20% to 30 kG; ±0.25% 30 to 35 kG	±0.09 G/°C	±0.015%/°C	Yes
HMFT-3E03-VF									DC to 800 Hz	HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.10% to 30 kG; ±0.15% 30 to 35 kG	±0.13 G/°C	–0.005%/°C	
HMFT-2903-VJ			2.16 (0.085) max	0.51 (0.020) max	1.65 ±0.13 (0.065 ±0.005)		Approx 0.76 dia (0.030 dia)		DC to 20 kHz	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	±0.50% to 35 kG	±0.09 G/°C	±0.015%/°C	
HMFT-2903-VH									DC to 800 Hz	HST-4 35 G, 350 G, 3.5 kG, 35 kG	±0.25% to 35 kG	±0.13 G/°C	–0.005%/°C	
for Models 460, 450, and 421														
MFT-3E03-VH	No	76.2 +12.7/-3.18 (3 +0.5/-0.125)	3.42 (0.135) max	0.64 (0.025) max	3.18 ±0.13 (0.125 ±0.005)	9.52 (0.375)	Approx 1.02 dia (0.040 dia)	Flexible plastic tubing	DC and 10 Hz to 400 Hz	HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.25% to 30 kG	±0.09 G/°C	450/460: ±0.015%/°C 421: -0.04%/°C	Yes
MFT-3E03-VG										HST-2 300 G, 3 kG, 30 kG	±0.15% to 30 kG	±0.13 G/°C	-0.005%/°C	No
MFT-2903-VJ			2.16 (0.085) max	0.51 (0.020) max	1.65 ±0.13 (0.065 ±0.005)		Approx 0.76 dia (0.030 dia)			HSE-1 30 G, 300 G, 3 kG, 30 kG	±0.50% to 30 kG	±0.09 G/°C	450/460: ±0.015%/°C 421: -0.04%/°C	Yes
MFT-2903-VH										HST-2 300 G, 3 kG, 30 kG	±0.25% to 30 kG	±0.13 G/°C	-0.005%/°C	No

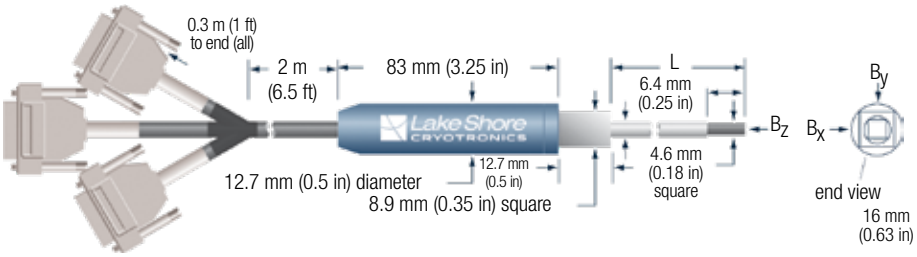
Note: 15 in flexible probes are no longer available. Please contact your local sales representative to discuss alternatives if you require a similar product for your application.

Tangential probes



	RoHS	L mm (in)	T mm (in)	W mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Models 475, 455, and 425														
HMNTAN-DQ02-TH	No	38.1 ±1.52 (1.5 ±0.060)	2.8 (0.11) max	6.6 (0.26) max	0.76 ±0.18 (0.030 ±0.005)	Approx 0.51 dia (0.020 dia)	Plastic	DC to 400 Hz	HSE 3.5 G, 35 G, 350 G, 3.5 kG, 35 kG	0.25% to 20 kG	0 °C to +75 °C	±0.1 G/°C	455/475: ±0.02%/°C 425: -0.05%/°C	Yes
for Models 460, 450, and 421														
MNTAN-DQ02-TH	No	38.1 ±1.52 (1.5 ±0.060)	2.8 (0.11) max	6.6 (0.26) max	0.76 ±0.18 (0.030 ±0.005)	Approx 0.51 dia (0.020 dia)	Plastic	DC and 10 Hz to 400 Hz	HSE-1 30 G, 300 G, 3 kG, 30 kG	0.25% to 20 kG	0 °C to +75 °C	±0.1 G/°C	-0.05%/°C	No

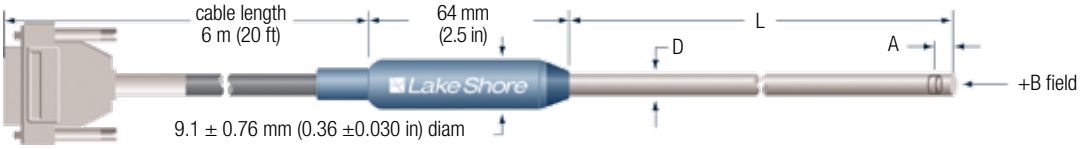
3-axis probes



	L mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) of sensitivity	Contains temp sensor
for Model 460 ONLY									
MMZ-2502-UH	54±3.2 (2.125±0.125)	Aluminum	DC and 10 Hz to 400 Hz	HSE-1 30 G, 300 G, 3 kG, 30 kG	0.25% to 20 kG; 0.5% from 20 kG to 30 kG	10 °C to 40 °C	±0.09 G/°C	±0.015%/°C	Yes
MMZ-2504-UH	104.8±3.2 (4.125±0.125)								
MMZ-2508-UH	206.4±3.2 (8.125±0.125)								
MMZ-2512-UH	308±3.2 (12.125±0.125)								
MMZ-2518-UH	460±6.4 (18.125±0.25)								
MMZ-2536-UH	918±6.4 (36.125±0.25)								
MMZ-2560-UH	1534±6.4 (60.375±0.5)								

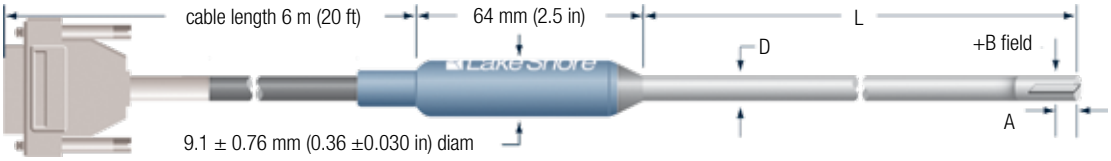
NOTE: The sensors at the ends of the multi-axis probes are quite fragile and susceptible to damage. Lake Shore offers an assortment of brass covers for probe protection during use with DC fields. For more information, contact Lake Shore.

Axial probes for cryogenic applications



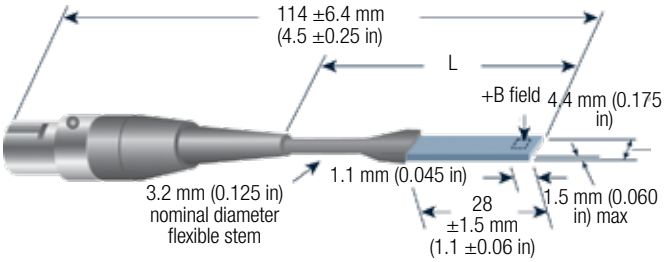
	RoHS	L mm (in)	D mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp error (approx) calibration		Contains temp sensor
for Models 475, 455, and 425												300 K	ref	
HMCA-2560-WN	No	1524 ±12.7 (60 ±0.50)	6.35 dia ±0.15 (0.25 dia ±0.006)	0.64 ±0.13 (0.025 ±0.005)	Approx 0.76 dia (0.030 dia)	Stainless steel	DC	HST-3 35 G, 350 G, 3.5 kG, 35 kG, 350 kG	±2% to 100 kG	1.5 K to 350 K	±0.13 G/°C	200 K	+0.05%	No
												100 K	-0.04%	
												80 K	-0.09%	
for Models 460, 450, and 421												20 K	-0.40%	
MCA-2560-WN	No	1524 ±12.7 (60 ±0.50)	6.35 dia ±0.15 (0.25 dia ±0.006)	0.64 ±0.13 (0.025 ±0.005)	Approx 0.76 dia (0.030 dia)	Stainless steel	DC	HST-1 300 G, 3 kG, 30 kG, 300 kG	±2% to 100 kG	1.5 K to 350 K	±0.13 G/°C	4 K	-0.70%	No
												1.5 K	-1.05%	

Transverse probes for cryogenic applications



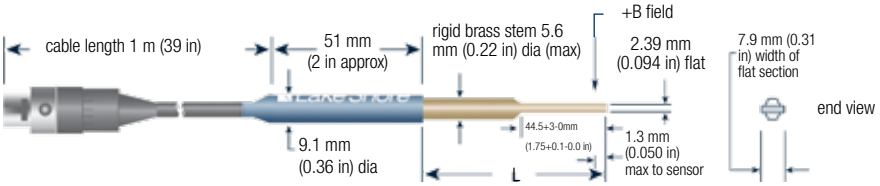
	RoHS	L mm (in)	D mm (in)	A mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Corrected accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp error (approx) calibration		Contains temp sensor
for Models 475, 455, and 425												300 K	ref	
HMCT-3160-WN	No	1549 ±25.4 (61 ±1)	6.35 dia ±0.25 (0.25 dia ±0.010)	5.33 ±1.27 (0.210 ±0.050)	Approx 1 dia (0.040 dia)	Stainless steel	DC to 800 Hz	HST-3 35 G, 350 G, 3.5 kG, 35 kG, 350 kG	±2% to 100 kG	1.5 K to 350 K	±0.13 G/°C	200 K	+0.05%	No
												100 K	-0.04%	
												80 K	-0.09%	
for Models 460, 450, and 421												20 K	-0.40%	
MCT-3160-WN	No	1549 ±25.4 (61 ±1)	6.35 dia ±0.25 (0.25 dia ±0.010)	5.33 ±1.27 (0.210 ±0.050)	Approx 1 dia (0.040 dia)	Stainless steel	DC and 10 Hz to 400 Hz	HST-1 300 G, 3 kG, 30 kG, 300 kG	±2% to 100 kG	1.5 K to 350 K	±0.13 G/°C	4 K	-0.70%	No
												1.5 K	-1.05%	

Transverse probes for Model 410 gaussmeter



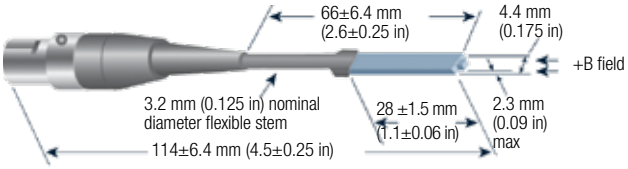
	L mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) calibration	Contains temp sensor
MST-410	66 ±6.4 (2.6 ±0.25)	0.13 x 0.13 (0.005 × 0.005)	Flexible plastic tubing	DC to 10 kHz	200 G, 2 kG, 20 kG	2%	-10 °C to +75 °C	0.1 G/°C	-0.06%/°C	No

Brass stem transverse probes for Model 410 gaussmeter



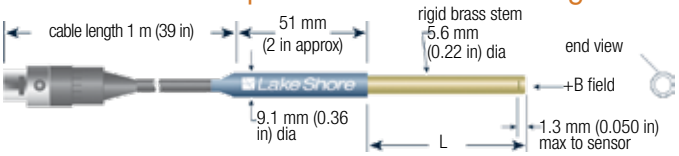
	L mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) calibration	Contains temp sensor
MST-9P02-410	50.8 ±3.2 (2 ±0.125)	0.13 x 0.13 (0.005 × 0.005)	Brass	DC	200 G, 2 kG, 20 kG	2%	-10 °C to +75 °C	0.1 G/°C	-0.06%/°C	No
MST-9P04-410	101.6 ±3.2 (4 ±0.125)									

Axial probes for Model 410 gaussmeter



	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Accuracy (% rdg)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) calibration	Contains temp sensor
MSA-410	0.13 x 0.13 (0.005 × 0.005)	Flexible plastic tubing	DC to 10 kHz	200 G, 2 kG, 20 kG	2%	-10 °C to +75 °C	0.1 G/°C	-0.06%/°C	No

Brass stem axial probes for Model 410 gaussmeter

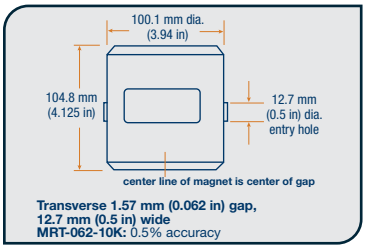


	L mm (in)	Active area mm (in)	Stem material	Frequency range	Usable full-scale ranges	Accuracy (% rdg at 25 °C)	Operating temp range	Temp coefficient (max) zero	Temp coefficient (max) calibration	Contains temp sensor
MSA-2202-410	50.8 ±3.2 (2 ±0.125)	0.13 x 0.13 (0.005 × 0.005)	Brass	DC	200 G, 2 kG, 20 kG	2%	-10 °C to +75 °C	0.1 G/°C	-0.06%/°C	No
MSA-2204-410	101.6 ±3.2 (4 ±0.125)									

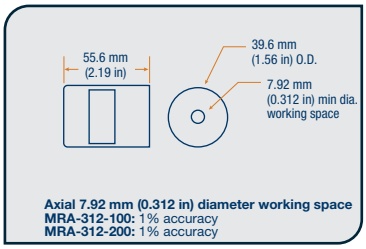
Magnetics accessories

Reference magnets

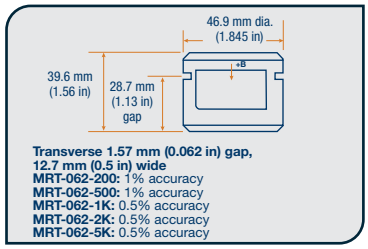
High quality reference magnets are available in transverse (flat) and axial (round) configurations—also see Helmholtz coil low field references on page 57.



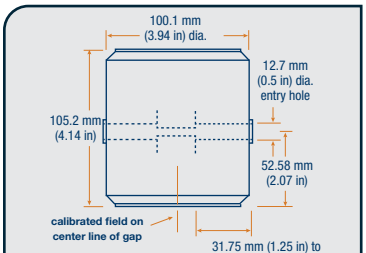
Transverse 1.57 mm (0.062 in) gap, 12.7 mm (0.5 in) wide
MRT-062-10K: 0.5% accuracy



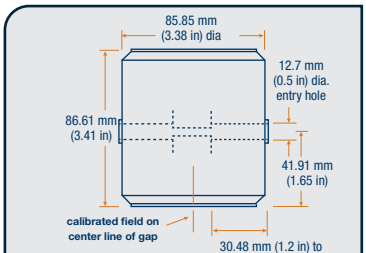
Axial 7.92 mm (0.312 in) diameter working space
MRA-312-100: 1% accuracy
MRA-312-200: 1% accuracy



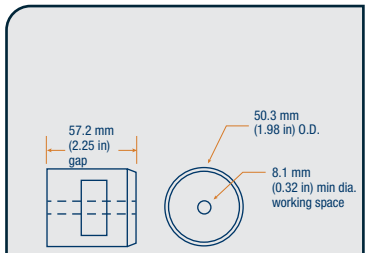
Transverse 1.57 mm (0.062 in) gap, 12.7 mm (0.5 in) wide
MRT-062-200: 1% accuracy
MRT-062-500: 1% accuracy
MRT-062-1K: 0.5% accuracy
MRT-062-2K: 0.5% accuracy
MRT-062-5K: 0.5% accuracy



MRT-343-1K: 1% accuracy
MRT-343-2K: 1% accuracy



MRT-343-50: 1% accuracy
MRT-343-100: 1% accuracy
MRT-343-200: 1% accuracy



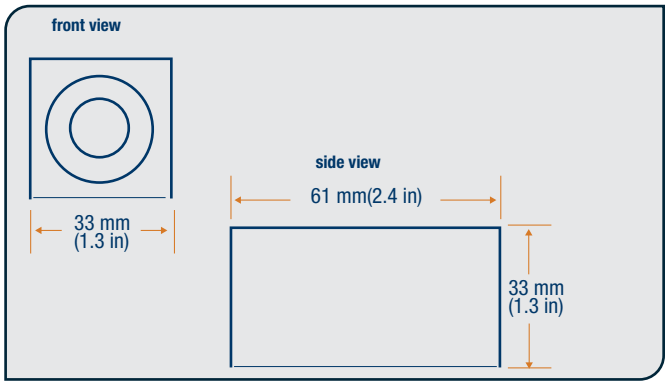
Axial 8.1 mm (0.32 in) diameter working space
MRA-312-2K: 1% accuracy
MRA-312-1K: 1% accuracy

Zero gauss chambers

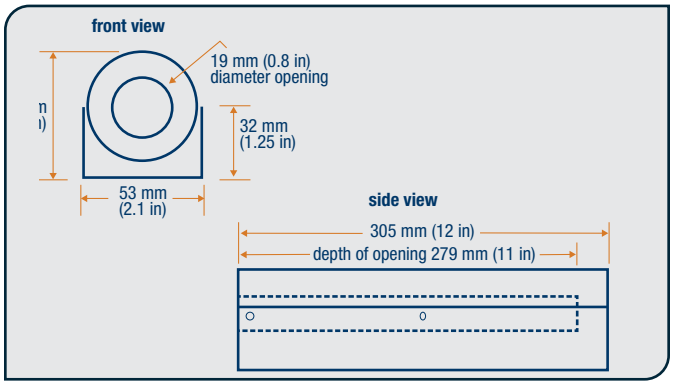
To obtain a null field reference, a zero gauss chamber must be used to shield the probe sensing area from external field.

	Size	Bore
4060 – Standard	33 mm × 33 mm × 61 mm (1.3 in × 1.3 in × 2.4 in)	13 mm diameter × 51 mm (0.5 in diameter × 2 in)
4065 – Large	58 mm × 53 mm × 305 mm (2.3 in × 2.1 in × 12 in)	19 mm diameter × 279 mm (0.75 in diameter × 11 in)

4060 Zero gauss chamber



4065 Zero gauss chamber



Hall probe stands

These moveable probe stands consist of a 30 mm (1.2 in) square post mounted on a 180 mm × 130 mm × 22.5 mm (7.1 × 5.1 × 0.9 in) thick base plate. A probe holder is integrated into the stand. The holder can be moved up or down and fixed at any angle and location along the post. Two standard models are available. Consult Lake Shore for other post heights.

Extension cables

To maintain probe accuracy, probes and extension cables for Models 460, 450, and 421 must be calibrated together at Lake Shore. When ordering an extension cable and more than one probe, it is necessary to specify with which probe the cable will be used. It should be noted that probes will exhibit their full accuracy specifications when used without an extension cable. Model 460 2- and 3-axis probes require 2- and 3-extension cables, respectively. Extension cables for Models 475 and 455 are field programmable, but can be ordered factory-calibrated.

Probe extension cables for Model 460, 450, and 421 gaussmeters

	Length
MPEC-10	3 m (10 ft)
MPEC-25	7.6 m (25 ft)
MPEC-50	15 m (50 ft)
MPEC-100	30 m (100 ft)

Probe extension cables for Model 475 and 455 gaussmeters

	Length
HMPEC-10	3 m (10 ft) calibrated
HMPEC-10-U	3 m (10 ft) uncalibrated
HMPEC-25	7.6 m (25 ft) calibrated
HMPEC-25-U	7.6 m (25 ft) uncalibrated
HMPEC-50	15 m (50 ft) calibrated
HMPEC-50-U	15 m (50 ft) uncalibrated
HMPEC-100	30 m (100 ft) calibrated
HMPEC-100-U	30 m (100 ft) uncalibrated

Ordering information

Part number	Description
Extension cables	
HMPEC-10	475/455 probe extension cable with EEPROM (10 ft), calibrated
HMPEC-10-U	475/455 probe extension cable with EEPROM (10 ft), uncalibrated
HMPEC-25	475/455 probe extension cable with EEPROM (25 ft), calibrated
HMPEC-25-U	475/455 probe extension cable with EEPROM (25 ft), uncalibrated
HMPEC-50	475/455 probe extension cable with EEPROM (50 ft), calibrated
HMPEC-50-U	475/455 probe extension cable with EEPROM (50 ft), uncalibrated
HMPEC-100	475/455 probe extension cable with EEPROM (100 ft), calibrated
HMPEC-100-U	475/455 probe extension cable with EEPROM (100 ft), uncalibrated
MPEC-10	460/450/421 calibrated probe extension cable (10 ft)
MPEC-25	460/450/421 calibrated probe extension cable (25 ft)
MPEC-50	460/450/421 calibrated probe extension cable (50 ft)
MPEC-100	460/450/421 calibrated probe extension cable (100 ft)
MPEC-410-10	410 universal probe extension cable (10 ft)
MPEC-410-3	410 universal probe extension cable (3 ft)
Hall probe stands	
4030-12	Hall probe stand, 12 in post, accepts 3/8 in dia. Hall probe handle
4030-24	Hall probe stand, 24 in post, accepts 3/8 in dia. Hall probe handle
Zero gauss chambers	
4060	Small zero gauss chamber
4065	Large zero gauss chamber
Reference magnets	
MRA-312-100	Axial reference magnet: 0.312 in inside diameter, 100 G, 1%
MRA-312-200	Axial reference magnet: 0.312 in inside diameter, 200 G, 1%
MRA-312-300	Axial reference magnet: 0.312 in inside diameter, 300 G, 1%
MRA-312-500	Axial reference magnet: 0.312 in inside diameter, 500 G, 1%
MRA-312-1K	Axial reference magnet: 0.312 in inside diameter, 1 kG, 1%
MRA-312-2K	Axial reference magnet: 0.312 in inside diameter, 2 kG, 1%
MRT-062-200	Transverse reference magnet: 0.062 in gap, 200 G, 1%
MRT-062-500	Transverse reference magnet: 0.062 in gap, 500 G, 1%
MRT-062-1K	Transverse reference magnet: 0.062 in gap, 1 kG, 0.5%
MRT-062-2K	Transverse reference magnet: 0.062 in gap, 2 kG, 0.5%
MRT-062-5K	Transverse reference magnet: 0.062 in gap, 5 kG, 0.5%
MRT-062-10K	Transverse reference magnet: 0.062 in gap, 10 kG, 0.5%
MRT-343-50	Transverse reference magnet: 0.343 in gap, 50 G, 1%
MRT-343-100	Transverse reference magnet: 0.343 in gap, 100 G, 1%
MRT-343-200	Transverse reference magnet: 0.343 in gap, 200 G, 1%
MRT-343-1K	Transverse reference magnet: 0.343 in gap, 1 kG, 1%
MRT-343-2K	Transverse reference magnet: 0.343 in gap, 2 kG, 1%

All specifications are subject to change without notice

InAs and GaAs Hall Sensors

Hall sensor theory

A Hall sensor is a solid state sensor which provides an output voltage proportional to magnetic flux density. As implied by its name, this device relies on the Hall effect. The Hall effect is the development of a voltage across a sheet of conductor when current is flowing and the conductor is placed in a magnetic field.

Electrons (the majority carrier most often used in practice) "drift" in the conductor when under the influence of an externally produced electric field. These moving electrons experience a force proportional and perpendicular to the product of their velocity and the magnetic field vector. This force causes the charging of the edges of the conductor, one side positive with respect to the other, resulting in an internally generated transverse electric field which exerts a force on the moving electrons equal and opposite to that caused by the magnetic-field-related Lorentz force. The resultant voltage potential across the width of the conductor is called the Hall voltage and can be measured by attaching two electrical contacts to the sides of the conductor.

The Hall voltage can be given by the expression:

$$V_H = \gamma_B B \sin\theta$$

where V_H = Hall voltage (mV)

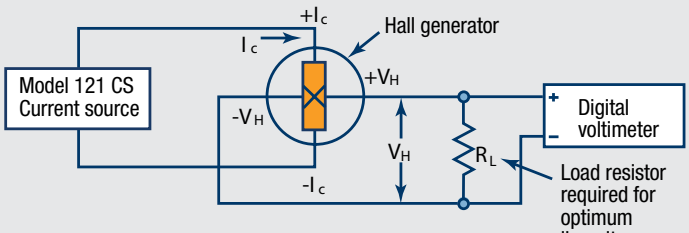
γ_B = Magnetic sensitivity (mV per kG, at a fixed current)

B = Magnetic field flux density (kG)

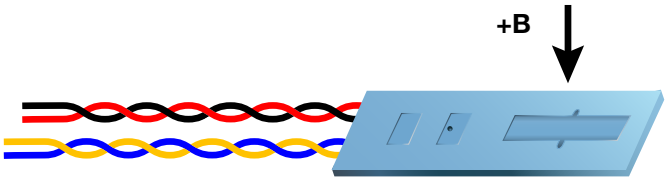
θ = Angle between magnetic flux vector and the plane of Hall sensor

As can be seen from the above formula, the Hall voltage varies with the angle of the sensed magnetic field, reaching a maximum when the field is perpendicular to the plane of the Hall sensor.

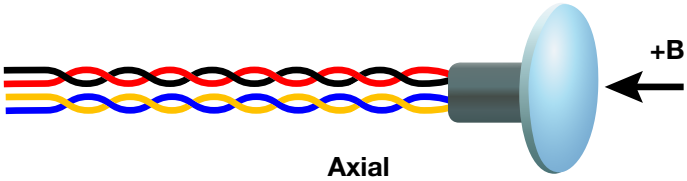
A typical Hall effect measurement scheme



CAUTION: These sensors are sensitive to electrostatic discharge (ESD). Use ESD precautionary procedures when handling, or making mechanical or electrical connections to these devices in order to avoid performance degradation or loss of functionality.



Transverse



Axial

Hall sensors come in axial and transverse configurations.

Transverse devices are generally thin and rectangular in shape. They are applied successfully in magnetic circuit gaps, surface measurements, and general open field measurements.

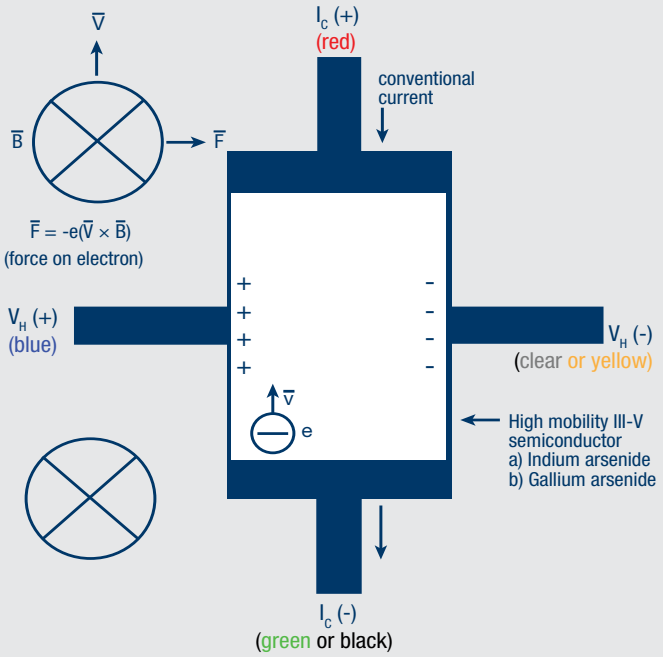
Axial sensors are mostly cylindrical in shape. Their applications include ring magnet center bore measurements, solenoids, surface field detection, and general field sensing. See the individual Hall sensor illustrations for physical dimensions.

Active area

The Hall sensor assembly contains the sheet of semiconductor material to which the four contacts are made. This entity is normally called a "Hall plate." The Hall plate is, in its simplest form, a rectangular shape of fixed length, width and thickness. Due to the shorting effect of the current supply contacts, most of the sensitivity to magnetic fields is contained in an area approximated by a circle, centered in the Hall plate, whose diameter is equal to the plate width. Thus, when the active area is given, the circle as described above is the common estimation.

Using a Hall sensor

A Hall sensor is a 4-lead device. The control current (I_C) leads are normally attached to a current source such as the Lake Shore Model 121. The Model 121 provides several fixed current values compatible with various Hall sensors.



Caution: Do not exceed the maximum continuous control current given in the specifications.

The Hall voltage leads may be connected directly to a readout instrument, such as a high impedance voltmeter, or can be attached to electronic circuitry for amplification or conditioning. Device signal levels will be in the range of microvolts to hundreds of millivolts.

The Hall sensor input is not isolated from its output. In fact, impedance levels on the order of the input resistance are all that generally exist between the two ports. To prevent erroneous current paths, which can cause large error voltages, the current supply must be isolated from the output display or the down stream electronics.

Ordering information

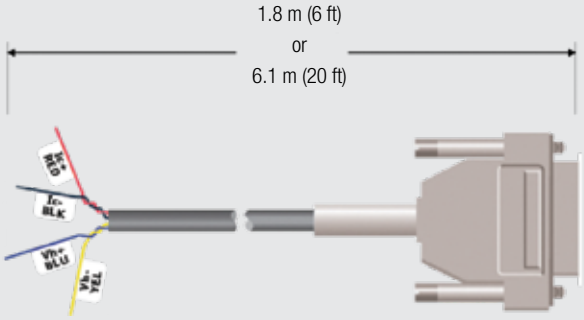
Part number	Description
HMCBL-6	1.8 m (6 ft) long cable for Model 475 and 455
HMCBL-20	6.1 m (20 ft) long cable for Model 475 and 455

All specifications are subject to change without notice

Attaching discrete Hall sensors to Lake Shore gaussmeters

Lake Shore provides cable assemblies containing the electronic memory (EEPROM) to interface a Hall sensor to a gaussmeter. This allows users to assemble a Hall sensor into a difficult to access area prior to gaussmeter attachment. The figure below shows the general cable configuration. While convenient, this method provides less than optimum performance. Because of the intricacies involved with proper calibration, the user is responsible for the measurement accuracy. A probe fully calibrated by Lake Shore is always suggested. Special probe mechanical configurations are also available.

Certain Hall sensor sensitivity constraints are applicable:



Sensitivities between 5.5 and 10.5 mV/kG at 100 mA control current.

Sensitivities between 0.55 and 1.05 mV/kGat 100 mA control current.

For the Model 475, 455, and 425 gaussmeters

2 m (6 ft) and 6.1 m (20 ft) cables are available.

The 475, 455, and 425 gaussmeters offer the convenience of front panel programming. No external computer is required. The Hall sensor serial number and single-point sensitivity are directly entered using the keypad.

For the Model 460, 450, and 421 gaussmeters

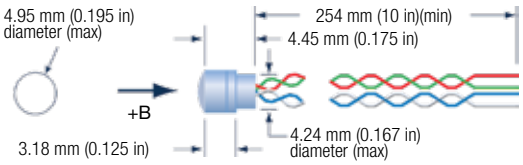
Connection of discrete Hall sensors to these instruments is no longer supported. Contact Service for ongoing support of these instruments.

Axial Hall sensors

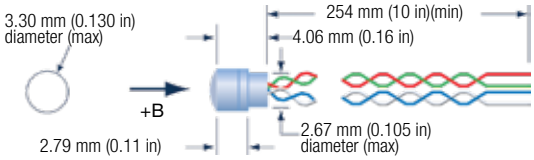
Lead colors:

Red	$+I_C$
Green	$-I_C$
Blue	$+V_H$
Clear	$-V_H$

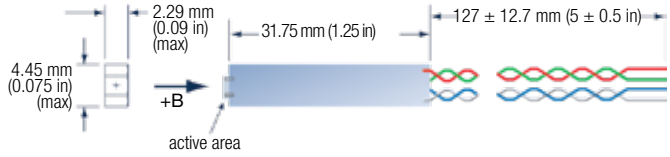
HGA-2303



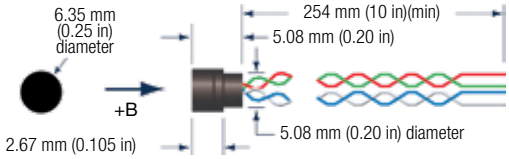
HGA-2302



HGA-2010



HGA-3010*, HGA-3030*



*The active area is symmetrical with the center line of the assembly and is located approximately 0.030 in behind the front surface of the assembly

	HGA-2010†	HGA-2302	HGA-2303	HGA-3010	HGA-3030
Description	General purpose axial; high sensitivity	General purpose axial; 3.30 mm (0.13 in) diameter	General purpose axial; 4.95 mm (0.195 in) diameter	Instrumentation quality axial; low temperature coefficient; phenolic package	Instrumentation quality axial; phenolic package
RoHS	No	No	No	Yes	Yes
Active area (approx)	0.127 × 0.127 mm (0.005 in × 0.005 in) square	0.51 × 1.02 mm (0.020 × 0.040 in) rectangle	0.51 × 1.02 mm (0.020 × 0.040 in) rectangle	0.76 mm (0.030 in) diameter circle	0.76 mm (0.030 in) diameter circle
Input resistance (approx)	450 Ω to 900 Ω	2 Ω	2 Ω	1 Ω	2 Ω
Output resistance (approx)	550 Ω to 1350 Ω	2 Ω	2 Ω	1 Ω	2 Ω
Nominal control current (I_{CN})	1 mA	100 mA			
Maximum continuous current (non-heat sinked, 25 °C)	10 mA	150 mA	200 mA	300 mA	
Magnetic sensitivity†† (I_C = nominal control current)	11 mV/kG to 28 mV/kG	5.5 mV/kG to 11.0 mV/kG	5.5 mV/kG to 11.0 mV/kG	0.55 mV/kG to 1.05 mV/kG	6.0 mV/kG to 10.0 mV/kG
Maximum linearity error (sensitivity vs. field, % rdg)	±1 (-10 kG to +10 kG) ±2 (-20 kG to +20 kG)	±1 (-10 kG to +10 kG)		±1 (-30 kG to +30 kG) ±1.5 (-100 kG to +100 kG)	±0.30 (-10 kG to +10 kG) ±1.25 (-30 kG to +30 kG)
Zero field offset voltage (I_C = nominal control current)	±2.8 mV (max)	±100 µV (max)		±50 µV (max)	±75 µV (max)
Operating temperature range	-40 °C to +100 °C				
Temperature coefficient of magnetic sensitivity	-0.06%/°C (max)	-0.08%/°C (max)		-0.005%/°C (max)	-0.04%/°C (max)
Temperature coefficient of offset (I_C = nominal control current)	±6 µV/°C (approx)	±1 µV/°C (approx)		±0.4 µV/°C (approx)	±0.3 µV/°C (approx)
Temperature coefficient of resistance	+0.3%/°C (approx)	+0.18%/°C (approx)	+0.18%/°C (approx)	+0.15%/°C (approx)	+0.18%/°C (approx)
Leads	34 AWG copper with poly-nylon insulation	36 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation
Data	Single sensitivity value at I_C = 1 mA	Single sensitivity value at I_C = 100 mA	Single sensitivity value at I_C = 100 mA	Room temperature, 30 kG data supplied	

† Not compatible with Lake Shore gaussmeters

††Sensitivity nominal control current without a linearizing resistor. A linearizing resistor may be required to achieve specified linearity, resulting in slightly reduced sensitivity. See Chapter 4.3 of the Hall sensor manual for more details.

Ordering information

Part number	Description
HGA-2010	General purpose axial Hall sensor; plastic package
HGA-2302	General purpose axial Hall sensor; phenolic shoulder
HGA-2303	General purpose axial Hall sensor; phenolic shoulder
HGA-3010	Instrumentation quality axial Hall sensor; phenolic package
HGA-3030	Instrumentation quality axial Hall sensor; phenolic package

Accessories available

CAL-1X-DATA	1-axis Hall sensor recalibration with certificate and data

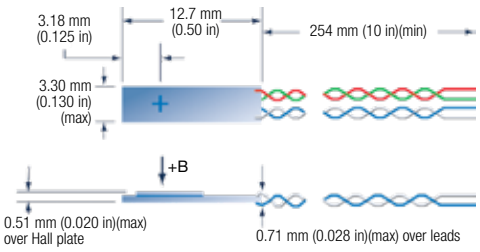
All specifications are subject to change without notice

Transverse Hall sensors

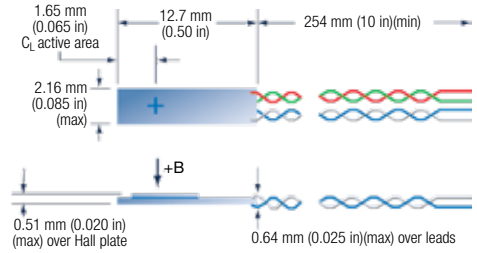
Lead Colors

Red	$+I_C$
Green	$-I_C$
Blue	$+V_H$
Clear	$-V_H$

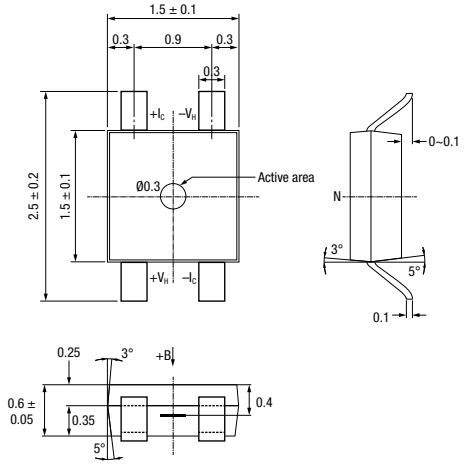
HGT-1010



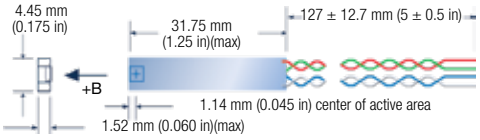
HGT-1020



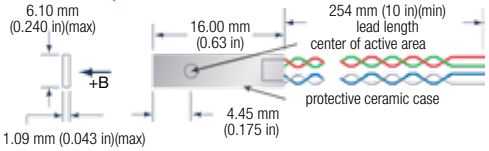
HGT-2101



HGT-2010



HGT-3010, HGT-3030



	HGT-1010	HGT-1020	HGT-2010*	HGT-2101*	HGT-3010	HGT-3030
Description	General purpose transverse		General purpose transverse; high sensitivity	Low cost; high sensitivity; surface mount	Instrumentation quality transverse; low temp coefficient; ceramic package	Instrumentation quality transverse ceramic package
RoHS	No	No	No	Yes	Yes	Yes
Active area (approx)	1.02 mm (0.040 in) diameter circle	0.76 mm (0.030 in) diameter circle	0.127 mm (0.005 in) square	0.3 mm (0.012 in) diameter circle	1.02 mm (0.040 in) diameter circle	
Input resistance (approx)	2 Ω		450 Ω to 900 Ω		1 Ω	2 Ω
Output resistance (approx)	2 Ω		550 Ω to 1350 Ω	600 Ω to 2000 Ω	1 Ω	2 Ω
Nominal control current (I_{CN})	100 mA		1 mA		100 mA	
Maximum continuous current (non-heat sinked, 25 °C)	250 mA	200 mA	10 mA		300 mA	
Magnetic sensitivity (I_C = nominal control current)	7.5 mV/kG to 12.5 mV/kG		11 mV/kG to 28 mV/kG		0.55 mV/kG to 1.05 mV/kG	6.0 mV/kG to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1.0% rdg (-10 to 10 kG)		±1% rdg (-10 to 10 kG) ±2% rdg (-20 to 20 kG)	±2.0% rdg (-10 to 10 kG)	±1% rdg (-30 to 30 kG) ±1.5% rdg (-100 to 100 kG)	±0.30% rdg (-10 to 10 kG) ±1.25% rdg (-30 to 30 kG)
Zero field offset voltage (I_C = nominal control current)	±100 µV (max)		±2.8 mV (max)		±50 µV (max)	±75 µV (max)
Operating temperature range	-40 °C to +100 °C			-40 °C to +125 °C	-40 °C to +100 °C	
Temperature coefficient of magnetic sensitivity	-0.08%/°C (max)		-0.06%/°C (max)		-0.005%/°C max	-0.04%/°C (max)
Temperature coefficient of offset (I_C = nominal control current)	±1 µV/°C (approx)		±6 µV/°C (approx)		±0.4 µV/°C (approx)	±0.3 µV/°C (approx)
Temperature coefficient of resistance	+0.18%/°C (approx)		+0.3%/°C (approx)		+0.15%/°C (approx)	+0.18%/°C (approx)
Leads	34 AWG copper with poly-nylon insulation	36 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation	NA	34 AWG copper with poly-nylon insulation	
Data	Single sensitivity value at I_C = 100 mA		Single sensitivity value at I_C = 1 mA	Uncalibrated	Room temperature, 30 kG data supplied	

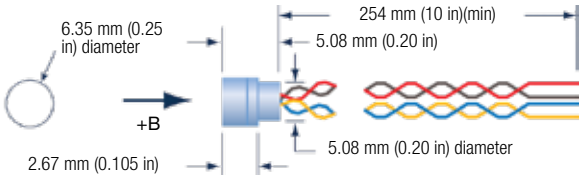
*Not compatible with Lake Shore gaussmeters

Cryogenic Hall sensors

Lead Colors:

Red	$+I_C$
Black	$-I_C$
Blue	$+V_H$
Yellow	$-V_H$

HGCA-3020



*The active area is symmetrical with the center line of the assembly and is located 0.9 mm (0.035 in) ± 0.3 mm (0.012 in) behind the front surface of the assembly

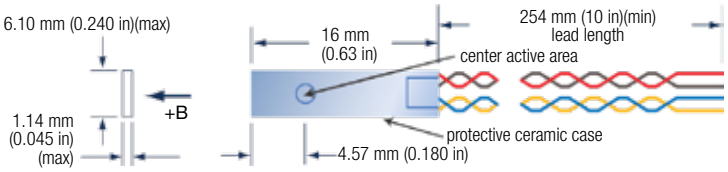
	HGCA-3020	HGCT-3020
Description	Cryogenic axial; phenolic package	Cryogenic transverse; ceramic package
RoHS	No	
Active area (approx)	0.76 mm (0.030 in) diameter circle	1.02 mm (0.040 in) diameter circle
Input resistance (approx)	1 Ω	
Output resistance (approx)	1 Ω	
Nominal control current (I_{CN})	100 mA	
Maximum continuous current (non-heat sinked, 25 °C)	300 mA	
Magnetic sensitivity (I_C = nominal control current)	0.55 mV/kG to 1.05 mV/kG	
Maximum linearity error (sensitivity vs field)	±1.0% rdg (-30 kG to +30 kG) ±2.0% rdg (-150 kG to +150 kG)	
Zero field offset voltage (I_C = nominal control current)	±200 µV (max)	
Operating temperature range	1.5 K to 375 K	
Mean temperature coefficient of magnetic sensitivity	see temperature error table below	
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/K (approx)	
Mean temperature coefficient of resistance	+0.6%/K (max)	
Leads	34 AWG copper with Teflon® insulation	
Data	Room temperature, 30 kG data supplied	

Temperature error table

The magnetic sensitivity generally increases as the temperature drops below 300 K. However, this trend reverses between 200 K and 100 K, and the sensitivity decreases at an increasing rate as the temperature cools. The sensitivity increase versus room temperature is as follows:

	Change in magnetic sensitivity (approximate)
Room temperature	Ref
200 K	+0.05%
100 K	–0.04%
80 K	–0.09%
20 K	–0.4%
4 K	–0.7%
1.5 K	–1.05%

HGCT-3020*



Ordering information

Axial Hall sensors

Part number	Description
HGA-2010	General purpose axial Hall sensor; plastic package
HGA-2302	General purpose axial Hall sensor; phenolic shoulder
HGA-2303	General purpose axial Hall sensor; phenolic shoulder
HGA-3010	Instrumentation quality axial Hall sensor; phenolic package
HGA-3030	Instrumentation quality axial Hall sensor; phenolic package

Transverse Hall sensors

Part number	Description
HGT-1010	General purpose transverse Hall sensor
HGT-1020	General purpose transverse Hall sensor
HGT-2010	General purpose transverse Hall sensor
HGT-2101	Surface mount transverse Hall sensor
HGT-3010	Instrumentation quality transverse Hall sensor; ceramic package
HGT-3030	Instrumentation quality transverse Hall sensor; ceramic package

Cryogenic Hall sensors

Part number	Description
HGCA-3020	Cryogenic axial Hall sensor; phenolic package
HGCT-3020	Cryogenic transverse Hall sensor; ceramic package

Accessories available

CAL-1X-DATA	1-axis Hall sensor recalibration with certificate and data

All specifications are subject to change without notice

Model 480 Fluxmeter RoHS

Model 480 features

- 5¾-digit DC resolution (1 part out of ±300,000)
- Automatic drift compensation
- Very fast peak capture
- AC frequency response to 50 kHz
- IEEE-488 and serial interfaces
- Storage of parameters for up to 10 existing coils
- CE mark certification

Product description

An advanced tool designed primarily for use in industrial and measurement systems settings, the Model 480 fluxmeter measures total flux from which B, flux density, and H, magnetic field strength, can be determined. The Model 480 is valuable for magnetizing, manual and automated magnet testing and sorting, and as the main component in BH loop or hysteresis measurement system applications. The Model 480 is compatible with most sensing coils and fixtures.

Manual magnet testing

A bright display and fast update rate make the Model 480 ideal for manual magnet sorting and testing. The instrument's low drift improves productivity with fewer adjustments. Remote terminals allow for foot pedal reading reset to keep hands on the work, not the instrument. Configurable alarms give an audible signal or relay closure to signify pass/fail.

Automated magnet testing

In automated testing, time is money. The Model 480 has many features to enhance throughput. The instrument has a fast update rate and fast settling time. It recovers quickly from reading reset to start a new reading cycle. The IEEE-488 and serial interfaces included with the Model 480 can be used to control most instrument functions. Relays and analog outputs can be used for automation without a computer interface.

Magnetizing

The magnetizing process places unique demands on all associated electronics. The Model 480 responds with a very fast peak capture that can keep up with the fastest magnetizing pulses. Both a positive and negative peak can be captured from the same pulse. The input of the Model 480 is protected against the high voltages present during magnetizing.

Materials analysis

High resolution and low drift define a fluxmeter's role in analytical measurement. The high resolution of the Model 480 is reinforced by a low noise floor. A configurable filter helps keep the readings quiet. Automatic and manual drift adjustment modes help optimize the integrators' low drift characteristics. The IEEE-488 and serial computer interfaces included with the 480 allow automated data taking.

AC magnetic fields

Sensing coils are sensitive to AC magnetic fields but many conventional integrating fluxmeters can not measure AC fields. The Model 480 has an AC mode that enables it to measure fields over a wide frequency range using simple sensing coils. Applications are limited to field volumes as large as or larger than the coil, but for some it is an inexpensive way to make low drift AC field measurements.

Drift adjustment

Adjusting or nulling the drift of an analog integrator wastes time—it can be the only unpleasant part of using an integrating fluxmeter. Lake Shore innovation brings some relief. The Model 480 has a built-in drift algorithm that continually adjusts drift when the instrument and coil are idle. It is ready when you are to make precision low-drift measurements. The adjustment algorithm has no effect during flux integration. Manual drift adjustment is also available.

Display

The Model 480 has a 2-line by 20-character vacuum fluorescent display. During normal operation, the display is used to report field readings and give results of other features such as max/min or relative. When setting instrument parameters, the display gives the operator meaningful prompts and feedback to simplify operation. The operator can also control display brightness.

Following are three examples of the various display configurations:

Normal reading—the default mode with the display of the live DC flux reading

DC positive and negative peak on—the display shows both the positive and negative DC peak readings

Alarm on—the alarm gives an audible and visual indication of when the flux value is selectively outside or inside a user-specified range

FH-series Helmholtz coils

Lake Shore coils can be used with the Model 480 fluxmeter as well as with other fluxmeters. When used with a Model 480 fluxmeter, calibration and set up data are automatically loaded into the instrument. These probes and coils are accurately calibrated, using field standards maintained at Lake Shore. Most standards are traceable to physical standards such as a coil or probe of carefully controlled dimensions, or in some cases, to proton resonance. The coil constants are measured on the basis of the field generated by a current through the coil.

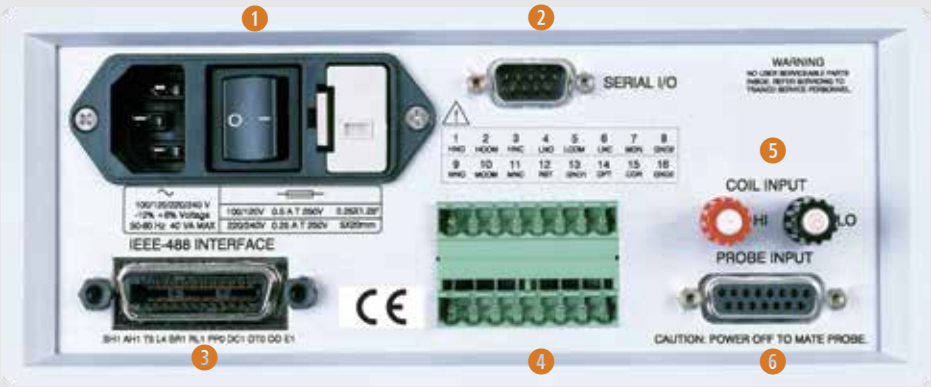
See pages 56, 57, and 58 for more information about available Helmholtz and search coils.

Helmholtz and search coils

Coils and probes wound by the user or from other manufacturers can be easily used with the Model 480. The Model 480 allows the user to save parameters for up to 10 existing coils/probes and quickly switch between them. Lake Shore also offers several sensing coils and probe assemblies for use with the Model 480 that have several conveniences. They are factory calibrated for accuracy and interchangeability. Calibration data is loaded into memory in the probe connector so it does not have to be entered by the user. Special coil assemblies are also available and can be designed to meet customer specifications.

Model 480 rear panel

1. Line input assembly
2. Serial I/O interface
3. IEEE-488 interface
4. Terminal block (for relays and analog signals)*
5. Coil input for user coils
6. Probe input for Lake Shore probes



* The Model 480 terminal block has connections for external reset. With this feature. a foot pedal or programmable logic controller (PLC) can be used to start a new measurement cycle. The external reset is TTL-compatible and a logic low will activate a reset. The signal is internally pulled up to allow operation with a simple switch closure between pins 12 and 13.

Model 480 specifications

Measurement

Number of inputs: 1
Input type: 2-lead, ground referenced
Input resistance: 100 kΩ or 10 kΩ
Maximum operating input voltage: 60 V
Absolute maximum input voltage: 100 V—**WARNING**—voltages between 60 V and 100 V will not damage the instrument but could result in personal injury or damage to other instruments
Update rate: 5 rdg/s display; 30 rdg/s IEEE-488; 30 rdg/s serial

DC

DC resolution: To 5¾ digits
DC integrator capacitance: 1 µF nominal

DC input resistance	100 kΩ	100 kΩ	10 kΩ	10 kΩ
DC ranges	300 mVs	30 mVs	30 mVs	3 mVs
DC resolution	0.001 mVs	0.0005 mVs	0.0005 mVs	0.0005 mVs

DC accuracy: Offset: ±10 µVs ±DC integrator drift; gain: ±0.25% of reading (<10 Vs/s maximum rate of change)
DC minimum dΦ/dt: 20 µVs/min
DC maximum dΦ/dt: 60 Vs/s
DC integrator drift: ±1 µVs/min, 0.0004% full scale/min on 300 mVs range (100 kΩ input resistance constant temperature environment)

DC peak

DC peak resolution: 4¾ digits
DC peak integrator capacitance: 1 µF nominal

DC peak input resistance	100 kΩ	100 kΩ	10 kΩ	10 kΩ
DC peak ranges	300 mVs	30 mVs	30 mVs	3 mVs
DC peak resolution	0.01 mVs	0.001 mVs	0.001 mVs	0.001 mVs
DC peak minimum reading	0.05 mVs	0.005 mVs	0.005 mVs	0.005 mVs

DC peak accuracy: Offset: ±100 µVs ±DC integrator drift; gain: ±5% of reading (<10 Vs/s maximum rate of change)
DC peak maximum dΦ/dt: 60 Vs/s
DC peak update rate: Reduces update rate to ¼ normal

AC

AC resolution: 4¾ digits (reduced to 3¾ digits on the 30 µVs range)
AC integrator capacitance: 0.1 µF nominal

AC input resistance	100 kΩ	100 kΩ	100 kΩ	100 kΩ
AC ranges	30 mVs	3 mVs	300 µVs	30 µVs
AC resolution	0.001 mVs	0.0001 mVs	0.01 µVs	0.01 µVs
AC minimum reading	3.000 mVs	0.3000 mVs	30.00 µVs	3.00 µVs

AC frequency response: 2 Hz to 50 kHz
AC accuracy: ±1% rdg ±10 µVs (10 Hz to 10 kHz sinusoidal); ±5% rdg ±10 µVs (2 Hz to 50 kHz sinusoidal)
AC integrator drift: NA

AC peak

AC peak resolution: 3¾ digits
AC peak integrator capacitance: 0.1 µF nominal

AC input resistance:	100 kΩ	100 kΩ	100 kΩ
AC peak ranges:	30 mVs	3 mVs	300 µVs
AC peak resolution:	0.01 mVs	0.001 mVs	1 µVs
AC minimum reading:	0.01 mVs	0.001 mVs	5 µVs

AC peak accuracy: ±5% rdg ±10 µVs (10 Hz to 10 kHz sinusoidal); ±10% rdg ±10 µVs (2 Hz to 50 kHz sinusoidal)
AC peak update rate: Reduces update rate to ¼ normal

Front panel

Display type: 2-line × 20-character vacuum fluorescent display
Display resolution: To ±5¾ digits
Display update rate: 5 rdg/s
Display units: Vs, MxN, WbN, VsΦ, MxΦ, WbΦ, G, T, Wbcm, A, %
Units multipliers: p, n, µ, m, k, M, G
Annunciators: AC—AC input signal, DC—DC input signal, ∧ ∨—positive and negative peaks, R—remote operation, ♪—alarm on
Keypad: 21 full-travel keys

Interfaces

IEEE-488.2 capabilities: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Serial interface: RS-232C electrical, DA-9 connector, 9600 baud
External reset type: Contact closure

Alarms

Number: 2
Settings: High and low setpoint, Inside/Outside, Audible
Actuators: Display annunciator, beeper, relays

Relays

Number: 3
Contacts: Normally open (NO), normally closed (NC), and common (C)
Contact rating: 30 VDC at 2 A
Operation: Follow high, low alarms with third relay indicating no alarm state—can be operated manually
Connector: Detachable terminal block

Monitor analog output

Scale: ±3 V = ±full scale on Vs range
Accuracy: ±1% of reading ±10 mV, (DC to 10 kHz); ±5% of reading ±10 mV, (10 kHz to 50 kHz)
Minimum load resistance: 1 kΩ
Connector: Detachable terminal block

Corrected analog output

Scale: User selected
Range: ±10 V
Resolution: 0.3 mV
Accuracy: ±2.5 mV
Minimum load resistance: 1 kΩ
Connector: Detachable terminal block

General

Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C with reduced accuracy
Power requirement: 100, 120, 220, 240 VAC, +5% -10%, 50 or 60 Hz, 20 VA
Size: 216 mm W × 89 mm H × 318 mm D (8.5 in × 3.5 in × 12.5 in), half rack
Weight: 3 kg (6.6 lb)
Approval: CE mark, RoHS

Ordering information

Part number	Description
480	Model 480 fluxmeter

Please indicate your power/cord configuration:

1	100 V—U.S. cord (NEMA 5-15)
2	120 V—U.S. cord (NEMA 5-15)
3	220 V—Euro cord (CEE 717)
4	240 V—Euro cord (CEE 717)
5	240 V—U.K. cord (BS 1363)
6	240 V—Swiss cord (SEV 1011)
7	220 V—China cord (GB 1002)

Accessories included

106-739	Two 8-pin terminal block mating connectors
119-028	Model 480 user manual

Accessories available

4005	1 m (3.3 ft) long IEEE-488 (GPIB) computer interface cable assembly—includes extender required for simultaneous use of IEEE cable and auxiliary terminal block
CAL-480-CERT	Instrument recalibration with certificate
CAL-480-DATA	Instrument recalibration with certificate and data
CAL-NEW-DATA	Calibration data for a new instrument
RM-1/2	Rack mount kit for mounting one Model 480 in 483 mm (19 in) rack
RM-2	Rack mount hit for mounting two Model 480s in 483 mm (19 in) rack

Coils—see pages 56, 57, and 58 for more information

FNT-6R04-100	100 cm² search coil
FNT-5P04-30	30 cm² search coil
FH-2.5	Helmholtz coil, 64 mm (2.5 in) ID
FH-6	Helmholtz coil, 152 mm (6 in) ID
FH-12	Helmholtz coil, 305 mm (12 in) ID
FCBL-6	User programmable cable with PROM, 1.5 m (5 ft) long

All specifications are subject to change without notice

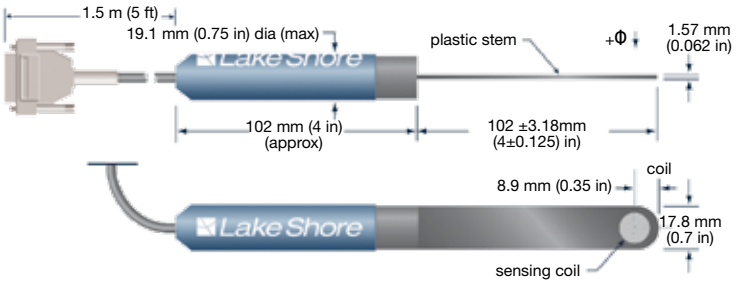
Search coils

(for use with the Model 480 fluxmeter only)

The 100 cm² field probe is the most commonly used search coil, while the 30 cm² field probe is useful for measurements in narrow gaps or where field gradients dictate the use of a smaller coil diameter.

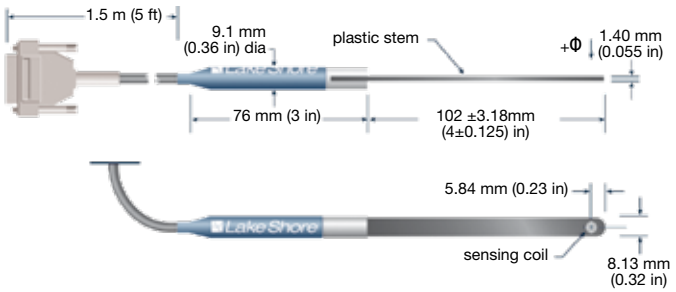
	FNT-6R04-100				FNT-5P04-30			
Calibration accuracy	0.25%				0.35%			
Area-turns (approx)	100 cm²				30 cm²			
Coil resistance (approx)	6.5 Ω				110 Ω			
Average coil diameter	10.4 mm				3.9 mm			
Operating temperature range	0 °C to 60 °C							
RoHS	Yes				No			
Input resistance (fluxmeter)	10 kΩ		100 kΩ		10 kΩ		100 kΩ	
DC ranges	Φ	B	Φ	B	Φ	B	Φ	B
	30 mV·s 3 mV·s	3 T 300 mT	300 mV·s 30 mV·s	30 T 3 T	30 mV·s 3 mV·s	10 T 1 T	300 mV·s 30 mV·s	100 T 10 T
Additional AC ranges	300 µV·s 30 µV·s 3 µV·s	30 mT 3 mT 300 µT	3 mV·s 300 µV·s 30 µV·s	300 mT 30 mT 3 mT	300 µV·s 30 µV·s 3 µV·s	100 mT 10 mT 1 mT	3 mV·s 300 µV·s 30 µV·s	1 T 100 mT 10 mT

FNT-6R04-100



NOTE: +Φ is designated as that flux passing through the coil, into the side with the Lake Shore logo on the probe handle

FNT-5P04-30



NOTE: +Φ is designated as that flux passing through the coil, into the side with the Lake Shore logo on the probe handle

Ordering information

Part number	Description
FNT-5P04-30	Field probe: 30 cm²
FNT-6R04-100	Field probe: 100 cm²

All specifications are subject to change without notice

Helmholtz Coils

Field standards

- Field accuracy of 0.75%
- Field uniformity of 0.5%*
- Standard field coil (field generation)
- Maximum field strengths from ≈26 G to ≈60 G
- Single axis configuration with 2.5 in, 6 in, and 12 in diameter coils

Magnet moment measurement

- Calibration accuracy of 0.5%
- Use with Model 480 fluxmeter only
- Inspection and research of magnets (measure moment)
- Single and 2-axis configurations with 2.5 in, 6 in and 12 in diameter coils

*Model dependent, see technical specifications

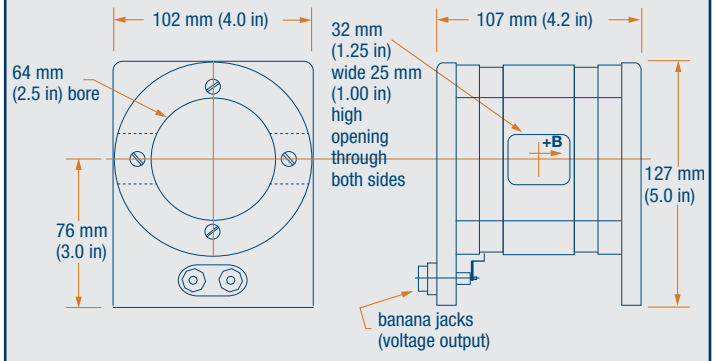
Magnet moment measurement

for use with the Model 480 fluxmeter only

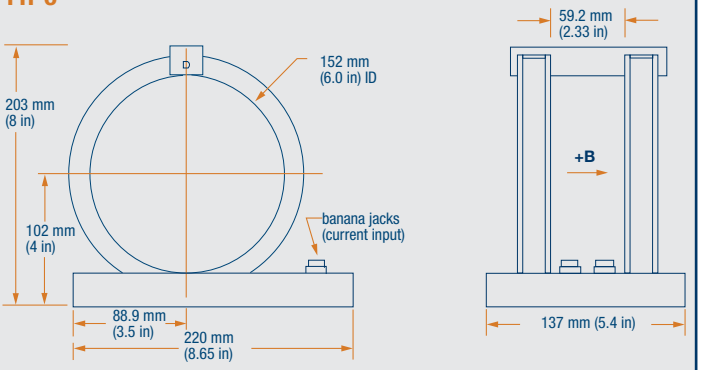
We offer 3 Helmholtz coils for fluxmeter moment measurements: 64 mm (2.5 in), 152 mm (6 in), and 305 mm (12 in) diameter.

	FH-2.5		FH-6		FH-12	
Calibration accuracy	0.75%					
Inside diameter	64 mm (2.5 in)		152 mm (6 in)		305 mm (12 in)	
Coil resistance (approx)	35 Ω		110 Ω		140 Ω	
Operating temperature range	0 °C to 60 °C					
Coil constant (approx)	0.013 Wb·cm/V·s		0.016 Wb·cm/V·s		0.047 Wb·cm/V·s	
Input resistance (fluxmeter)	10 kΩ	100 kΩ	10 kΩ	100 kΩ	10 kΩ	100 kΩ
Range (approx)	390 µWb·cm	3.9 mWb·cm	480 µWb·cm	4.8 mWb·cm	1.4 mWb·cm	14 mWb·cm
	39 µWb·cm	390 µWb·cm	48 µWb·cm	480 µWb·cm	140 µWb·cm	1.4 mWb·cm

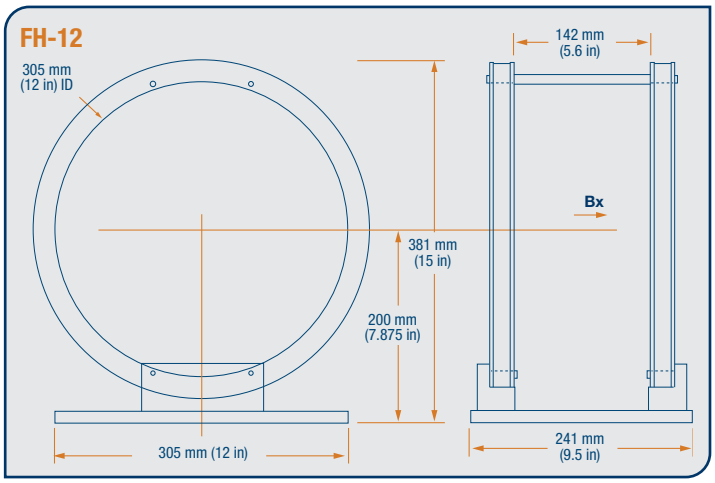
FH-2.5



FH-6



FH-12



Ordering information

Part number	Description
FH-2.5	64 mm (2.5 in) Helmholtz coil
FH-6	152 mm (6 in) Helmholtz coil
FH-12	305 mm (12 in) Helmholtz coil

All specifications are subject to change without notice

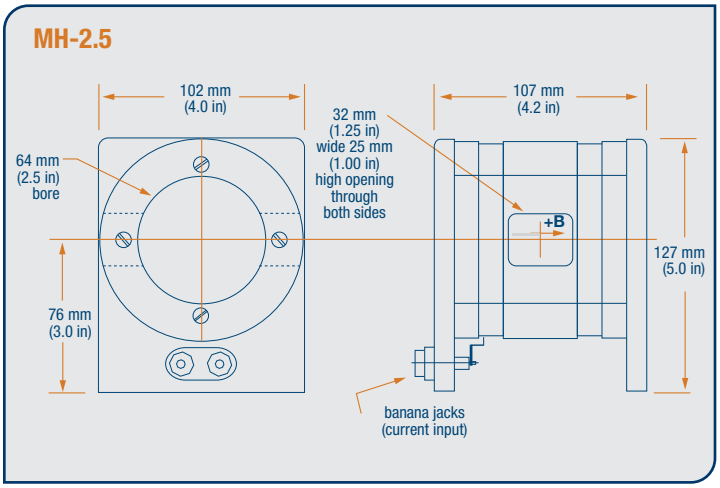
NOTE: The FH Series coils are for use with the Lake Shore Model 480 fluxmeter only. They cannot be used with the Model 475, 455, 460, 450, or 421 gaussmeters.

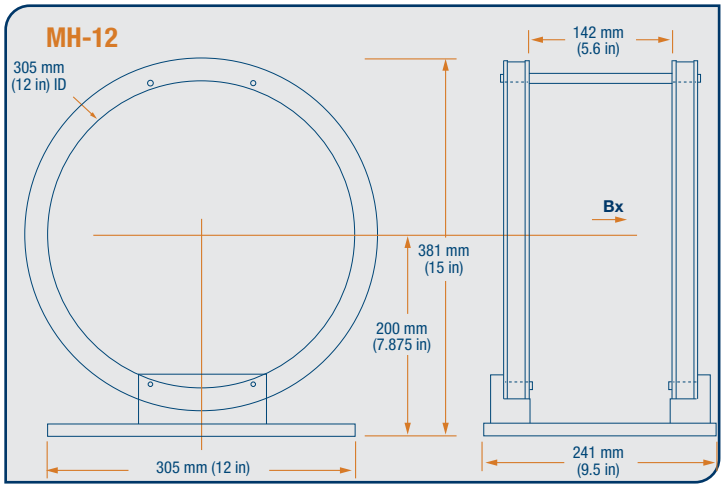
Field standards

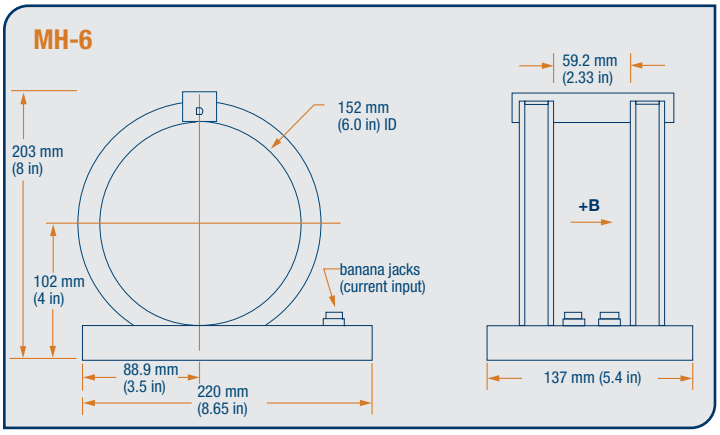
for use with current source or power supply only

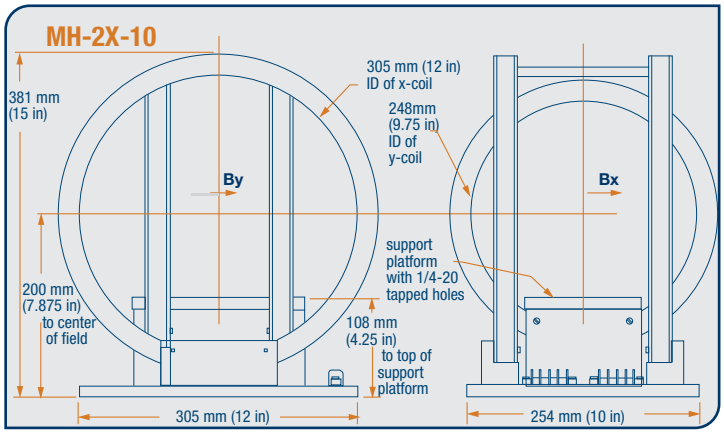
We offer 4 Helmholtz coils for field standards: 64 mm (2.5 in), 152 mm (6 in), and 305 mm (12 in) diameter single-axis, and the MX-2X-10 double-axis.

	MH-2.5	MH-6	MH-12	MH-2X-10
Field accuracy (center)	0.75%			
Inside diameter	64 mm (2.5 in)	152 mm (6 in)	305 mm (12 in)	305 mm (12 in) x-axis and 248 mm (9.75 in) y-axis
Field strength	≈30 G/A	≈25 G/A	≈13 G/A	≈30 G/A (note: coils are not exactly matched)
Max continuous current	2 A (DC or RMS)			
Field uniformity	0.5% within a cylindrical volume 19 mm (0.75 in) long, 19 mm (0.75 in) diameter, at center of coil	0.5% within a cylindrical volume 41 mm (1.6 in) long, 41 mm (1.6 in) diameter, at center of coil	0.5% within a cylindrical volume 76 mm (3.0 in) long, 76 mm (3.0 in) diameter, at center of coil	≈0.5% within a 64 mm (2.5 in) cube, at center of coil
DC coil resistance/ inductance (approx)	3 Ω/6.3 mH	10 Ω/36 mH	20 Ω/93 mH	20 Ω (x-axis), 15 Ω (y-axis)/128 mH (x-axis), 74 mH (y-axis)
Operating temp range	-20 °C to 40 °C (-4 °F to 104 °F)			









Ordering Information

Part number	Description
MH-2.5	64 mm (2.5 in) inside diameter, maximum field approximately 60 G
MH-6	152 mm (6 in) inside diameter, maximum field approximately 50 G
MH-12	305 mm (12 in) inside diameter, maximum field approximately 26 G
MH-2X-10	305 mm (12 in) inside diameter (x-axis), 248 mm (9.75 in) inside diameter (y-axis), maximum field approximately 30 G

NOTE: The MH Series coils are for use as low field standards. They cannot be used with the Model 480 fluxmeter.

All specifications are subject to change without notice

Measure**Ready**

MCS Series Modular Characterization Systems

Research platforms that quickly adapt to a wide range of material characterization applications, now and into the future.

MCS-EMP
Electromagnet platform

Key features

- Variable magnetic fields to over 3 T
- Low-noise 4-quadrant power supply
- Integrated teslameter for closed loop field control
- MeasureLINK™-MCS control software license and script library

Measurement options

- Fully-integrated measurement modules, e.g., Hall effect
- Measurement instrumentation
- Variable temperature
- Sample holders
- Ferromagnetic resonance (FMR)*

Typical applications

- Electronic/electro-transport measurements
- Magnetic/magneto-transport measurements
- Specialized, customer-built measurements

MCS-CPS
Cryogenic probe station

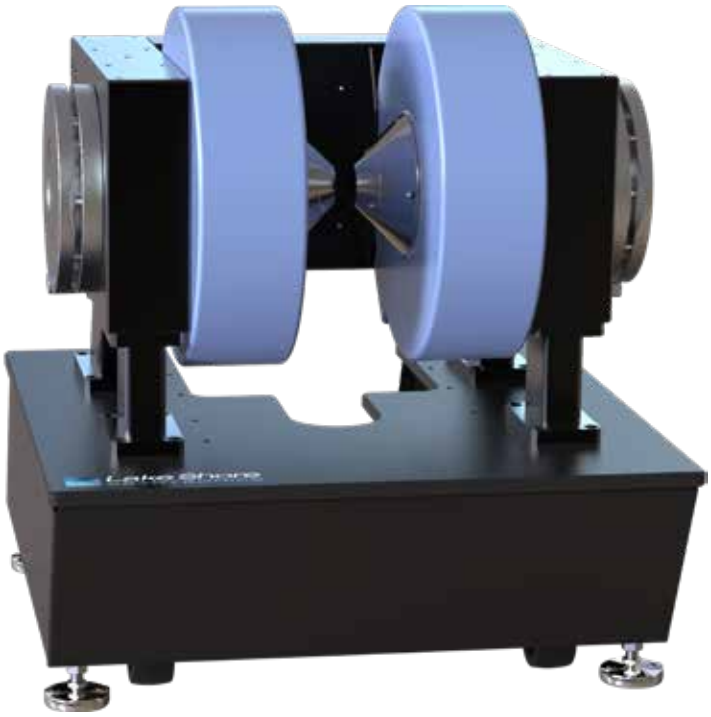
Key features

- Automated temperature control
- Automated field control

* *CPW, Helmholtz coils, cables, and FMR instrument from NanOsc Instruments AB required*

See the full MCS Modular Characterization Systems catalog for more details

EM-V Series Electromagnets



Introduction

The Lake Shore EM-4V and EM-7V electromagnets (EM-V Series) produce magnetic fields with a variety of indexed air gap and pole cap configurations. The EM-V Series are ideally suited for integration into customer-designed magnetic test platforms for applications including magneto-optical studies, magnetic hysteresis studies, in-line annealing, Hall effect studies, susceptibility measurements, spin magnetic resonance demonstrations, and biological studies.

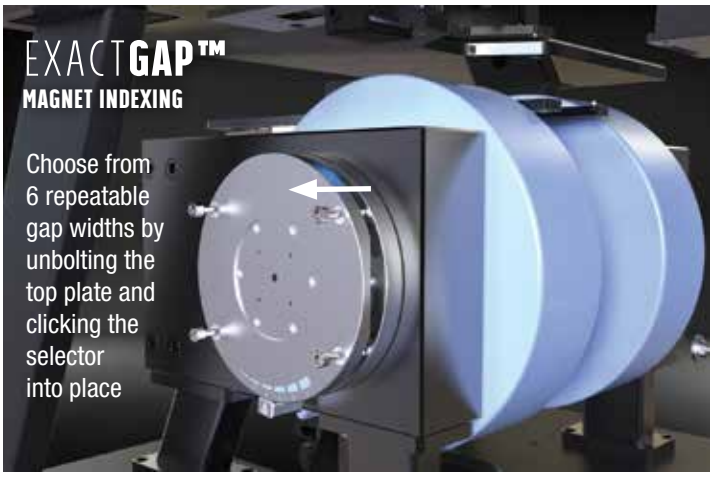
The EM-V Series magnet coupled with a Lake Shore magnet power supply (MPS) and teslameter form a versatile laboratory electromagnet capable of producing magnetic fields up to 3.22 T and supporting very fast ramp rates of up to 1 T/s. This system, with true bipolar MPS power output, provides rapid uniform magnetic field ramping and field reversal to avoid discontinuities that occur during zero crossover when using unipolar power supplies.

EM-4V, EM-7V features

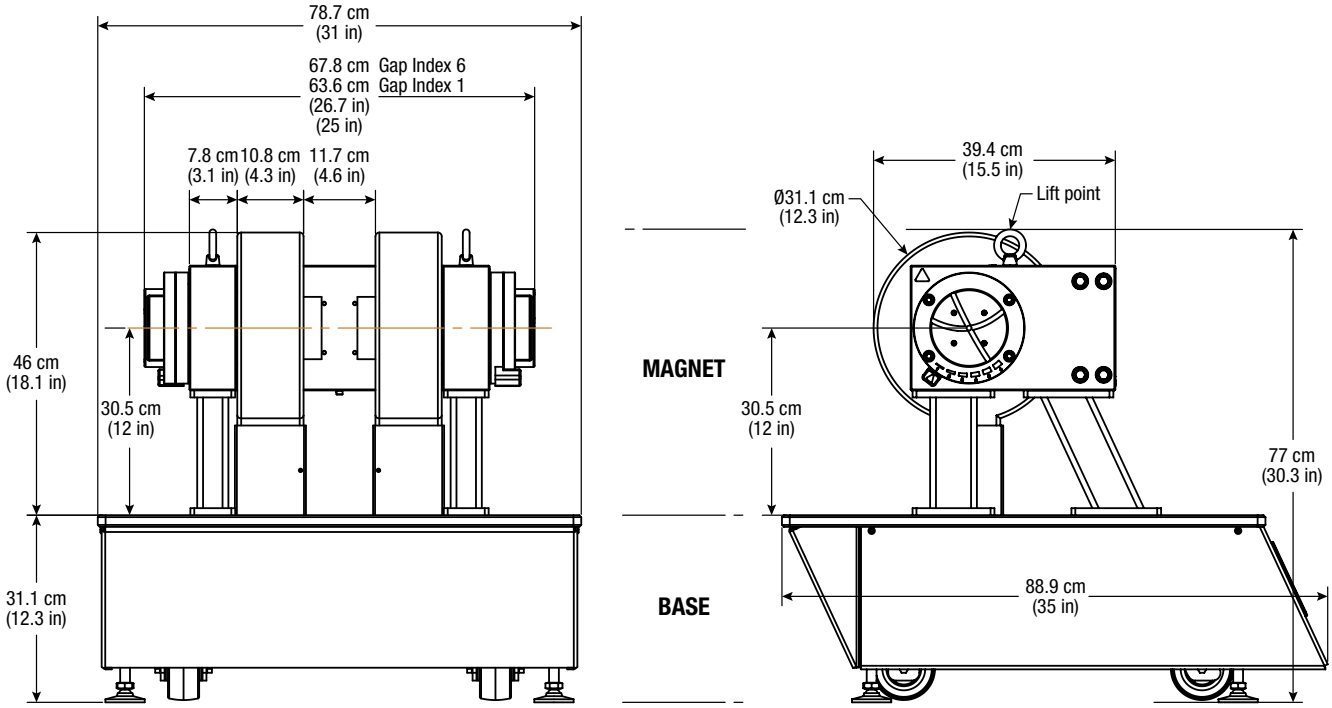
- Indexed pole gap settings (ExactGAP™) allow repeatable air gap changes without having to re-calibrate between changes
- Exceptional field intensities achieved with cylindrical or tapered pole caps
- Water-cooled coils provide excellent field stability and uniformity
- Removable pole caps facilitate variable pole face configurations and easy pole cap exchange
- Accurate pole alignment by precise construction of the air gap adjustment mechanism
- The EM-4V/EM-7V yoke designed for optimum air gap accessibility for both top and bottom of the magnet
- Compact size of the EM-4V permits convenient bench-top mounting
- Optional optical access pole caps available
- Optional shim kit is available

ExactGAP™ indexed gap settings

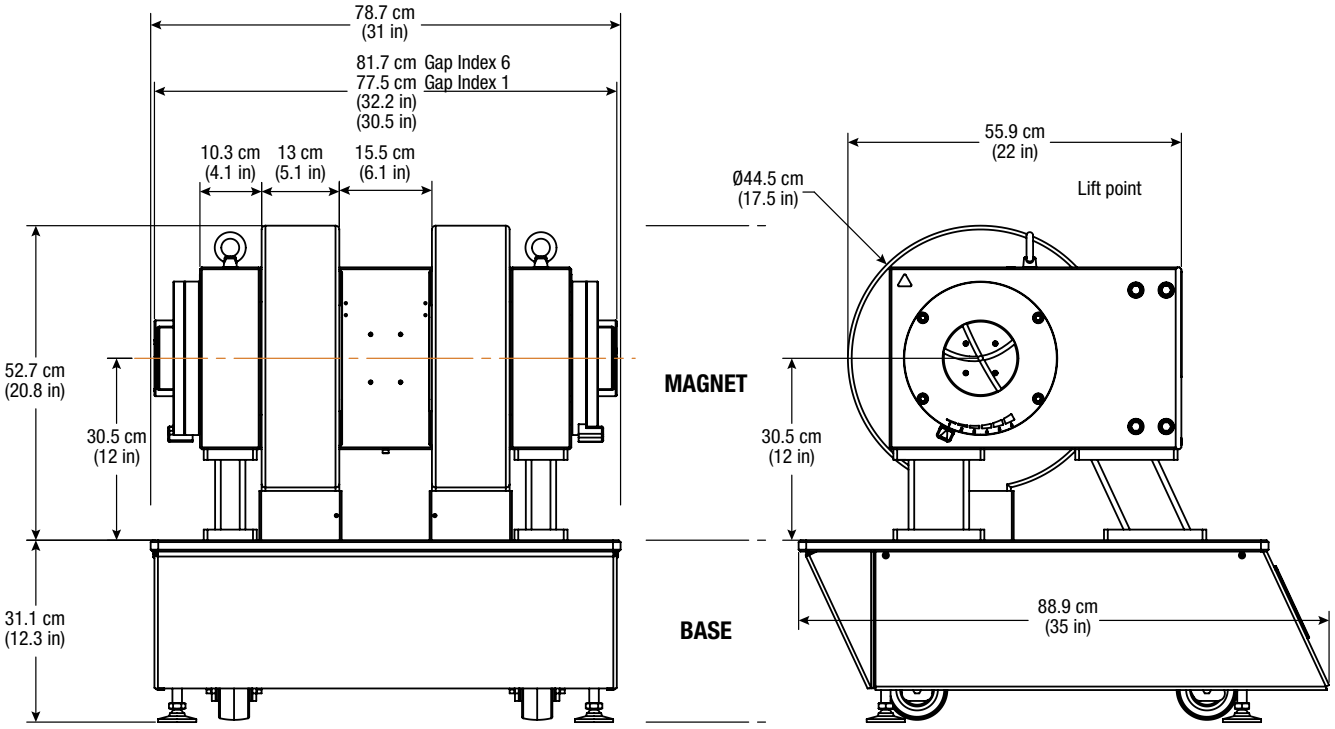
The EM-V Series electromagnets feature ExactGAP™ indexed pole settings. The ExactGAP™ pole gap indexing makes it fast and easy to reconfigure the magnet gap for the required sample or option size without having to re-calibrate the magnet after changing the gap. Choose from 6 repeatable gap widths by unbolting the top plate and clicking the selector into place. The EM-V Series incorporate water-cooled coils and precision yokes made of magnetically soft, ultra-pure steel, assuring precise pole cap alignment as well as excellent field homogeneity and stability.



EM-4V



EM-7V



See the full EM-V Series Electromagnets catalog for more details

Model 643 Electromagnet Power Supply

Model 643 features

- Low noise
- Compact design
- CE mark certification
- ±70 A/±35 V, 2450 W
- Built-in fault protection
- Analog programming and IEEE-488 and USB interfaces
- Bipolar, linear, true 4-quadrant output
- 0.1 mA of programmed current resolution
- Can be modulated to frequencies up to 0.17 Hz at ±70 A

Introduction

The Model 643 electromagnet power supply is a linear, bipolar current source providing true 4-quadrant output, eliminating the need for external switching or operator intervention to reverse current polarity. The Model 643 is capable of supplying ±70 A/±35 V to a nominal 0.5 Ω, 0.5 H load, and the output can be modulated from an external source to frequencies up to 0.17 Hz at ±70 A. Internally programmed output provides 20-bit resolution, while externally programmed output provides unlimited resolution.

The compact, low noise design of the Model 643 makes it the ideal supply for use in laboratory settings. When combined with a Lake Shore EM4 4-inch electromagnet and Model 475 DSP gaussmeter, the Model 643 provides a versatile field control system ideal for a wide range of user defined applications. These include but are not limited to magneto-optical, magnetic hysteresis and susceptibility, and Hall effect measurements, as well as in-line annealing.

Output architecture

The Model 643 output architecture relies on low noise linear input and output stages. The linear circuitry of the Model 643 permits operation with less electrical noise than switch-mode electromagnet power supplies. The clean field background allows greater resolution and finer detail in results drawn from data taken during high sensitivity experiments. One key benefit of this architecture is CE compliance to the electromagnetic compatibility (EMC) directive, including the radiated emissions requirement.

The true 4-quadrant output capability of the Model 643 is ideal for sweeping through both positive and negative fields. Tightly integrated analog control of the 4-quadrant output provides smooth current change with very low overshoot. This eliminates the need for external switching or operator intervention to reverse the polarity, significantly simplifying system design. The transition through zero current is smooth and continuous, allowing the user to readily control the magnetic field as polarity changes. This is achieved without reversal contactors or relays, which would produce unintended field spikes and other discontinuities. As a result, field hysteresis and other biases are avoided in the experimental data.

Output programming

The Model 643 output current is programmed internally via the keypad or the computer interface, externally by analog programming input, or by the sum of the external and internal settings. For internal programming, the Model 643 incorporates a proprietary 20-bit digital-to-analog converter (DAC) that is monotonic over the entire output range and provides resolution of 0.1 mA. External programming provides unlimited resolution.

The Model 643 generates extremely smooth and continuous ramps with virtually no overshoot. The digitally generated constant current ramp rate is variable between 0.1 mA/s and 50 A/s. To ensure smooth ramp rate, the power supply updates the high-resolution DAC 23.7 times per second. A low-pass filter on the output DAC smooths the transitions at step changes during ramping.

Output reading

The Model 643 provides high-resolution output readings. The output current reading reflects the actual current in the magnet, and has a resolution of 0.1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 0.1 mV. All output readings can be prominently displayed on the front panel and read over the computer interface.

Protection

The Model 643 provides built-in protection against short circuit, open circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and abrupt change of the external programming input. In the event of water flow failure, flow sensors provide feedback to the Model 643 and output current is set to 0 A. Internal heat sink, cold plate, and transformer temperatures are also monitored. Warnings are displayed before temperature limits are exceeded and current is set to 0 A. If temperatures continue to increase over safety limits, the Model 643 turns off.

A proprietary circuit limits the power dissipated in the water-cooled cold plate should low resistance and high line conditions exist. The Model 643 protects itself if operated into resistances outside of nominal limits. By limiting current output, the power supply will safely operate into a shorted load, and it operates safely into high resistance loads by limiting voltage output. The Model 643 is also protected against power loss under full operation and nominal magnet load. Both low and high power line conditions are reported on the front panel display.

Interfaces

The Model 643 includes both parallel IEEE-488 and universal serial bus (USB) computer interfaces that provide access to operating data, stored parameters, and remote control of all front panel operating functions. The USB interface emulates an RS-232C serial port at a fixed 57,600 baud rate, but with the physical connections of a USB. This allows you to download firmware upgrades, ensuring your power supply is using the most current firmware version with no need for any physical changes. The Model 643 also provides two analog monitors for output current and voltage. Each monitor is a buffered, differential, analog voltage representation of the signal being monitored. The current monitor has a sensitivity of 7 V/70 A output, while the voltage monitor has a sensitivity of 3.5 V/35 V output.

Display and keypad

The Model 643 incorporates a large 8-line by 40-character vacuum fluorescent display. Output current and output voltage readings are displayed simultaneously. Five front panel LEDs provide quick verification of instrument status, including ramping, compliance, fault, power limit, and computer interface mode. Error conditions are indicated on the main display along with an audible beeper. Extended error descriptions are available under the status key.

The keypad is arranged logically to separate the different functions of the power supply. The most common functions of the power supply are accessed using a single button press. The keypad can be locked in order to secure either all changes or just the instrument setup parameters allowing the supply output to be changed.

Model 643 specifications

Output

Type: Bipolar, 4-quadrant, DC current source
Current generation: Fully linear regulation with digital setting and analog control
Current range: ±70 A
Compliance voltage (DC): ±35 V nominal
Power: 2450 W nominal
Nominal load: 0.5 Ω, 0.5 H
Maximum load resistance: 0.6 Ω for ±70 A DC operation at +10% to -5% line voltage
Minimum load resistance: 0.4 Ω for ±70 A DC operation at +5% to -10% line voltage
Load inductance range: 0 H to 1 H
Current ripple: 5 mA RMS (0.007%) at 70 A into nominal load
Current ripple frequency: Dominated by the line frequency and its harmonics
Temperature coefficient: ±15 ppm of full scale/°C
Line regulation: ±60 ppm of full scale/10% line change
Stability (1 h): 1 mA/h (after warm-up)
Stability (24 h): 5 mA/24 h (typical, dominated by temperautre coefficient and line regulation)
Isolation: Differential output is optically isolated from chassis to prevent ground loops
Slew rate: 50 A/s into nominal load, 100 A/s maximum into a resistive load
Compliance voltage (AC): ±43 V at +10% to -5% line
Settling time: <1 s for 10% step to within 1 mA of output into nominal load
Modulation response: ≤0.17 Hz at ±70 A sine wave into nominal load, <0.02% THD; ≤1 Hz at ±10 A sine wave into nominal load, <0.05% THD; ≤10 Hz at ±1 A sine wave into nominal load, <0.10% THD
Attenuation: -0.5 dB at 10 Hz
Protection: Short circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, and over temperature
Connector: Two lugs with 6.4 mm (0.25 in) holes for M6 or 0.25 in bolts

Output programming

Internal current setting
Resolution: 0.1 mA (20-bit)
Settling time: 600 ms for 1% step to within 1 mA (of internal setting)
Accuracy: ±10 mA ±0.05% of setting
Operation: Keypad, computer interface
Protection: Programmable current setting limit

Internal current ramp
Ramp rate: 0.0001 A/s to 50.0000 A/s (compliance limited)
Update rate: 23.7 increments/s
Ramp segments: 5
Operation: Keypad, computer interface
Protection: Programmable ramp rate limit

External current programming
Sensitivity: 10 V/70 A
Resolution: Analog
Accuracy: ±10 mA ±1% of setting
Input resistance: 20 kΩ
Operation: Voltage program through rear panel, can be summed with internal current setting
Limits: Internally clamped at ±10.1 V and bandwidth limited at 40 Hz to protect output
Connector: Shared 15-pin D-sub

Readings

Output current
Resolution: 0.1 mA
Accuracy: ±10 mA ±0.05% of rdg
Update rate: 2.5 rdg/s display, 10 rdg/s interface

Output voltage (at supply terminals)
Resolution: 1 mV
Accuracy: ±5 mV ±0.05% of rdg
Update rate: 2.5 rdg/s display, 5 rdg/s interface

Front panel

Display type: 8-line by 40-character graphic vacuum fluorescent display module
Display readings: Output current, output voltage, and internal water temperature
Display settings: Output current and ramp rate
Display annunciators: Status and errors
LED annunciators: Fault, Compliance, Power Limit, Ramping, Remote
Audible annunciator: Errors and faults
Keypad type: 26 full-travel keys
Keypad functions: Direct access to common operations, menu-driven setup
Power: Green flush ON and red extended OFF push buttons

Interface

IEEE-488.2 interface
Features: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Reading rate: To 10 rdg/s
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

USB interface
Function: Emulates a standard RS-232 serial port
Baud rate: 57,600
Reading rate: To 10 rdg/s
Connector: B-type USB connector
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

Output current monitor
Sensitivity: 7 V/70 A
Accuracy: ±1.5% of full scale
Noise: 1 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Output voltage monitor
Sensitivity: 3.5 V/35 V
Accuracy: 1% of full scale
Noise: 1 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Power supply cooling water
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block; Flow switch and water valve optional

Magnet cooling water
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block
Flow, temperature switch, and water valve not included

Auxiliary
Emergency stop: Requires 1 A, 24 VAC normally closed (NC) contact to enable power-up; jumper required if unused
Fault output: Relay with normally open (NO) or normally closed (NC) contact, 30 VDC at 1 A
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Connector: Shared 8-pin detachable terminal block
Emergency stop and inhibit switches not included

General

Line power
Power: 5500 VA max
Voltage and current: 200/208 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
Protection: 3-phase thermal relay with adjustable current setting; two class CC 0.25 A fuses; over-voltage lockout circuit
Frequency: 50 Hz or 60 Hz
Configuration: 3-phase delta
Connector: 4-pin terminal block
Features: Soft start circuit, rear panel voltage selection indicator
Line voltage must be specified at time of order but is field reconfigurable; cable from power supply to facility power not included

Cooling water
Flow rate: 5.7 L (1.5 gal)/min minimum
Pressure range: 34 kPa (5 psi) to 552 kPa (80 psi)
Pressure drop: 10 kPa (1.5 psi) at 5.7 L (1.5 gal)/min minimum for power supply only
Temperature: 15 °C to 30 °C (non-condensing)
Connection: Two 10 mm (0.38 in) hose barbs
CAUTION: Internal condensation can cause damage to the power supply
Enclosure type: 7 U high, 19 in rack mount with integral rack mount ears (25 mm (1 in) air space required on each side for ventilation)
Size: 483 mm W × 310 mm H × 572 mm D (19 in × 12.2 in × 22.5 in) with handles removed
Weight: 74 kg (163 lb)
Shipping size: 635 mm W × 559 mm H × 736 mm D (25 in × 22 in × 29 in)
Shipping weight: 103.4 kg (228 lb)
Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C at reduced accuracy
Humidity: Non-condensing
Warm-up: 30 min at output current setting
Approvals: CE mark—low voltage compliance to EN61010-3, EMC compliance to EN55022-1

Ordering information

Part #	Description
643	Model 643 ±70 A ±35 V, 2.5 kW—specify 204/208 VAC, 220/230 VAC, 380 VAC, or 400/415 VAC

Accessories included

6031	Two front handles
6032	Two rear handles
6051	Terminal block, 4-pin
6052	Terminal block, 8-pin
6252	15-pin D-sub mating connector, analog I/O
—	Hose clamps
—	Power cable strain relief (power cable not included)
—	Calibration certificate
119-056	Model 643 user manual

Accessories available

6201	1 m (3.3 ft long) IEEE-488 (GPIB) computer interface cable assembly
6261	3 m (10 ft) magnet cable kit, AWG 4
6262	6 m (20 ft) magnet cable kit, AWG 4
CAL-643-CERT	Instrument recalibration w/ certificate
CAL-643-DATA	Instrument recalibration w/ certificate & data
6041	Water flow switch
6042	Water valve

All specifications are subject to change without notice

Model 648 Bipolar Magnet Power Supply

Model 648 features

- Low noise
- CE mark certification
- ±135 A/±75 V, 9.1 kW
- Built-in fault protection
- Bipolar, linear, 4-quadrant output
- 1 mA of programmed current resolution
- Analog programming and IEEE-488 and USB interfaces

Introduction

The Model 648 electromagnet power supply is a robust, fault-tolerant 9 kW supply optimized for powering large 7 or 10 in research electromagnets. It is specifically designed for high precision laboratory use requiring extremely low electrical noise. The linear design removes undesirable higher frequency noise typical of switch mode power supplies. Eliminating the need for external switching or operator intervention to reverse current polarity, the Model 648 uses convenient bipolar, 4-quadrant operation. It is capable of supplying ±135 A/±75 V to a nominal 0.5 Ω, 0.5 H load. The Model 648 is built to last with a rugged design, integrated fault protection, and a simple, clean interior electronic design.

This robust power supply is developed to minimize downtime. It uses worry-free water cooling for quiet efficient operation compared to air-cooled power supplies. The seamless water lines only have external junctions, eliminating internal water leaks. In addition, safety interlocks ensure that cooling water is always flowing to the supply while operating. Magnet water can also be interlocked into the power supply if desired. Internal software controls manage water usage intelligently.

Output architecture

The low electrical noise design of the Model 648 makes it the ideal power supply for use with large electromagnets in high precision laboratory settings, ensuring greater resolution and finer detail in data taken during highly sensitive measurements. Because low noise is critical to measurement systems, the Model 648 implements both a linear design and bipolar architecture. Linear magnet power supplies have several advantages over switch mode power supplies, primarily smooth field generation that is nearly free from offending electromagnetic signatures. The bipolar, 4-quadrant operation required to safely operate an inductive load provides clean transitions through zero without discontinuities.

Output programming

The Model 648 output current is programmed internally via the keypad or the computer interface, externally by analog programming input, or by the sum of the external and internal settings. External programming via analog input signal provides analog resolution. The Model 648 generates extremely smooth and continuous ramps — the digitally generated constant current ramp rate is variable between 0.1 mA/s and 50.000 A/s. To ensure a smooth ramp rate, the power supply updates the high-resolution DAC 12.3 times per second.

Output reading

The Model 648 provides high-resolution output current readings that reflect the actual current in the magnet, and have a resolution of 1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 1 mV. All output readings can be prominently displayed on the front panel and read over the computer interface.

Protection

The Model 648 provides built-in protection against short circuit, open circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and abrupt change of the external programming input. A proprietary circuit limits the power dissipated in the water-cooled cold plate should low resistance and high line conditions exist. The Model 648 protects itself if operated into resistances outside of nominal limits. By limiting current output, it will safely operate into a shorted load, and operate safely into high resistance loads by limiting voltage output. The Model 648 is also protected against power loss under full operation and nominal magnet load. Both low and high power line conditions are reported on the front panel display.

Specifications

Output

Type: Bipolar, 4-quadrant, DC voltage/current source
Current generation: Fully linear regulation with digital setting and analog control
Current range: ±135 A nominal
Compliance voltage (DC): ±75 V
Power: 9.1 kW nominal
Nominal load: 0.5 Ω, 0.5 H
Maximum load resistance: 0.55 Ω for ±135 A DC operation at +10% to -5% line voltage
Minimum load resistance: 0.41 Ω for ±135 A DC operation at +5% to -10% line voltage
Load inductance range: 0 H to 1 H
Current ripple: 10 mA RMS (0.007%) at 135 A into nominal load
Current ripple frequency: Dominated by the line frequency and its harmonics
Temperature coefficient: ±50 ppm of full scale/°C
Line regulation: ±75 ppm of full scale/10% line change
Stability (1 h): 2 mA/h (after warm-up, internal setting)
Stability (24 h): 10 mA/24 h (typical, internal setting, dominated by temperature coefficient and line regulation)
Isolation: Differential output is optically isolated from chassis to prevent ground loops
Slew rate: 50 A/s into nominal load (dominated by magnet characteristics), 100 A/s maximum into a resistive load
Settling time: <1 s for 10% step to within 1 mA of output into nominal load
Harmonic distortion: ≤0.1 Hz at ±135 A sine wave into resistive load, <0.02% THD; ≤10 Hz at ±10 A sine wave into resistive load, <0.30% THD
Attenuation: -0.5 dB at 10 Hz (external programming input)
Protection: Short circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, and over temperature
Connector: Two lugs with 8.64 mm (0.34 in) holes for M8 or 5/16 in bolts

Output programming

Internal current setting

Resolution: 1.0 mA (20-bit)
Settling time: 600 ms for 1% step to within 1 mA (of internal setting)
Accuracy: ±20 mA ±0.05% of setting
Operation: Keypad, computer interface
Protection: Programmable current setting limit

Internal current ramp

Ramp rate: 0.1 mA/s to 50.000 A/s (compliance limited)
Update rate: 12.3 increments/s
Ramp segments: 5
Operation: Keypad, computer interface
Protection: Programmable ramp rate limit

External current programming

Sensitivity: 10 V/135 A
Resolution: Analog
Accuracy: ±20 mA ±1% of setting
Input resistance: 20 kΩ differential, 50 kΩ common-mode
Operation: Voltage program through rear panel, can be summed with internal current setting
Limits: Internally clamped at ±10.1 V and bandwidth limited -3 dB at 40 Hz (2 pole, low pass filter)
Connector: Shared 15-pin D-sub

Readings

Output current

Resolution: 1.0 mA
Accuracy: ±20 mA ±0.05% of rdg
Update rate: 2.5 rdg/s display, 10 rdg/s interface

Output voltage (at supply terminals)

Resolution: 1.0 mV
Accuracy: ±10 mV ±0.05% of rdg
Update rate: 2.5 rdg/s display, 5 rdg/s interface

Front panel

Display type: 8-line by 40-character graphic vacuum fluorescent display module
Display readings: Output current, output voltage, and internal water temperature
Display settings: Output current and ramp rate
Display annunciators: Status and errors
LED annunciators: Fault, Compliance, Power Limit, Ramping, Remote
Audible annunciator: Errors and faults
Keypad type: 20 full-travel keys
Keypad functions: Direct access to common operations, menu-driven setup
Power: Green flush ON and red extended OFF push buttons

Interface

IEEE-488.2 interface

Features: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Reading rate: To 10 rdg/s
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

USB interface

Function: Emulates a standard RS-232 serial port
Baud rate: 57,600
Reading rate: To 10 rdg/s
Connector: Type B USB connector
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

Output current monitor

Sensitivity: 7 V/135 A
Accuracy: ±1.5% of full scale
Noise: 5 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Output voltage monitor

Sensitivity: 7 V/70 V
Accuracy: 1% of full scale
Noise: 2 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Power supply cooling water

Remote enable input: TTL low or contact closure to enable output; used for mandatory 1 gal/min flow switch (included)
Connector: 2-pin detachable terminal block connector
Valve power output: 24 VAC at 1.5 A maximum, automatic or manual control
Connector: 2-pin detachable terminal block connector
Water valve optional

Magnet cooling water

Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1.5 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block
Flow, temperature switch, and water valve not included

Auxiliary

Emergency stop: Requires 1 A, 24 VAC normally closed (NC) contact to enable power-up; jumper required if unused
Fault output: Relay with normally open (NO) or normally closed (NC) contact, 30 VDC at 1 A
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Connector: Shared 8-pin detachable terminal block; Emergency stop and inhibit switches not included

General

Line power
Power: 15.5 kVA max
Voltage and current: 200 VAC ±5%, 41 A/phase; 208 VAC ±5%, 40 A/phase; 220 VAC ±5%, 38 A/phase; 230 VAC ±5%, 37 A/phase; 380 VAC ±5%, 23 A/phase; 400 VAC ±5%, 21 A/phase; 415 VAC ±5%, 21 A/phase
Protection: 3-phase thermal relay with adjustable current setting; two class CC 2 A fuses; over-voltage lockout circuit
Frequency: 50 Hz or 60 Hz
Configuration: 3-phase delta
Connector: 4-pin terminal block;
Line voltage must be specified at time of order but is field reconfigurable; cable from power supply to facility power not included

Cooling water

Flow rate: 7.6 L (2.0 gal)/min minimum
Maximum pressure: 552 kPa (80 psi)
Pressure drop: 159 kPa (23 psi) at 7.6 L (2.0 gal)/min minimum for power supply and mandatory flow switch
Temperature: 15 °C to 30 °C (non-condensing)
Connection: Two 12.7 mm (0.5 in) hose barbs
CAUTION: Internal condensation can cause damage to the power supply
Enclosure type: Custom 19 in rack cabinet
Size: 559 mm W × 673 mm D × 1054 mm H (22 in × 26 in × 42 in)
Weight: 225 kg (495 lb)
Shipping size: 914 mm W × 1168 mm D × 1219 mm H (36 in × 46 in × 48 in)
Shipping weight: 281 kg (620 lb)
Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C at reduced accuracy
Humidity: Non-condensing
Warm-up: 30 min at output current setting
Approvals: CE mark—low voltage compliance to EN61010-1, EMC compliance to EN61326-1

Ordering information

Part number	Description
648	Model 648—specify 200 VAC, 208 VAC, 220 VAC, 230 VAC, 380 VAC, 400 VAC, or 415 VAC

All specifications are subject to change without notice

Units for magnetic measurement

	Symbol	Gaussian & cgs emu[a]	Conversion Factor, C[b]	SI & rationalized mks[c]
Magnetic flux density, magnetic induction	B	gauss (G)[d]	10^{-4}	tesla (T), Wb/m^2
Magnetic flux	Φ	maxwell (Mx), $G \cdot cm^2$	10^{-8}	weber (Wb), volt second (V·s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe),[e] Gb/cm	$10^3/4\pi$	A/m[f]
(Volume) magnetization[g]	M	emu/cm[3h]	10^3	A/m
(Volume) magnetization	4πM	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm^3	$4\pi \times 10^{-4}$	T, Wb/m^2[i]
(Mass) magnetization	σ, M	emu/g	1 $4\pi \times 10^{-7}$	$A \cdot m^2/kg$ Wb·m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	$A \cdot m^2$, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	Wb·m[i]
(Volume) susceptibility	χ, κ	dimensionless, emu/cm^3	4π $(4\pi)^2 \times 10^{-7}$	dimensionless henry per meter (H/m), Wb/(A·m)
(Mass) susceptibility	χ_ρ, κ_ρ	cm^3/g, emu/g	$4\pi \times 10^{-3}$ $(4\pi)^2 \times 10^{-10}$	m^3/kg $H \cdot m^2/kg$
(Molar) susceptibility	χ_{mol}, κ_{mol}	cm^3/mol, emu/mol	$4\pi \times 10^{-6}$ $(4\pi)^2 \times 10^{-13}$	m^3/mol $H \cdot m^2/mol$
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A·m)
Relative permeability[j]	μ_r	not defined	—	dimensionless
(Volume) energy density, energy product[k]	W	erg/cm^3	10^{-1}	J/m^3
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

a. *Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.*
b. *Multiply a number in Gaussian units by C to convert it to SI (e.g., 1 G × 10^{-4} T/G = 10^{-4} T).*
c. *SI (Système International d'Unités) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where $\mu_0 = 4\pi \times 10^{-7}$ H/m. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.*
d. *1 gauss = 10^5 gamma (γ).*
e. *Both oersted and gauss are expressed as $cm^{-1/2} \cdot g^{1/2} \cdot s^{-1}$ in terms of base units.*
f. *A/m was often expressed as "ampere-turn per meter" when used for magnetic field strength.*
g. *Magnetic moment per unit volume*
h. *The designation "emu" is not a unit*
i. *Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.*
j. *$\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ.*
k. *$B \cdot H$ and $\mu_0 M \cdot H$ have SI units J/m^3; $M \cdot H$ and $B \cdot H/4\pi$ have Gaussian units erg/cm^3.*

R. B. Goldfarb and F. R. Fickett, U.S. Department of Commerce, National Bureau of Standards, Boulder, Colorado 80303, March 1985
NBS Special Publication 696 for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402

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