User's Manual
Model 450
Gaussmeter

LIMITED WARRANTY STATEMENT
WARRANTY PERIOD: ONE (1) YEAR

1. Lake Shore warrants that this Lake Shore product (the "Product") will be free from defects in materials and workmanship for the Warranty Period specified above (the "Warranty Period"). If Lake Shore receives notice of any such defects during the Warranty Period and the Product is shipped freight prepaid, Lake Shore will, at its option, either repair or replace the Product if it is so defective without charge to the owner for parts, service labor or associated customary return shipping cost. Any such replacement for the Product may be either new or equivalent in performance to new. Replacement or repaired parts will be warranted for only the unexpired portion of the original warranty or 90 days (whichever is greater).

2. Lake Shore warrants the Product only if it has been sold by an authorized Lake Shore employee, sales representative, dealer or original equipment manufacturer (OEM).

3. The Product may contain remanufactured parts equivalent to new in performance or may have been subject to incidental use.

4. The Warranty Period begins on the date of delivery of the Product or later on the date of installation of the Product if the Product is installed by Lake Shore, provided that if you schedule or delay the Lake Shore installation for more than 30 days after delivery the Warranty Period begins on the 31st day after delivery.

5. This limited warranty does not apply to defects in the Product resulting from (a) improper or inadequate maintenance, repair or calibration, (b) fuses, software and non-rechargeable batteries, (c) software, interfacing, parts or other supplies not furnished by Lake Shore, (d) unauthorized modification or misuse, (e) operation outside of the published specifications or (f) improper site preparation or maintenance.

6. TO THE EXTENT ALLOWED BY APPLICABLE LAW, THE ABOVE WARRANTIES ARE EXCLUSIVE AND NO OTHER WARRANTY OR CONDITION, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED. LAKE SHORE SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTIES OR CONDITIONS OF MERCHANTABILITY, SATISFACTORY QUALITY AND/OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE PRODUCT. Some countries, states or provinces do not allow limitations on an implied warranty, so the above limitation or exclusion might not apply to you. This warranty gives you specific legal rights and you might also have other rights that vary from country to country, state to state or province to province.

7. TO THE EXTENT ALLOWED BY APPLICABLE LAW, THE REMEDIES IN THIS WARRANTY STATEMENT ARE YOUR SOLE AND EXCLUSIVE REMEDIES.

8. EXCEPT TO THE EXTENT PROHIBITED BY APPLICABLE LAW, IN NO EVENT WILL LAKE SHORE OR ANY OF ITS SUBSIDIARIES, AFFILIATES OR SUPPLIERS BE LIABLE FOR DIRECT, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR OTHER DAMAGES (INCLUDING LOST PROFIT, LOST DATA OR DOWNTIME COSTS) ARISING OUT OF THE USE, INABILITY TO USE OR RESULT OF USE OF THE PRODUCT, WHETHER BASED IN WARRANTY, CONTRACT, TORT OR OTHER LEGAL THEORY, AND WHETHER OR NOT LAKE SHORE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. Your use of the Product is entirely at your own risk. Some countries, states and provinces do not allow the exclusion of liability for incidental or consequential damages, so the above limitation may not apply to you.

LIMITED WARRANTY STATEMENT (Continued)

9. EXCEPT TO THE EXTENT ALLOWED BY APPLICABLE LAW, THE TERMS OF THIS LIMITED WARRANTY STATEMENT DO NOT EXCLUDE, RESTRICT OR MODIFY, AND ARE IN ADDITION TO, THE MANDATORY STATUTORY RIGHTS APPLICABLE TO THE SALE OF THE PRODUCT TO YOU.

CERTIFICATION

Lake Shore certifies that this product has been inspected and tested in accordance with its published specifications and that this product met its published specifications at the time of shipment. The accuracy and calibration of this product at the time of shipment are traceable to the United States National Institute of Standards and Technology (NIST); formerly known as the National Bureau of Standards (NBS).

FIRMWARE LIMITATIONS

Lake Shore has worked to ensure that the Model 450 firmware is as free of errors as possible, and that the results you obtain from the instrument are accurate and reliable. However, as with any computer-based software, the possibility of errors exists.

In any important research, as when using any laboratory equipment, results should be carefully examined and rechecked before final conclusions are drawn. Neither Lake Shore nor anyone else involved in the creation or production of this firmware can pay for loss of time, inconvenience, loss of use of the product, or property damage caused by this product or its failure to work, or any other incidental or consequential damages. Use of our product implies that you understand the Lake Shore license agreement and statement of limited warranty.

FIRMWARE LICENSE AGREEMENT

The firmware in this instrument is protected by United States copyright law and international treaty provisions. To maintain the warranty, the code contained in the firmware must not be modified. Any changes made to the code is at the user's risk. Lake Shore will assume no responsibility for damage or errors incurred as result of any changes made to the firmware.

Under the terms of this agreement you may only use the Model 450 firmware as physically installed in the instrument. Archival copies are strictly forbidden. You may not decompile, disassemble, or reverse engineer the firmware. If you suspect there are problems with the firmware, return the instrument to Lake Shore for repair under the terms of the Limited Warranty specified above. Any unauthorized duplication or use of the Model 450 firmware in whole or in part, in print, or in any other storage and retrieval system is forbidden.

TRADEMARK ACKNOWLEDGMENT

Many manufacturers and sellers claim designations used to distinguish their products as trademarks. Where those designations appear in this manual and Lake Shore was aware of a trademark claim, they appear with initial capital letters and the ™ or ® symbol.

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NI-488.2™ is a trademark of National Instruments.

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DECLARATION OF CONFORMITY

CE

We: **Lake Shore Cryotronics, Inc.**
575 McCorkle Blvd.
Westerville OH 43082-8888 USA

hereby declare that the equipment specified conforms to the following
Directives and Standards:

Application of Council Directives: **73/23/EEC**
89/336/EEC

Standard to which Conformity is declared: ....**EN 61010-1:2001**
Overvoltage II
Pollution Degree 2
EN 61326 A2:2001
Class A
Annex B

Model Number:..**450**

Ed Maloof   *1-7-2004*

_____   _____
Signature   *Date*

Ed Maloof
Printed Name

Vice President of Engineering
Position

Electromagnetic Compatibility (EMC) for the Model 450 Gaussmeter

Electromagnetic Compatibility (EMC) of electronic equipment is a growing concern worldwide. Emissions of and immunity to electromagnetic interference is now part of the design and manufacture of most electronics. To qualify for the CE Mark, the Model 450 meets or exceeds the generic requirements of the European EMC Directive 89/336/EEC. The instrument was tested under normal operating conditions with sensor and interface cables attached. If the installation and operating instructions in the User's Manual are followed, there should be no degradation in EMC performance.

Pay special attention to instrument cabling. Improperly installed cabling may defeat even the best EMC protection. For the best performance from any precision instrument, follow the grounding and shielding instructions in the User's Manual. In addition, the installer of the Model 450 should consider the following:

• Leave no unused or unterminated cables attached to the instrument.

• Make cable runs as short and direct as possible.

• Do not tightly bundle cables that carry different types of signals.

• Add the clamp-on ferrite filter (Part Number 109-053) included with the connector kit to the serial interface cable near the instrument rear panel when that interface is used.

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CHAPTER 1

INTRODUCTION

1.0   GENERAL

This chapter provides an introduction to the Lake Shore Model 450 Gaussmeter. The Model 450 was designed and manufactured in the United States of America by Lake Shore Cryotronics, Inc. The Model 450 is a high-accuracy, full-featured gaussmeter ideally suited for the laboratory. It features:

- **Field Measurement:**
  – High Accuracy with High Resolution.
  – Auto Range.
  – DC or AC Field Measurement.
  – Individual Linearization of Hall Probes.
  – Temperature Compensation of Hall Probes (certain models only).

- **Alphanumeric Display:**
  – 4¾-digit, 1 Part In 30,000 Resolution On All Ranges.
  – 5¾-digit with DC and Filter, 1 Part In 300,000 Resolution.
  – 2 Line by 20 Character Vacuum Fluorescent Display.

- **Other Major Operating Functions:**
  – Display Filter.
  – Gauss or Tesla Units.
  – Max Hold.
  – Relative Reading.
  – Audible Alarm for High and Low Field.

- **Interface:**
  – IEEE-488.2 Interface.
  – Serial Interface (RS-232C Electrical Format).
  – Corrected and Monitor Analog Outputs.
  – Fast Data Acquisition Mode.

- **Probe Compatibility:**
  – High Stability Probes (HST) – 300 G to 300 kG Full-Scale Ranges.
  – High Sensitivity Probes (HSE) – 30 G to 30 kG Full-Scale Ranges.
  – Ultra High Sensitivity Probes (UHS) – 300 mG to 30 G Full-Scale Ranges.

- **Software Available:**
  – LabVIEW Driver Available.

We welcome comments concerning this manual. Although every effort has been made to keep it free from errors, some may occur. When reporting a specific problem, describe it briefly and include the appropriate paragraph, figure, table, and page number. Send comments to Lake Shore Cryotronics, Attn: Technical Publications, 575 McCorkle Blvd., Westerville, Ohio 43082-8888. The material in this manual is subject to change without notice.

1.1 MODEL 450 GAUSSMETER SYSTEM DESCRIPTION

The Model 450 is an extremely accurate full-featured gaussmeter. The Model 450 covers a wide range of magnetic fields and applications. The instrument provides easy-to-use front panel programming and a vacuum fluorescent alphanumeric display. This alphanumeric format allows for message-based front panel operation. Most operations can be performed and monitored through the front panel keypad and message display. A list of specifications is provided in Table 1-1.

The Model 450 measures fields in either gauss (G) or tesla (T). Set magnetic field ranges manually or with auto ranging. The gaussmeter measures both DC and AC magnetic field values. In DC operation, the display shows the DC field at the probe with the sign (orientation) followed by the appropriate field units. In AC operation, the display shows a Peak or RMS value for the field at the probe.

The Max Hold function captures and displays the largest field magnitude seen since the last Max Reset. The maximum value is shown in the lower display while the upper display contains the live field reading. In AC RMS, the Max Hold feature displays the maximum RMS value of the waveform. In AC Peak, the Max Hold feature displays the magnitude of the peak value of a non-periodic waveform.

The relative function lets the user see small variations in larger fields. The user defined setpoint becomes the center or zero point of the relative reading and is shown on the lower line of the display. The difference from the setpoint or the relative reading appears in the top display with a ▲ symbol.

"Corrected" and "Monitor" analog outputs provide high accuracy and waveform monitoring. The Corrected Analog Output is a DC voltage proportional to the reading displayed on the front panel. A default voltage range of ±10 volts or ±3 volts for ±full scale field can be selected, or the voltage range can be customized using the Analog Out function on the keypad.

The Monitor Analog Output is a real-time analog signal proportional to the magnetic field. The scale of the Monitor Analog Output is ±3 volts for full scale of selected range. The Monitor Analog Output is not as accurate as the Corrected Analog Output, but it has the full DC to 400 Hz bandwidth. The Monitor Analog Output allows the user to observe the actual magnetic field waveform on an oscilloscope.

A Fast Data Acquisition Mode is included that shuts down the front panel display and provides up to 18 field readings per second over the IEEE-488 Interface. In addition, the Serial interface at 9600 Baud can return 15 readings per second. Fast data mode is activated by issuing a **FAST** command using one of the remote interfaces, then using the **FIELD?** command to return a string of data.

450_Front.bmp

Figure 1-1. Model 450 Gaussmeter Front Panel

1.2   SPECIFICATIONS

Measurement:

Number of Inputs: One

Update Rate: Five Per Second

Autorange: Yes

Electronic DC Accuracy: ±0.10% of reading ±0.005% of range at 25 °C

Drift of DC Electronics: 0.02% of reading + 0.003% of range/°C

AC Frequency Range: 10 to 400 Hertz

Overall AC Accuracy: ±5% or better

AC Peak Accuracy: ±5% typical

Field Ranges/Resolutions: Are provided in the following three tables; listed by type of probe:

High Stability Probe (HST)

Gauss			Tesla		
	Resolution			**Resolution**	
Range	**AC or DC w/ Filter Off**	**DC Filter On**	**Range**	**AC, or DC w/ Filter Off**	**DC Filter On**
±300 kG	±0.01 kG	±0.001 kG	±30 T	±0.001 T	±0.0001 T
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT

High Sensitivity Probe (HSE)

Gauss			Tesla		
	Resolution			**Resolution**	
Range	**AC or DC w/ Filter Off**	**DC Filter On**	**Range**	**AC or DC w/ Filter Off**	**DC Filter On**
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT

Ultra-High Sensitivity Probe (UHS)

Gauss			Tesla		
	Resolution			**Resolution**	
Range	**AC or DC w/ Filter Off**	**DC Filter On**	**Range**	**AC or DC w/ Filter Off**	**DC Filter On**
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT
±3 G	±0.0001 G	±0.00001 G	±300 µT	±0.01 µT	±0.001 µT
±300 mG	±0.01 mG	±0.001 mG	±30 µT	±0.001 µT	±0.0001 µT

Interfaces:

Audible Alarm: High and Low Setpoints

Corrected Analog Output Accuracy: ±0.1% of ±3 volt or ±10 volt range

Monitor Analog Output Accuracy: Probe Dependent

IEEE-488 Capabilities: Complies with IEEE-488.2 = SH1,AH1,SR1,RL1,PP0,DC1,DT0,C0,E1

Serial Communication in RS-232C Electrical Format: 300, 1200, or 9600 Baud; RJ-11 connector

Fast Data Acquisition Mode: (Refer to Paragraph 3.16)

With the IEEE-488 Interface: 18 reading per second

With Serial Interface at 9600 Baud: 15 readings per second

Specifications (Continued)

Front Panel:

Display Type: 2 line by 20 characters, vacuum fluorescent

Units:
kG
G
mG
T
mT
uT

Alarm

Probe Orientation
(DC Only)

DC
PK
RMS

Relative
On

Remote
On

Field Reading

Lower row used for Max Hold (MAX) (shown above) and Relative
Setpoint (SP) readings. Also used for various on/off messages.
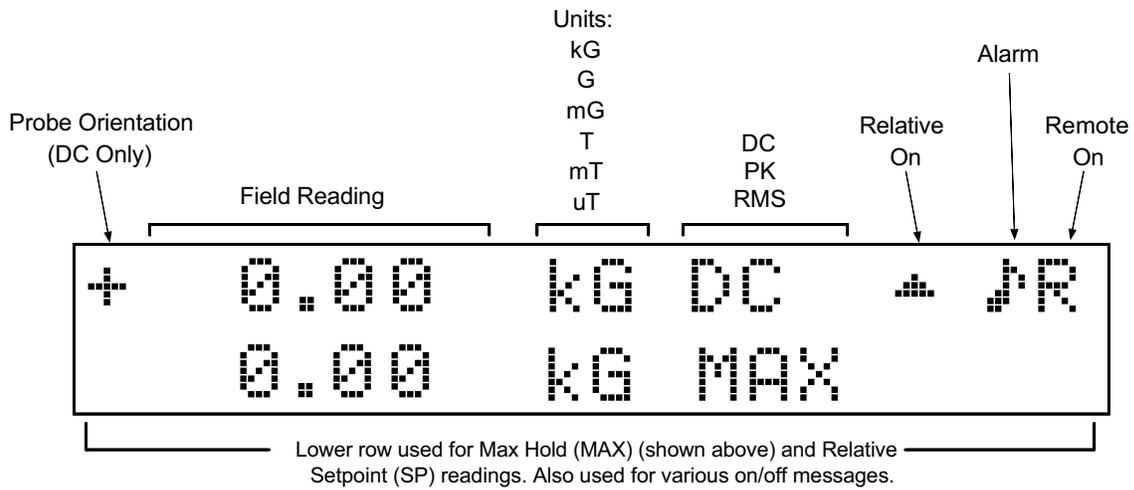
C-450-1-2.eps

Display Resolution: 4¾-digit, 5¾-digit with DC & Filter (see field ranges on previous page)

Display Units: Gauss (G) or tesla (T)

Instrument General:

Ambient Temperature Range: 15 °C to 35 °C (59 °F to 95 °F)

Power Requirement: 100, 120, 220, 240 VAC (+5% –10%), 50 or 60 Hz, 20 watts

Size: 217 mm wide × 90 mm high × 317 mm deep (8.5 × 3.5 × 12.5 inches); half-rack package

Weight: 3 kilograms (6.6 pounds)

1.3 SAFETY SUMMARY

Observe the following general safety precautions during all phases of instrument operation, service, and repair. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Lake Shore Cryotronics, Inc. assumes no liability for customer failure to comply with these requirements.

The Model 450 protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument. Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area.

- Temperature: 5° to 40° C.
- Maximum relative humidity: 80% for temperatures up to 31° C decreasing linearly to 50% at 40° C.
- Power supply voltage fluctuations not to exceed ±10% of the nominal voltage.

Ground The Instrument

To minimize shock hazard, connect instrument chassis and cabinet to electrical ground. The instrument is equipped with a 3-conductor AC power cable; either plug it into an approved 3-contact outlet or use a 3-contact adapter with the grounding wire (green) firmly connected to a ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

Do Not Operate In An Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes. It is a safety hazard.

Keep Away From Live Circuits Inside the Instrument

Operating personnel must not remove instrument covers. Refer component replacement and internal adjustments to qualified maintenance personnel. Do not replace components with power cable connected. To avoid injuries, always disconnect power and discharge circuits before touching them.

Do Not Substitute Parts Or Modify Instrument

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an authorized Lake Shore Cryotronics, Inc. representative for service and repair to ensure that safety features are maintained.

Do Not Place Conductive Probes Against Exposed Electrical Circuits

Some gaussmeter probes are equipped with conductive sheaths. Keep these probes away from live electrical circuits near magnetic fields.

1.4 SAFETY SYMBOLS

⎓	Direct current (power line).	▣	Equipment protected throughout by double insulation or reinforced insulation (equivalent to Class II of IEC 536 - see Annex H).
∿	Alternating current (power line).		
∿̄	Alternating or direct current (power line).		
3∿	Three-phase alternating current (power line).	⚡	Caution: High voltages; danger of electric shock. Background color: Yellow; Symbol and outline: Black.
⏚	Earth (ground) terminal.		
⏦	Protective conductor terminal.	⚠	Caution or Warning - See instrument documentation. Background color: Yellow; Symbol and outline: Black.
⏛	Frame or chassis terminal.		
I	On (supply).		
○	Off (supply).	⊟	Fuse.

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CHAPTER 2

INSTALLATION

2.0 GENERAL

This chapter covers general Model 450 installation instructions: Inspection and unpacking in Paragraph 2.1, repackaging for shipment in Paragraph 2.2, definition of rear panel connections in Paragraph 2.3, and initial setup and system checkout procedure in Paragraph 2.4.

2.1 INSPECTION AND UNPACKING

Inspect shipping containers for external damage. Make all claims for damage (apparent or concealed) or partial loss of shipment in writing to Lake Shore within five (5) days from receipt of goods. If damage or loss is apparent, please notify the shipping agent immediately.

Open the shipping containers. Use the packing list included with the system to verify receipt of the instrument, sensor, accessories, and manual. Inspect for damage. Inventory all components supplied before discarding any shipping materials. If there is freight damage to the instrument, file proper claims promptly with the carrier and insurance company and notify Lake Shore. Notify Lake Shore immediately of any missing parts. Lake Shore cannot be responsible for any missing parts unless notified within 60 days of shipment. Refer to the standard Lake Shore Warranty on the A Page (immediately behind the title page).

2.2 REPACKAGING FOR SHIPMENT

To return the Model 450, sensor, or accessories for repair or replacement, obtain a Return Goods Authorization (RGA) number from Technical Service in the United States, or from the authorized sales/service representative from which the product was purchased. Instruments may not be accepted without a RGA number. When returning an instrument for service, Lake Shore must have the following information before attempting any repair.

1. Instrument model and serial number.
2. User name, company, address, and phone number.
3. Malfunction symptoms.
4. Description of system.
5. Returned Goods Authorization (RGA) number.

Wrap instrument in a protective bag and use original spacers to protect controls. Repack the system in the Lake Shore shipping carton (if available) and seal it with strong paper or nylon tape. Affix shipping labels and FRAGILE warnings. Write the RGA number on the outside of the shipping container or on the packing slip.

Because of their fragility, Lake Shore probes ship in special cardboard and foam boxes. Retain these boxes to store probes when not in use, or return probes to Lake Shore for re-calibration or repair.

2.3 DEFINITION OF REAR PANEL CONNECTIONS

The Model 450 rear panel consists of the power and fuse assembly, IEEE-488 Interface Connector, Serial I/O Connector, Corrected and Monitor Analog Output BNCs, and a DA-15 Probe Input Connector. See Figure 2-1, Refer to Chapter 5 for rear panel connector pin-out details.
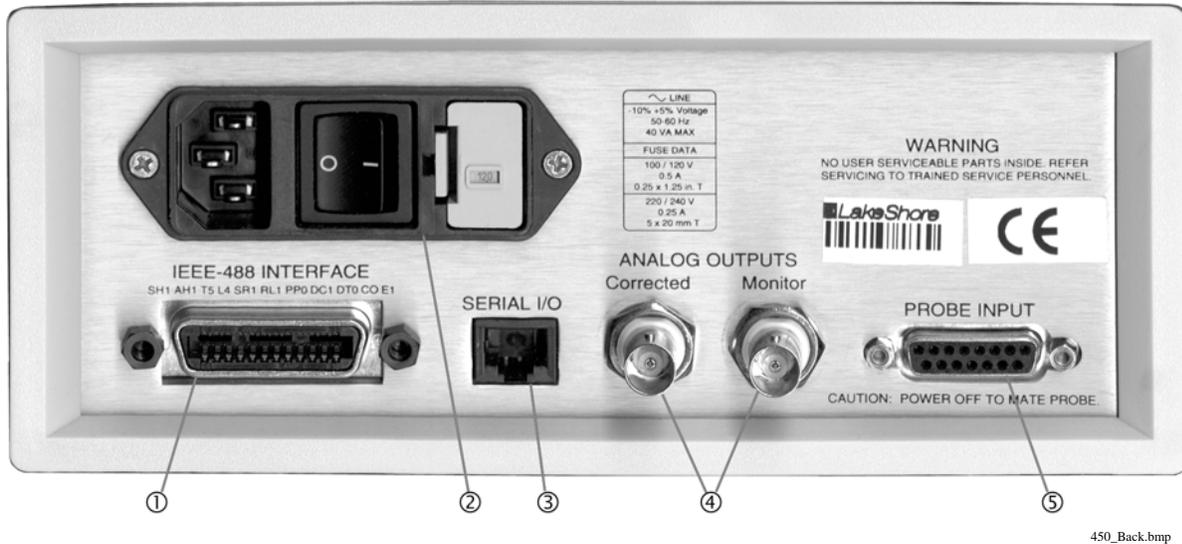
450_Back.bmp

Figure 2-1. Model 450 Rear Panel

CAUTION: Verify AC Line Voltage shown in the fuse holder window is appropriate for the intended AC power input. Also remove and verify the proper fuse is installed before plugging in and turning on the instrument.

CAUTION: Always turn off the instrument before making any rear panel connections. This is especially critical when making probe to instrument connections.

1. **IEEE-488 Interface Connector**. The standard 24-pin connector connects the gaussmeter to any computer suitably equipped with a IEEE-488 interface. Refer to Paragraph 4.1.

2. **Power and Fuse Assembly**. The power and fuse assembly is the primary entry and control point for AC power to the unit. The assembly consists of three parts: power line jack, power on/off switch, and the fuse drawer. The line cord connects to the power line jack. The on/off switch controls power to the unit. The "I" symbol shows when power is on and the "O" shows when power is off. The fuse drawer has a dual purpose: housing the fuse and setting unit input power.

3. **Serial I/O Connector**. The Serial I/O (Input/Output) Connector accepts the standard RJ-11 telephone connector. Lake Shore offers RJ-11 to DE-9 or DB-25 Adapters that permit connection to a computer. Refer to Paragraph 4.2.

4. **Corrected and Monitor Analog Outputs**. Analog outputs are available on two Bayonet Nut Connectors (BNCs). The signal is on the center conductor while the outer casing is for ground. Both outputs may be used simultaneously. The corrected output is not a real-time signal, but updates at the same rate as the display. The default range of the corrected output is ±3 volts equals ± full scale for the range. However, the scaling of the corrected output may be reconfigured. The monitor output is a live analog signal proportional to the magnetic flux density waveform. Refer to Paragraph 3.12 for further operational information.

5. **Probe Input Connector**. The probe plugs into the DA-15 connector. Always turn off the instrument before connecting the probe. Align the probe connector with the rear panel connector and push straight in to avoid bent pins. For best results, secure the connector to the rear panel using the two thumbscrews. A tight connector keeps the cable secure and prevents interference. Refer to Paragraph 3.15 for additional probe considerations.

2.4 LINE INPUT ASSEMBLY

This section covers line voltage and fuse verification in Paragraph 2.4.1, power cord in Paragraph 2.4.2, and power switch in Paragraph 2.4.3.

2.4.1 Line Voltage and Fuse Verification

To verify proper line voltage selection look at the indicator in the window on the fuse drawer of the line input assembly. Line voltage should be in the range shown in the specifications listed on the back of the instrument. See Figure 2-2. If not, change the line voltage selector per instructions in Paragraph 6.3. The fuse must be removed to verify its value, refer to the procedure in Paragraph 6.4. Use slow-blow fuses of the value specified on back of the instrument.

2.4.2 Power Cord

The Model 450 includes a three-conductor power cord. Line voltage is present across the outer two conductors. The center conductor is a safety ground and connects to the instrument metal chassis. For safety, plug the cord into a properly grounded three-pronged receptacle.

2.4.3 Power Switch

The power switch turns the instrument On and Off and is located in the line input assembly on the instrument rear. When **I** is raised, the instrument is On. When **O** is raised, the instrument is Off.

450_Power.bmp
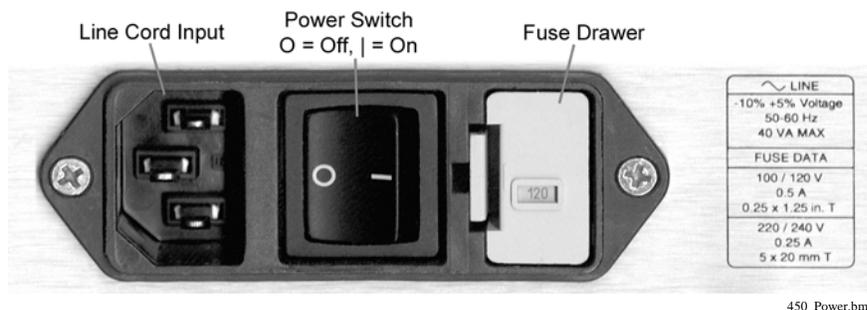
Figure 2-2. Line Input Assembly

2.5 PROBE INPUT CONNECTION

WARNING: Some probes used with the gaussmeter have conductive parts. Never probe near exposed live voltage. Personal injury and damage to the instrument may result.

CAUTION: Always turn off the instrument before making any rear panel Probe Input connections.

The Lake Shore probe plugs into the 15 pin D-style connector on the rear panel. Turn the instrument off before attaching the probe. Align the probe connector with the rear panel connector and push straight in to avoid bending the pins. For best results, secure the connector to the rear panel using the two thumbscrews. A tight connector keeps the cable secure and prevents interference. Refer to Paragraph 3.15 for additional probe considerations.

When power is turned on, the instrument reads parameters from probe memory. The probe is ready to use. No parameters need to be entered into the Model 450. However, the Zero Probe function should be performed the first time a probe is used with the instrument and periodically during use.

2.5.1 Attachment To A Hall Generator

The Model MCBL-XX has a 15 pin D-Style connector on one end for direct attachment to the PROBE INPUT connection on the back panel of the Model 450 Gaussmeter. Four tinned wires are provided for connection to the Hall Generator. The leads may be soldered directly to these wires. The cable comes in two lengths: the MCBL-6 is 2 meters (6 feet) and the MCBL-20 is 6 meters (20 feet).

F-450-2-3.eps
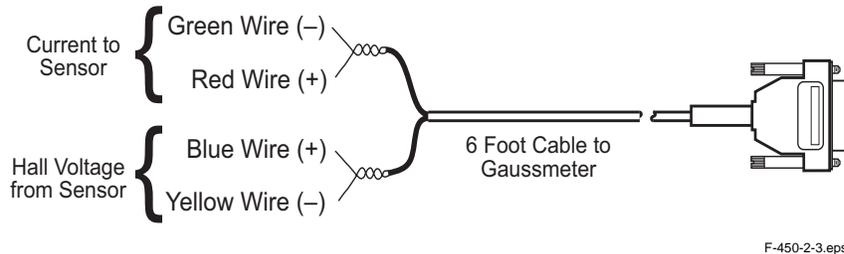
Figure 2-3. Model MCBL-XX User Programmable Cable Accessory

CAUTION: The Hall Generator should be isolated from all line voltages (or voltages referenced to earth ground). *If not, damage to the Model 450 Gaussmeter is almost a certainty.*

Refer to Appendix C for a complete list of compatible Hall generators manufactured by Lake Shore. Once connections are made, refer to Paragraph C6.0 for instructions on using the Hallcall.exe program to store probe parameters in the internal EPROM.

2.6 CORRECTED AND MONITOR ANALOG OUTPUTS

Analog outputs are available on Bayonet Nut Connectors (BNCs). The signal is on the center conductor while the outer casing is for ground. Both outputs may be used simultaneously. The Corrected output is not a real-time signal, but is updated at the same rate as the display. The Monitor output is a live analog signal proportional to the magnetic flux density waveform of the respective channel. Refer to Paragraph 3.12 for further operational information.

2.7 INITIAL SETUP AND SYSTEM CHECKOUT PROCEDURE

This procedure verifies basic unit operation before initial use for measurements.

CAUTION: Check power source for proper voltage before connecting line cord to the Model 450. Check power setting on fuse drawer window. Damage may occur if connected to improper voltage.

1. Check power source for proper voltage. The Model 450 operates with 100, 120, 220, or 240 (+5%, –10%) AC input voltage.

2. Check fuse drawer window for proper voltage setting. If incorrect, refer to Paragraph 5.2.

3. Ensure power switch is off (**O**).

CAUTION: The probe must be connected to the rear of the unit before applying power to the gaussmeter. Damage to the probe may occur if connected with power on.

4. Plug in the DA-15 probe connector to PROBE INPUT. Use thumbscrews to tighten connector to unit.

5. Connect and check all other rear panel connections (IEEE-488, SERIAL I/O, or ANALOG OUTPUTS) before applying power to the unit.

6. Plug line cord into receptacle.

Initial Setup And System Checkout Procedure (Continued)

7. Turn power switch on (**I**). The front panel display turns on and briefly displays the following message.

```
Lake Shore 450
Field Monitor
```

8. The normal gaussmeter display appears, similar to the following screen.

```
+   0.00   kG DC
```

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

Some Lake Shore probes come with a clear plastic sleeve to protect the probe tip when not in use. The sleeve slides up and down the probe cable. To place the probe in the zero gauss chamber, slide the protective sleeve back, exposing the probe tip, before placing the tip in the chamber.

9. Place the probe in the zero gauss chamber and press the front panel **Zero Probe** key. The display to the right appears.

```
Press Enter With
Probe At Zero
```

10. Press the **Enter** key. The *CALIBRATING* message briefly displays, followed by the normal display. Do not move the probe while the *CALIBRATING* message displays.

NOTE: If the unit performs well to this point, the unit is functioning properly. If there is a reference magnet available, continue the test using the magnet to verify the Model 450 accuracy.

11. If continuing the procedure with a reference magnet, verify the probe accommodates the magnet range. Use the **Range Select** key to select the proper range (or press **Auto Range**). Set the display for DC. Finally, since probe orientation is very selective, press the **Max Hold** key to capture the highest reading.

CAUTION: Take care when handling the probe; its tip is very fragile. Any excess force may break it.

NOTE: Probe readings depend on the angle of the tip in relation to the magnetic field. The greater the angle, the higher the percentage of error. For example, a 5° angle causes a 0.4% error, a 10° angle induces a 1.5% error, etc. Refer to Paragraph 3.15.

Initial Setup And System Checkout Procedure (Continued)

12. Carefully place probe in contact with reference magnet and hunt a bit for the maximum reading. For this example, we used a 999 ±1% Gauss probe reference magnet.

```
+0.9729   kG DC
 0.9952   kG MAX
```

The top line displays the current reading. The bottom line displays the maximum reading captured, which is within the tolerance of our reference magnet. The top line continually changes as the probe moves, but the bottom remains fixed on the highest reading. To capture a new maximum value, press the **Max Reset** key.

After successfully completing this checkout procedure, the unit is ready for normal operation.

CHAPTER 3

OPERATION

3.0   GENERAL

This chapter covers aspects of Model 450 operation: Front panel controls are defined in Paragraph 3.1, front panel functions in Paragraphs 3.2 thru 3.13, default settings in Paragraph 3.14, and probe handling considerations in Paragraph 3.15. Refer to Chapter 4 for remote operation (IEEE-488/Serial).

3.1   DEFINITION OF FRONT PANEL CONTROLS

The front panel consists of two major sections: the 21 front panel keys described in Paragraph 3.1.1, and the 2 row by 20 character vacuum fluorescent display described in Paragraph 3.1.2.

3.1.1   Front Panel Keypad Definitions

Max Reset: Works with Max Hold function. Returns Max reading to normal field reading. Refer to Paragraph 3.2.

Max Hold: Turns Max Hold feature ON and OFF. Captures and displays the highest field reading. Use Max Reset key to clear reading. Refer to Paragraph 3.2.

Zero Probe: Zeros or nulls effects of ambient low level fields from the probe. To use, place tip of probe into Zero Gauss Chamber, press Zero Probe, then Enter. Refer to Paragraph 3.3.

Select Range: Manually selects field measurement range. Available ranges depend on which probe is installed. Refer to Paragraph 3.4.

Auto Range: Turns Auto Range feature ON and OFF. Allows the Model 450 to automatically select field measurement range. Refer to Paragraph 3.4.

AC/DC: Selects periodic (AC) or static (DC) magnetic fields. The AC selection provides the option of Peak or RMS readings. Refer to Paragraph 3.5.

Peak/RMS: The AC selection provides the option of Peak or Root Mean Square (RMS) readings. Also use Peak with the Max Hold feature to measure single peaks. Refer to Paragraph 3.5.

450_Front.bmp

Figure 3-1. Model 450 Front Panel

Front Panel Keypad Definitions (Continued)

Filter: Turns filter ON or OFF and configures filter. Filter ON enables high resolution DC readings. Press and hold Filter to select Field Compensation and Temperature Compensation ON or OFF. Refer to Paragraph 3.6.

Gauss/Tesla: Changes display units from gauss to tesla. Gauss (G) is used in the cgs system, where 1 G = 10^{-4} T. Tesla (T) is used in the SI system, where 1 T = 10^4 G. Refer to Paragraph 3.7.

Relative Set: With the relative feature turned ON, this key captures the field reading as the relative setpoint, or the user may enter a number via the keypad. Works with the Relative On/Off key. Refer to Paragraph 3.8.

Relative On/Off: Displays the positive or negative deviation from setpoint in the lower line of the display. Often used to offset large magnetic fields. May also be used with Max Hold and Alarm. Refer to Paragraph 3.8.

Alarm Set: Sets high and low alarm points. The alarm setpoints are absolute (unsigned) i.e., the positive or negative aspect of the field reading is ignored. Refer to Paragraph 3.9.

Alarm On/Off: Turns alarm feature ON or OFF. After setting high and low alarm points with Alarm Set, the alarm is activated whenever the magnetic field goes inside or outside the range defined—regardless of the sign (positive or negative) of the reading. Press and hold Alarm On/Off to turn the alarm ON or OFF and select the alarm to sound inside or outside the range. Refer to Paragraph 3.9.

Local: Selects local or remote operation. When set to Local, the unit responds to front panel controls. When set to Remote, the unit is controlled via the IEEE-488 Interface. Remote users have the option to lock out front panel controls. Refer to Paragraph 3.10.

Address: If using the IEEE-488 Interface, press this key to adjust the bus address of the Model 450 and terminators. Refer to Paragraph 3.10.

Baud: If using the Serial Interface, press this key to select the Model 450 Baud Rate from 300, 1200, or 9600. Refer to Paragraph 3.11.

Analog Out: Adjusts the scaling of the Corrected Analog Output. The default setting makes the currently selected range the maximum and minimum values corresponding to the +3 volt and –3 volt outputs. The Monitor Analog Output scaling cannot be modified. Refer to Paragraph 3.12.

Escape: Terminates a function without changing existing settings. Press and hold Escape for about 20 seconds to reset the instrument, returning many parameters to factory defaults. Refer to Paragraph 3.14.

▲: Toggles between various settings shown in the display and increments a numerical display.

▼: Toggles between various settings shown in the display and decrements a numerical display.

Enter: Accepts changes in the field display. Press and hold Enter to access the Keypad Lock display, and enter a 3-digit code to lockout the keypad from accepting changes.

3.1.2   Front Panel Display

In normal operation, the two row by twenty character vacuum fluorescent display provides magnetic readings on the top row and special information or readings on the bottom row. Other information displays when using the various functions on the keypad. Each character is comprised of a 5 by 7 dot matrix. See Figure 3-2.
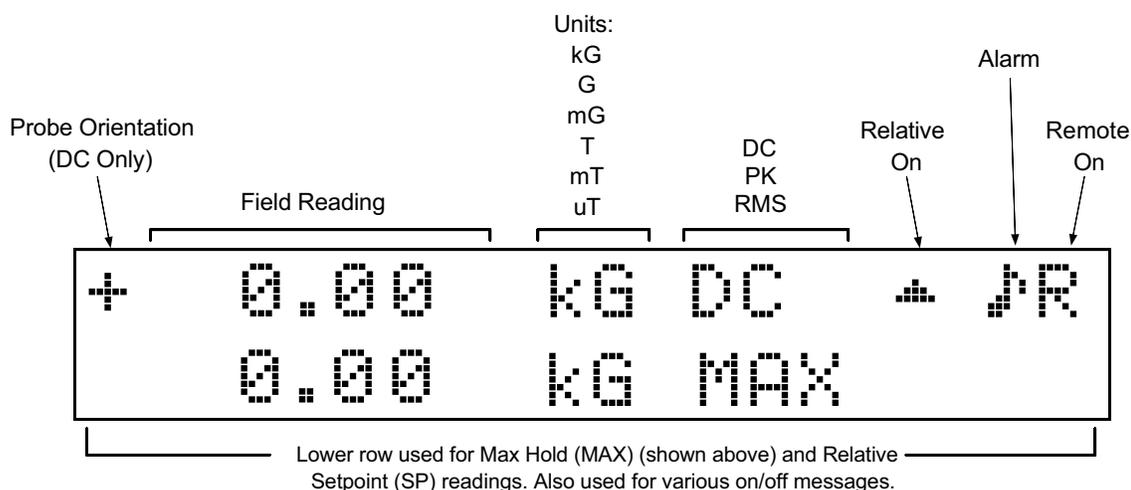
Figure 3-2. Front Panel Display Definition

3.2   MAX HOLD AND MAX RESET

Max Hold displays the largest field magnitude measured since the last **Max Reset**. Press **Max Hold** to view the maximum value in the lower line of the display and the field reading in the upper line.

```
+0.5729    kG DC
 0.5892    kG MAX
```
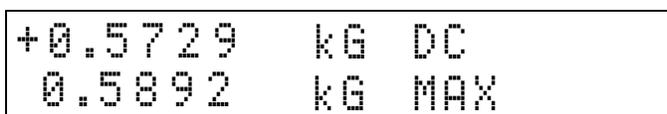
Max Hold may also be used in conjunction with the Relative display (Refer to Paragraph 3.7).

Max Reset clears the **Max Hold** value. The **Max Hold** value also resets upon power up or when changing from AC or DC.

Max Hold functions differently with AC and DC fields. In DC operation, **Max Hold** captures the largest magnitude field reading. This monitors slowly changing signals. A field change not visible on the display can not be recorded in DC Max Hold. The display shows only the magnitude of the maximum reading.

In AC RMS operation, **Max Hold** captures the maximum RMS value (i.e., operates the same as DC Max). In AC Peak operation, **Max Hold** uses a hardware circuit to trap peaks in the Hall voltage. In this mode, the unit displays the magnitude of the actual peak of an impulse or event. For best accuracy, the event must be at full amplitude for at least a few milliseconds.

3.3   ZERO PROBE

The zero probe function cancels out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an unshielded probe (registering the local earth magnetic field). To cancel large magnetic fields, use the Relative function.

NOTE: For best results, allow the instrument and probe to warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

To zero the probe in the zero gauss chamber, first allow the temperature of the probe and chamber to equalize. (A large temperature discrepancy affects the quality of the calibration.) Carefully place the probe tip into the chamber. Orientation of the probe is not critical. Once inserted, press **Zero Probe** to display the screen above.

```
Press Enter With
Probe At Zero
```
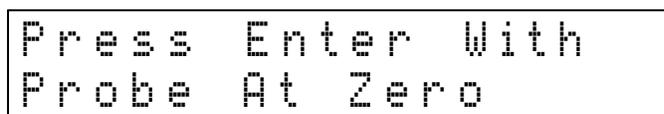
Press **Enter** to display the ***CALIBRATING*** message, followed by a return to the normal display. Do not move the probe while calibrating. The probe is now zeroed. For best results, periodically zero the probe.

3.4   SELECT RANGE AND AUTO RANGE

The Model 450 reads each Lake Shore probe type: High Stability, High Sensitivity, or Ultra-High Sensitivity. These probes sense fields as low as 0.01 mG and as high as 300 kG. The tables below list full scale ranges for each probe sensitivity, along with fixed display resolution.

High Stability Probe (HST)

Gauss			Tesla		
	Resolution			Resolution	
Range	AC, or DC w/ Filter Off	DC Filter On	Range	AC, or DC w/ Filter Off	DC Filter On
±300 kG	±0.01 kG	±0.001 kG	±30 T	±0.001 T	±0.0001 T
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT

High Sensitivity Probe (HSE)

Gauss			Tesla		
	Resolution			Resolution	
Range	AC, or DC w/ Filter Off	DC Filter On	Range	AC, or DC w/ Filter Off	DC Filter On
±30 kG	±0.001 kG	±0.0001 kG	±3 T	±0.0001 T	±0.00001 T
±3 kG	±0.0001 kG	±0.00001 kG	±300 mT	±0.01 mT	±0.001 mT
±300 G	±0.01 G	±0.001 G	±30 mT	±0.001 mT	±0.0001 mT
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT

Ultra-High Sensitivity Probe (UHS)

Gauss			Tesla		
	Resolution			Resolution	
Range	AC, or DC w/ Filter Off	DC Filter On	Range	AC, or DC w/ Filter Off	DC Filter On
±30 G	±0.001 G	±0.0001 G	±3 mT	±0.0001 mT	±0.00001 mT
±3 G	±0.0001 G	±0.00001 G	±300 µT	±0.01 µT	±0.001 µT
±300 mG	±0.01 mG	±0.001 mG	±30 µT	±0.001 µT	±0.0001 µT

For manual ranging, press **Select Range** to view the full scale value for the present range. The display to the right appears.

```
Select With  ▲▼
+/-3.0000  kG  Range
```
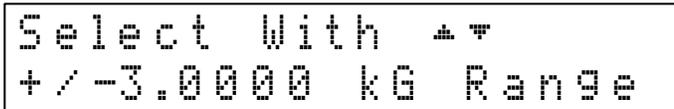
Press **Select Range** or the ▲ or ▼ keys to cycle through allowable full-scale ranges for the installed probe. Press **Enter** to accept the new range or **Escape** to retain the old range. Changing ranges in this way disables the Auto Range function until **Auto Range** is pressed.

NOTE: In AC Peak Mode only, you cannot select the lowest range for the installed probe. This is true for both Manual and Auto Range.

In Auto Range mode, the Model 450 selects the range with the best resolution for the measured field. It can take up to 2 seconds for Auto Range to work, so manual ranging may be better in some conditions. Press **Auto Range** to display the screen to the right.

```
Select With  ▲▼
Auto Range  →On  Off
```
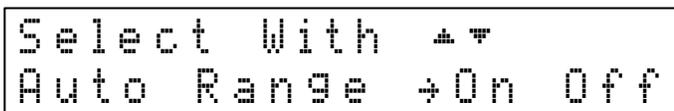
Press **Auto Range** or the ▲ or ▼ keys to cycle between On and Off. Push **Enter** to accept the new setting or **Escape** to retain the old setting and return to the normal display.

Do not use Auto Ranging with Peak and Max Hold operation or during small field measurement in a large background field, such as measuring a small DC field in presence of a large AC field, or vice versa.

3.5 AC/DC AND PEAK/RMS

The **AC/DC** key toggles between AC and DC measurements. The annunciator immediately changes from "DC" to "PK" or "RMS," as applicable. One update cycle is required for a new display value. The Model 450 updates the field reading 5 times per second. For faster updates, refer to Fast Data Mode in Paragraph 3.16.

In DC operation, the display shows the DC field at the probe with sign (orientation) followed by the appropriate field units, the letters DC, displaying 4¾ digits with filter OFF or 5¾ digits with Filter ON. The DC value is available over the IEEE-488 and Serial Interfaces and both Analog Outputs.

In AC operation, select either RMS or Peak. Both meet specified accuracy from 10 to 400 Hz. The lowest range for the type probe installed is not available in the AC Peak mode. The AC RMS reading is a measurement of true RMS, defined as the square root of the average of the square of the field function taken through one period. The RMS reading works on complex waveforms to a crest factor of 7 and rejects the DC component if it is not large enough to overload the selected range.

The AC Peak readings can be used in two different ways. With **Max Hold** OFF, it measures the Peak (Crest) of a periodic, symmetrical waveform. If field change at the probe is unpredictable, the peak reading will not always show the largest field value. In this case, check monitor output with an oscilloscope to see how the reading relates to the field. With **Max Hold** ON, the Peak reading measures the amplitude of a single peak like a magnetizing pulse. It captures the reading until reset with **Max Reset**.

The AC value is available over the IEEE-488 and Serial Interfaces. The Corrected Analog Output yields a DC voltage representation of the Peak or RMS reading, while the Monitor Analog Output yields a true analog waveform. (In fact, the Monitor Analog Output is not affected by the selection of AC or DC.)

When changing to AC or DC, the unit maintains previously established Relative and Alarm setpoints, but Max Hold operation changes (Paragraph 3.3).

3.6 FILTER

The **Filter** key initiates the display filter function (Paragraph 3.6.1). Press and hold **Filter** for about 5 seconds to display field and temperature compensation (Paragraph 3.6.2).

3.6.1 Display Filter

The display filter function quiets the display making it more readable when the probe is exposed to a noisy field. Take care when using the filter on changing fields; it may level off peaks and slow instrument response. Users may configure the filter function to view desired field changes and block noise. The filter also quiets noise within the instrument by adding a digit of usable resolution in DC.

To turn ON the display filter, press **Filter** to display the screen to the right. Press **Filter** or the ▲ or ▼ keys to toggle between ON and OFF. Press **Enter** to accept the new setting or **Escape** to retain the old setting and return to the normal display.

```
Select  With  ▲▼
Filter     On   →Off
```

With Filter turned on, two additional displays appear: the Filter Points display and the Filter Window display. The Filter Points display sets the number of points to use in the filter algorithm. Enter from 2 to 64 points; 8 is the default. The unit takes one point each display update cycle, so filter settling time depends on update speed and number of samples.

```
Select  With  ▲▼
Filter  Points  08
```

The Filter Window display sets a limit for restarting the filter. If a single field reading differs from the filter value by more than the limit specified, the instrument assumes an intentional change and restarts the filter at the new reading value. This allows faster instrument response to changing fields than if the filter functioned continually. Enter settings from 1% to 10%; 1% is the default.

```
Select  With  ▲▼
Filter  Window  01%
```

The Model 450 uses two different filter algorithms that result in slightly different settling time computations. For 2 to 8 filter points, a linear average is used for the fastest response. In this case, the filter settles in the same number of samples as entered. For example, when set at 8 points and updating at 5 readings per second, the filter settles in 1.6 seconds.

For 9 to 64 filter points, an exponential algorithm is used for a smooth response. The settling time for a 1% change to full display resolution is about the same as the

Figure 3-3. Display Filter Response Examples

number of filter points in seconds. For example, a setting of 10 filter points settles in about 10 seconds. Figure 3-3 illustrates the difference between linear and exponential response.

3.6.2   Field and Temperature Compensation

NOTE: Unless there is a specific reason, Lake Shore strongly advises customers *not* to turn field and temperature compensation off; it may reduce reading accuracy substantially.

To disable Field and Temperature Compensation, press and hold the **Filter** key for about 5 seconds to display the Field Compensation screen. To improve accuracy, all probes have a magnetic field compensation table stored in a PROM. Turning Field Compensation OFF causes the Model 450 to ignore this table. Press the ▲ or ▼ keys to cycle between ON and OFF. Push **Enter** to accept the new setting or **Escape** to retain the old setting and return to the normal display. If the probe has no field compensation, the setting is ignored.

```
Select With  ▲▼
Field Comp  On →Off
```

Some high-sensitivity probes also feature temperature compensation. Turning Temperature Compensation OFF causes the Model 450 to ignore this data. Press the ▲ or ▼ keys to cycle between ON and OFF. Push **Enter** to accept the new setting or **Escape** to retain the old setting and return to the normal display. If the probe has no temperature compensation, the setting is ignored.

```
Select With  ▲▼
Temp Comp  On →Off
```

3.7   GAUSS / TESLA

The Model 450 displays magnetic field values in gauss (G) or tesla (T). Press **Gauss/Tesla** to toggle the display between the two units. The relation between gauss and tesla is 1 G = 0.0001 T, or 1 T = 10,000 G. When field units are changed, relative and alarm setpoints convert to the new units with no interruption in operation. The Corrected and Monitor Analog Outputs are not affected by a change in units.

When tesla is selected, the Model 450 displays AC or DC field values followed by T for tesla, mT for millitesla, or uT for microtesla and formats field values over the IEEE-488/Serial Interface accordingly.

When gauss is selected, the Model 450 displays AC or DC field values followed by kG for kilogauss, G for gauss, or mG for milligauss and formats field values over the IEEE-488/Serial Interface accordingly.

3.8 RELATIVE SET AND RELATIVE ON/OFF

The relative function lets the user see small variations in larger fields. Set the setpoint (or center) of the relative reading with **Relative Set**. There are two ways to enter the relative setpoint.

```
Enter  Relative  Setp.
       +0.5392  kG
```

The first method captures the field reading, nulling the present field. The field reading displays as the setpoint upon pressing **Relative Set**. Press **Enter** to accept the setpoint or **Escape** to retain the old value and quit the Relative Set function.

The second method is by keypad entry. Press **Relative Set** and change the setpoint by pressing number keys or using the ▲ or ▼ keys. Press **Select Range** to enter a setpoint different from the current range. Press **Enter** to accept the new setpoint or **Escape** to return to the old value.

Once the relative setpoint is established, push **Relative On/Off** to initiate the relative function. The "Relative On" message briefly appears on the lower line of the display, followed by the selected setpoint (SP). The plus or minus

```
-0.0037   kG DC  ▲
+0.5392   kG SP
```

deviation from that setpoint displays on the upper line. A small delta (▲) signifies the relative display.

The relative feature also interacts with other features. When alarm is active, the alarm points follow the relative reading. When Relative and Max Hold functions are used at the same time, the relative reading is still displays on the top line with proper annunciators, but the bottom line shows the relative maximum instead of the relative setpoint.

```
-0.0037   kG DC  ▲
+0.0054   kG MAX
```

Press **Max Hold** again to turn OFF the maximum hold function, returning the relative reading to the display. Press **Relative On/Off** to turn OFF the relative function. The "Relative Off" message displays.

3.9 ALARM SET AND ALARM ON/OFF

The alarm gives an audible and visual indication when the field value is outside or inside a user-specified range. Two settings define alarm operating parameters. First is whether the audible alarm is ON or OFF. Second is whether readings inside or outside the defined field range trigger the alarm. (Default settings are audible alarm on and alarm triggered outside the low and high alarm setpoints.) To set these parameters, press and hold **Alarm On/Off** until the display to the right appears. Use the ▲ or ▼ keys to cycle between audible alarm on or off. Press **Enter** to accept the new value or **Escape** to step to the next function and retain the old setting.

```
Select  With  ▲▼
Audible  →On    Off
```

The Model 450 proceeds to the next display:

Use the ▲ or ▼ keys to cycle between the alarm triggered inside or outside alarm setpoints. Press **Enter** to accept the changes or **Escape** to exit

```
Select  With  ▲▼
Alarm  Inside→Outside
```

the function and retain the old settings. All alarm functions are also available over the IEEE-488 and Serial Interfaces.

The example below details operation with the Alarm **Outside** setting. For example, with the reading centered on 1 kG, the high alarm point at 1.5 kG, and the low alarm point at 0.5 kG, the diagram below illustrates when the alarm is ON or OFF.

Example of operation with alarm triggered by readings OUTSIDE user defined setpoints.

To enter this alarm setup, push **Alarm Set**. The unit prompts for the High Alarm Point:

```
High Alarm Point
      +1.5000 kG
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push **Select Range** until the proper range displays. Then use the numeric keypad to enter the high alarm point. After entering the desired high alarm point, press **Enter** to accept the new value or **Escape** to retain the old value.

The display proceeds to the Low Alarm Point:

```
Low Alarm Point
      +0.5000 kG
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push **Select Range** until the proper range displays. Then use the numeric keypad to enter the low alarm point. After entering the desired alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. The alarm setpoints are absolute (unsigned), i.e., only the magnitude of the field reading is used.

After entering proper high and low alarm points, press **Alarm On/Off** to activate the alarm. The message "Alarm On" appears on the lower line of the display, and the musical note appears in the upper right-hand corner of the display, signifying alarm ON. When the field reading is outside the alarm setpoints, the musical note flashes and, if turned ON, the alarm sounds. To turn the alarm OFF, press **Alarm On/Off** again. The message " Alarm Off" appears.

The example below details how the alarm operates on the **Inside** setting. Use the alarm inside setup to look for good readings. For example, to check 1 kG magnets for a tolerance of ±0.25 kG, set the high alarm point 1.25 kG and the low alarm point to 0.75 kG. The diagram below illustrates when the alarm is ON or OFF.
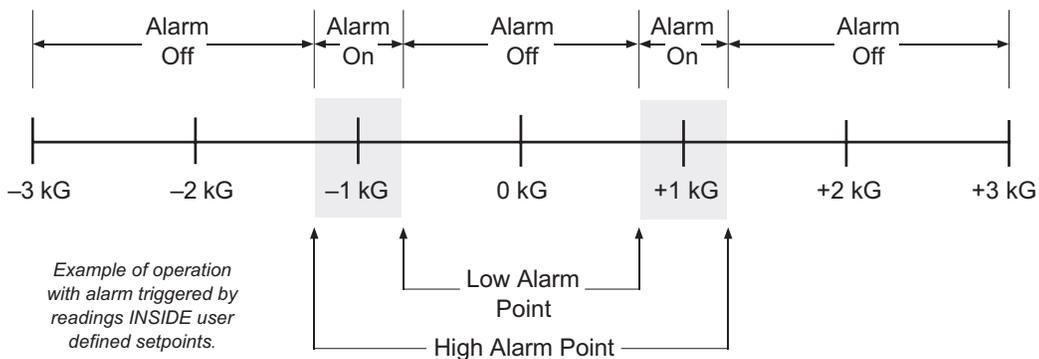
Example of operation with alarm triggered by readings INSIDE user defined setpoints.

To enter this alarm setup, push **Alarm Set**. The unit prompts for the High Alarm Point:

```
High Alarm Point
       +1.2500 kG
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push **Select Range** until the proper range displays. Then use the numeric keypad to enter the high alarm point. After entering the desired high alarm point, press **Enter** to accept the new value or **Escape** to retain the old value.

The display proceeds to the Low Alarm Point:

```
Low Alarm Point
       +0.7500 kG
```

The initial range displayed is the same as the latest probe range. To set an alarm in a different range, push **Select Range** until the proper range displays. Then use the numeric keypad to enter the low alarm point. After entering the desired alarm point, press **Enter** to accept the new value or **Escape** to retain the old value. The alarm setpoints are absolute (unsigned) i.e., only the magnitude of the field reading is used.

After entering proper high and low alarm points, press **Alarm On/Off** to activate the alarm. The message "Alarm On" appears on the lower line of the display the musical note appears in the upper right-hand corner of the display, signifying alarm on. To turn the alarm off, again press the **Alarm On/Off** key. The message " Alarm Off" appears. When the field reading is inside the alarm setpoints, the musical note flashes and, if turned ON, the alarm sounds.

3.10 LOCAL AND ADDRESS

Normal front panel operation is called Local operation. However, the IEEE-488 Interface provides remote operation. A Model 450 connected to a suitably equipped computer may either permit or inhibit front panel operation. The **Local** key toggles between local (front panel functional) or remote (front panel disabled). The letter "R" displays in the upper right side of the display to signify Remote mode activation.

Before using the IEEE-488 Interface, set the IEEE Address and Terminators. Press **Address** to display the screen to the right. Press the ▲ or ▼ keys to increment or decrement the IEEE Address to the required number. Press **Enter** to accept the new number or **Escape** to retain the existing number.

```
Select With  ▲▼
IEEE Address  12
```

The Model 450 automatically proceeds to the IEEE-488 Terminator display. Press the ▲ or ▼ keys to cycle through the following IEEE-488 Terminator choices:

```
Select With  ▲▼
Terminators  Cr Lf
```

Cr Lf Carriage Return and Line Feed.
Lf Cr Line Feed and Carriage Return.
LF Line Feed.
EOI End Or Identify.

Terminators are fixed to Cr Lf for the Serial Interface.

3.11 BAUD

To use the Serial Interface, set the Baud rate. Press **Baud** to display the screen to the right. Press the ▲ or ▼ keys to cycle through the choices of 300, 1200, or 9600 Baud. Press **Enter** to accept the new number or **Escape** to keep the existing setting and return to the normal display.

```
Select With  ▲▼
Baud  3  →12   96
```

3.12 ANALOG OUT

There are two rear panel analog outputs on the Model 450 called the Corrected and Monitor Analog Outputs. Both use BNC connectors with the center conductor carrying the signal and the outer portion the ground. Refer to Paragraph 3.12.1 for Corrected Analog Output and Paragraph 3.12 2 for Monitor Analog Output.

3.12.1 Corrected Analog Out

The Corrected Analog Output is a DC value proportional to the displayed field. The displayed field reading may be corrected for probe nonlinearity, zero offset, and temperature. This output is not a real time signal, but updates at the same rate as the display.

The standard Model 450 has a Corrected output where ±3 volts equals ± full scale for the selected range. The Model 450-10 features a modified Corrected Analog Output where ±10 volts equals ± full scale for the selected range. The examples in this section assume the standard ±3 volt setting. For the example below, the 3 kG range was selected.

Display Reading	−3 kG	−2 kG	−1 kG	0 kG	+1 kG	+2 kG	+3 kG
Output Voltage	−3 V	−2 V	−1 V	0 V	+1 V	+2 V	+3 V
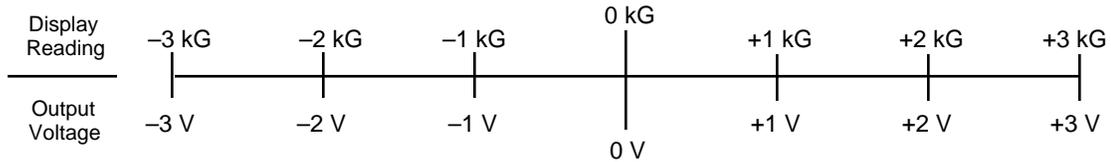
To select the default range, press the Analog Out key to display the screen to the right. Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to Def (Default). Press **Enter** to set the Corrected Analog Output for ±3V = ±3 kG.

```
Select With  ▲▼
Analog Out, →Def User
```

The user may also change Corrected Analog Output scaling. User-defined scaling can improve resolution over a selected area. For example, below is a symmetrical scaling similar to the default scale.
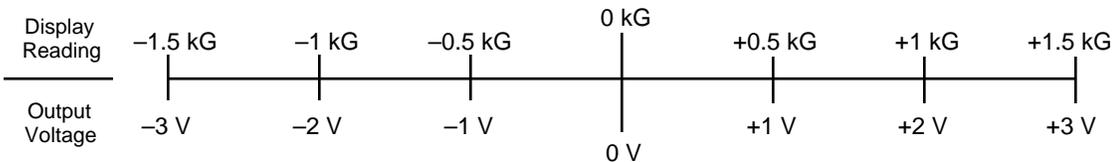
Display Reading	−1.5 kG	−1 kG	−0.5 kG	0 kG	+0.5 kG	+1 kG	+1.5 kG
Output Voltage	−3 V	−2 V	−1 V	0 V	+1 V	+2 V	+3 V

To enter this scale, press **Analog Out**. Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to User as shown.

```
Select With  ▲▼
Analog Out Def→User
```

Press **Enter** to display the Max Output screen.

Enter the numbers 1.5 on the numerical keypad and press **Enter**. The unit places a maximum output of +1.5 kG into memory and displays the Min Output screen.

```
Enter Max Output
      +1.5000 kG
```

Enter the numbers −1.5 on the numerical keypad and press **Enter**. The unit places a minimum output of −1.5 kG into memory. Changes to the Corrected Analog Output are immediately observable.

```
Enter Min Output
      -1.5000 kG
```

The example below is an asymmetrical scaling which demonstrates the versatility of user-selectable scaling.
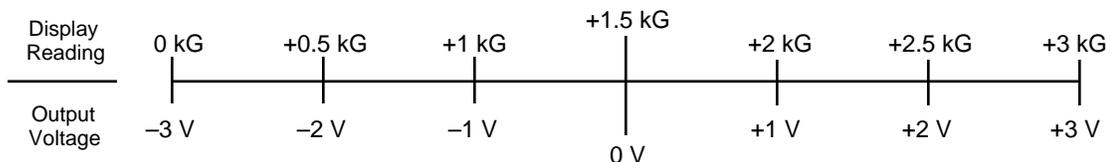
Display Reading	0 kG	+0.5 kG	+1 kG	+1.5 kG	+2 kG	+2.5 kG	+3 kG
Output Voltage	−3 V	−2 V	−1 V	0 V	+1 V	+2 V	+3 V

To enter this scale, press **Analog Out**. Press the **Analog Out**, ▲, or ▼ key to cycle the arrow (→) to User as shown.

```
Select With  ▲▼
Analog Out Def→User
```

Press **Enter** to display the Max Output screen.

Enter the number 3 on the numerical keypad and press **Enter**. The unit places a maximum output of +3.0 kG into memory and displays the Min Output screen.

```
Enter  Max  Output
      +3.0000  kG
```
```
Enter  Min  Output
      +0.0000  kG
```

Enter the numbers 0.0 on the numerical keypad and press **Enter**. The unit places a minimum output of 0.0 kG into memory. Changes to the Corrected Analog Output are immediately observable.

For best results, put at least 100 counts between minimum and maximum for the range. For example, if the 3.0000 kG range was selected with a minimum scale of 1.0000 kG, enter a maximum setting of 1.0100 kG or greater.

3.12.2 Monitor Analog Out

The Monitor Analog Output is a real-time analog signal proportional to the magnetic field and scaled to ±3 volts for full scale of selected range. It is not as accurate as the Corrected Monitor Output, but it has the full 400 Hz bandwidth of the AC measurement. Most of the error is on lower ranges and results from zero offsets in the probe and instrument. The error can be minimized by subtracting output voltage observed at zero field from the live output.

3.12.3 Analog Output Control Mode

It is sometimes convenient to use the corrected analog output as a control voltage output instead of an analog output proportional to measured field. A set of computer interface commands control the digital-to-analog converter (DAC) for the corrected analog output. One common application is using the output to program an electromagnet power supply. By using the analog output, the user can avoid purchasing a magnet supply controller and adding a separate interface to their computer.

The Model 450 software dated 10/1/94 and newer supports this feature. Update older Model 450 software at no charge. The actual output voltage and voltage resolution depends on an instrument hardware setting. The Model 450 comes with standard ±3 volt output or optional ±10 volt output. To upgrade from ±3 volt output to ±10 volt output, consult the factory.

Output Range:	±3 volts	±10 volts
Resolution:	0.37 mV	1.2 mV

Two commands control the corrected analog output via the IEEE-488 or Serial Interface. The **ANOD** command specifies interface control of the output; set it to "2". Send this command only once. The **ANOD?** query confirms the change. This setting will not change if the instrument is powered off, but it can be changed back to normal operation from the front panel.

The **AOCON** command sets bipolar output voltage in percent of full scale. The setting format of ±xxx.xx; allows for a sign and a resolution of 0.01%. As a safety precaution, this setting always equals zero if the instrument looses power or is turned off. The setting cannot be changed from the front panel. The **AOCON?** query confirms the change. Example: Sending **AOCON –50.25** sets output to –50.25% of full scale. This is –5.025 V for a ±10 V output or –1.5075 V for a ±3 V output.

3.13 LOCKING AND UNLOCKING THE KEYBOARD

The Model 450 front panel keyboard may be locked, preventing unauthorized changes to the settings. To lock the keyboard, press and hold **Enter** (about 10 seconds) until the following display appears.

```
Enter Code To
Lock Keypad
```

Enter the 3-digit lock code (the default is 123). Upon entry of the third number, the display reverts to the normal display. The keyboard is now locked. After locking the keypad, any attempt to change settings displays the following *Locked* message.

```
*Locked*
```

To unlock the keyboard, press and hold the **Enter** key until the following message is displayed.

```
Enter Code To
Unlock Keypad
```

Enter the lock code again. Upon entry of the third number, the display reverts to the normal display and the keyboard is unlocked.

Change the lock code using either the IEEE-488 or RS-232C Computer Interface. For future reference, record the lock code for your installation. If the instrument is reset (Paragraph 3.14), the lock code reverts to 123. The instrument cannot be reset when the keyboard is locked.

3.14 FACTORY DEFAULT SETTINGS

With the keypad unlocked and the Model 450 in local mode, the user may press and hold **Escape** for about 20 seconds to return the instrument to factory default settings:

AC/DC: DC	Filter Number: 8
Address: 12	Filter Window %: 1%
Alarm: Off	Gauss/Tesla: Gauss
Alarm Trigger: Outside	Keypad: Not Locked
Analog Out: Default	Local/Remote: Local
Audible Alarm: On	Lock Code: 123
Auto Range: Off	Max Hold: Off
Baud: 300	Peak/RMS: RMS
Brightness: 4	Range: Highest Range For Probe
Fast Data Mode: Off	Relative: Off
Field Compensation: On	Temperature Compensation: On
Filter: Off	Terminators: CR/LF

Other gaussmeter calibration information and probe data are not affected by this reset. Zero the probe after completing this operation.

3.15 PROBE CONSIDERATIONS

To avoid damage and for best results during use, the probes have a number of handling and accuracy requirements that must be observed. Changing probes is discussed in Paragraph 3.16.1. Probe handling is discussed in Paragraph 3.16.2. Probe operation is discussed in Paragraph 3.16.3. Finally, accuracy considerations are provided in Paragraph 3.16.4.

3.15.1 Changing Probes

A 512-byte Electrically Erasable Programmable Read Only Memory (EEPROM) is included in each probe. The EEPROM stores specific information that the gaussmeter requires for operation. The information includes serial number, probe sensitivity, and field compensation data.

CAUTION: **The probe must be connected to the rear of the instrument before applying power to the gaussmeter. Probe memory may be erased if connected with power on.**

When the instrument is powered up, the probe memory is downloaded to the gaussmeter. This is how the gaussmeter knows which ranges are available and which error correction to apply. To change probes, first turn power off, remove the existing probe, and then plug in the new probe. When power is restored, the characteristics of the new probe are downloaded to the gaussmeter memory. Normal operation may continue after the new probe offset is nulled using the Zero Probe operation.

If the instrument is powered up with no probe attached, the following message is displayed.

```
* * NO PROBE * *
Power off to attach!
```

3.15.2 Probe Handling

Although every attempt has been made to make the probes as sturdy as possible, the probes are still fragile. This is especially true for the exposed sensor tip of some transverse probes. Care should be taken during measurements that no pressure is placed on the tip of the probe. The probe should only be held in place by securing at the handle. The probe stem should never have force applied. Any strain on the sensor may alter the probe calibration, and excessive force may destroy the Hall generator.

CAUTION: **Care must be exercised when handling the probe. The tip of the probe is very fragile. Stressing the Hall sensor can alter its calibration. Any excess force can easily break the sensor. Broken sensors are not repairable.**

Avoid repeated flexing of the stem of a flexible probe. As a rule, the stem should not be bent more than 45° from the base. See Figure 3-4. Force should never be applied to the tip of the probe. On all probes, do not pinch or allow cables to be struck by any heavy or sharp objects. Although damaged or severed cables should be returned to Lake Shore for repair, please understand that probes are not always repairable.

When probes are installed on the gaussmeter but not in use, the protective tubes provided with many probes should be placed over the probe handle and stem in order to protect the tip. When the gaussmeter is not in use, the probes should be stored separately in some type of rigid container. The cardboard and foam container that Lake Shore probes are shipped in may be retained for probe storage. For further details on available accessories and probes, refer to Chapter 5.
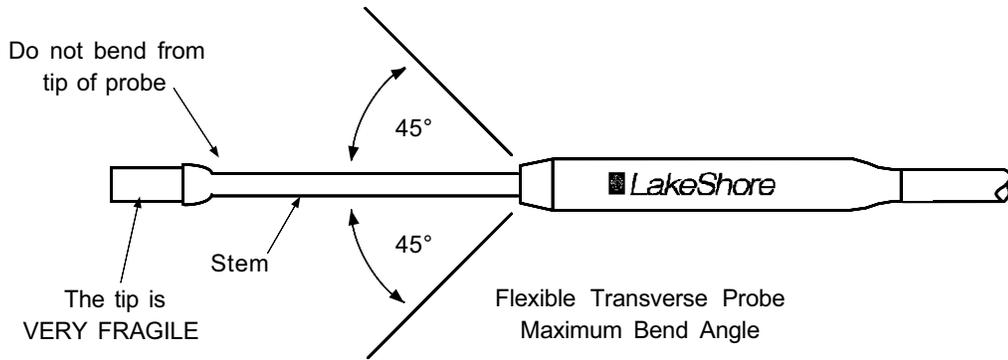
C-421-3-4.eps

Figure 3-4. Maximum Flexible Probe Bend Radius

3.15.3 Probe Operation

In the DC mode of operation, the orientation of the probe affects the polarity reading of the gaussmeter. On a transverse probe, the Lake Shore name printed on the handle indicates the side for positive (+) flux entry. On an axial probe, positive (+) flux entry is always from the front of the probe. See Figure 3-5.

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

If the exact direction of the magnetic field is unknown, the proper magnitude is determined by turning on **Max Hold** and slowly adjusting the probe. As the probe turns and the measured field rises and falls, its maximum value is held on the display. Make note of the probe orientation at the maximum reading to identify the field orientation.
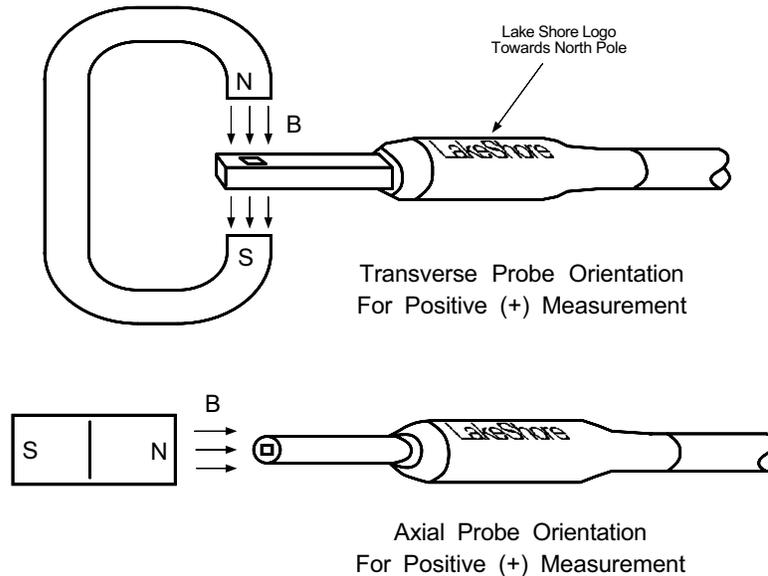
C-421-3-5.eps

Figure 3-5. Probe Orientation For Positive Measurement

3.15.4 Probe Accuracy Considerations

NOTE: Probe readings are dependent upon the angle of the sensor in relation to the magnetic field. The farther from 90° the angle between the probe and the field, the greater the percentage of error. For example, a 5° deviation causes a 0.4% error, a 10° deviation causes a 1.5% error, etc.

NOTE: For best results, the instrument and probe should warm up for at least 5 minutes before zeroing the probe, and at least 30 minutes for rated accuracy. The probe and the zero gauss chamber should be at the same temperature.

The user must consider all the possible contributors to the accuracy of the reading. Both the probe and gaussmeter have accuracy specifications that may impact the actual reading. The probe should be zeroed before making critical measurements. The zero probe function is used to null (cancel) out the zero offset of the probe or small magnetic fields. It is normally used in conjunction with the zero gauss chamber, but may also be used with an open probe (registering the local earth magnetic field). Users wishing to cancel out large magnetic fields should use the Relative function. Refer to Paragraph 3.8.

Probe temperature can also affect readings. Refer to the two separate temperature coefficients listed on the specification sheet. The High Stability (HST) probes exhibit a low temperature coefficient of gain due to the inherent thermal stability of the materials used in its construction.

Probe readings are dependent on the angle of the sensor (Hall sensor) in relation to the magnetic field. Maximum output occurs when the flux vector is perpendicular to the plane of the sensor. This is the condition that exists during factory calibration. The greater the deviation from orthogonality (from right angles in either of three axes), the larger the error of the reading. For example, a 5° variance on any one axis causes a 0.4% error, a 10° misalignment induces a 1.5% error, etc. See Figure 3-6.

Tolerance of instrument, probe, and magnet must be considered for making critical measurements. The accuracy of the gaussmeter reading is better than ±0.20% of reading and ±0.05% of range. Absolute accuracy readings for gaussmeters and Hall probes is a difficult specification to give, because all the variables of the measurement are difficult to reproduce. For example, a 1° error in alignment to the magnetic field causes a 0.015% reading error. Finally, the best probes have an accuracy of ±0.15%. This implies that the absolute accuracy measurement of a magnetic field is not going to reliably be better than ±0.15% under the best of circumstances, and more likely to be 0.20% to 0.25%.

Effect of angular variations on percentage of reading error
where % Error = $(1 - \cos \theta)\, 100$
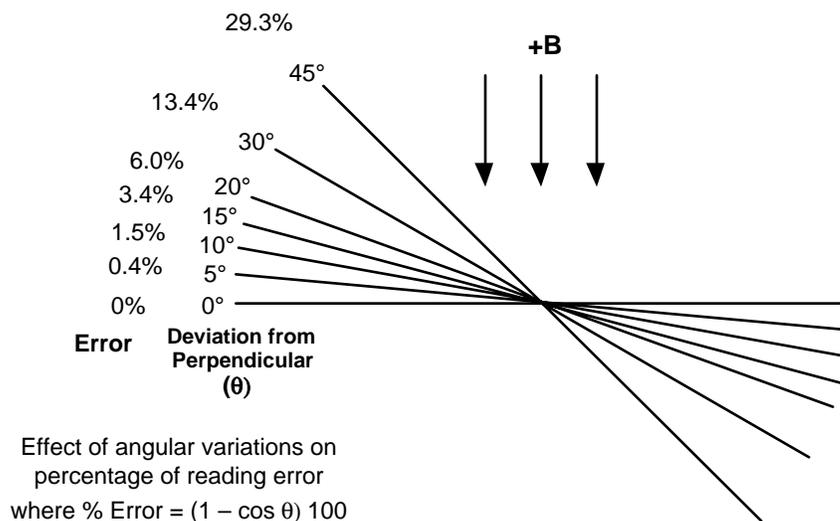
Figure 3-6. Effect Of Angle On Measurements

3.16 FAST DATA MODE

In normal operation, the instrument updates the display, computer interfaces, and the corrected analog output at a rate of 5 readings per second. Fast Data Mode increases the data rate when operating with either the IEEE-488 or Serial Interface. While the corrected analog output update rate does correspond to the Fast Data Mode, the front panel display will not operate in this mode. In Fast Data Mode, the front panel screen displays the message below.

```
Fast Data Mode
```

To place the instrument in Fast Data Mode, use the interface command: `FAST 1`.

To leave fast data mode, use this command: `FAST 0`.

To query the status of Fast Data Mode, use this command: `FAST?` The unit returns **0** if Fast Data Mode is Off, and **1** if On.

NOTE: Fast Data Mode activation disables the following Model 450 functions: Relative, Max Hold, Alarms, and Autorange. Temperature compensation (if applicable) is based on the last temperature reading prior to FAST DATA MODE activation. The temperature is not updated during FAST DATA MODE.

Use the normal interface command to query field measurement data. Without display overhead, the instrument can take 18 new readings each second. An efficiently written IEEE-488 program can return all 18 readings without slowing the instrument down. When using the IEEE-488 Interface, never try to read faster than 18 readings a second.

The additional overhead associated with Serial Communication slows instrument Serial Interface communications to a maximum of 15 readings per second at 9600 Baud. When using the Serial Interface, never try to read faster than 15 readings a second.

CHAPTER 4

COMPUTER INTERFACE OPERATION

4.0 GENERAL

This chapter provides operational instructions for the computer interface for the Lake Shore Model 450 Gaussmeter. Either of the two computer interfaces provided with the Model 450 permit remote operation. The first is the IEEE-488 Interface described in Paragraph 4.1. The second is the Serial Interface described in Paragraph 4.2. The two interfaces share a common set of commands detailed in Paragraph 4.3. Only one of the interfaces can be used at a time.

4.1 IEEE-488 INTERFACE

The IEEE-488 Interface is an instrumentation bus with hardware and programming standards that simplify instrument interfacing. The Model 450 IEEE-488 Interface complies with the IEEE-488.2-1987 standard and incorporates its functional, electrical, and mechanical specifications unless otherwise specified in this manual.

All instruments on the interface bus perform one or more of the interface functions of TALKER, LISTENER, or BUS CONTROLLER. A TALKER transmits data onto the bus to other devices. A LISTENER receives data from other devices through the bus. The BUS CONTROLLER designates to the devices on the bus which function to perform. The Model 450 performs the functions of TALKER and LISTENER but cannot be a BUS CONTROLLER. The BUS CONTROLLER is the digital computer which tells the Model 450 which functions to perform.

Below are Model 450 IEEE-488 interface capabilities:
- **SH1:** Source handshake capability.
- **RL1:** Complete remote/local capability.
- **DC1:** Full device clear capability.
- **DT0:** No device trigger capability.
- **C0:** No system controller capability.
- **T5:** Basic TALKER, serial poll capability, talk only, unaddressed to talk if addressed to listen.
- **L4:** Basic LISTENER, unaddressed to listen if addressed to talk.
- **SR1:** Service request capability.
- **AH1:** Acceptor handshake capability.
- **PP0:** No parallel poll capability.
- **E1:** Open collector electronics.

NOTE: The Model 450 IEEE-488 Interface requires that repeat addressing be enabled on the bus controller.

Instruments are connected to the IEEE-488 bus by a 24-conductor connector cable as specified by the standard. Refer to Paragraph 6.5.1. Cables can be purchased from Lake Shore or other electronic suppliers. Cable lengths are limited to 2 meters for each device and 20 meters for the entire bus. The Model 450 can drive a bus with up to 10 loads. If more instruments or cable length is required, a bus expander must be used.

4.1.1 Changing IEEE-488 Interface Parameters

Two interface parameters, address and terminators, must be set from the front panel before communication with the instrument can be established. Other interface parameters can be set with device specific commands using the interface (Paragraph 4.3).

Press **Address** to display the following screen.

```
Select With ▲▼
IEEE Address  12
```

Press the ▲ or ▼ keys to increment or decrement the IEEE Address to the desired number. Valid addresses are 1 thru 30. Default is 12. Press **Enter** to accept new number or **Escape** to retain the existing number. Pressing either Enter or Escape displays the Terminators screen.

```
Select With ▲▼
IEEE Term  Cr Lf
```

Press the ▲ or ▼ keys to cycle through the following Terminator choices: CR/LF, LF/CR, LF, and EOI. To accept changes or the currently displayed setting, push **Enter**. To cancel changes, push **Escape**. Power down the Model 450 then power it up again to allow other devices on the IEEE-488 bus to recognize a new Address or Terminator setting.

4.1.2 IEEE-488 Command Structure

The Model 450 supports several command types. These commands are divided into three groups.

1. **Bus Control** – Refer to Paragraph 4.1.2.1.
   a. Universal
      (1) Uniline
      (2) Multiline
   b. Addressed Bus Control
2. **Common** – Refer to Paragraph 4.1.2.2.
3. **Device Specific** – Refer to Paragraph 4.1.2.3.
4. **Message Strings** – Refer to Paragraph 4.1.2.4.

4.1.2.1 Bus Control Commands

A Universal Command addresses all devices on the bus. Universal Commands include Uniline and Multiline Commands. A Uniline Command (Message) asserts only a single signal line. The Model 450 recognizes two of these messages from the BUS CONTROLLER: **Remote (REN)** and **Interface Clear (IFC)**. The Model 450 sends one Uniline Command: **Service Request (SRQ)**.

REN (Remote) – Puts the Model 450 into remote mode.

IFC (Interface Clear) – Stops current operation on the bus.

SRQ (Service Request) – Tells the bus controller that the Model 450 needs interface service.

A Multiline Command asserts a group of signal lines. All devices equipped to implement such commands do so simultaneously upon command transmission. These commands transmit with the Attention (ATN) line asserted low. The Model 450 recognizes two Multiline commands:

LLO (Local Lockout) – Prevents the use of instrument front panel controls.

DCL (Device Clear) – Clears Model 450 interface activity and puts it into a bus idle state.

Bus Control Commands (Continued)

Finally, Addressed Bus Control Commands are Multiline commands that must include the Model 450 listen address before the instrument responds. Only the addressed device responds to these commands. The Model 450 recognizes three of the Addressed Bus Control Commands:

SDC (Selective Device Clear) – The SDC command performs essentially the same function as the DCL command except that only the addressed device responds.

GTL (Go To Local) – The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

SPE (Serial Poll Enable) and **SPD (Serial Poll Disable)** – Serial polling accesses the Service Request Status Byte Register. This status register contains important operational information from the unit requesting service. The SPD command ends the polling sequence.

4.1.2.2 Common Commands

Common Commands are addressed commands which create commonalty between instruments on the bus. All instruments that comply with the IEEE-488 1987 standard share these commands and their format. Common commands all begin with an asterisk. They generally relate to "bus" and "instrument" status and identification. Common query commands end with a question mark (?). Model 450 common commands are detailed in Paragraph 4.3.

4.1.2.3 Device Specific Commands

Device specific commands are addressed commands. The Model 450 supports a variety of device specific commands to program instruments remotely from a digital computer and to transfer measurements to the computer. Most device specific commands perform functions also performed from the front panel. Model 450 device specific commands are detailed in Paragraph 4.3.

4.1.2.4 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings can be chained together in one communication but they must be separated by a semi-colon (;). Only one query is permitted per communication but it can be chained to the end of a command. The total communication string must not exceed 64 characters in length.

A command string is issued by the computer and instructs the instrument to perform a function or change a parameter setting. When a command is issued, the computer is acting as 'talker' and the instrument as 'listener'. The format is:

`<command mnemonic><space><parameter data><terminators>.`

Command mnemonics and parameter data necessary for each one is described in Paragraph 4.3. Terminators must be sent with every message string.

A query string is issued by the computer and instructs the instrument which response to send. Queries are issued similar to commands with the computer acting as 'talker' and the instrument as 'listener'. The query format is:

`<query mnemonic><?><space><parameter data><terminators>.`

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Paragraph 4.3. Terminators must be sent with every message string. Issuing a query does not initiate a response from the instrument.

A response string is sent by the instrument only when it is addressed as a 'talker' and the computer becomes the 'listener'. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Paragraph 4.3.

4.1.3 Status Registers

There are two status registers: the Status Byte Register described in Paragraph 4.1.3.1, and the Standard Event Status Register in Paragraph 4.1.3.2.

4.1.3.1 Status Byte Register and Service Request Enable Register

The Status Byte Register consists of one data byte containing six bits of information about Model 450 status.

STATUS BYTE REGISTER FORMAT

Bit –	7	6	5	4	3	2	1	0
Weighting –	128	64	32	16	8	4	2	1
Bit Name –	Not Used	SRQ	ESB	OVI	Not Used	ALM	RNG	FDR

If the Service Request is enabled, setting any of these bits causes the Model 450 to pull the SRQ management low to signal the BUS CONTROLLER. These bits reset to zero upon a serial poll of the Status Byte Register. Inhibit or enable these reports by turning their corresponding bits off or on in the Service Request Enable Register. The *SRE command sets the bits. Setting a bit in the Service Request Enable Register, enables that function. Refer to the *SRE command.

Service Request (SRQ) Bit (6) – Determines whether the Model 450 reports via the SRQ line. Four bits determine which status reports to make. If bits 0, 1, 2, 4, and/or 5 are set, then the corresponding bit in the Status Byte Register is set. The Model 450 produces a service request only if bit 6 of the Service Request Enable Register is set. If disabled, the BUS CONTROLLER still examines Status Byte Register status reports by serial poll (SPE), but the Service Request cannot interrupt the BUS CONTROLLER. The *STB common command reads the Status Byte Register but will not clear the bits.

The Status Byte Register bit assignments are described below. These reports occur only if enabled in the Service Request Enable Register.

Field Data Ready (FDR) Bit (0) – When set, new valid field readings are available.

Range Change (RNG) Bit (1) – Range changed in Auto Range mode on any channel.

Alarm (ALM) Bit (2) – When set, an alarm condition exists on any channel. This condition latches until acknowledged by the bus controller.

Overload Indicator (OVI) Bit (4) – When set, indicates a display overload on any selected channel. Issues a Service Request if enabled.

Standard Event Status (ESB) Bit (5) – When set, indicates if one of the bits from the Standard Event Status Register has been set (Paragraph 4.1.4.2.).

4.1.3.2 Standard Event Status Register and Standard Event Status Enable Register

The Standard Event Status Register supplies various conditions of the Model 450.

STANDARD EVENT STATUS REGISTER FORMAT

Bit –	7	6	5	4	3	2	1	0
Weighting –	128	64	32	16	8	4	2	1
Bit Name –	PON	Not Used	CME	EXE	DDE	QYE	Not Used	OPC

Bits 1 and 6 are not used. Reports of this register interrupt the user only if the bits are enabled in the Standard Event Status Enable Register and if bit 5 of the Service Request Enable Register is set.

The Standard Event Status Enable Register allows the user to enable any of the Standard Event Status Register reports. The Standard Event Status Enable command (*ESE) sets the Standard Event Status Enable Register bits. Setting a bit of this register, enables that function. To set a bit, send the command *ESE with the sum of the bit weighting for each bit to be set. Refer to the *ESE command.

Standard Event Status Register and Standard Event Status Enable Register (Continued)

The Standard Event Status Enable Query, ∗ESE?, reads the Standard Event Status Enable Register. ∗ESR? reads the Standard Event Status Register. Once this register is read, the bits reset to zero.

Power On (PON) Bit (7) – Set to indicate a controller off-on-off transition.

Command Error (CME) Bit (5) – Set to indicate a command error since the last reading. Controller unable to interpret a command due to syntax error, unrecognized header or terminators, or unsupported command.

Execution Error (EXE) Bit (4) – Set to indicate an execution error. This occurs when the controller is instructed to do something not within its capabilities.

Device Dependent Error (DDE) Bit (3) – Set to indicate a device dependent error. Determine the actual device dependent error by executing the various device dependent queries.

Query Error (QYE) Bit (2) – Set to indicate a query error. Occurs rarely, but involves data loss due to full output queue.

Operation Complete (OPC) Bit (0) – This bit is generated in response to the ∗OPC common command. It indicates when the Model 450 has completed all selected pending operations.

4.1.4   IEEE Interface Example Programs

Two BASIC programs are included to illustrate the IEEE-488 communication functions of the instrument. The first program was written in Visual Basic. Refer to Paragraph 4.1.4.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 4-2. The second program is written in Quick Basic. Refer to Paragraph 4.1.4.3 for instructions on how to setup the program. The Quick Basic code is provided in Table 4-3. Finally, a description of operation common to both programs is provided in Paragraph 4.1.4.5. While the hardware and software required to produce and implement these programs not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

4.1.4.1   IEEE-488 Interface Board Installation for Visual Basic Program

This procedure works for Plug and Play GPIB Hardware and Software for Windows 98/95. This example uses the AT-GPIB/TNT GPIB card.

1. Install the GPIB Plug and Play Software and Hardware using National Instruments instructions.
2. Verify that the following files have been installed to the Windows System folder:
    a. gpib-32.dll
    b. gpib.dll
    c. gpib32ft.dll

    Files b and c will support 16-bit Windows GPIB applications if any are being used.
3. Locate the following files and make note of their location. These files will be used during the development process of a Visual Basic program.
    a. Niglobal.bas
    b. Vbib-32.bas

NOTE: If the files in Steps 2 and 3 are not installed on your computer, they may be copied from your National Instruments setup disks or they may be downloaded from www.ni.com.

4. Configure the GPIB by selecting the System icon in the Windows 98/95 Control Panel located under Settings on the Start Menu. Configure the GPIB Settings as shown in Figure 4-1. Configure the DEV12 Device Template as shown in Figure 4-2. Be sure to check the Readdress box.
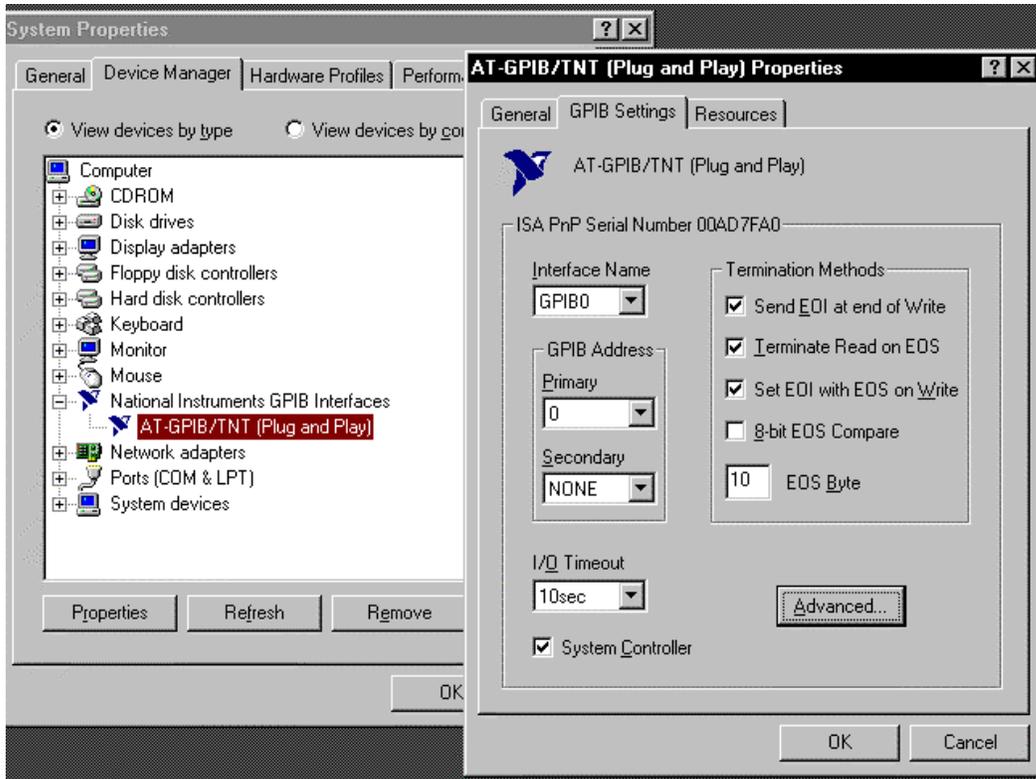
Figure 4-1. GPIB Setting Configuration
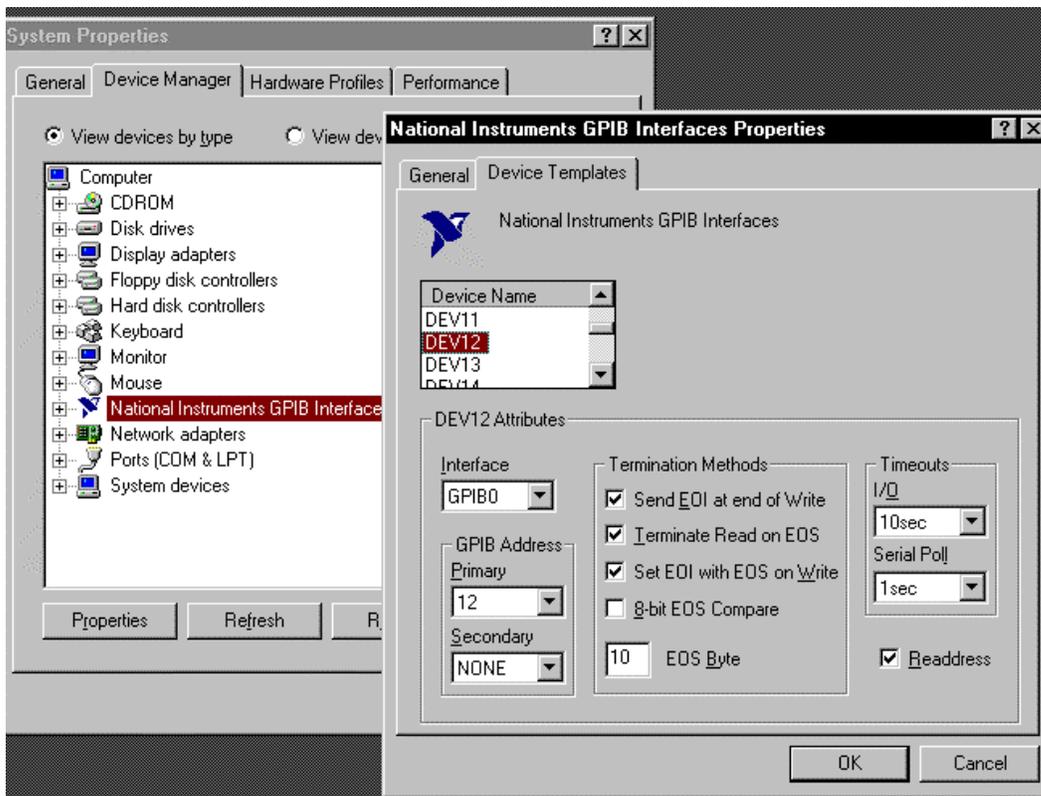
Figure 4-2. DEV 12 Device Template Configuration

4.1.4.2 Visual Basic IEEE-488 Interface Program Setup

This IEEE-488 interface program works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better. It assumes your IEEE-488 (GPIB) card is installed and operating correctly (refer to Paragraph 4.1.4.1). Use the following procedure to develop the IEEE-488 Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, select Add Module, select the Existing tab, then navigate to the location on your computer to add the following files: Niglobal.bas and Vbib-32.bas.
5. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
6. On the View Menu, select Properties Window.
7. In the Properties window, use the dropdown list to select between the different controls of the current project.
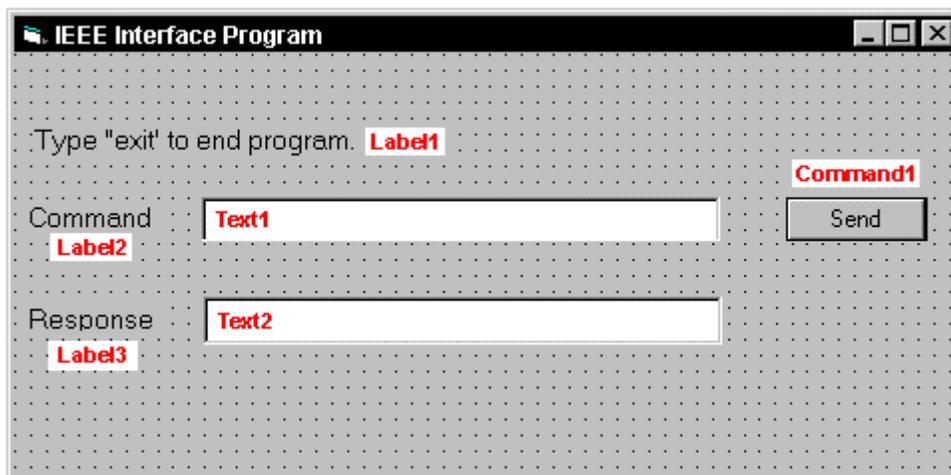
10. Set the properties of the controls as defined in Table 4-1.
11. Save the program.

Table 4-1. IEEE-488 Interface Program Control Properties

Current Name	Property	New Value
Label1	Name Caption	lblExitProgram Type "exit" to end program.
Label2	Name Caption	lblCommand Command
Label3	Name Caption	lblResponse Response
Text1	Name Text	txtCommand <blank>
Text2	Name Text	txtResponse <blank>
Command1	Name Caption Default	cmdSend Send True
Form1	Name Caption	frmIEEE IEEE Interface Program

12. Add code (provided in Table 4-2).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 4-2.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 4-2.
13. Save the program.
14. Run the program. The program should resemble the following.
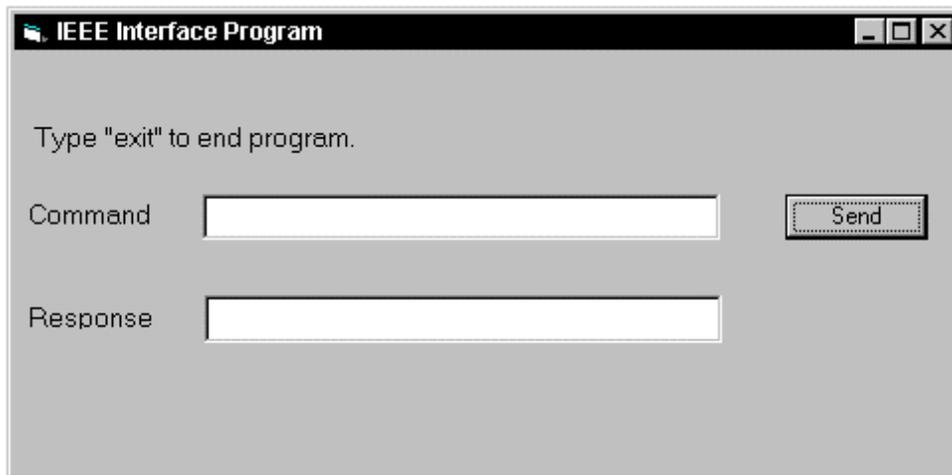
15. Type in a command or query in the Command box as described in Paragraph 4.1.4.5.
16. Press Enter or select the Send button with the mouse to send command.
17. Type Exit and press Enter to quit.

Table 4-2. Visual Basic IEEE-488 Interface Program

```
Public gSend As Boolean                                  'Global used for Send button state
```
```
Private Sub cmdSend_Click()                              'Routine to handle Send button press
    gSend = True                                         'Set Flag to True
End Sub
```
```
Private Sub Form_Load()                                  'Main code section
    Dim strReturn As String                             'Used to return response
    Dim term As String                                  'Terminators
    Dim strCommand As String                            'Data string sent to instrument
    Dim intDevice As Integer                            'Device number used with IEEE

    frmIEEE.Show                                        'Show main window
    term = Chr(13) & Chr(10)                            'Terminators are <CR><LF>
    strReturn = ""                                      'Clear return string

    Call ibdev(0, 12, 0, T10s, 1, &H140A, intDevice)   'Initialize the IEEE device
    Call ibconfig(intDevice, ibcREADDR,1)              'Setup Repeat Addressing
    Do
        Do                                              'Wait loop
        DoEvents                                        'Give up processor to other events
        Loop Until gSend = True                         'Loop until Send button pressed
        gSend = False                                   'Set Flag as False

        strCommand = frmIEEE.txtCommand.Text            'Get Command
        strReturn = ""                                  'Clear response display

        strCommand = UCase(strCommand)                  'Set all characters to upper case
        If strCommand = "EXIT" Then                     'Get out on EXIT
            End
        End If

        Call ibwrt(intDevice, strCommand & term)        'Send command to instrument
        If (ibsta And EERR) Then                        'Check for IEEE errors
            'do error handling if needed                'Handle errors here
        End If

        If InStr(strCommand, "?") <> 0 Then             'Check to see if query
            strReturn = Space(100)                       'Build empty return buffer
            Call ibrd(intDevice, strReturn)             'Read back response
            If (ibsta And EERR) Then                    'Check for IEEE errors
                'do error handling if needed            'Handle errors here
            End If

            If strReturn <> "" Then                     'Check if empty string
                strReturn = RTrim(strReturn)            'Remove extra spaces and Terminators
                Do While Right(strReturn, 1) = Chr(10) Or Right(strReturn, 1) = Chr(13)
                    strReturn = Left(strReturn, Len(strReturn) - 1)
                Loop
            Else
                strReturn = "No Response"               'Send No Response
            End If

            frmIEEE.txtResponse.Text = strReturn        'Put response in text on main form
        End If
    Loop
End Sub
```

4.1.4.3   IEEE-488 Interface Board Installation for Quick Basic Program

This procedure works on an IBM PC (or compatible) running DOS or in a DOS window. This example uses the National Instruments GPIB-PCII/IIA card.

1. Install GPIB-PCII/IIA card using National Instruments instructions.

2. Install NI-488.2 software (for DOS). Version 2.1.1 was used for the example.

3. Verify that config.sys contains the command: device = \gpib-pc\gpib.com.

4. Reboot the computer.

5. Run IBTEST to test software configuration. Do not install the instrument before running IBTEST.

6. Run IBCONF to configure the GPIB – PCII/IIA board and dev 12. Set the EOS byte to 0AH and Enable Repeat Addressing to Yes. See Figure 4-3. IBCONF modifies gpib.com.

7. Connect the instrument to the interface board and power up the instrument. Verify the address is 12 and terminators are CR LF.

4.1.4.4   Quick Basic Program

The IEEE-488 interface program in Table 4-3 works with QuickBasic 4.0/4.5 or Qbasic on an IBM PC (or compatible) running DOS or in a DOS window. It assumes your IEEE-488 (GPIB) card is installed and operating correctly (refer to Paragraph 4.1.4.3). Use the following procedure to develop the Serial Interface Program in Quick Basic.

1. Copy c:\gpib-pc\Qbasic\qbib.obj to the QuickBasic directory (QB4).

2. Change to the QuickBasic directory and type: link /q qbib.obj,,,bqlb4x.lib; where x = 0 for QB4.0 and 5 for QB4.5 This one-time only command produces the library file qbib.qlb. The procedure is found in the National Instruments QuickBasic readme file Readme.qb.

3. Start QuickBasic. Type: qb /l qbib.qlb. Start QuickBasic in this way each time the IEEE interface is used to link in the library file.

4. Create the IEEE example interface program in QuickBasic. Enter the program exactly as presented in Table 4-3. Name the file "ieeeexam.bas" and save.

5. Run the program.

6. Type a command query as described in Paragraph 4.1.4.5.

7. Type "EXIT" to quit the program.

```
National Instruments          GPIB0 Configuration        GPIB-PC2/2A Ver 2.1

Primary GPIB Address ........ →0        Select the primary GPIB address by
Secondary GPIB Address ...... NONE      using the left and right arrow keys.
Timeout setting ............. 10sec
                                        This address is used to compute the
Terminate Read on EOS ....... Yes       talk and listen addresses which
Set EOI with EOS on Writes .. Yes       identify the board or device on the
Type of compare on EOS ...... 7-Bit     GPIB. Valid primary addresses range
EOS byte .................... 0Ah       from 0 to 30 (00H to 1EH).
Send EOI at end of Write .... Yes
                                        * Adding 32 to the primary address
System Controller ........... Yes          forms the Listen Address (LA).
Assert REN when SC .......... No        * Adding 64 to the primary address
Enable Auto Serial Polling .. No           forms the Talk Address (TA).
Enable CIC Protocol ......... No
Bus Timing .................. 500nsec   EXAMPLE: Selecting a primary address
Parallel Poll Duration ...... Default   of 10 yields the following:

Use this GPIB board ......... Yes          10 + 32 = 42    (Listen address)
Board Type .................. PCII         10 + 64 = 74    (Talk address)
Base I/O Address ............ 02B8h
F1: Help  F6: Reset Value  F9/Esc: Return to Map  Ctl PgUp/PgDn: Next/Prev Board
```

```
National Instruments          DEV12 Configuration        GPIB-PC2/2A Ver 2.1

Primary GPIB Address ........ →12       Select the primary GPIB address by
Secondary GPIB Address ...... NONE      using the left and right arrow keys.
Timeout setting ............. 10sec
Serial Poll Timeout ......... 1sec      This address is used to compute the
                                        talk and listen addresses which
Terminate Read on EOS ....... Yes       identify the board or device on the
Set EOI with EOS on Writes .. Yes       GPIB. Valid primary addresses range
Type of compare on EOS ...... 7-Bit     from 0 to 30 (00H to 1EH).
EOS byte .................... 0Ah
Send EOI at end of Write .... Yes       * Adding 32 to the primary address
                                           forms the Listen Address (LA).
Enable Repeat Addressing .... Yes       * Adding 64 to the primary address
                                           forms the Talk Address (TA).

                                        EXAMPLE: Selecting a primary address
                                        of 10 yields the following:

                                           10 + 32 = 42    (Listen address)
                                           10 + 64 = 74    (Talk address)

F1: Help  F6: Reset Value  F9/Esc: Return to Map  Ctl PgUp/PgDn: Next/Prev Board
```

IBCONF.EXE.eps

Figure 4-3. Typical National Instruments GPIB Configuration from IBCONF.EXE

Table 4-3. Quick Basic IEEE-488 Interface Program

```
'       IEEEEXAM.BAS    EXAMPLE PROGRAM FOR IEEE-488 INTERFACE
'
'       This program works with QuickBasic 4.0/4.5 on an IBM PC or compatible.
'
'       The example requires a properly configured National Instruments GPIB-PC2 card. The REM
'       $INCLUDE statement is necessary along with a correct path to the file QBDECL.BAS.
'       CONFIG.SYS must call GPIB.COM created by IBCONF.EXE prior to running Basic. There must
'       be QBIB.QBL library in the QuickBasic Directory and QuickBasic must start with a link
'       to it. All instrument settings are assumed to be defaults: Address 12, Terminators
'       <CR> <LF> and EOI active.
'
'       To use, type an instrument command or query at the prompt. The computer transmits to
'       the instrument and displays any response. If no query is sent, the instrument responds
'       to the last query received. Type "EXIT" to exit the program.
'
        REM $INCLUDE: 'c:\gpib-pc\qbasic\qbdecl.bas'         'Link to IEEE calls
        CLS                                                  'Clear screen
        PRINT "IEEE-488 COMMUNICATION PROGRAM"
        PRINT

        CALL IBFIND("dev12", DEV12%)                         'Open communication at address 12
        TERM$ = CHR$(13) + CHR$(10)                          'Terminators are <CR><LF>

LOOP2:  IN$ = SPACE$(2000)                                   'Clear for return string

        LINE INPUT "ENTER COMMAND (or EXIT):"; CMD$          'Get command from keyboard
        CMD$ = UCASE$(CMD$)                                  'Change input to upper case
           IF CMD$ = "EXIT" THEN END                         'Get out on Exit
        CMD$ = CMD$ + TERM$

        CALL IBWRT(DEV12%, CMD$)                             'Send command to instrument

        CALL IBRD(DEV12%, IN$)                               'Get data back each time

        ENDTEST = INSTR(IN$, CHR$(13))                       'Test for returned string
           IF ENDTEST > 0 THEN                               'String is present if <CR> is seen
              IN$ = MID$(IN$, 1, ENDTEST – 1)                'Strip off terminators
              PRINT "RESPONSE:", IN$                         'Print return string
           ELSE
              PRINT "NO RESPONSE"                            'No string present if timeout
           END IF
        GOTO LOOP2                                           'Get next command
```

4.1.4.5 Program Operation

Once either example program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

```
ENTER COMMAND? *IDN?              Identification query. Instrument will return a string
                                 identifying itself.
RESPONSE: LSCI,MODEL450,0,020303[term]

ENTER COMMAND? FIELD?            Field reading query. Instrument will return a string with
                                 the present field reading.

RESPONSE: +12.345[term]

ENTER COMMAND? FIELDM?           Field multiplier query. Instrument will return a string with
                                 the field units multiplier. Blank indicated gauss,
                                 k indicates kilo gauss, etc.

RESPONSE: k[term]

ENTER COMMAND? RANGE 0           Range command. Instrument will change the field range
                                 to the highest setting. No response will be sent.

ENTER COMMAND? RANGE?            Range query. Instrument will return a string with the
                                 present range setting.

RESPONSE: 0[term]
```

The following are additional notes on using either IEEE-488 Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries and should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but are sent in response to a query. A leading "**+**" is not required but a leading "**–**" *is* required.

4.1.5 Troubleshooting

New Installation

1. Check instrument address.
2. Always send terminators.
3. Send entire message string at one time including terminators.
4. Send only one simple command at a time until communication is established.
5. Be sure to spell commands correctly and use proper syntax.
6. Attempt both 'Talk' and 'Listen' functions. If one works but not the other, the hardware connection is working, so look at syntax, terminators, and command format.
7. If only one message is received after resetting the interface, check the "repeat addressing" setting. It should be enabled.

Old Installation No Longer Working

1. Power instrument off then on again to see if it is a soft failure.
2. Power computer off then on again to see if the IEEE card is locked up.
3. Verify that the address has not been changed on the instrument during a memory reset.
4. Check all cable connections.

Intermittent Lockups

1. Check cable connections and length.
2. Increase delay between commands to 50 ms to make sure instrument is not being over loaded.

4.2 SERIAL INTERFACE OVERVIEW

The serial interface used in the Model 450 is commonly referred to as an RS-232C interface. RS-232C is a standard of the Electronics Industries Association (EIA) that describes one of the most common interfaces between computers and electronic equipment. The RS-232C standard is quite flexible and allows many different configurations. However, any two devices claiming RS-232C compatibility cannot necessarily be plugged together without interface setup. The remainder of this paragraph briefly describes the key features of a serial interface that are supported by the instrument. A customer supplied computer with similarly configured interface port is required to enable communication.

4.2.1 Physical Connection

The Model 450 has an RJ-11 connector on the rear panel for serial communication. The original RS-232C standard specifies 25 pins, but 9-pin, 25-pin, and RJ-11 connectors are commonly used in the computer industry. For you convenience, Lake Shore offers a Model 4001 RJ-11 Cable. When combined with either the Model 4002 DB-25 Adapter or Model 4003 DE-9 Adapter, this cable assembly can be used to connect the instrument to a computer with the corresponding connector type. See Figure 4-4. These adapters are described in Chapter 6 – Options and Accessories and are schematically diagramed in Figures 6-6 thru 6-8.

Equipment with Data Communications Equipment (DCE) wiring can be connected to the instrument with a straight through cable. However, if the interface is for Data Terminal Equipment (DTE), a Null Modem Adapter is required to exchange the transmit (TxD) and receive (RxD) lines.

The instrument uses drivers to generate the transmission voltage levels required by the RS-232C standard. These voltages are considered safe under normal operating conditions because of their relatively low voltage and current limits. The drivers are designed to work with cables up to 50 feet in length.
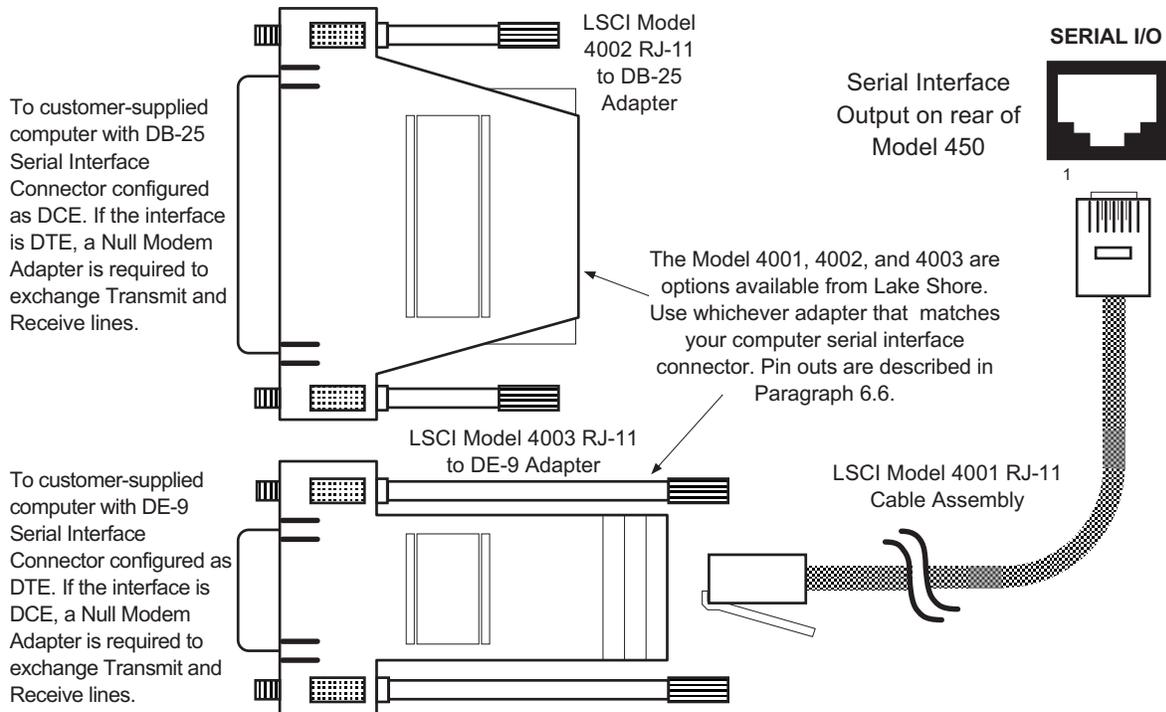
Figure 4-4. Serial Interface Adapters

4.2.2 Hardware Support

The Model 450 interface hardware supports the following features. Asynchronous timing is used for the individual bit data within a character. This timing requires start and stop bits as part of each character so the transmitter and receiver can resynchronized between each character. Half duplex transmission allows the instrument to be either a transmitter or a receiver of data but not at the same time. Communication speeds of 300, 1200 or 9600 Baud are supported. The Baud rate is the only interface parameter that can be changed by the user.

Hardware handshaking is not supported by the instrument. Handshaking is often used to guarantee that data message strings do not collide and that no data is transmitted before the receiver is ready. In this instrument appropriate software timing substitutes for hardware handshaking. User programs must take full responsibility for flow control and timing as described in Paragraph 4.2.5.

4.2.3 Character Format

A character is the smallest piece of information that can be transmitted by the interface. Each character is 10 bits long and contains data bits, bits for character timing and an error detection bit. The instrument uses 7 bits for data in the ASCII format. One start bit and one stop bit are necessary to synchronize consecutive characters. Parity is a method of error detection. One parity bit configured for odd parity is included in each character.

ASCII letter and number characters are used most often as character data. Punctuation characters are used as delimiters to separate different commands or pieces of data. Two special ASCII characters, carriage return (CR 0DH) and line feed (LF 0AH), are used to indicate the end of a message string.

Table 4-4. Serial Interface Specifications

Transmission	Three-Wire
Connector	RJ-11 Modular Socket
Timing Format	Asynchronous, RS-232C Electrical Format
Transmission Mode	Half Duplex
Baud Rate	300, 1200, or 9600
Bits per Character	1 Start, 7 Data, 1 Parity, and 1 Stop
Parity Type	Odd
Data Interface Levels	Transmits and Receives Using EIA Voltage Levels
Fixed Terminator	CR (0DH) LF (0AH)

4.2.4 Message Strings

A message string is a group of characters assembled to perform an interface function. There are three types of message strings commands, queries and responses. The computer issues command and query strings through user programs, the instrument issues responses. Two or more command strings can be chained together in one communication but they must be separated by a semi-colon (;). Only one query is permitted per communication but it can be chained to the end of a command. The total communication string must not exceed 64 characters in length.

A command string is issued by the computer and instructs the instrument to perform a function or change a parameter setting. The format is:

> **`<command mnemonic><space><parameter data><terminators>.`**

Command mnemonics and parameter data necessary for each one is described in Paragraph 4.3. Terminators must be sent with every message string.

Message Strings (Continued)

A query string is issued by the computer and instructs the instrument to send a response. The query format is:

<query mnemonic><?><space><parameter data><terminators>.

Query mnemonics are often the same as commands with the addition of a question mark. Parameter data is often unnecessary when sending queries. Query mnemonics and parameter data if necessary is described in Paragraph 4.3. Terminators must be sent with every message string. The computer should expect a response very soon after a query is sent.

A response string is the instruments response or answer to a query string. The instrument will respond only to the last query it receives. The response can be a reading value, status report or the present value of a parameter. Response data formats are listed along with the associated queries in Paragraph 4.3. The response is sent as soon as possible after the instrument receives the query. Typically it takes 10 ms for the instrument to begin the response. Some responses take longer.

4.2.5   Message Flow Control

It is important to remember that the user program is in charge of the serial communication at all times. The instrument can not initiate communication, determine which device should be transmitting at a given time or guarantee timing between messages. All of this is the responsibility of the user program.

When issuing commands only the user program should:
• Properly format and transmit the command including terminators as one string.
• Guarantee that no other communication is started for 50 ms after the last character is transmitted.
• Not initiate communication more than 20 times per second.

When issuing queries or queries and commands together the user program should:
• Properly format and transmit the query including terminators as one string.
• Prepare to receive a response immediately.
• Receive the entire response from the instrument including the terminators.
• Guarantee that no other communication is started during the response or for 50 ms after it completes.
• Not initiate communication more than 20 times per second.

Failure to follow these simple rules will result in inability to establish communication with the instrument or intermittent failures in communication.

4.2.6   Changing Baud Rate

To use the Serial Interface, you must first set the Baud rate. Press **Interface** key to display the following screen.

```
Select With ▲▼
Baud  3  →12   96
```

Press the ▲ or ▼ key to cycle through the choices of 300, 1200, or 9600 Baud. Press the **Enter** key to accept the new number.

4.2.7 Serial Interface Example Programs

Two BASIC programs are included to illustrate the serial communication functions of the instrument. The first program was written in Visual Basic. Refer to Paragraph 4.2.7.1 for instructions on how to setup the program. The Visual Basic code is provided in Table 4-6. The second program was written in Quick Basic. Refer to Paragraph 4.2.7.2 for instructions on how to setup the program. The Quick Basic code is provided in Table 4-7. Finally, a description of operation common to both programs is provided in Paragraph 4.2.7.3. While the hardware and software required to produce and implement these programs not included with the instrument, the concepts illustrated apply to almost any application where these tools are available.

4.2.7.1 Visual Basic Serial Interface Program Setup

The serial interface program works with Visual Basic 6.0 (VB6) on an IBM PC (or compatible) with a Pentium-class processor. A Pentium 90 or higher is recommended, running Windows 95 or better, with a serial interface. It uses the COM1 communications port at 9600 Baud. Use the following procedure to develop the Serial Interface Program in Visual Basic.

1. Start VB6.
2. Choose Standard EXE and select Open.
3. Resize form window to desired size.
4. On the Project Menu, click Components to bring up a list of additional controls available in VB6.
5. Scroll through the controls and select Microsoft Comm Control 6.0. Select OK. In the toolbar at the left of the screen, the Comm Control will have appeared as a telephone icon.
6. Select the Comm control and add it to the form.
7. Add controls to form:
   a. Add three Label controls to the form.
   b. Add two TextBox controls to the form.
   c. Add one CommandButton control to the form.
   d. Add one Timer control to the form.
8. On the View Menu, select Properties Window.
9. In the Properties window, use the dropdown list to select between the different controls of the current project.

10. Set the properties of the controls as defined in Table 4-5.
11. Save the program.

Table 4-5. Serial Interface Program Control Properties

Current Name	Property	New Value
Label1	Name	lblExitProgram
	Caption	Type "exit" to end program.
Label2	Name	lblCommand
	Caption	Command
Label3	Name	lblResponse
	Caption	Response
Text1	Name	txtCommand
	Text	<blank>
Text2	Name	txtResponse
	Text	<blank>
Command1	Name	cmdSend
	Caption	Send
	Default	True
Form1	Name	frmSerial
	Caption	Serial Interface Program
Timer1	Enabled	False
	Interval	10

12. Add code (provided in Table 4-6).
    a. In the Code Editor window, under the Object dropdown list, select (General). Add the statement: Public gSend as Boolean
    b. Double Click on cmdSend. Add code segment under Private Sub cmdSend_Click( ) as shown in Table 4-6.
    c. In the Code Editor window, under the Object dropdown list, select Form. Make sure the Procedure dropdown list is set at Load. The Code window should have written the segment of code: Private Sub Form_Load( ). Add the code to this subroutine as shown in Table 4-6.
    d. Double Click on the Timer control. Add code segment under Private Sub Timer1_Timer() as shown in Table 4-6.
    e. Make adjustments to code if different Com port settings are being used.
13. Save the program.
14. Run the program. The program should resemble the following.
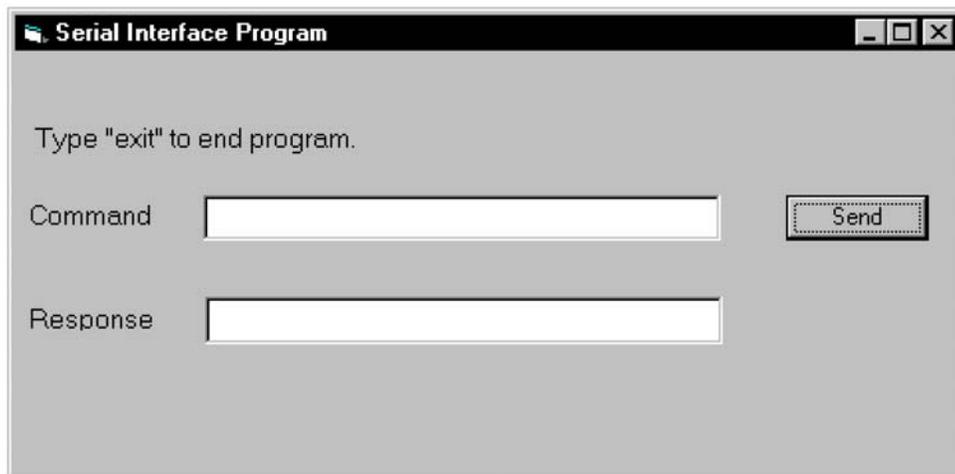
15. Type in a command or query in the Command box as described in Paragraph 4.2.7.3.
16. Press Enter or select the Send button with the mouse to send command.
17. Type Exit and press Enter to quit.

Table 4-6. Visual Basic Serial Interface Program

```
Public gSend As Boolean                              'Global used for Send button state

Private Sub cmdSend_Click()                          'Routine to handle Send button press
    gSend = True                                     'Set Flag to True
End Sub

Private Sub Form_Load()                              'Main code section
    Dim strReturn As String                          'Used to return response
    Dim strHold As String                            'Temporary character space
    Dim Term As String                               'Terminators
    Dim ZeroCount As Integer                         'Counter used for Timing out
    Dim strCommand As String                         'Data string sent to instrument

    frmSerial.Show                                   'Show main window
    Term = Chr(13) & Chr(10)                          'Terminators are <CR><LF>
    ZeroCount = 0                                     'Initialize counter
    strReturn = ""                                    'Clear return string
    strHold = ""                                      'Clear holding string
    If frmSerial.MSComm1.PortOpen = True Then         'Close serial port to change settings
        frmSerial.MSComm1.PortOpen = False
    End If
    frmSerial.MSComm1.CommPort = 1                    'Example of Comm 1
    frmSerial.MSComm1.Settings = "9600,o,7,1"        'Example of 9600 Baud,Parity,Data,Stop
    frmSerial.MSComm1.InputLen = 1                    'Read one character at a time
    frmSerial.MSComm1.PortOpen = True                 'Open port

  Do
    Do                                               'Wait loop
    DoEvents                                          'Give up processor to other events
    Loop Until gSend = True                           'Loop until Send button pressed
    gSend = False                                     'Set Flag as false

    strCommand = frmSerial.txtCommand.Text            'Get Command
    strReturn = ""                                    'Clear response display

    strCommand = UCase(strCommand)                    'Set all characters to upper case
    If strCommand = "EXIT" Then                       'Get out on EXIT
        End
    End If

    frmSerial.MSComm1.Output = strCommand & Term      'Send command to instrument
    If InStr(strCommand, "?") <> 0 Then               'Check to see if query
        While (ZeroCount < 20) And (strHold <> Chr$(10))  'Wait for response
            If frmSerial.MSComm1.InBufferCount = 0 Then    'Add 1 to timeout if no character
                frmSerial.Timer1.Enabled = True
                Do
                DoEvents                              'Wait for 10 millisecond timer
                Loop Until frmSerial.Timer1.Enabled = False
                ZeroCount = ZeroCount + 1              'Timeout at 2 seconds
            Else
                ZeroCount = 0                          'Reset timeout for each character
                strHold = frmSerial.MSComm1.Input      'Read in one character
                strReturn = strReturn + strHold        'Add next character to string
            End If
        Wend                                           'Get characters until terminators

        If strReturn <> "" Then                        'Check if string empty
            strReturn = Mid(strReturn, 1, InStr(strReturn, Term) - 1)   'Strip terminators
        Else
            strReturn = "No Response"                  'Send No Response
        End If
        frmSerial.txtResponse.Text = strReturn         'Put response in textbox on main form
        strHold = ""                                   'Reset holding string
        ZeroCount = 0                                  'Reset timeout counter
    End If
  Loop
End Sub

Private Sub Timer1_Timer()                            'Routine to handle Timer interrupt
    frmSerial.Timer1.Enabled = False                  'Turn off timer
End Sub
```

4.2.7.2   Quick Basic Serial Interface Program Setup

The serial interface program listed in Table 4-7 works with QuickBasic 4.0/4.5 or Qbasic on an IBM PC (or compatible) running DOS or in a DOS window with a serial interface. It uses the COM1 communication port at 9600 Baud. Use the following procedure to develop the Serial Interface Program in Quick Basic.

1. Start the Basic program.
2. Enter the program exactly as presented in Table 4-7.
3. Adjust the Com port and Baud rate in the program as necessary.
4. Lengthen the "TIMEOUT" count if necessary.
5. Save the program.
6. Run the program.
7. Type a command query as described in Paragraph 4.2.7.3.
8. Type "EXIT" to quit the program.

Table 4-7. Quick Basic Serial Interface Program

```
      CLS                                            'Clear screen
      PRINT " SERIAL COMMUNICATION PROGRAM"
      PRINT
      TIMEOUT = 2000                                 'Read timeout (may need more)
      BAUD$ = "9600"
      TERM$ = CHR$(13) + CHR$(10)                    'Terminators are <CR><LF>
      OPEN "COM1:" + BAUD$ + ",O,7,1,RS" FOR RANDOM AS #1 LEN = 256

LOOP1: LINE INPUT "ENTER COMMAND (or EXIT):"; CMD$   'Get command from keyboard
      CMD$ = UCASE$(CMD$)                            'Change input to upper case
        IF CMD$ = "EXIT" THEN CLOSE #1: END          'Get out on Exit
      CMD$ = CMD$ + TERM$
      PRINT #1, CMD$;                                'Send command to instrument

      IF INSTR(CMD$, "?") <> 0 THEN                  'Test for query
        RS$ = ""                                     'If query, read response
        N = 0                                        'Clr return string and count

        WHILE (N < TIMEOUT) AND (INSTR(RS$, TERM$) = 0)    'Wait for response
          IN$ = INPUT$(LOC(1), #1)                   'Get one character at a time
          IF IN$ = "" THEN N = N + 1 ELSE N = 0      'Add 1 to timeout if no chr
          RS$ = RS$ + IN$                            'Add next chr to string
        WEND                                         'Get chrs until terminators

        IF RS$ <> "" THEN                            'See if return string is empty
          RS$ = MID$(RS$, 1, (INSTR(RS$, TERM$) - 1))'Strip off terminators
          PRINT "RESPONSE:"; RS$                     'Print response to query
        ELSE
          PRINT "NO RESPONSE"                        'No response to query
        END IF
      END IF                                         'Get next command
      GOTO LOOP1
```

4.2.7.3 Program Operation

Once either example program is running, try the following commands and observe the response of the instrument. Input from the user is shown in **bold** and terminators are added by the program. The word [term] indicates the required terminators included with the response.

```
ENTER COMMAND? FIELD?    Field Reading Query. Unit returns field reading in the form
                         ±XXX.XX. Decimal point placement appropriate to range.
+000.12
ENTER COMMAND? RANGE?    Range Query. Unit returns appropriate range: 0 = highest range
                         through 3 = lowest range.
0
ENTER COMMAND? UNITS?    Units Query. Unit returns appropriate units: G = gauss, T = tesla.

G
ENTER COMMAND? ACDC?     AC or DC Query. Unit returns appropriate setting: 0 = DC, 1 = AC.

0
ENTER COMMAND? FILT?     Filter Query. Unit returns appropriate setting: 0 = Off, 1 = On.

0
ENTER COMMAND? FILT 1;FILT?   Unit turns the filter On, then returns a 1 to verify the change.

1
ENTER COMMAND?
```

The following are additional notes on using either Serial Interface program.

- If you enter a correctly spelled query without a "**?**," nothing will be returned. Incorrectly spelled commands and queries are ignored. Commands and queries and should have a space separating the command and associated parameters.
- Leading zeros and zeros following a decimal point are not needed in a command string, but they will be sent in response to a query. A leading "**+**" is not required but a leading "**–**" *is* required.

4.2.8 Troubleshooting

New Installation
1. Check instrument Baud rate.
2. Make sure transmit (TD) signal line from the instrument is routed to receive (RD) on the computer and vice versa. (Use a null modem adapter if not).
3. Always send terminators.
4. Send entire message string at one time including terminators. (Many terminal emulation programs do not.)
5. Send only one simple command at a time until communication is established.
6. Be sure to spell commands correctly and use proper syntax.

Old Installation No Longer Working
1. Power instrument off then on again to see if it is a soft failure.
2. Power computer off then on again to see if communication port is locked up.
3. Verify that Baud rate has not been changed on the instrument during a memory reset.
4. Check all cable connections.

Intermittent Lockups
1. Check cable connections and length.
2. Increase delay between commands to 100 ms to make sure instrument is not being over loaded.

4.3   IEEE-488/SERIAL INTERFACE COMMAND SUMMARY

There are four command groups: Common Commands in Paragraph 4.3.2, Interface Commands in Paragraph 4.3.3, Device Specific Commands in Paragraph 4.3.4, and Probe Commands in Paragraph 4.3.5.

4.3.1   Command List Structure

Command Name

Brief Description of Function

RANGE?   Manual Reading Query

Syntax of what user must input.

Input: RANGE?

Information returned in response to the query.

Returned: 0, 1, 2, or 3

Remarks:

Explanation and definition of returned data.

Used to query the unit for manual range. Range is dependent on type of probe installed. There are four ranges possible for each probe, where 0 is the highest and 3 is the lowest range.

4.3.2 Common Commands

∗CLS   Clear Interface Command
   Input: ***CLS**
   Returned: Nothing
   Remarks: Clears the bits in the Status Byte Register and Standard Event Status Register and terminates all pending operations. Clears the interface, but *not* the controller. The controller related command is ***RST**.

∗ESE   Configure Status Reports in the Standard Event Status Register
   Input: ***ESE <bit weighting>**
   Returned: Nothing
   Remarks: Each bit is assigned a bit weighting and represents the enable/disable status of the corresponding event flag bit in the Standard Event Status Register. To enable an event flag bit, send the command ***ESE** with the sum of the bit weighting for each desired bit. See the ***ESR?** command for a list of event flags.
   Example: To enable event flags 0, 3, 4, and 7, send the command ***ESE 143[term]**. 143 is the sum of the bit weighting for each bit.

Bit	Bit Weighting	Event Name
0	1	OPC
3	8	DDE
4	16	EXE
7	128	PON
	143	

∗ESE?   Query the Configuration of Status Reports in the Standard Event Status Register
   Input: ***ESE?**
   Returned: **<ESE bit weighting>**. Format: **nnn[term]**
   Remarks: The integer returned represents the sum of the bit weighting of the enable bits in the Standard Event Status Enable Register.

∗ESR?   Query Standard Event Status Register
   Input: ***ESR?**
   Returned: **<ESR bit weighting>**. Format: **nnn[term]**
   Remarks: Queries for various Model 450 error conditions and status. The integer returned represents the sum of the bit weighting of the event flag bits in the Standard Event Status Register.

∗IDN?   Query Identification
   Input: ***IDN?**
   Returned: **<manufacturer>, <model number>, <serial number>, <firmware date>**
           Format: **LSCI,MODEL450,a,nnnnnn[term]**
   Remarks: Identifies the instrument model and software level.

∗OPC   Operation Complete Command
   Input: ***OPC**
   Returned: Nothing
   Remarks: Generates an Operation Complete event in the Event Status Register upon completion of all pending selected device operations. Send it as the last command in a command string.

∗OPC?   Query Operation Complete
   Input: ***OPC?**
   Returned: **1**. Format: **n[term]**
   Remarks: Places a "1" in the controller output queue upon completion of all pending selected device operations. Send as the last command in a command string. *Not* the same as ***OPC**.

✱RST   Reset Instrument
    Input: ***RST**
    Returned: Nothing
    Remarks: Sets controller parameters to power-up settings.

✱SRE   Configure Status Reports in the Service Request Enable Register
    Input: ***SRE <bit weighting>**
    Returned: Nothing
    Remarks: Each bit has a bit weighting and represents the enable/disable status of the corresponding status flag bit in the Status Byte Register. To enable a status flag bit, send the command ***SRE** with the sum of the bit weighting for each desired bit. See the ***STB?** command for a list of status flags.
    Example: To enable status flags 0, 3, 4, and 6, send the command ***SRE 89[term]**. 89 is the sum of the bit weighting for each bit.

Bit	Bit Weighting	Event Name
0	1	New A&B
3	8	Alarm
4	16	Error
6	64	SRQ
	89	

✱SRE?   Query the Configuration of Status Reports in the Service Request Enable Register
    Input: ***SRE?**
    Returned: **<SRE bit weighting>**. Format: **nnn[term]**
    Remarks: The integer returned represents the sum of the bit weighting of the enabled bits in the Service Request Enable Register. See the ***STB?** command for a list of status flags.

✱STB?   Query Status Byte
    Input: ***STB?**
    Returned: **<STB bit weighting>**. Format: **nnn[term]**
    Remarks: Acts like a serial poll, but does not reset the register to all zeros. The integer returned represents the sum of the bit weighting of the status flag bits that are set in the Status Byte Register.

✱TST?   Query Self-Test
    Input: ***TST?**
    Returned: **0** or **1**. Format: **n[term]**
    Remarks: The Model 330 performs a self-test at power-up. **0** = no errors found, **1** = errors found.

✱WAI   Wait-to-Continue
    Input: ***WAI**
    Returned: Nothing
    Remarks: Prevents execution of any further commands or queries until completion of all previous ones. Changing the sample sensor and reading it immediately with a device dependent query may result in a reading error because the sensor needs time to stabilize. Place a *WAI between the sensor change and query for a correct reading. Achieve the same results with repeated queries or using a Service Request, but *WAI is easier.

        Send *WAI as the last command in a command string followed by appropriate termination. It cannot be embedded between other commands.

4.3.3 INTERFACE COMMANDS

ADDR   Set IEEE Address.

Input: `ADDR [address]`
[address]: An integer from 1 to 30. Address 0 and 31 are reserved.
Returned: Nothing
Remarks: Sets the IEEE address. The Model 450 is factory preset to 12.

ADDR?   IEEE Address Query.

Input: `ADDR?`
Returned: 1 to 30.
Remarks: Returns the current IEEE address setting. The Model 450 is factory preset to 12.

BAUD   Set Serial Interface Baud Rate.

Input: `BAUD 0`, `BAUD 1`, or `BAUD 2`
[type]:   There are three settings for the type parameter: **0** = 300 Baud
                                                          1 = 1200 Baud
                                                          2 = 9600 Baud

Returned: Nothing
Remarks: Sets the Serial Interface Baud rate.

BAUD?   Serial Interface Baud Rate Query.

Input: `BAUD?`
Returned: Returns current Serial Baud rate, where: **0** = 300 Baud, **1** = 1200 Baud, and **2** = 9600 Baud

---

END   Set End Or Identify (EOI) Status.

Input: `END 0` or `END 1`
Returned: Nothing
Remarks: Sets the EOI status: **0** = enabled, **1** = disabled. When enabled, the hardware EOI line becomes active with the last byte of a transfer. The EOI identifies the last byte allowing for variable length data transmissions.

END?   End Or Identify (EOI) Status Query.

Input: `END?`
Returned: Current EOI status: **0** = EOI enabled, **1** = EOI disabled.

MODE   Set Local, Remote, or Remote With Local Lockout Mode.

Input: `MODE 0`, `MODE 1`, or `MODE 2`
Returned: Nothing
Remarks: Sets the Model 330 mode: **0** = Local Mode, **1** = Remote Mode, **2** = Remote Mode with Local Lockout. Press the front panel **Local** key to set the Model 330 to local provided the key has not been disabled by local lockout. The Model 330 powers up in local mode.
Example: At the end of a command string, `MODE 0` maintains constant local operation.

MODE?   Mode Query.

Input: `MODE?`
Returned: Current mode setting: **0** = local mode, **1** = remote mode, **2** = remote mode with local lockout.

TERM   Set Terminating Character Type.

Input: **TERM 0**, **TERM 1**, **TERM 2**, or **TERM 3**

Returned: Nothing

Remarks: Sets the terminating character type from 0 to 3 defined as follows:
0 = Carriage return and line feed (CR)(LF^{EOI})
1 = Line feed and carriage return (LF)(CR^{EOI})
2 = Line feed (LF^{EOI})
3 = No terminating characters – EOI line set with last data byte if enabled (End)
Terminating characters are sent when the Model 330 completes its message transfer on output. They also identify the end of an input message. This command works only with the IEEE-488 Interface and does not change the serial terminators.

TERM?   Terminator Query.

Input: **TERM?**

Returned: Returns the current terminating character type:
0 = Carriage return and line feed (CR)(LF^{EOI})
1 = Line feed and carriage return (LF)(CR^{EOI})
2 = Line feed (LF^{EOI})
3 = No terminating characters – EOI line set with last data byte if enabled (End)

Remarks: This command works only with the IEEE-488 Interface.

4.3.4   Device Specific Commands

ACDC   Set AC or DC Magnetic Field Reading Status.

Input: **ACDC 0** or **ACDC 1**

Returned: Nothing

Remarks: Configures the unit for AC or DC measurements: **0** = DC, **1** = AC. The AC field is further defined by the PRMS (Peak or RMS) command.

ACDC?   AC or DC Magnetic Field Reading Query.

Input: **ACDC?**

Returned: 0 or 1

Remarks: Queries current AC or DC measurement status: **0** = DC, **1** = AC. The AC field is further defined by the PRMS (Peak or RMS) command.

ALARM   Set Alarm Function On/Off.

Input: **ALARM 0** or **ALARM 1**

Returned: Nothing

Remarks: Sets the alarm function: **0** = Off, **1** = On.

ALARM?   Alarm Query.

Input: **ALARM?**

Returned: 0 or 1

Remarks: Queries unit for alarm function: **0** = Off, **1** = On.

ALMB   Set Audible Alarm Status.

Input: `ALMB 0` or `ALMB 1`
Returned: Nothing
Remarks: Sets the audible alarm status: **0** = Off, **1** = On.

ALMB?   Audible Alarm Query.

Input: `ALMB?`
Returned: `0` or `1`
Remarks: Queries current audible alarm status: **0** = Off, **1** = On.

ALMH   Set Alarm High Point.

Input: `ALMH XXX.XX`
Returned: Nothing
Remarks: Enter up to 5 digits with decimal point. No sign required. Place decimal appropriate to range.

ALMH?   Alarm High Point Query.

Input: `ALMH?`
Returned: `XXX.XX`
Remarks: Returns up to 5 digits with decimal point. Places decimal appropriate to range.

ALMHM?   Alarm High Point Multiplier Query.

Input: `ALMHM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries alarm high point multiplier: **u** = micro (✕ 1/1,000,000), **m** = milli (✕ 1/1,000),
k = kilo (✕ 1,000), and **_** (Blank) = unity (✕ 1).

ALMIO   Set Alarm Trigger Inside/Outside Status.

Input: `ALMIO 0` or `ALMIO 1`
Returned: Nothing
Remarks: Sets alarm trigger inside/outside status: **0** = Outside, **1** = Inside. This setting determines
whether readings inside or outside the defined magnetic field range trigger the alarm.

ALMIO?   Alarm Trigger Inside/Outside Query.

Input: `ALMIO?`
Returned: `0` or `1`
Remarks: Queries alarm trigger inside/outside status: **0** = Outside, **1** = Inside. This setting determines
whether readings inside or outside the defined magnetic field range trigger the alarm.

ALML   Set Alarm Low Point.

Input: `ALML XXX.XX`
Returned: Nothing
Remarks: Enter up to 5 digits with decimal point. No sign required. Place decimal appropriate to range.

ALML?   Alarm Low Point Query.

Input: `ALML?`
Returned: `XXX.XX`
Remarks: Returns up to 5 digits with decimal point. Places decimal appropriate to range.

ALMLM? Alarm Low Point Multiplier Query.

Input: `ALMLM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries alarm low point multiplier: **u** = micro (✕ 1/1,000,000), **m** = milli (✕ 1/1,000), **k** = kilo (✕ 1,000), and _ (Blank) = unity (✕ 1).

ALMS? Alarm Status Query.

Input: `ALMS?`
Returned: `0 or 1`
Remarks: Queries current alarm status: **0** = Off, **1** = On. Off means no alarm condition exists; On means an alarm exists.

ANOD Set Default Analog Out Status.

Input: `ANOD 0`, `ANOD 1`, or `ANOD 2`
Returned: Nothing
Remarks: Sets default analog output status: **0** = Off, **1** = On, **2** = analog output controlled by remote interface (see `AOCON`). Set `ANOD` to 0 for user scaling (Paragraph 3.12.1), then use `ANOH` and `ANOL` to define maximum and minimum.

ANOD? Default Analog Out Query.

Input: `ANOD?`
Returned: `0`, `1`, or `2`
Remarks: Refer to ANOD command for description.

ANOH Define Analog Out High Setpoint.

Input: `ANOH ±XXX.XX`
Returned: Nothing
Remarks: Set `ANOD` to Mode 0 for user scaling. Enter sign, up to 5 digits, and decimal point. Place decimal appropriate to range.

ANOH? Analog Out High Setpoint Query.

Input: `ANOH?`
Returned: `±XXX.XX`
Remarks: Returns sign, up to five digits, and decimal point. Places decimal appropriate to range.

ANOHM? Analog Out High Setpoint Multiplier Query.

Input: `ANOHM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries analog out high setpoint multiplier: **u** = micro (✕ 1/1,000,000), **m** = milli (✕ 1/1,000), **k** = kilo (✕ 1,000), and _ (Blank) = unity (✕ 1).

ANOL Define Analog Out Low Setpoint.

Input: `ANOL ±XXX.XX`
Returned: Nothing
Remarks: Set `ANOD` to Mode 0 for user scaling. Enter sign, up to 5 digits, and decimal point. Place decimal appropriate to range.

ANOL? Analog Out Low Setpoint Query.

Input: `ANOL?`
Returned: `±XXX.XX`
Remarks: Returns sign, up to five digits, and decimal point. Places decimal appropriate to range.

ANOLM?   Analog Out Low Setpoint Multiplier Query.

Input: `ANOLM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries analog out low setpoint multiplier: **u** = micro (× 1/1,000,000), **m** = milli (× 1/1,000), **k** = kilo (× 1,000), and _ (Blank) = unity (× 1).

AOCON   Set Analog Output Control Mode.

Input: `AOCON ±XXX.XX`
Returned: Nothing
Remarks: `ANOD` must set to Mode 2 before `AOCON` will function. The `AOCON` command sets bipolar output voltage in percent of full scale. Allows a resolution of 0.01%. For safety, this setting always equals zero if the instrument loses power or is turned off. The setting cannot be changed from the front panel. Refer to Paragraph 3.12.3.
Example: The command `AOCON –50.25` sets output to –50.25% of full scale. This is –5.025 volts for a ±10 volt output or –1.5075 volts for a ±3 volt output.

AOCON?   Analog Output Control Mode Query.

Input: `AOCON?`
Returned: `±XXX.XX`
Remarks: Queries the unit for the current analog output control mode percentage of full scale reading. Refer to `AOCON` command for description.

AUTO   Set Auto Range Status.

Input: `AUTO 0` or `AUTO 1`
Returned: Nothing
Remarks: Sets the Auto Range status: **0** = Auto Range Off, **1** = Auto Range On.

AUTO?   Auto Range Query.

Input: `AUTO?`
Returned: `0` or `1`
Remarks: Queries Auto Range status: **0** = Off, **1** = On.

BRIGT   Set Front Panel Display Brightness.

Input: `BRIGT 0` thru `7`
Returned: Nothing
Remarks: Sets front panel display brightness: **0** = lowest through **7** = highest. Default = **4**.

BRIGT?   Front Panel Display Brightness Query.

Input: `BRIGT?`
Returned: `0` thru `7`
Remarks: Returns a single digit corresponding to the current display brightness setting: **0** = lowest through **7** = highest. Default = **4**.

CODE   Set Front Panel Keyboard Lock Code.

Input: `CODE XXX`
Returned: Nothing
Remarks: Sets front panel keyboard lock code: Default = **123**. Enter any three numbers.

CODE?   Front Panel Keyboard Lock Code Query.

Input: `CODE?`
Returned: `XXX`
Remarks: Returns the 3 numbers that comprise the front panel keyboard lock code.

FAST   Set Fast Data Mode.

Input: `FAST 0` or `FAST 1`
Returned: Nothing
Remarks: Sets Fast Data Mode which obtains data rates up to 18 readings per second via IEEE-488 or 15 readings per second via Serial Interface with a corresponding increase in corrected analog output. The front panel display does not function in this mode. Refer to Paragraph 3.16.

FAST?   Fast Data Mode Status Query.

Input: `FAST?`
Returned: 0 or 1
Remarks: Queries Fast Data Mode status: **0** = Off, **1** = On. Obtains data rates up to 18 readings per second via IEEE-488 or 15 readings per second via the Serial Interface with a corresponding increase in corrected analog output. The front panel display does not function in this mode. Refer to Paragraph 3.16.

FIELD?   Present Magnetic Field Reading.

Input: `FIELD?`
Returned: ±XXX.XX
Remarks: Returns sign, six numbers if the filter is on, five numbers if the filter is off, and decimal point. Places decimal appropriate to range. Requires MULT? and UNITS? commands to fully define the reading.

FIELDM?   Field Reading Multiplier Query.

Input: `FIELDM?`
Returned: u, m, k, or _
Remarks: Queries field reading multiplier: **u** = micro (× 1/1,000,000), **m** = milli (× 1/1,000), **k** = kilo (× 1,000), and _ (Blank) = unity (× 1).

FILT   Set Display Filter Status.

Input: `FILT 0` or `FILT 1`
Returned: Nothing
Remarks: Turns display filter On or Off: **0** = Off, **1** = On. Quiets the display reading by a degree depending on the points (FNUM) and window (FWIN) settings. Refer to Paragraph 3.6.1.

FILT?   Display Filter Query.

Input: `FILT?`
Returned: 0 or 1
Remarks: Queries display filter status: **0** = Off, **1** = On. Quiets the display reading by a degree depending on the points (FNUM) and window (FWIN) settings. Refer to Paragraph 3.6.1.

FNUM   Set Display Filter Points.

Input: `FNUM XX`
Returned: Nothing
Remarks: Sets filter points: XX = 2 thru 64. Numbers 2 thru 8 produce a linear filter response. Numbers 9 thru 64 produce an exponential filter response. In general, the higher the number, the longer the display settle time. Refer to Paragraph 3.6.1.

FNUM?   Display Filter Points Query.

Input: `FNUM?`
Returned: `XX`
Remarks: Queries filter points setting: XX = 2 thru 64. Numbers 2 thru 8 produce a linear filter response. Numbers 9 thru 64 produce an exponential filter response. In general, the higher the number, the longer the display settle time. Refer to Paragraph 3.6.1.

FWIN   Set Display Filter Points.

Input: `FWIN XX`
Returned: Nothing
Remarks: Sets the filter window: XX = 1% thru 10%. The smaller the percentage, the smaller the change in magnetic field that causes the filter to restart. Refer to Paragraph 3.6.1.

FWIN?   Display Filter Points Query.

Input: `FWIN?`
Returned: `XX`
Remarks: Queries filter window setting: XX = 1% thru 10%. The smaller the percentage, the smaller the change in magnetic field that causes the filter to restart. Refer to Paragraph 3.6.1.

LOCK   Set Front Panel Keyboard Lock Status.

Input: `LOCK 0` or `LOCK 1`
Returned: Nothing
Remarks: Sets front panel keyboard lock status: **0** = Unlocked, **1** = Locked.

LOCK?   Front Panel Keyboard Lock Query.

Input: `LOCK?`
Returned: `0` or `1`
Remarks: Queries front panel keyboard lock status: **0** = Unlocked, **1** = Locked.

MAX   Set Max Hold Status.

Input: `MAX 0` or `MAX 1`
Returned: Nothing
Remarks: Sets Max Hold feature: **0** = Off, **1** = On. Works with MAXC, MAXR, and MAXRM commands.

MAX?   Max Hold Query.

Input: `MAX?`
Returned: `0` or `1`
Remarks: Queries Max Hold status: **0** = Off, **1** = On. Works with MAXC, MAXR, & MAXRM commands.

MAXC   Initiate Max Clear (Reset).

Input: `MAXC`
Returned: Nothing
Remarks: Initiate a Max Clear (or reset). Upon entry, Max Hold zeros out and captures a new peak.

MAXR?   Max Reading Query.

Input: `MAXR?`
Returned: `+XXX.XX`
Remarks: Queries Max Hold reading. Returns 5 digits and decimal point. Places decimal appropriate to range. NOTE: The plus sign is displayed but is insignificant. The reading is magnitude only.

MAXRM?   Max Reading Multiplier Query.

Input: `MAXRM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries maximum reading multiplier: **u** = micro (✗ 1/1,000,000), **m** = milli (✗ 1/1,000),
k = kilo (✗ 1,000), and _ (Blank) = unity (✗ 1).

PRMS   Set Peak or RMS Magnetic Field Reading Status.

Input: `PRMS 0` or `PRMS 1`
Returned: Nothing
Remarks: Configures unit for RMS or Peak measurements: **0** = RMS, **1** = Peak. RMS or Peak is
selected after ACDC is set to AC.

PRMS?   Peak or RMS Magnetic Field Reading Query.

Input: `PRMS?`
Returned: `0` or `1`
Remarks: Queries Peak or RMS measurement status: **0** = RMS or **1** = Peak. RMS or Peak is selected
after ACDC is set to AC.

RANGE   Set Manual Range Status.

Input: `RANGE X`
Returned: Nothing
Remarks: Range depends on type of probe installed. There are four ranges possible for each probe:
0 = highest through **3** = lowest. Refer to Paragraph 3.4.

RANGE?   Manual Range Query.

Input: `RANGE?`
Returned: `0`, `1`, `2`, or `3`
Remarks: Queries manual range. Range depends on type of probe installed. There are four ranges
possible for each probe: **0** = highest through **3** = lowest. Refer to Paragraph 3.4.

REL   Set Relative Mode Status.

Input: `REL 0` or `REL 1`
Returned: Nothing
Remarks: Sets Relative Mode Status: **0** = Off, **1** = On.

REL?   Relative Mode Query.

Input: `REL?`
Returned: **0** or **1**
Remarks: Queries Relative Mode status: **0** = Off, **1** = On.

RELR?   Relative Mode Reading Query.

Input: `RELR?`
Returned: `±XXX.XX`
Remarks: Returns sign, up to 5 digits, and decimal point. Places decimal appropriate to range.

RELRM?   Relative Mode Reading Multiplier Query.

Input: `RELRM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries relative reading multiplier: **u** = micro (× 1/1,000,000), **m** = milli (× 1/1,000), **k** = kilo (× 1,000), and _ (Blank) = unity (× 1).

RELS   Set Relative Mode Setpoint.

Input: `RELS ±XXX.XX`
Returned: Nothing
Remarks: Enter sign, up to 5 digits, and decimal point. Place decimal appropriate to range.

RELS?   Relative Mode Setpoint Query.

Input: `RELS?`
Returned: `±XXX.XX`
Remarks: Returns sign, up to 5 digits, and decimal point. Places decimal appropriate to range.

RELSM?   Relative Mode Setpoint Multiplier Query.

Input: `RELSM?`
Returned: `u`, `m`, `k`, or `_`
Remarks: Queries relative setpoint multiplier: **u** = micro (× 1/1,000,000), **m** = milli (× 1/1,000), **k** = kilo (× 1,000), and _ (Blank) = unity (× 1).

UNIT   Set Gauss or Tesla Unit Status.

Input: `UNIT G` or `UNIT T`
Returned: Nothing
Remarks: Sets unit status: **G** = gauss, **T** = tesla.

UNIT?   Gauss or Tesla Unit Query.

Input: `UNIT?`
Returned: `G` or `T`
Remarks: Queries unit status: **G** = gauss, **T** = tesla.

4.3.5   Probe Specific Commands

FCOMP   Set Field Compensation Status.

Input: **FCOMP 0** or **FCOMP 1**
Returned: Nothing
Remarks: Turns set field compensation On or Off: **0** = Off, **1** = On. If Off, probe field compensation table, if present, is ignored.

FCOMP?   Field Compensation Query.

Input: **FCOMP?**
Returned: 0 or 1
Remarks: Queries field compensation status: **0** = Off, **1** = On. If Off, probe field compensation table, if present, is ignored.

SNUM?   Probe Serial Number Query.

Input: **SNUM?**
Returned: **XXXXXXXXXX**
Remarks: Queries probe serial number. The latest probe serial number format is HXXXXX, though there is room for up to a ten-character response.

TCOMP   Set Temperature Compensation Status.

Input: **TCOMP 0** or **TCOMP 1**
Returned: Nothing
Remarks: Turns set temperature compensation On or Off: **0** = Off, **1** = On. If off, probe temperature compensation, if present, is ignored.

TCOMP?   Temperature Compensation Query.

Input: **TCOMP?**
Returned: 0 or 1
Remarks: Queries temperature compensation status: **0** = Off, **1** = On. If off, probe temperature compensation, if present, is ignored.

TYPE?   Probe Type Query.

Input: **TYPE?**
Returned: 0, 1, or 2
Remarks: Queries probe type: **0** = high sensitivity, **1** = high stability, **2** = ultra-high sensitivity.

ZCAL   Initiate Zero Probe Command.

Input: **ZCAL**
Returned: Nothing
Remarks: Initiates zero probe function. Place probe in the Zero Gauss Chamber first and then enter the ZCAL command.

CHAPTER 5

ACCESSORIES AND PROBES

5.0 GENERAL

This chapter provides information on the accessories and probes available for the Model 450 Gaussmeter. Model numbers are detailed in Paragraph 5.1; accessories in Paragraph 5.2, Lake Shore standard probes in Paragraph 5.3, Helmholtz coils in Paragraph 5.4, and reference magnets in Paragraph 5.5.

5.1 MODELS

The list of Model 450 Model numbers is provided as follows.

Model	Description
450	**Standard Model 450 Gaussmeter.** Features ±3 volt corrected analog output.
450-10	**Optional Model 450 Gaussmeter.** Features ±10 volt corrected analog output.

5.2 ACCESSORIES

Accessories are devices that perform a secondary duty as an aid or refinement to the primary unit.

Model	Description
4001	**RJ-11 Cable Assembly**. Four-Wire Cable Assembly with RJ-11 plugs on each end. Used with RS-232C Interface. Cable is 4.3 meters (14 feet) long. See Figure 5-14.
4002	**RJ-11 to DB-25 Adapter**. Adapts RJ-11 receptacle to female DB-25 connector. Connects Model 450 to RS-232C Serial Port on rear of Customer's computer. See Figure 5-15.
4003	**RJ-11 to DE-9 Adapter**. Adapts RJ-11 receptacle to female DE-9 connector. Connects Model 450 to RS-232C Serial Port on rear of Customer's computer. See Figure 5-16.
4004	**IEEE-488 Interface Cable.** Connects Model 450 to customer-supplied computer with IEEE-488 Interface. Cable is 1 meter (3.3 feet) long. See Figure 6-5.
RM-1/2	**Half-Rack Mounting Kit for One 1/2 Rack Gaussmeter.** Half-length mounting panel and mounting ears to attach one Model 450 Gaussmeter to a 483 mm (19-inch) rack mount space. See Figure 5-17.
RM-2	**Dual Mounting Shelf for Two 1/2 Rack Gaussmeters.** Mounting panel and mounting ears to attach two Model 450 Gaussmeters to a 483 mm (19-inch) rack mount space. See Figure 5-18.
4060	**Standard Zero Gauss Chamber.** For standard probe calibration. Size: 32 × 32 × 61 mm (1.3 × 1.3 × 2.4 in.). Bore: 12 mm dia. × 51 mm deep (0.5 × 2 in.). See Figure 5-12.
4065	**Large Zero Gauss Chamber.** For Gamma™ Probe calibration. Size: 57 × 53 × 305 mm (2.3 × 2 × 12 in.). Bore: 19 mm dia. × 279 mm deep (0.75 × 11 in.). See Figure 5-13.
MAN-450	**Model 450 Gaussmeter User's Manual**.
MCBL-XX	**Hall Generator Cable Assembly**. The MCBL Cable Assembly connects a discrete Hall generator to the Model 450 Gaussmeter. See Paragraph 2.5.1. The cable ships with the HALLCAL.EXE program which permits cable PROM programming through a PC (or compatible) computer serial port. Because of the many calibration intricacies, the user is responsible for measurement accuracy. Refer to Appendix C. **MCBL-6** Hall Generator Cable Assembly – 2 meters (6 feet) long **MCBL-20** Hall Generator Cable Assembly – 6 meters (20 feet) long

Accessories (Continued)

Model	Description
MH-XX	**Helmholtz Coils**. Provides stable low magnetic field when used with customer-supplied power supply. Often used to provide reference field to help check gaussmeter accuracy. Three coils are available as follows. Refer to Paragraph 5.4. **MH-2.5** Helmholtz Coil, 2.5-inch inner diameter, field strength: ≈30 G @ 1 A, maximum continuous current: 2 A, coil resistance: ≈3 Ω. See Figure 5-8. **MH-6** Helmholtz Coil, 6-inch inner diameter, field strength: ≈25 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈10 Ω. See Figure 5-9. **MH-12** Helmholtz Coil. 12-inch inner diameter, field strength: ≈12 G @ 1 A, maximum continuous current: 2 A, Coil Resistance: ≈20 Ω. See Figure 5-10.
MRA-XXX **MRT-XXX**	**Reference Magnets**. High-quality reference magnets are available in transverse (flat) and axial (round) configurations. Refer to Paragraph 5.5 and see Figure 5-11. **MRA-312-100** Axial Reference Magnet: 0.312 inch inside diameter, 100 G, 1% **MRA-312-200** Axial Reference Magnet: 0.312 inch inside diameter, 200 G, 1% **MRA-312-300** Axial Reference Magnet: 0.312 inch inside diameter, 300 G, 1% **MRA-312-500** Axial Reference Magnet: 0.312 inch inside diameter, 500 G, 1% **MRA-312-1K** Axial Reference Magnet: 0.312 inch inside diameter, 1 kG, 1% **MRA-312-2K** Axial Reference Magnet: 0.312 inch inside diameter, 2 kG, 1% **MRT-062-200** Transverse Reference Magnet: 0.062 inch gap, 200 G, 1% **MRT-062-500** Transverse Reference Magnet: 0.062 inch gap, 500 G, 1% **MRT-062-1K** Transverse Reference Magnet: 0.062 inch gap, 1 kG, 0.5% **MRT-062-2K** Transverse Reference Magnet: 0.062 inch gap, 2 kG, 0.5% **MRT-062-5K** Transverse Reference Magnet: 0.062 inch gap, 5 kG, 0.5% **MRT-062-10K** Transverse Reference Magnet: 0.062 inch gap, 10 kG, 5% **MRT-343-50** Transverse Reference Magnet: 0.343 inch gap, 50 G, 1% **MRT-343-100** Transverse Reference Magnet: 0.343 inch gap, 100 G, 1%
MPEC-XXX	**Probe Extension Cables**. Four cables are available. Each extension cable contains a EEPROM for calibration data. Each extension cable must be matched to a specific probe. To maintain probe accuracy, that probe and extension cable must be calibrated together at Lake Shore. The probe will exhibit its full accuracy if used without the extension cable. Part numbers and cables lengths are defined as follows: **MPEC-10** Probe Extension Cable – 3 meters (10 feet) **MPEC-25** Probe Extension Cable – 7.6 meters (25 feet) **MPEC-50** Probe Extension Cable – 15.2 meters (50 feet) **MPEC-100** Probe Extension Cable – 30.5 meters (100 feet)

5.3 LAKE SHORE STANDARD PROBES

There are several types of Lake Shore Model 460 probes available: Axial, Transverse, Tangential, and Gamma — named for the Hall sensor orientation. Because the Model 450 covers such a wide magnetic field range (0.01 mG to 300 kG), three probe ranges are available: High Stability (HST), High Sensitivity (HSE), and Ultra-High Sensitivity (UHS). Please consult the factory for availability of probe types not detailed in this section. Information on Hall generators is presented in Appendix C of this manual.

5.3.1 Probe Selection Criteria

Some guidelines are provided below to aid in the selection of a probe for you application.

1. Choose a probe to match the application. Do not buy more accuracy, field range, or fragility than is actually necessary.
2. The thinner a probe, the more fragile it is. Try to avoid the temptation to select an easily damaged probe based on a possible, but not probable, future application. For instance, avoid using an exposed-device probe such as a Model MFT-3E03 or MNA-1904 type for general field measurements. *Once a stem or sensor has been damaged, the probe is not repairable.*
3. Metal enclosed probes, such as the Model MMT-6J08 and MMA-2508 types, offer the greatest amount of protection to the Hall sensor, and therefore are the most rugged types.
4. Be cautious about using aluminum stemmed, transverse probes, such as the Model MMT-6J08 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 b the Model MNT-4E04 type fiberglass-epoxy stem probes.
5. Several stem lengths are offered for each probe type. User preferences 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). Stem length does not affect performance.
6. 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 (keeping in mind, however, the fragility rule in number 2 above).
7. Lake Shore gaussmeter probes exhibit different ranges of magnetic fields over which they will provide valid readings. Check the specification sheet for these usable ranges. High Stability probes, such as those whose model numbers end in -VG, are usable on full scale ranges of 300 gauss (30 millitesla) to 30 kilogauss (3 tesla). The High Sensitivity family of probes (i.e., -VH models) can be used on 30 G (3 mT) to 30 kG (3 T) full scale ranges. High field probes are specially calibrated to provide use above 30 kG (3 T), and the Gamma Probe operates on the 300 mG (30 µT) and 3 G (300 µT) ranges.
8. If none of the standard probe configurations seem to fit your needs, always remember that Lake Shore can provide custom probes to meet your physical, temperature, and accuracy requirements. Contact Lake Shore with details of your special requirements.

5.3.2 Radiation Effects on Gaussmeter 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 generators is as follows:

- Gamma radiation seems to have little effect on the Hall generators.
- Proton radiation up to 10 Mrad causes sensitivity changes <0.5%.
- Neutron cumulative radiation (>0.1 MeV, 10^{15}/sq. cm.) 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.

5.3.3 Probe Specifications

Terminology used in Figures 5-1 thru 5-7 are defined as follows:

Definition of Probe Terminology
A = Distance from tip to center line of active area +B = Magnetic flux density vector (for + reading) HST = High Stability Probe HSE = High Sensitivity Probe UHS = Ultra-High Sensitivity Probe

Usable Full-Scale Ranges Vs. Probe Type				
Type	HST-1	HST-2	HSE-1	UHS-1
Usable on Ranges	300 G	300 G	30 G	300 mG
	3 kG	3 kG	300 G	3 G
	30 kG	30 kG	3 kG	30 G
	300 kG	—	30 kG	—

GAMMA PROBE
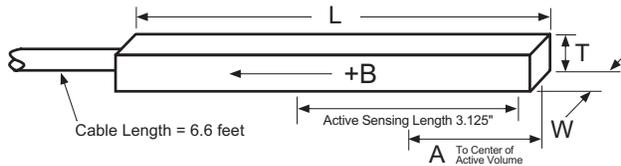
Small variations in, or low values of large volume magnetic fields, such as that of the Earth or fringe fields, around large solenoids, can be measured with these ultra-high sensitivity probes. Resolutions of several gammas (10^{-5} G) to tens of gammas are available depending on the mating gaussmeter. Application is optimum when fields are homogeneous over lengths greater than 1 foot. The active sensing length of the gamma probe is 3.125 inches.

Model No.	W	T	A	L	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (Maximum)	
									Zero	Calibration
MLA-5006-HJ	0.25 ±0.03"	0.5"	2.2"	5.7"	DC, 10 to 400 Hz	UHS-1	±0.5% to 2 gauss	0 °C to +75 °C	1 mG/°C	±0.02%/°C

Gamma.eps

Figure 5-1. Definition of Lake Shore Gamma Probe

ROBUST (BRASS STEM) TRANSVERSE PROBES
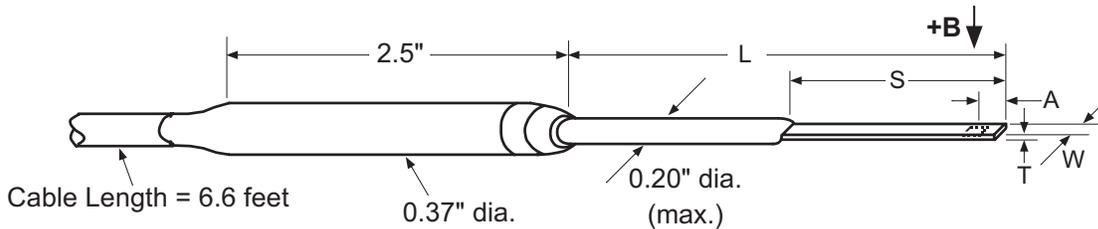
Model No.	L	S	W	T	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (maximum)	
												Zero	Calibration
MMTB-6J02-VH	2 ±0.125"	1.75"	0.22"	0.061" max	0.150"	0.040" dia. approx.	Brass	DC	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C
MMTB-6J04-VH	4 ±0.125"	3.5" to 4"											
MMTB-6J08-VH	8 ±0.125"												
MMTB-6J02-VG	2 ±0.125"	1.75"							HST-2	±0.15% to 30 kG		±0.13 G/°C	−0.005%/°C
MMTB-6J04-VG	4 ±0.125"	3.5" to 4"											
MMTB-6J08-VG	8 ±0.125"												

Brass_Transverse.eps

Figure 5-2. Definition of Lake Shore Robust (Brass Stem) Transverse Probes

TRANSVERSE PROBES

Cable length = 6.6 feet

0.36 ±0.030" dia.

Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)	
											Zero	Calibration
MMT-6J02-VH	2 ±0.125"	0.061" max.	0.180 ±0.005"	0.150 ± 0.050"	0.040" dia. approx.	Alum.	DC	HSE-1	±0.25% to 30 kG	0 °C to +75 °C	±0.09 Gauss per °C	±0.015% per °C
MMT-6J04-VH	4 ±0.125"											
MMT-6J08-VH	8 ±0.125"											
MMT-6J18-VH	18 ±0.25"											
MNT-4E02-VH	2 ±0.125"	0.045" max.	0.150 ±0.005"			Rigid Glass Epoxy	DC, 10 to 400 Hz					
MNT-4E04-VH	4 ±0.125"											
MMT-6J02-VG	2 ±0.125"	0.061" max.	0.180 ±0.005"			Alum.	DC	HST-2	±0.15% to 30 kG		±0.13 Gauss per °C	−0.005% per °C
MMT-6J04-VG	4 ±0.125"											
MMT-6J08-VG	8 ±0.125"											
MMT-6J18-VG	18 ±0.125"											
MNT-4E02-VG	2 ±0.125"	0.045" max.	0.150 ±0.005"			Rigid Glass Epoxy	DC, 10 to 400 Hz					
MNT-4E04-VG	4 ±0.125"											
MCT-3160-WN	61 ±1"	0.25 dia. ±0.010"		0.210 ±0.050"		Stainless Steel		HST-1	±2% to 100 kG	1.5 K to 350 K		±0.010% per °C

Transverse.eps

Figure 5-3. Definition of Lake Shore Transverse Probes

TANGENTIAL PROBE

Cable length = 6.6 feet

0.36 ±0.030" dia.

Active Area 0.015 ±0.005"

Model No.	L	T	W	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% of rdg)	Op. Temp. Range	Temperature Coefficient (Max.)	
											Zero	Calibration
MNTAN-DQ02-TH	1.5" ±0.125"	0.125" max.	0.38" max.	0.030" ±0.005"	0.020" dia. approx.	Plastic	DC, 10 to 400 Hz	HSE-1	±0.25% to 20 kG	0 °C to +75 °C	±0.1 G/°C	−0.05%/°C

Tangential.eps

Figure 5-4. Definition of Lake Shore Tangential Probe

AXIAL PROBES

Figure showing axial probe with dimensions: 2.5", L, A, +B, D, Cable Length = 6.6 feet, 0.36 ±0.030" dia.
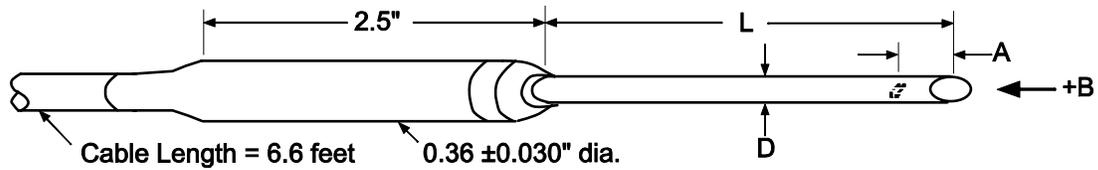
Model	L	D	A	Active Area	Stem Material	Freq. Range	Type	Corrected Accuracy (% Reading)	Op. Temp. Range	Temp. Coefficient (Max.) Zero	Calibration
MMA-0602-TH	2 ±0.125"	0.060 dia. +0.001 -0.003"	0.005 ± 0.003"	0.020" dia. approx.	Alum.	DC, 10 to 400 Hz	HST-2	±0.25% to 10 kG		±0.13 G per °C	±0.01% per °C
MMA-0604-TH	4 ±0.125"										
MMA-0608-TH	8 ±0.125"										
MMA-0618-TH	18 ±0.125"										
MMA-0802-UH	2 ±0.125"	0.080" dia. ±0.005"	0.010"			DC		±0.25% to 20 kG			
MMA-0804-UH	4 ±0.125"										
MMA-0808-UH	8 ±0.125"										
MNA-1902-VH	2 ±0.125"	0.187 dia. ±0.005"	0.005 ± 0.003"	0.030" dia. approx.	Fiber-glass Epoxy	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G per °C	±0.015% per °C
MNA-1904-VH	4 ±0.125"										
MNA-1908-VH	8 ±0.125"										
MMA-1802-VH	2 ±0.063"	0.180 dia. +0.002 -0.004"	0.016 ± 0.005"		Alum.						
MMA-1808-VH	8 ±0.125"										
MMA-1818-VH	18 ±0.25"										
MMA-1836-VH	36 ±0.25"										
MMA-2502-VH	2 ±0.063"	0.25 dia. ±0.006"									
MMA-2508-VH	8 ±0.125"										
MNA-1902-VG	2 ±0.125"	0.187 dia. ±0.005"	0.005 ± 0.003"		Fiber-glass Epoxy		HST-2	0.15% to 30 kG		±0.13 G per °C	−0.005% per °C
MNA-1904-VG	4 ±0.125"										
MNA-1908-VG	8 ±0.125"										
MMA-1802-VG	2 ±0.063"	0.180 dia. +0.002 −0.004"			Alum.						
MMA-1808-VG	8 ±0.125"										
MMA-1818-VG	18 ±0.25"										
MMA-1836-VG	36 ±0.25"										
MMA-2502-VG	2 ±0.063"	0.25 dia. ±0.006"	0.016 ± 0.005"								
MMA-2508-VG	8 ±0.125"										
MMA-1808-WL	8 ±0.125"	0.180 dia. +0.002 −0.004"					HST-1	±1% to 100 kG			
MMA-2536-WL	36 ±0.25"	0.25 dia. ±0.006"				DC					
MCA-2560-WN	60 ±0.50"	0.25 dia. ±0.005"	0.025 ±0.005"		Stainless Steel			±2% to 100 kG	1.5 K to 350 K		±0.010% per °C

Axial.eps

Figure 5-5. Definition of Lake Shore Axial Probes

FLEXIBLE TRANSVERSE PROBES

Cable Length = 6.6 feet
0.36 ±0.030" dia.
0.125 ±0.020"
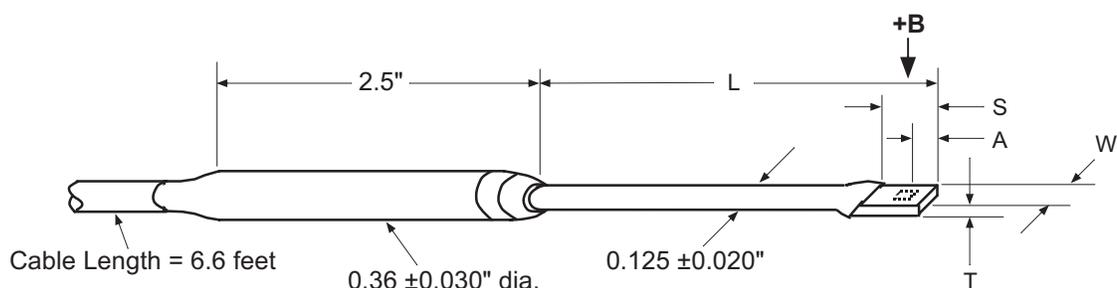
This table is for L = 3 inches and S = 0.375 inch

Model No.	W	T	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (maximum)	
										Zero	Calibration
MFT-3E03-VH	0.135" max	0.025" max	0.125" ±0.005"	0.040" dia. approx.	Flexible Tubing	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C
MFT-3E03-VG							HST-2	±0.15% to 30 kG		±0.13 G/°C	−0.005%/°C
MFT-2903-VJ	0.085" max	0.020" max	0.065" ±0.005"	0.030" dia. approx.			HSE-1	±0.50% to 30 kG		±0.09 G/°C	±0.015%/°C
MFT-2903-VH							HST-2	±0.25% to 30 kG		±0.13 G/°C	−0.005%/°C

This table is for L = 15 ±0.5 inches and S = 0.75 inch

| MFT-4F15-VH | 0.150" ±0.005" | 0.045" max | 0.150" ±0.050" | 0.040" dia. approx. | Flexible Tubing & Epoxy Fiber-glass | DC, 10 to 400 Hz | HSE-1 | ±0.25% to 30 kG | 0 °C to 75 °C | ±0.09 G/°C | ±0.015%/°C |
| MFT-4F15-VG | | | | | | | HST-2 | ±0.15% to 30 kG | | ±0.13 G/°C | −0.005%/°C |

Flexible_Transverse.eps

Figure 5-6. Definition of Lake Shore Flexible Transverse Probes

FLEXIBLE AXIAL PROBE

Cable Length = 6.6 feet
0.36 ±0.030" dia.
0.125 ±0.020"
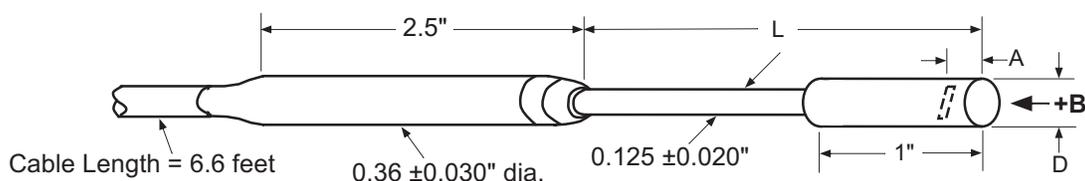
Model No.	L	D	A	Active Area	Stem Material	Frequency Range	Type	Corrected Accuracy (% of Reading)	Operating Temperature Range	Temperature Coefficient (max.)	
										Zero	Calibration
MFA-1815-VH	15" ±0.5"	0.025" max	0.125" ±0.005"	0.040" dia. approx.	Flexible Tubing	DC, 10 to 400 Hz	HSE-1	±0.25% to 30 kG	0 °C to 75 °C	±0.09 G/°C	±0.015%/°C

Flexible_Axial.eps

Figure 5-7. Definition of Lake Shore Flexible Axial Probe

5.4 HELMHOLTZ COIL LOW FIELD STANDARDS

Lake Shore offers three Helmholtz coils: 2.5-, 6-, and 12-inch diameter. Check the latest Lake Shore brochures or our website for any recent additions to this line.

These coils are accurately calibrated using field standards maintained at Lake Shore. Most standards are traceable to physical standards such as a coil of carefully controlled dimensions, or in some cases, to proton resonance. The field strengths are measured on the basis of the field generated by a current through the coil.

When combined with a customer-supplied power supply, these coils can be used as low-field reference magnets to compliment our set of standard reference magnets (defined in Paragraph 5.5). The power supply must be capable of 2 A output and a constant-current mode is recommended.

	MH-2.5	MH-6	MH-12
Inside Diameter	2.5 inches	6 inches	12 inches
Field Accuracy	±0.5%		
Field Strength	≈30 G @ 1 A	≈25 G @ 1 A	≈12 G @ 1 A
Field Homogeneity	0.5% within a cylindrical volume 0.75" long, 0.75" diameter, located at center of coil	0.5% within a cylindrical volume 1.6" long, 1.6" diameter, located at center of coil	0.5% within a cylindrical volume 3.2" long, 3.2" diameter, located at center of coil
Coil Resistance/Inductance	≈3 Ω / 6.3 mH	≈10 Ω / 36 mH	≈20 Ω / 93 mH
Maximum Continuous Current	2 A DC or AC RMS		
Operating Temperature Range	10 to 40 °C (50 to 104 °F)		
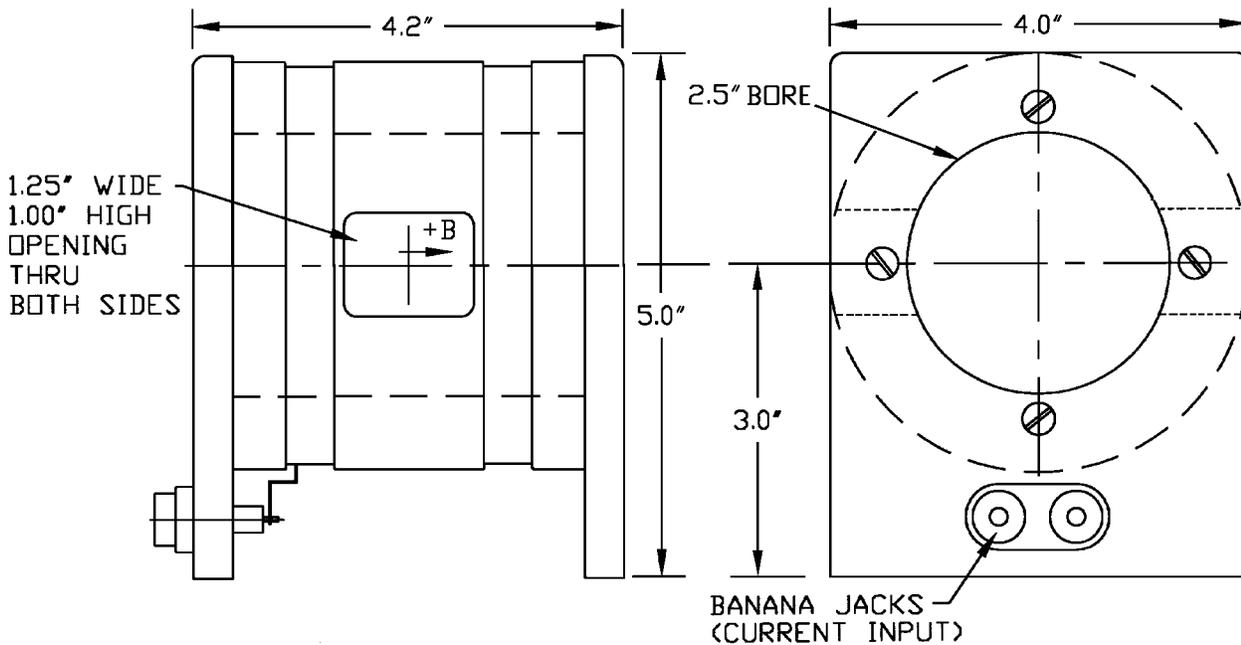
P-450-5-08.bmp

Figure 5-8. Model MH-2.5 Helmholtz Coil
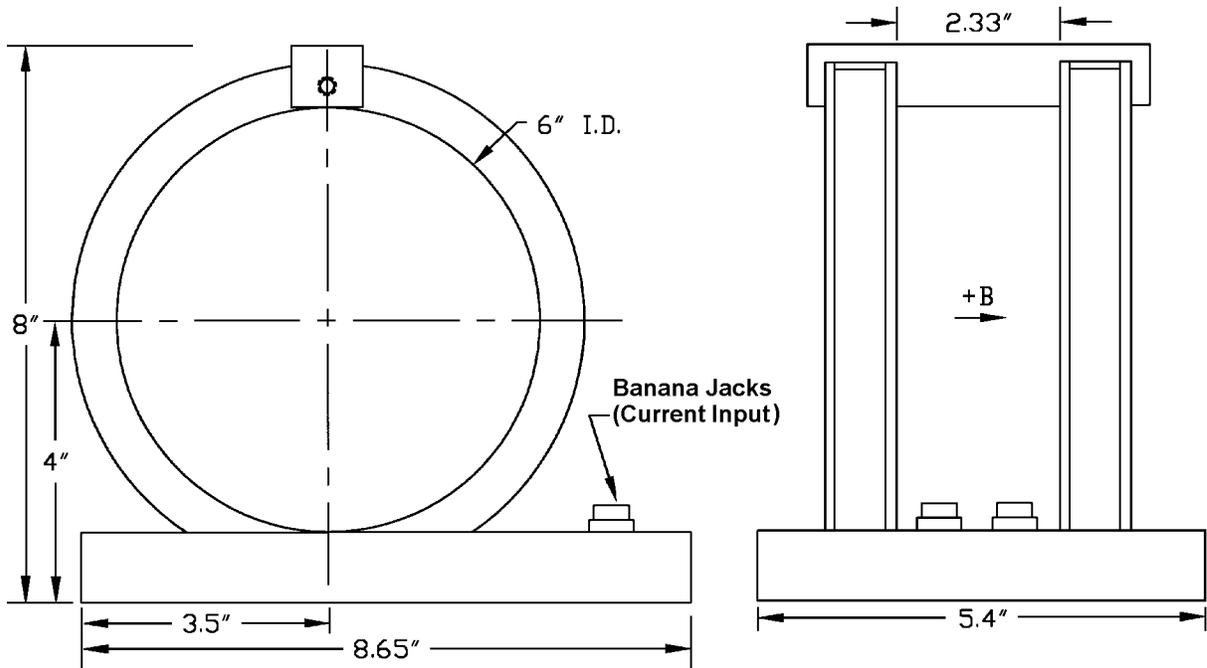
P-450-5-09.bmp

Figure 5-9. Model MH-6 Helmholtz Coil
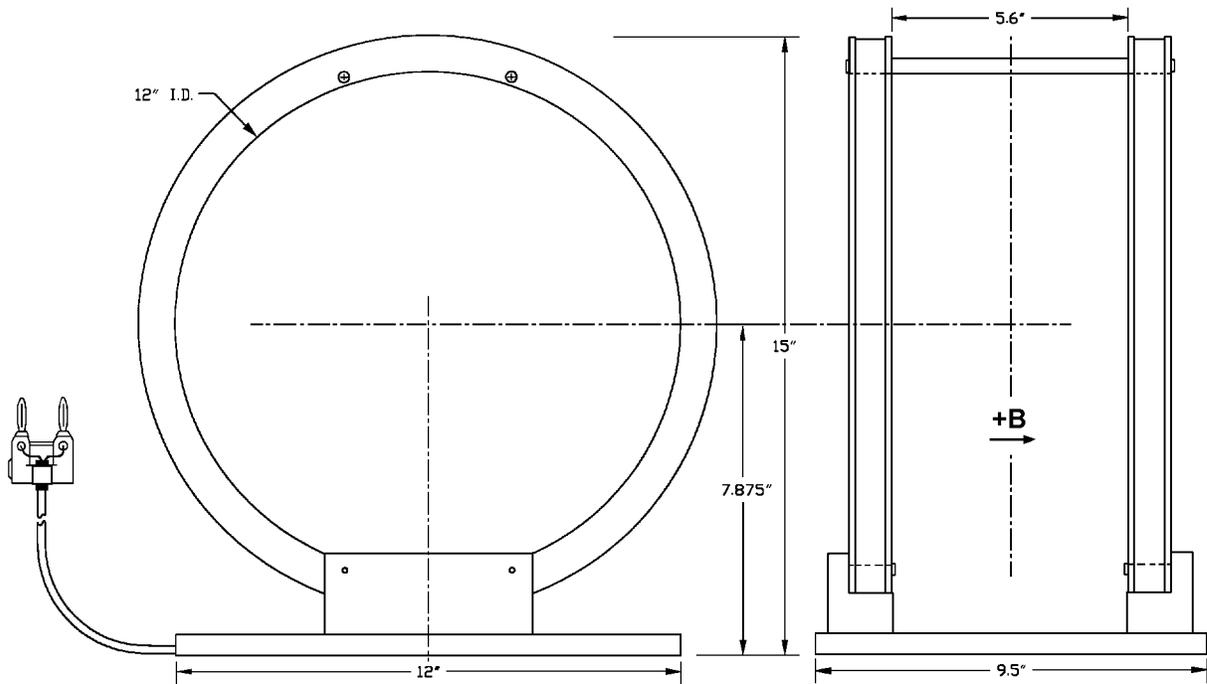
P-450-5-10.bmp

Figure 5-10. Model MH-12 Helmholtz Coil

5.5   REFERENCE MAGNETS

Magnetic reference standards containing highly stable permanent magnets have been in use for many years. The highest quality units are usually shielded from external magnetic effects and use Alnico V or VI magnets for long-term stability. They are supplied in both transverse (flat) and axial configurations.

Typical transverse reference magnets are usually stabilized for use at ambient temperatures between 0−50 °C and have nominal temperature coefficients of about –0.02%/°C. Because the temperature coefficient is negative, the field strength will be reduced as the temperature rises. Since these references are temperature cycled during manufacture, their change with temperature is predictable and retraceable; they will always return to a known value at any specific ambient temperature.

The high-permeability shell which surrounds the reference magnet serves two function: (1) it shields the magnet from external field, and (2) serves as the flux return path. Physical damage to the outer shell can cause a permanent change in the gap flux density. Reference magnets should not be dropped or physically abused. Magnets of this type can have magnetic reference values ranging from 100 G to 20 kG, but the most widely-used value is 1 kG. Reference magnet accuracy is typically ±0.5%, except for magnets of 200 G or less; for these magnets, the limit of error is generally ±1%. The reference magnet gap is nominally 0.060 inch but may range from 0.040 to 0.250 inch for special units. The usable "plateau" in the reference gap generally encompasses an area of about 0.5 square inches.

In reference magnets used for axial field probes, Alnico V or VI is the usual magnet material, charged to saturation and stabilized down to a particular value. The same temperature coefficients hold true as in the transverse probe and the same care in handling must be observed. This assembly uses concentric mu-metal shield cans to protect the magnet from the effects of external magnetic field. Axial reference magnets are available in values up to 2 kG, with 500 G being the most widely-used value.

When a probe is inserted completely through the access guide, three distinct magnetic peaks will be observed on the gaussmeter. One peak occurs as the probe enters the magnet, a second (and greater) peak is observed as the midpoint is reached, and a third (smaller) peak is read as the probe leaves the magnet. The calibration point is the largest reading in the midpoint area. Its amplitude will be approximately twice that of the readings that occur where the probe enters or leaves the magnet.
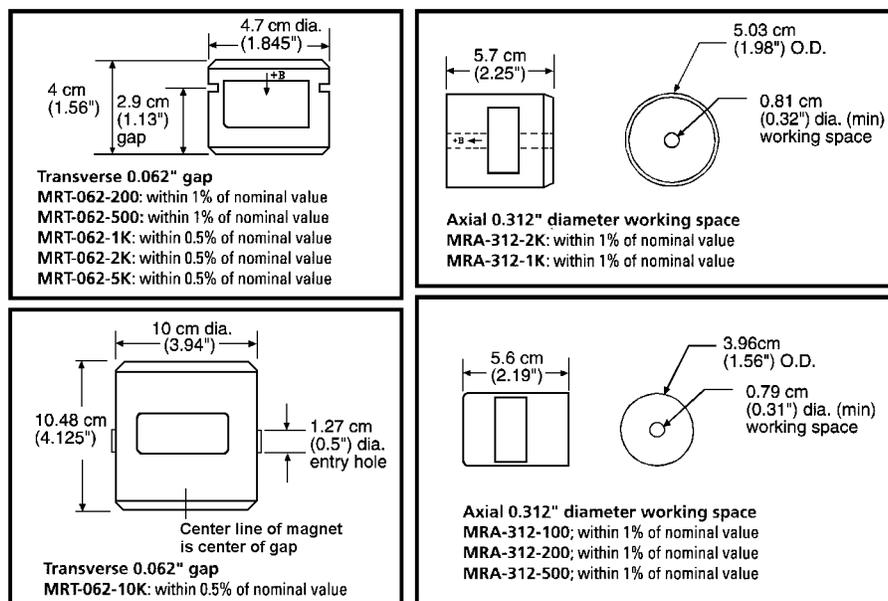
P-450-5-11.bmp

Figure 5-11. Lake Shore Reference Magnets

NOTE: Use care to ensure the Zero Gauss Chamber does not become magnetized. Using a magnetized chamber to zero a probe can lead to erroneous field readings. It is a good practice to periodically degauss the chamber. If no professional degausser is available, a bulk tape degausser (Verity VS250, Data Devices PF211, or equivalent) may be used.
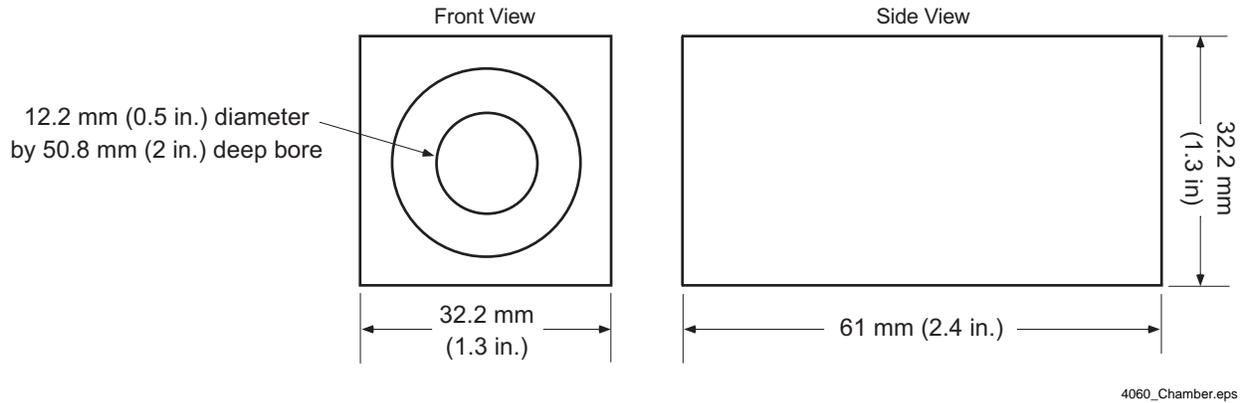
Figure 5-12. Model 4060 Zero Gauss Chamber
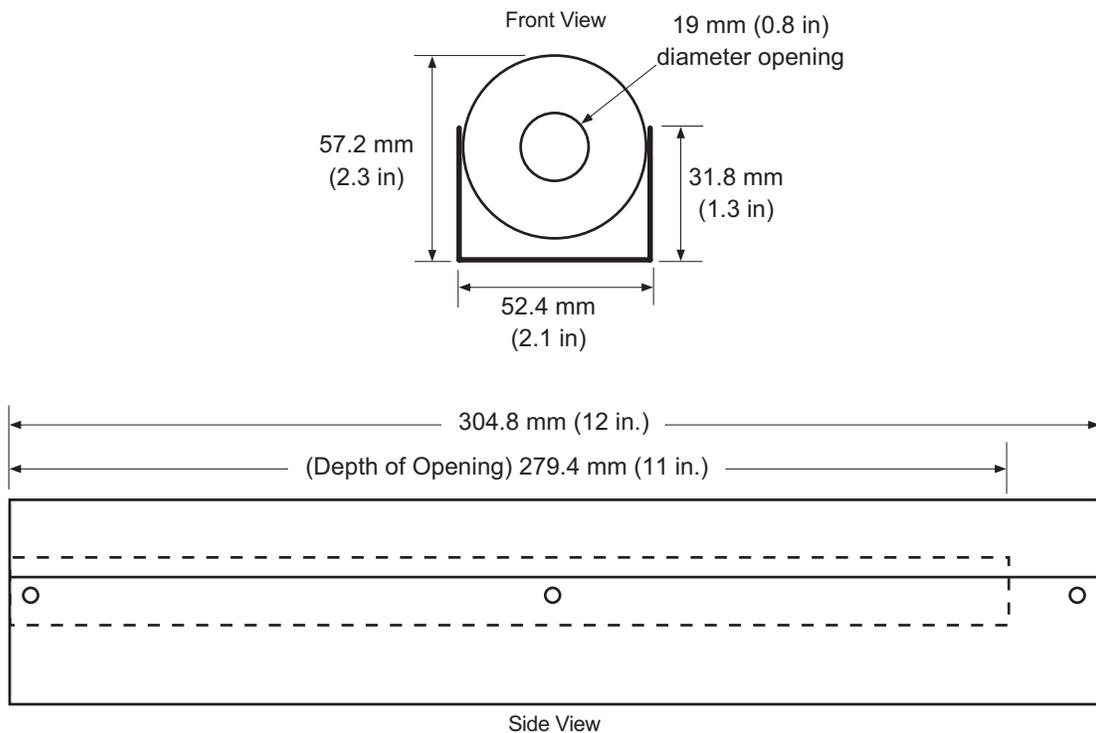
Figure 5-13. Model 4065 Large Zero Gauss Chamber
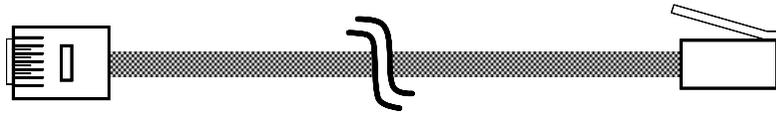
Cable Length: 4.3 meters (14 feet)

C-450-5-14.eps

Figure 5-14. Model 4001 RJ-11 Cable Assembly

43 mm
(1.7 inches)

55 mm (2.2 inches)

15.8 mm
(0.6 inches)
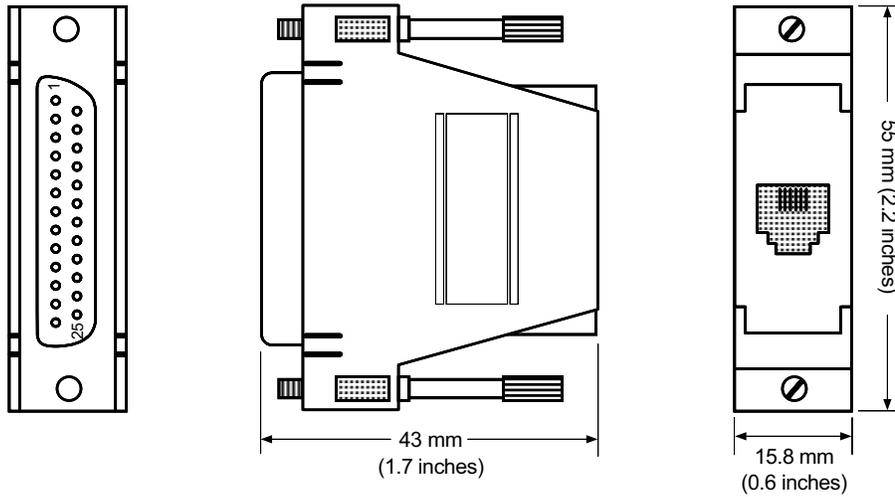
C-450-5-15.eps

Figure 5-15. Model 4002 RJ-11 to DB-25 Adapter

60.3 mm (2.4 inches)

32.5 mm
(1.3 inches)

15.9 mm
(0.6 inches)
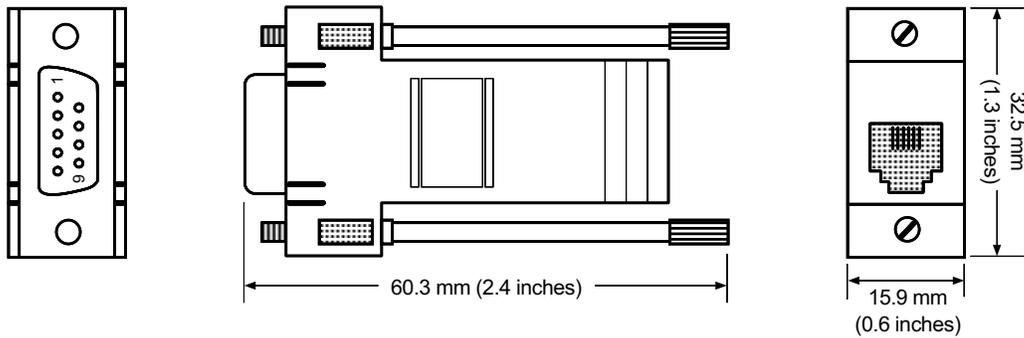
C-450-5-16.eps

Figure 5-16. Model 4003 RJ-11 to DE-9 Adapter

Refer to
"Note"
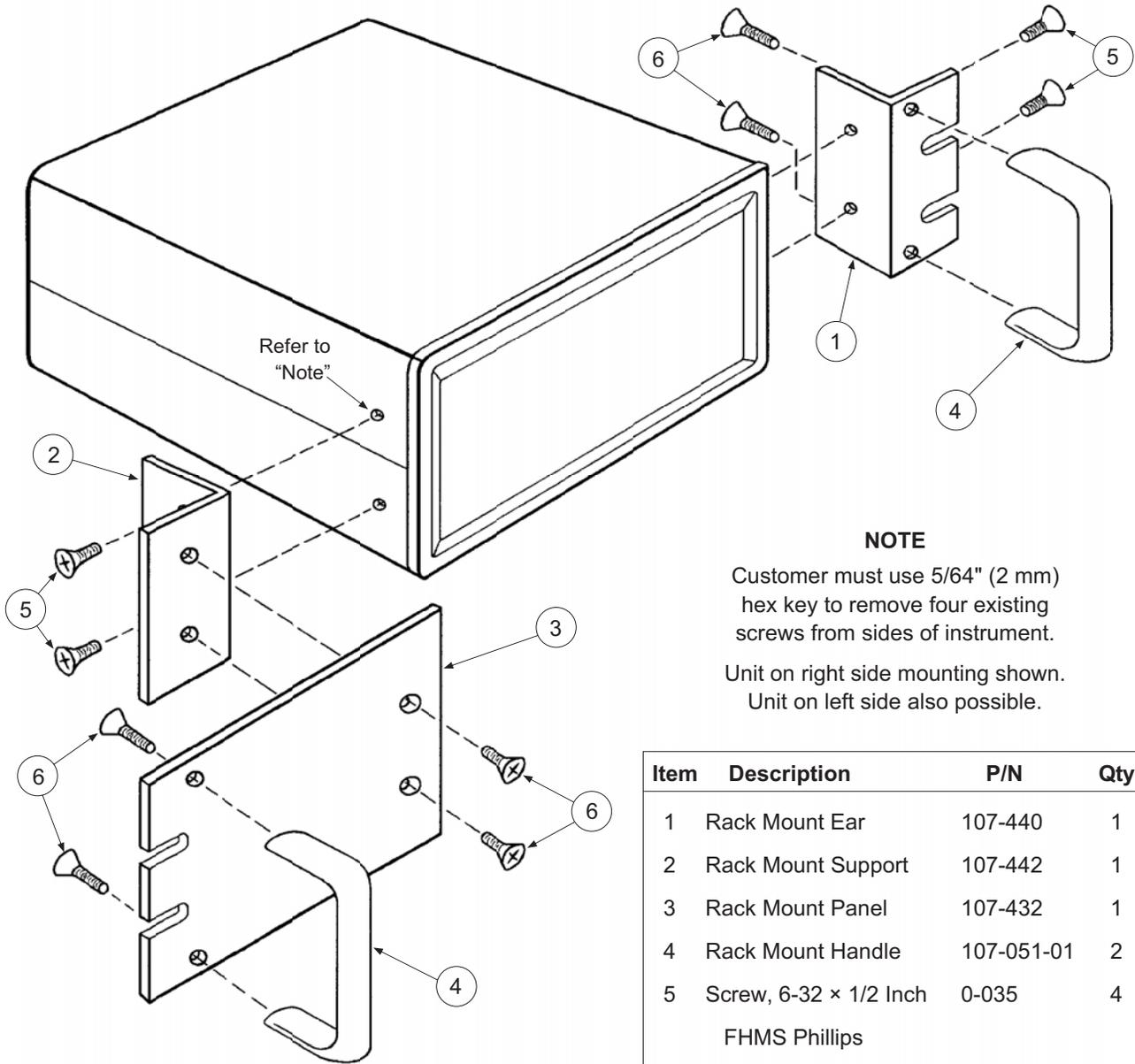
NOTE

Customer must use 5/64" (2 mm)
hex key to remove four existing
screws from sides of instrument.

Unit on right side mounting shown.
Unit on left side also possible.

Item	Description	P/N	Qty
1	Rack Mount Ear	107-440	1
2	Rack Mount Support	107-442	1
3	Rack Mount Panel	107-432	1
4	Rack Mount Handle	107-051-01	2
5	Screw, 6-32 × 1/2 Inch FHMS Phillips	0-035	4
6	Screw, 8-32 × 3/8 Inch FHMS Phillips	0-081	6

C-450-5-17.eps

Figure 5-17. Model RM-1/2 Rack-Mount Kit

Refer to
"Installation
Procedure"
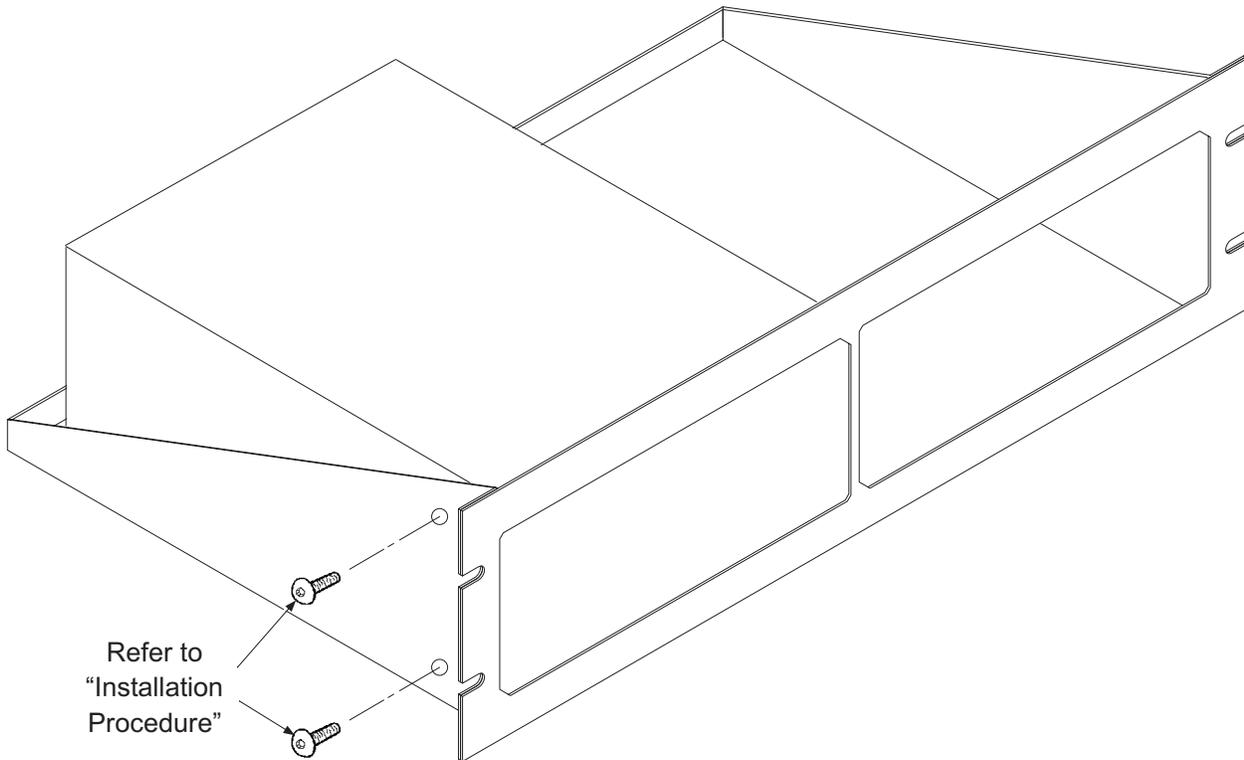
Installation Procedure

1. Use 5/64 inch (2 mm) hex key to remove two 6-32 x 1/4 black button head screws from side of Gaussmeter.

2. Place Gaussmeter on shelf.

3. Use 5/64 inch (2 mm) hex key to reinstall two 6-32 x 1/4 black button head screws through side of rack into corresponding holes in the side of the Gaussmeter.

C-450-5-18.eps

Figure 5-18. Model RM-2 Dual Rack-Mount Shelf

CHAPTER 6

SERVICE

6.0   GENERAL

This chapter covers general maintenance precautions in Paragraph 6.1, electrostatic discharge in Paragraph 6.2, line voltage selection in Paragraph 6.3, fuse replacement in Paragraph 6.4, rear panel connector definitions in Paragraph 6.5, optional serial interface cable and adapters in Paragraph 6.6, operating software EPROM replacement in Paragraph 6.7, and error messages in Paragraph 6.8.

There are no field serviceable parts inside the Model 450. Contact Lake Shore about specific problems with the Model 450.

6.1   GENERAL MAINTENANCE PRECAUTIONS

The following are general safety precautions unrelated to any other procedure in this publication. Keep away from live circuits. Installation personnel shall observe all safety regulations at all times. Turn off system power before making or breaking electrical connections. Regard any exposed connector, terminal board, or circuit board as a possible shock hazard. Discharge charged components only when such grounding results in no equipment damage. If a test connection to energized equipment is required, make the test equipment ground connection before probing the voltage or signal to be tested.

Do not install or service equipment alone. Do not reach into or adjust the equipment without having another person nearby capable of rendering aid.

If there is no power, verify the power cord is plugged into a live outlet and that both ends are securely plugged in. Next, check the fuse (refer to Paragraph 6.4).

Use this procedure to periodically clean the instrument to remove dust, grease, and other contaminants:

1. Clean front and back panels and case with soft cloth dampened with a mild detergent and water solution.

NOTE: Do *not* use aromatic hydrocarbons or chlorinated solvents to clean the instrument. They may react with the plastic materials used in the case or the silk screen printing on the back panel.

2. Clean the surface of printed circuit boards (PCBs) with clean, dry air at low pressure.

If the keyboard locks up, hold the **Escape** key for about 20 seconds to reset the Model 450 to factory defaults. The gaussmeter then requires the user to re-enter setpoints and zero the probe.

6.2   ELECTROSTATIC DISCHARGE

Electrostatic Discharge (ESD) may damage electronic parts, assemblies, and equipment. ESD is a transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. The low-energy source that most commonly destroys Electrostatic Discharge Sensitive (ESDS) devices is the human body, which generates and retains static electricity. Simply walking across a carpet in low humidity may generate up to 35,000 volts of static electricity.

Current technology trends toward greater complexity, increased packaging density, and thinner dielectrics between active elements, which results in electronic devices with even more ESD sensitivity. Some electronic parts are more ESDS than others. ESD levels of only a few hundred volts may damage electronic components such as semiconductors, thick and thin film resistors, and piezoelectric crystals during testing, handling, repair, or assembly. Discharge voltages below 4000 volts cannot be seen, felt, or heard.

6.2.1 Identification of Electrostatic Discharge Sensitive Components

Below are various industry symbols used to label components as ESDS:
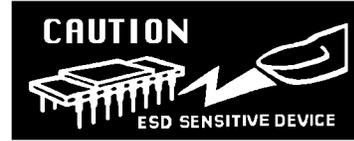
6.2.2 Handling Electrostatic Discharge Sensitive Components

Observe all precautions necessary to prevent damage to ESDS components before attempting installation. Bring the device and everything that contacts it to ground potential by providing a conductive surface and discharge paths. As a minimum, observe these precautions:

1. De-energize or disconnect all power and signal sources and loads used with unit.
2. Place unit on a grounded conductive work surface.
3. Ground technician through a conductive wrist strap (or other device) using 1 MΩ series resistor to protect operator.
4. Ground any tools, such as soldering equipment, that will contact unit. Contact with operator's hands provides a sufficient ground for tools that are otherwise electrically isolated.
5. Place ESDS devices and assemblies removed from a unit on a conductive work surface or in a conductive container. An operator inserting or removing a device or assembly from a container must maintain contact with a conductive portion of the container. Use only plastic bags approved for storage of ESD material.
6. Do not handle ESDS devices unnecessarily or remove from the packages until actually used or tested.

6.3 LINE VOLTAGE SELECTION

Use the following procedure to change the instrument line voltage selector. Verify the fuse value whenever line voltage is changed.

WARNING: To avoid potentially lethal shocks, turn off gaussmeter and disconnect it from AC power before performing these procedures.

1. Identify the line input assembly on the instrument rear panel. See Figure 6-1.
2. Turn the line power switch OFF (**O**).
3. Remove the instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Slide out the removable plastic fuse holder from the drawer.
6. Rotate the fuse holder until the proper voltage indicator shows through the window.
7. Verify the proper fuse value.
8. Re-assemble the line input assembly in the reverse order.
9. Verify the voltage indicator in the window of the line input assembly.
10. Connect the instrument power cord.
11. Turn the line power switch On (**I**).
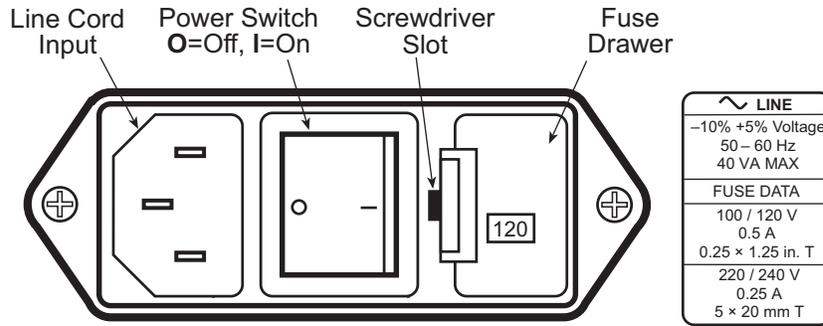
Figure 6-1. Power Fuse Access

6.4 FUSE REPLACEMENT

Below is the procedure to remove and replace a line fuse. There are two basic power configurations: U.S. and International. Units produced for use in the U.S. have a single fuse on the hot. Units produced for International use have a double fuse for the hot and neutral. To change line input from the factory setting, use the appropriate fuse in the connector kit shipped with the instrument. Test fuse with ohmmeter. Do not rely on visual inspection of fuse.

WARNING: **To avoid potentially lethal shocks, turn off gaussmeter and disconnect it from AC power before performing these procedures.**

CAUTION: For continued protection against fire hazard, replace only with the same fuse type and rating specified for the line for the line voltage selected.

1. Locate line input assembly on the instrument rear panel. See Figure 6-1.
2. Turn power switch Off (**O**).
3. Remove instrument power cord.
4. With a small screwdriver, release the drawer holding the line voltage selector and fuse.
5. Remove existing fuse(s). Replace with proper Slow-Blow fuse ratings as follows:

100/120 V	0.5 A T 250 V	0.25 × 1.25 inches
220/240 V	0.25 A T 250 V	5 × 20 mm

6. Re-assemble line input assembly in reverse order.
7. Verify voltage indicator in the line input assembly window.
8. Connect instrument power cord.
9. Turn power switch On (**I**).

6.5 REAR PANEL CONNECTOR DEFINITIONS

PROBE INPUT

DA-15 Connector – View looking at rear panel

C450-6-2.eps
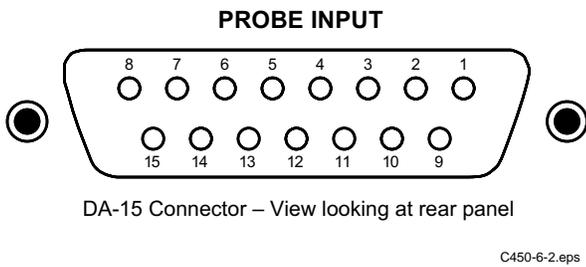
PIN	DESCRIPTION
1	Input + (Analog Signal)
2	No Connection
3	No Connection
4	ITEMP +
5	ITEMP –
6	No Connection
7	No Connection
8	I_C +
9	Input – (Analog Signal Ground)
10	No Connection
11	Digital Ground
12	+5 Volts (Power Output To Probe EEPROM)
13	EE-CLK (Output To Probe EEPROM)
14	EE-DATA (Serial Input From Probe EEPROM)
15	I_C –

Figure 6-2. DA-15 PROBE INPUT Connector Details

ANALOG OUTPUTS

Corrected   **Monitor**

C450-6-3.eps
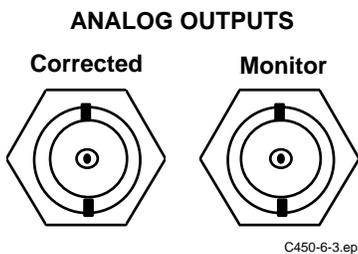
PIN	DESCRIPTION
1	Analog Output – Center Conductor
2	Ground – Connector Shell

Figure 6-3. Corrected and Monitor ANALOG OUTPUTS Connector Details

SERIAL I/O

RJ-11
Receptacle

C450-6-4.eps
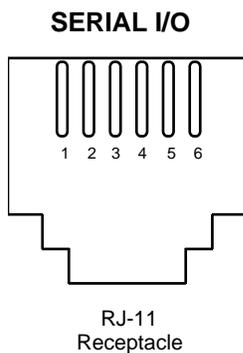
PIN	DESCRIPTION
1	Serial In (RxD)
2	Serial In (RxD)
3	Serial Ground
4	Serial Ground
5	Serial Out (TxD)
6	Serial Out (TxD)

Figure 6-4. SERIAL I/O RJ-11 Connector Details

6.5.1 IEEE-488 INTERFACE CONNECTOR

Connect to the IEEE-488 Interface connector on the Model 450 rear with cables specified in the IEEE-488-1978 standard document. The cable has 24 conductors with an outer shield. The connectors are 24-way Amphenol 57 Series (or equivalent) with piggyback receptacles to allow daisy-chaining in multiple device systems. The connectors are secured in the receptacles by two captive locking screws with metric threads.

The total length of cable allowed in a system is 2 meters for each device on the bus, or 20 meters maximum. A system may be composed of up to 15 devices. Figure 6-5 shows the IEEE-488 Interface connector pin location and signal names as viewed from the Model 450 rear panel.

IEEE-488 INTERFACE

SH1 AH1 T5 L4 SR1 RL1 PP0 DC1 DT0 C0 E1
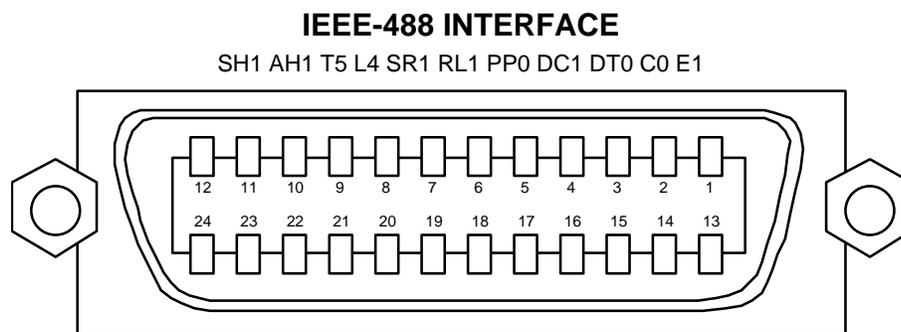
C450-6-5.eps

PIN	SYMBOL	DESCRIPTION
1	DIO1	Data Input/Output Line 1
2	DIO2	Data Input/Output Line 2
3	DIO3	Data Input/Output Line 3
4	DIO4	Data Input/Output Line 4
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable Shield
13	DIO5	Data Input/Output Line 5
14	DIO6	Data Input/Output Line 6
15	DIO7	Data Input/Output Line 7
16	DIO8	Data Input/Output Line 8
17	REN	Remote Enable
18	GND 6	Ground Wire – Twisted pair with DAV
19	GND 7	Ground Wire – Twisted pair with NRFD
20	GND 8	Ground Wire – Twisted pair with NDAC
21	GND 9	Ground Wire – Twisted pair with IFC
22	GND 10	Ground Wire – Twisted pair with SRQ
23	GND11	Ground Wire – Twisted pair with ATN
24	GND	Logic Ground

Figure 6-5. IEEE-488 Rear Panel Connector Details

6.6   OPTIONAL SERIAL INTERFACE CABLE AND ADAPTERS

To aid in Serial Interface troubleshooting, Figures 6-6 thru 6-8 show wiring information for the optional cable assembly and the two mating adapters.
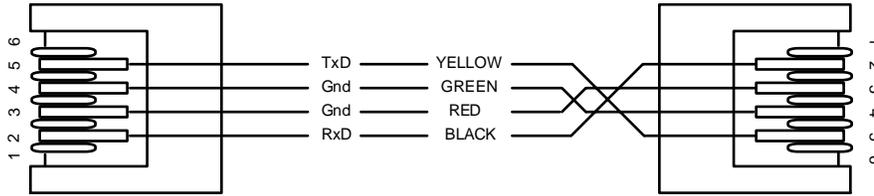
Figure 6-6. Model 2001 RJ-11 Cable Assembly Wiring Details
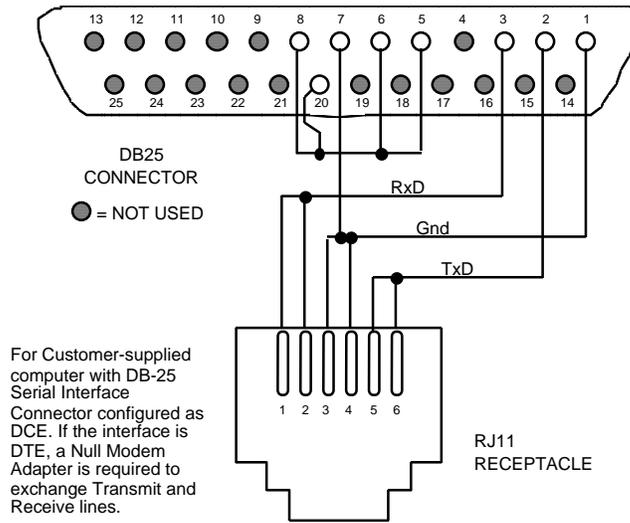
Figure 6-7. Model 2002 RJ-11 to DB-25 Adapter Wiring Details
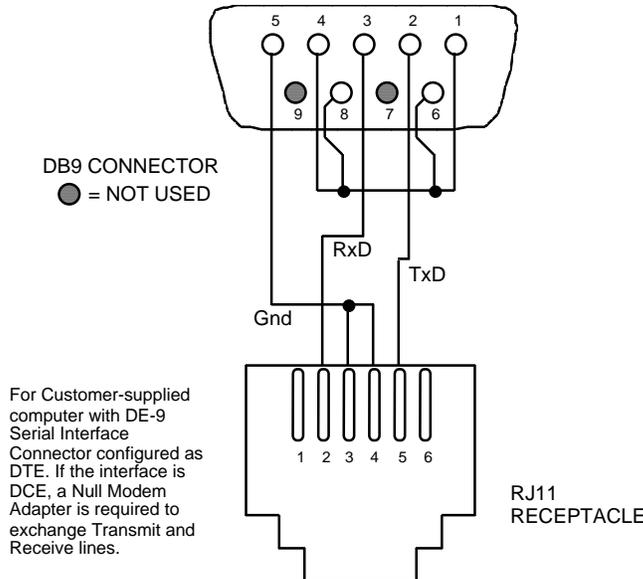
Figure 6-8. Model 2003 RJ-11 to DE-9 Adapter Wiring Details

6.7   OPERATING SOFTWARE EPROM REPLACEMENT

The operating software for the Model 450 is contained on one Erasable Programmable Read Only Memory (EPROM) Integrated Circuit (IC). The EPROM is numbered U36 and located just behind the microprocessor IC (U31). The EPROM also has a label on top identifying the software version and date (see Figure 6-9). Use the procedure below to replace the operating software EPROM.

WARNING: To avoid potentially lethal shocks, turn off the instrument and disconnect it from the AC power line before performing this procedure.

1. Set power switch to Off (**O**) and disconnect power cord from rear of unit.

2. Use 5/64 hex key to remove four screws attaching top panel to unit.

3. Use 5/64 hex key to loosen two screws attaching bottom panel to unit.

4. Carefully remove back bezel.

5. Slide top panel back and remove from unit.

6. Locate software EPROM U36 on main circuit board. Note its orientation (circular notch on front of IC). See Figure 6-9.

7. Use IC puller to remove existing EPROM from socket.

8. Use IC insertion tool to place new EPROM into socket, noting its orientation.

9. Replace top of enclosure and secure with four screws.

10. Replace back bezel and use 5/64 hex key to tighten two screws attaching bottom panel to unit.

11. Reconnect power cord to rear of unit and set power switch to On (**I**).

12. Perform the initial setup and system checkout (Paragraph 2.4). When replacing the operating software EPROM, all operating parameters reset to factory defaults specified in Paragraph 3.14.
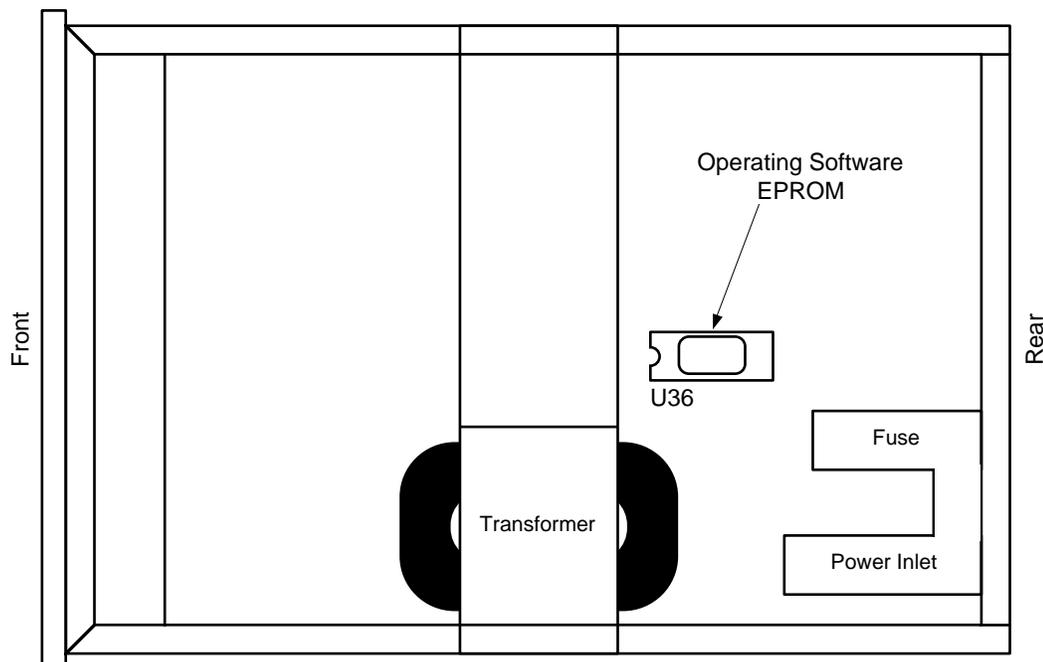
C-450-U-6-9

Figure 6-9. Location Of Operating Software EPROM

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APPENDIX A

GLOSSARY OF TERMINOLOGY

accuracy. The degree of correctness with which a measured value agrees with the true value.[2]

    electronic accuracy. The accuracy of an instrument independent of the sensor.

    sensor accuracy. The accuracy of a Hall generator and its associated calibration.

algorithm. A set of well-defined rules for the solution of a problem in a finite number of steps.[1]

American Standard Code for Information Exchange (ASCII). A standard code used in data transmission, in which 128 numerals, letters, symbols, and special control codes are represented by a 7-bit binary number as follows:

Bits → b7 b6 b5 →	$\begin{smallmatrix}0&0&0\end{smallmatrix}$ 0	$\begin{smallmatrix}0&0&1\end{smallmatrix}$ 1	$\begin{smallmatrix}0&1&0\end{smallmatrix}$ 2	$\begin{smallmatrix}0&1&1\end{smallmatrix}$ 3	$\begin{smallmatrix}1&0&0\end{smallmatrix}$ 4	$\begin{smallmatrix}1&0&1\end{smallmatrix}$ 5	$\begin{smallmatrix}1&1&0\end{smallmatrix}$ 6	$\begin{smallmatrix}1&1&1\end{smallmatrix}$ 7
b4 b3 b2 b1 / Col Row	0	1	2	3	4	5	6	7
0 0 0 0 0	NUL	DLE	SP	0	@	P	`	p
0 0 0 1 1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0 2	STX	DC2	"	2	B	R	b	r
0 0 1 1 3	ETX	DC3	#	3	C	S	c	s
0 1 0 0 4	EOT	DC4	$	4	D	T	d	t
0 1 0 1 5	ENQ	NAK	%	5	E	U	e	u
0 1 1 0 6	ACK	SYN	&	6	F	V	f	v
0 1 1 1 7	BEL	ETB	'	7	G	W	g	w
1 0 0 0 8	BS	CAN	(	8	H	X	h	x
1 0 0 1 9	HT	EM	)	9	I	Y	i	y
1 0 1 0 10	LF	SS	*	:	J	Z	j	z
1 0 1 1 11	VT	ESC	+	;	K	[	k	{
1 1 0 0 12	FF	FS	,	<	L	\	l	|
1 1 0 1 13	CR	GS	–	=	M	]	m	}
1 1 1 0 14	SO	RS	.	>	N	^	n	~
1 1 1 1 15	SI	US	/	?	O	_	o	DEL

American Wire Gage (AWG). Wiring sizes are defined as diameters in inches and millimeters as follows:

AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm	AWG	Dia. In.	Dia. mm
1	0.2893	7.348	11	0.0907	2.304	21	0.0285	0.7230	31	0.0089	0.2268
2	0.2576	6.544	12	0.0808	2.053	22	0.0253	0.6438	32	0.0080	0.2019
3	0.2294	5.827	13	0.0720	1.829	23	0.0226	0.5733	33	0.00708	0.178
4	0.2043	5.189	14	0.0641	1.628	24	0.0207	0.5106	34	0.00630	0.152
5	0.1819	4.621	15	0.0571	1.450	25	0.0179	0.4547	35	0.00561	0.138
6	0.1620	4.115	16	0.0508	1.291	26	0.0159	0.4049	36	0.00500	0.127
7	0.1443	3.665	17	0.0453	1.150	27	0.0142	0.3606	37	0.00445	0.1131
8	0.1285	3.264	18	0.0403	1.024	28	0.0126	0.3211	38	0.00397	0.1007
9	0.1144	2.906	19	0.0359	0.9116	29	0.0113	0.2859	39	0.00353	0.08969
10	0.1019	2.588	20	0.0338	0.8118	30	0.0100	0.2546	40	0.00314	0.07987

ampere. The constant current that, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one meter apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.[2] This is one of the base units of the SI.

ampere-turn. A MKS unit of magnetomotive force equal to the magnetomotive force around a path linking one turn of a conducting loop carrying a current of one ampere; or 1.26 gilberts.

ampere/meter (A/m). The SI unit for magnetic field strength (H). 1 ampere/meter = $4\pi/1000$ oersted ≈0.01257 oersted.

analog data. Data represented in a continuous form, as contrasted with digital data having discrete values.[1]

analog output. A voltage output from an instrument that is proportional to its input. From an instrument such as a digital voltmeter, the output voltage is generated by a digital-to-analog converter with a discrete number of voltage levels.

anode. The terminal that is positive with respect to the other terminal when the diode is biased in the forward direction.[2]

<div align="center">+   Anode ▶┤├ Cathode   –</div>

area. A measure of the size of a two-dimensional surface, or of a region on such a surface.[1]

area·turns. A coil parameter produced by the multiplication of a magnet's area and number of turns. Gives an indication of the sensitivity of a coil. In the Model 480, the area turns of a coil must be entered to perform flux density measurements in units of gauss (G) or tesla (T).

B. Symbol for magnetic flux density. *See* Magnetic Flux Density.

baud. A unit of signaling speed equal to the number of discrete conditions or signal events per second, or the reciprocal of the time of the shortest signal element in a character.[2]

bit. A contraction of the term "binary digit"; a unit of information represented by either a zero or a one.[2]

calibration. To determine, by measurement or comparison with a standard, the correct (accurate) value of each scale reading on a meter or other device, or the correct value for each setting of a control knob.[1]

cathode. The terminal from which forward current flows to the external circuit.[2]

+ Anode ▶|— Cathode −

Celsius (°C) Scale. A temperature scale that registers the freezing point of water as 0 °C and the boiling point as 100 °C under normal atmospheric pressure. Celsius degrees are purely derived units, calculated from the Kelvin Thermodynamic Scale. Formerly known as "centigrade." *See* Temperature for conversions.

cgs system of units. A system in which the basic units are the centimeter, gram, and second.[2]

coercive force (coercive field). The magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero.

coercivity. generally used to designate the magnetic field strength (H) required to reduce the magnetic induction (B) in a magnetic material to zero from saturation. The coercivity would be the upper limit to the coercive force.

compliance voltage. *See* current source.

Curie temperature (Tc). Temperature at which a magnetized sample is completely demagnetized due to thermal agitation. Named for Pierre Curie (1859-1906), a French chemist.

current source. A type of power supply that supplies a constant current through a variable load resistance by automatically varying its compliance voltage. A single specification given as "compliance voltage" means the output current is within specification when the compliance voltage is between zero and the specified voltage.

demagnetization. when a sample is exposed to an applied field (H_a), poles are induced on the surface of the sample. Some of the returned flux from these poles is inside of the sample. This returned flux tends to decrease the net magnetic field strength internal to the sample yielding a true internal field (H_{int}) given by: $H_{int} = H_a - DM$,where M is the volume magnetization and D is the demagnetization factor. D is dependent on the sample geometry and orientation with respect to the field.

deviation. The difference between the actual value of a controlled variable and the desired value corresponding to the setpoint.[1]

differential permeability. The slope of a B versus H curve: $\mu_d = dB/dH$.

differential susceptibility. The slope of a M versus H curve: $\chi_d = dM/dH$.

digital controller. A feedback control system where the feedback device (sensor) and control actuator (heater) are joined by a digital processor. In Lake Shore controllers the heater output is maintained as a variable DC current source.

digital data. Pertaining to data in the form of digits or interval quantities. Contrast with analog data.[2]

dimensionless sensitivity. Sensitivity of a physical quantity to a stimulus, expressed in dimensionless terms. The dimensionless temperature sensitivity of a resistance temperature sensor is expressed as $S_d = (T/R)(dR/dT)$ which is also equal to the slope of R versus T on a log-log plot, that is $S_d = d\ln R / d\ln T$. Note that the absolute temperature (in kelvin) must be used in these expressions.

drift, instrument. An undesired but relatively slow change in output over a period of time, with a fixed reference input. *Note:* Drift is usually expressed in percent of the maximum rated value of the variable being measured.[2]

dynamic data exchange (DDE). A method of interprocess communication which passes data between processes and synchronized events. DDE uses shared memory to exchange data between applications and a protocol to synchronize the passing of data.

dynamic link library (DLL). A module that contains code, data, and Windows resources that multiple Windows programs can access.

electromagnet. A device in which a magnetic field is generated as the result of electrical current passing through a helical conducting coil. It can be configured as an iron-free solenoid in which the field is produced along the axis of the coil, or an iron-cored structure in which the field is produced in an air gap between pole faces. The coil can be water cooled copper or aluminum, or superconductive.

electron. An elementary particle containing the smallest negative electric charge. *Note:* The mass of the electron is approximately equal to 1/1837 of the mass of the hydrogen atom.[2]

electrostatic discharge (ESD). A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

error. Any discrepancy between a computed, observed, or measured quantity and the true, specified, or theoretically correct value or condition.[2]

Fahrenheit (°F) Scale. A temperature scale that registers the freezing point of water as 32 °F and the boiling point as 212 °F under normal atmospheric pressure. *See* Temperature for conversions.

flux (ϕ). The electric or magnetic lines of force in a region.[1]

flux density (B). Any vector field whose flux is a significant physical quantity; examples are magnetic flux density, electric displacement, and gravitational field.[1]

gamma. A cgs unit of low-level flux density, where 100,000 gamma equals one oersted, or 1 gamma equals 10^{-5} oersted.

gauss (G). The cgs unit for magnetic flux density (B). 1 gauss = 10^{-4} tesla = 1 Mx/cm^2 = line/cm^2. Named for Karl Fredrich Gauss (1777-1855) a German mathematician, astronomer, and physicist.

gaussian system (units). A system in which centimeter-gram-second units are used for electric and magnetic qualities.

general purpose interface bus (GPIB). Another term for the IEEE-488 bus.

gilbert (Gb). A cgs electromagnetic unit of the magnetomotive force required to produce one maxwell of magnetic flux in a magnetic circuit of unit reluctance. One gilbert is equal to $10/4\pi$ ampere-turn. Named for William Gilbert (1540-1603), an English physicist; hypothesized that the earth is a magnet.

gilbert per centimeter. Practical cgs unit of magnet intensity. Gilberts per cm are the same as oersteds.

Greek alphabet. The Greek alphabet is defined as follows:

Alpha	α	A	Iota	ι	I	Rho	ρ	P
Beta	β	B	Kappa	κ	K	Sigma	σ	Σ
Gamma	γ	Γ	Lambda	λ	Λ	Tau	τ	T
Delta	δ	Δ	Mu	μ	M	Upsilon	υ	Y
Epsilon	ε	E	Nu	ν	N	Phi	φ	Φ
Zeta	ζ	Z	Xi	ξ	Ξ	Chi	χ	X
Eta	η	H	Omicron	o	O	Psi	ψ	Ψ
Theta	θ	Θ	Pi	π	Π	Omega	ω	Ω

ground. A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth, or to some conducting body of large extent that serves in place of the earth. *Note:* It is used for establishing and maintaining the potential of the earth (or of the conducting body) or approximately that potential, on conductors connected to it, and for conducting ground current to and from the earth (or of the conducting body).[2]

H. Symbol for magnetic field strength. *See* Magnetic Field Strength.

Hall effect. The generation of an electric potential perpendicular to both an electric current flowing along a thin conducting material and an external magnetic field applied at right angles to the current. Named for Edwin H. Hall (1855-1938), an American physicist.

Hall mobility. The quantity μH in the relation $\mu H = R\sigma$, where R = Hall coefficient and σ = conductivity.[2]

Helmholtz coils. A pair of flat, circular coils having equal numbers of turns and equal diameters, arranged with a common axis, and connected in series; used to obtain a magnetic field more nearly uniform than that of a single coil.[1]

hertz (Hz). A unit of frequency equal to one cycle per second.

hole. A mobile vacancy in the electronic valence structure of a semiconductor that acts like a positive electron charge with a positive mass.[2]

hysteresis. The dependence of the state of a system on its previous history, generally in the form of a lagging of a physical effect behind its cause.[1] Also *see* magnetic hysteresis.

IEEE. Institute of Electrical and Electronics Engineers.

IEEE-488. An instrumentation bus with hardware and programming standards designed to simplify instrument interfacing. The addressable, parallel bus specification is defined by the IEEE.

initial permeability. The permeability determined at H = 0 and B = 0.

initial susceptibility. The susceptibility determined at H = 0 and M = 0.

integrator. A circuit or network whose output waveform is the time integral of its input waveform.[1] In the Model 480, the input is a voltage with the integral output being in volt seconds (V·s).

international system of units (SI). A universal coherent system of units in which the following seven units are considered basic: meter, kilogram, second, ampere, kelvin, mole, and candela. The International System of Units, or Système International d'Unités (SI), was promulgated in 1960 by the Eleventh General Conference on Weights and Measures. For definition, spelling, and protocols, *see* Reference 3 for a short, convenient guide.

interpolation table. A table listing the output and sensitivity of a sensor at regular or defined points which may be different from the points at which calibration data was taken.

intrinsic coercivity. The magnetic field strength (H) required to reduce the magnetization (M) or intrinsic induction in a magnetic material to zero.

intrinsic induction. The contribution of the magnetic material (B_i) to the total magnetic induction (B).

$$B_i = B - \mu_0 H \quad \text{(SI)} \qquad\qquad B_i = B - H \quad \text{(cgs)}$$

isolated (neutral system). A system that has no intentional connection to ground except through indicating, measuring, or protective devices of very-high impedance.[2]

Kelvin (K). The unit of temperature on the Kelvin Scale. It is one of the base units of SI. The word "degree" and its symbol (°) are omitted from this unit. *See* Temperature Scale for conversions.

Kelvin Scale. The Kelvin Thermodynamic Temperature Scale is the basis for all international scales, including ITS-90. It is fixed at two points: the absolute zero of temperature (0 K), and the triple point of water (273.16 K), the equilibrium temperature that pure water reaches in the presence of ice and its own vapor.

line regulation. The maximum steady-state amount that the output voltage or current will change as the result of a specified change in input line voltage (usually for a step change between 105-125 or 210-250 volts, unless otherwise specified).

line of flux. An imaginary line in a magnetic field of force whose tangent at any point gives the direction of the field at that point; the lines are spaced so that the number through a unit area perpendicular to the field represents the intensity of the field. Also know as a Maxwell in the cgs system of units.

line voltage. The RMS voltage of the primary power source to an instrument.

load regulation. A steady-state decrease of the value of the specified variable resulting from a specified increase in load, generally from no-load to full-load unless otherwise specified.

M. Symbol for magnetization. *See* magnetization.

magnetic air gap. The air space, or non-magnetic portion, of a magnetic circuit.

magnetic field strength (H). The magnetizing force generated by currents and magnetic poles. For most applications, the magnetic field strength can be thought of as the applied field generated, for example, by a superconducting magnet. The magnetic field strength is not a property of materials. Measure in SI units of A/m or cgs units of oersted.

magnetic flux density (B). Also referred to as magnetic induction. This is the net magnetic response of a medium to an applied field, H. The relationship is given by the following equation: $B = \mu_o(H + M)$ for SI, and $B = H + 4\pi M$ for cgs, where H = magnetic field strength, M = magnetization, and μ_o = permeability of free space = $4\pi \times 10^{-7}$ H/m.

magnetic hysteresis. The property of a magnetic material where the magnetic induction (B) for a given magnetic field strength (H) depends upon the past history of the samples magnetization.

magnetic induction (B). *See* magnetic flux density.

magnetic moment (m). This is the fundamental magnetic property measured with dc magnetic measurements systems such as a vibrating sample magnetometer, extraction magnetometer, SQUID magnetometer, etc. The exact technical definition relates to the torque exerted on a magnetized sample when placed in a magnetic field. Note that the moment is a total attribute of a sample and alone does not necessarily supply sufficient information in understanding material properties. A small highly magnetic sample can have exactly the same moment as a larger weakly magnetic sample (*see* Magnetization). Measured in SI units as $A \cdot m^2$ and in cgs units as emu. 1 emu = 10^{-3} $A \cdot m^2$.

magnetic scalar potential. The work which must be done against a magnetic field to bring a magnetic pole of unit strength from a reference point (usually at infinity) to the point in question. Also know as magnetic potential.[1]

magnetic units. Units used in measuring magnetic quantities. Includes ampere-turn, gauss, gilbert, line of force, maxwell, oersted, and unit magnetic pole.

magnetization (M). This is a material specific property defined as the magnetic moment (m) per unit volume (V). M = m/V. Measured in SI units as A/m and in cgs units as emu/cm^3. 1 emu/cm^3 = 10^3 A/m. Since the mass of a sample is generally much easier to determine than the volume, magnetization is often alternately expressed as a mass magnetization defined as the moment per unit mass.

magnetostatic. Pertaining to magnetic properties that do not depend upon the motion of magnetic fields.[1]

Maxwell (Mx). A cgs electromagnetic unit of magnetic flux, equal to the magnetic flux which produces an electromotive force of 1 abvolt in a circuit of one turn link the flux, as the flux is reduced to zero in 1 second at a uniform rate.[1]

MKSA System of Units. A system in which the basic units are the meter, kilogram, and second, and the ampere is a derived unit defined by assigning the magnitude $4\pi \times 10^{-7}$ to the rationalized magnetic constant (sometimes called the permeability of space).

NBS. National Bureau of Standards. Now referred to as NIST.

National Institute of Standards and Technology (NIST). Government agency located in Gaithersburg, Maryland and Boulder, Colorado, that defines measurement standards in the United States. *See* Standards Laboratories for an international listing.

noise (electrical). Unwanted electrical signals that produce undesirable effects in circuits of control systems in which they occur.[2]

normalized sensitivity. For resistors, signal sensitivity (dR/dT) is geometry dependent; i.e., dR/dT scales directly with R; consequently, very often this sensitivity is normalized by dividing by the measured resistance to give a sensitivity, s_T, in percent change per kelvin. $s_T = (100/R) (dR/dT)$ %K, where T is temperature in kelvin and R is resistance in ohms.

normally closed (N.C.). A term used for switches and relay contacts. Provides a closed circuit when actuator is in the free (unenergized) position.

normally open (N.O.). A term used for switches and relay contacts. Provides an open circuit when actuator is in the free (unenergized) position.

oersted (Oe). The cgs unit for the magnetic field strength (H). 1 oersted = $10^3/4\pi$ ampere/meter ≈ 79.58 ampere/meter.

ohm (Ω). The SI unit of resistance (and of impedance). The ohm is the resistance of a conductor such that a constant current of one ampere in it produces a voltage of one volt between its ends.[2]

pascal (Pa). The SI unit of pressure equal to 1 N/m^2. Equal to 1.45×10^{-4} psi, 1.0197×10^{-5} kg_f/cm^2, 7.5×10^{-3} torr, 4.191×10^{-3} inches of water, or 1×10^{-5} bar.

permeability. Material parameter which is the ratio of the magnetic induction (B) to the magnetic field strength (H): $\mu = B/H$. Also *see* Initial Permeability and Differential Permeability.

polynomial fit. A mathematical equation used to fit calibration data. Polynomials are constructed of finite sums of terms of the form $a_i x_i$, where a_i is the ith fit coefficient and x_i is some function of the dependent variable.

pounds per square inch (psi). A unit of pressure. 1 psi = 6.89473 kPa. Variations include psi absolute (psia) measured relative to vacuum (zero pressure) where one atmosphere pressure equals 14.696 psia and psi gauge (psig) where gauge measured relative to atmospheric or some other reference pressure.

ppm. Parts per million, e.g., 4×10^{-6} is four parts per million.

precision. Careful measurement under controlled conditions which can be repeated with similar results. *See* repeatability. Also means that small differences can be detected and measured with confidence. *See* resolution.

prefixes. SI prefixes used throughout this manual are as follows:

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

probe. A long, thin body containing a sensing element which can be inserted into a system in order to make measurements. Typically, the measurement is localized to the region near the tip of the probe.

remanence. The remaining magnetic induction in a magnetic material when the material is first saturated and then the applied field is reduced to zero. The remanence would be the upper limit to values for the remanent induction. Note that no strict convention exists for the use of remanent induction and remanence and in some contexts the two terms may be used interchangeably.

remanent induction. The remaining magnetic induction in a magnetic material after an applied field is reduced to zero. Also *see* remanence.

repeatability. The closeness of agreement among repeated measurements of the same variable under the same conditions.[2]

resolution. The degree to which nearly equal values of a quantity can be discriminated.[2]

display resolution. The resolution the physical display of an instrument. This is not always the same as the measurement resolution of the instrument. Decimal display resolution specified as "*n* digits" has 10^{n} possible display values. A resolution of *n* and one-half digits has 2×10^{n} possible values.

measurement resolution. The ability of an instrument to resolve a measured quantity. For digital instrumentation this is often defined by the analog to digital converter being used. A n-bit converter can resolve one part in 2^{n}. The smallest signal change that can be measured is the full scale input divided by 2^{n} for any given range. Resolution should not be confused with accuracy.

root mean square (RMS). The square root of the time average of the square of a quantity; for a periodic quantity the average is taken over one complete cycle. Also known as effective value.[1]

RS-232C. Bi-directional computer serial interface standard defined by the Electronic Industries Association (EIA). The interface is single-ended and non-addressable.

scalar. A quantity which has magnitude only and no direction, in contrast to a vector.[1]

semiconducting material. A conducting medium in which the conduction is by electrons, and holes, and whose temperature coefficient of resistivity is negative over some temperature range below the melting point.[2]

semiconductor. An electronic conductor, with resistivity in the range between metals and insulators, in which the electric charge carrier concentration increases with increasing temperature over some temperature range. Note: Certain semiconductors possess two types of carriers, namely, negative electrons and positive holes.[2]

sensitivity. The ratio of the response or change induced in the output to a stimulus or change in the input. Temperature sensitivity of a resistance temperature detector is expressed as $S = dR/dT$.

setpoint. The value selected to be maintained by an automatic controller.[1]

serial interface. A computer interface where information is transferred one bit at a time rather than one byte (character) at a time as in a parallel interface. RS-232C is a common serial interface.

SI. Système International d'Unités. *See* International System of Units.

stability. The ability of an instrument or sensor to maintain a constant output given a constant input.

susceptance. In electrical terms, susceptance is defined as the reciprocal of reactance and the imaginary part of the complex representation of admittance: [suscept(ibility) + (conduct)ance].

susceptibility (χ). Parameter giving an indication of the response of a material to an applied magnetic field. The susceptibility is the ratio of the magnetization (M) to the applied field (H). $\chi = M/H$. In both SI units and cgs units the volume susceptibility is a dimensionless parameter. Multiply the cgs susceptibility by 4π to yield the SI susceptibility. *See* also Initial Susceptibility and Differential Susceptibility. As in the case of magnetization, the susceptibility is often seen expressed as a mass susceptibility or a molar susceptibility depending upon how M is expressed.

temperature scales. *See* Kelvin Scale, Celsius Scale, and ITS-90. Proper metric usage requires that only kelvin and degrees Celsius be used. However, since degrees Fahrenheit is in such common use, all three scales are delineated as follows:

Boiling point of water	373.15 K	100 °C	212 °F
Triple point of water	273.16 K		
Freezing point of water	273.15 K	0 °C	32 °F
Absolute zero	0 K	−273.15 °C	−459.67 °F
	kelvin	Celsius	Fahrenheit
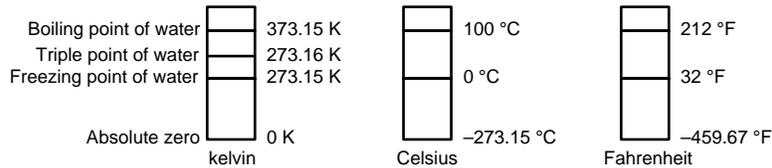
To convert kelvin to Celsius, subtract 273.15.
To convert Celsius to Fahrenheit: multiply °C by 1.8 then add 32, or: °F = (1.8 × °C) + 32.
To convert Fahrenheit to Celsius: subtract 32 from °F then divide by 1.8, or: °C = (°F. 32)/ 1.8.

temperature coefficient, measurement. The measurement accuracy of an instrument is affected by changes in ambient temperature. The error is specified as an amount of change (usually in percent) for every one degree change in ambient temperature.

tesla (T). The SI unit for magnetic flux density (B). 1 tesla = 10^4 gauss

thermal emf. An electromotive force arising from a difference in temperature at two points along a circuit, as in the Seebeck effect.[1]

tolerance. The range between allowable maximum and minimum values.

turns (N). One complete loop of wire. In the Model 480, the turns of a coil must be entered to perform flux measurements in units of Volt seconds (V·sϕ), Webers (Wbϕ), or Maxwells (Mxϕ).

Underwriters Laboratories (UL). An independent laboratory that establishes standards for commercial and industrial products.

unit magnetic pole. A pole with a strength such that when it is placed 1 cm away from a like pole, the force between the two is 1 dyne.

vector. A quantity that has both magnitude and direction, and whose components transform from one coordinate system to another in the same manner as the components of a displacement. Also known as a polar vector.[1]

volt (V). The difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.[2]

volt-ampere (VA). The SI unit of apparent power. The volt-ampere is the apparent power at the points of entry of a single-phase, two-wire system when the product of the RMS value in amperes of the current by the RMS value in volts of the voltage is equal to one.[2]

watt (W). The SI unit of power. The watt is the power required to do work at the rate of 1 joule per second.[2]

weber (Wb). The unit of magnetic flux in the mks system, equal to the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.[1]

References:

1   Sybil P. Parker, Editor. *Dictionary of Scientific and Technical Terms: Third Edition*. New York: McGraw Hill, 1969 (IBSN 0-395-20360-0)

2   Christopher J. Booth, Editor. *The New IEEE Standard Dictionary of Electrical and Electronic Terms: IEEE Std 100-1992, Fifth Edition.* New York: Institute of Electrical and Electronics Engineers, 1993 (IBSN 1-55937-240-0). Definitions printed with permission of the IEEE.

3   Nelson, Robert A. *Guide For Metric Practice,* Page BG7 - 8, Physics Today, Eleventh Annual Buyer's Guide, August 1994 (ISSN 0031-9228 coden PHTOAD)

APPENDIX B

UNITS FOR MAGNETIC PROPERTIES

Table B-1. Conversion from CGS to SI Units

Quantity	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), $G \bullet cm^2$	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	$4\pi M$	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^{2i}
(Mass) magnetization	σ, M	emu/g	1 $4\pi \times 10^{-7}$	$A \bullet m^2/kg$ $Wb \bullet m/kg$
Magnetic moment	m	emu, erg/G	10^{-3}	$A \bullet m^2$, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	$Wb \bullet m^i$
(Volume) susceptibility	χ, κ	dimensionless emu/cm^3	$-$ $(4\pi)^2 \times 10^{-7}$	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 $H \bullet m^2/kg$
(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 $H \bullet m^2/mol$
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

NOTES:

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 $\times$ 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 to $\mu_0 = 4\pi \times 10^{-7}$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 $cm^{-\frac{1}{2}} \bullet g^{\frac{1}{2}} \bullet s^{-1}$ 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 • H and $\mu_0 M$ • H have SI units J/m^3, M • H and B • $H/4\pi$ have Gaussian units erg/cm^3.

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

Table B-2. Recommended SI Values for Physical Constants

Quantity	Symbol	Value (SI units)
Permeability of Vacuum	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Speed of Light in Vacuum	c	2.9979×10^{8} m s^{-1}
Permitivity of Vacuum	$\varepsilon_0 = (\mu_0 c^2)^{-1}$	8.8542×10^{-12} F m^{-1}
Fine Structure Constant, µ0ce2/2h	α α^{-1}	0.0073 137.0360
Elementary Charge	e	1.6022×10^{-19} C
Plank's Constant	h $\hbar = h/2\pi$	6.6262×10^{-34} J Hz^{-1} 1.0546×10^{-34} J s
Avogadro's Constant	N_A	6.0220×10^{23} mol^{-1}
Atomic Mass Unit	1 u = 10^{-3} kg mol^{-1}/N_A	1.6605×10^{-27} kg
Electron Rest Mass	m_e	0.9109×10^{-30} kg 5.4858×10^{-4} u
Proton Rest Mass	m_p	1.6726×10^{-27} kg 1.0073 u
Neutron Rest Mass	m_n	1.6749×10^{-27} kg 1.0087 u
Magnetic Flux Quantum	$\phi = h/2e$ h/e	2.0679×10^{-15} Wb 4.1357×10^{-15} J Hz^{-1} C^{-1}
Josephson Frequency-Voltage Ratio	$2e/h$	483.5939 THz V^{-1}
Quantum of Circulation	$h/2m_e$ h/m_e	3.6369×10^{-4} J Hz^{-1} kg^{-1} 7.2739×10^{-4} J Hz^{-1} C^{-1}
Rydberg Constant	R_∞	1.0974×10^{7} m^{-1}
Proton Moment in Nuclear Magnetons	μ_P/μ_N	2.7928
Bohr Magneton	$\mu_B = eh/2m_e$	9.2741×10^{-24} J T^{-1}
Proton Gyromagnetic Ratio	γ_p	2.6752×10^{8} s^{-1} T^{-1}
Diamagnetic Shielding Factor, Spherical H$_2$O Sample	$1 + \sigma(H_2O)$	1.0000
Molar Mass Constant	R	8.3144 J mol^{-1} K^{-1}
Molar Volume, Ideal Gas (T_0 = 273.15K, p_0 = 1 atm)	$V_m = RT_0/p_0$	0,0224 m^3 mol^{-1}
Boltzman Constant	$k = R/N_A$	1.3807×10^{-23} J K^{-1}
Stefan-Boltzman Constant	$\sigma = (\pi^2/60) k^4/h^3 c^2$	5.6703×10^{-8} W m^{-2} K^{-4}
First Radiation Constant	$c_1 = 2\pi hc^2$	3.7418×10^{-16} W m^{-2}
Second Radiation Constant	$c_2 = hc/k$	0.0144 mK
Gravitation Constant	G	6.6720×10^{-11} N m^2 kg^{-2}

Data (abbreviated to 4 decimal places) from CODATA Bulletin No. 11, ICSU CODATA Central Office, 19 Westendstrasse, 6 Frankfurt/Main, Germany. Copies of this bulletin are available from this office.

APPENDIX C

HALL GENERATORS

C1.0 GENERAL

This chapter provides theory of operation, specifications, mechanical drawings, and definition of terminology. Hall Generator theory of operation is detailed in Paragraph C2.0. Generic Hall generator hookup is detailed in Paragraph C3.0. Hookup to a Model 450 Gaussmeter is discussed in Paragraph C4.0. Specifications of the various available Hall generators are detailed in Paragraph C5.0. Finally, the HALLCAL.EXE program is detailed in Paragraph C6.0. Additional installation and calibration information is available in Lake Shore Document Number C2S001 – Hall Generator Installation Instructions.

C2.0 THEORY OF OPERATION

The Hall effect was discovered by E. H. Hall in 1879. For nearly 70 years it remained a laboratory curiosity. Finally, development of semiconductors brought Hall generators into the realm of the practical.

A Hall generator 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. See Figure C-1.

Electrons (the majority carrier most often used in practice) "drift" in the conductor when under the influence of an external driving electric field. When exposed to a magnetic field, these moving charged particles experience a force perpendicular to both the velocity and magnetic field vectors. This force causes the charging of the edges of the conductor, one side positive with respect to the other. This edge charging sets up an electric field which exerts a force on the moving electrons equal and opposite to that caused by the magnetic-field-related Lorentz force. The voltage potential across the width of the conductor is called the Hall voltage. This Hall voltage can be utilized in practice 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/kG) (at a fixed current)
B = Magnetic field flux density (kilogauss)
θ = Angle between magnetic flux vector and the plane of Hall generator.

As can be seen from the formula, above, 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 generator.

C2.1 ACTIVE AREA

The Hall generator 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.

$$\overline{F} = -e\,(\overline{v} \times \overline{B})$$
(force on electron)
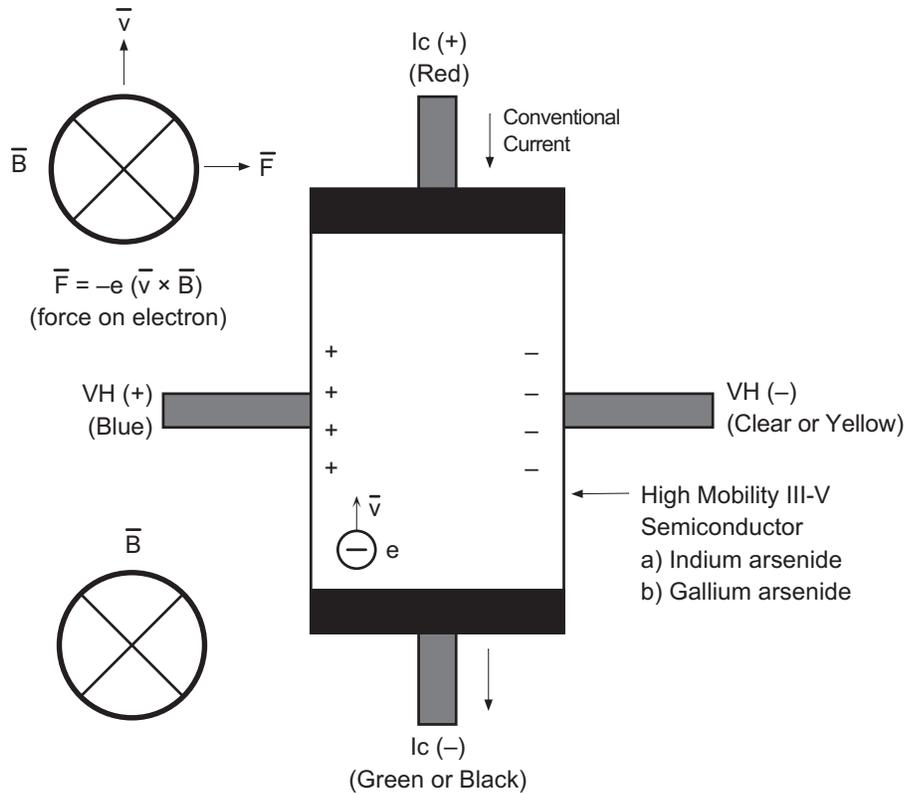
Figure C-1. Hall Generator Theory

C-421-C-1.eps

C2.2 ORIENTATION

Hall generators come in two main configurations, axial and transverse. 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.

Transverse
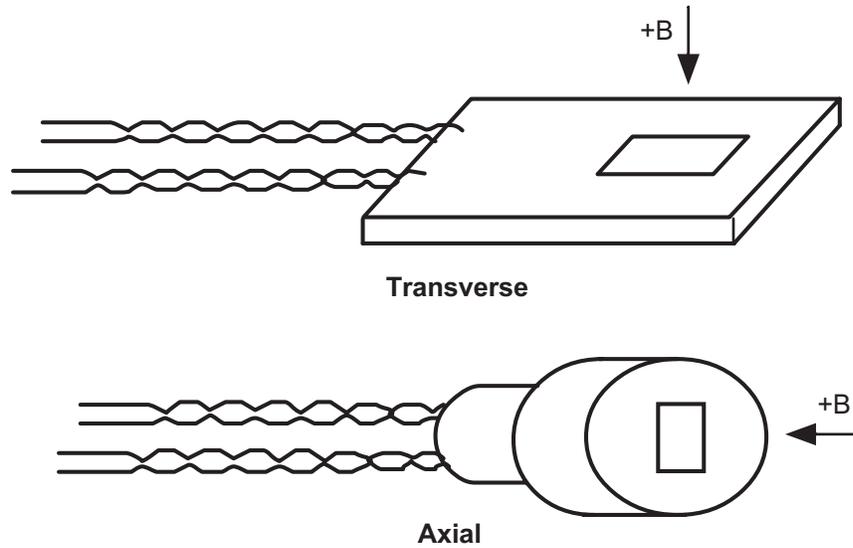
Axial

C-421-C-2.eps

Figure C-2. Axial and Transverse Configurations

C2.3   HANDLING

>   **CAUTION:** Care must be exercised when handling the Hall generator. The Hall
>   generator is very fragile. Stressing the Hall generator can alter its output. Any excess
>   force can easily break the Hall generator. Broken Hall generators are not repairable.

Hall Generators are very fragile and require delicate handling. The ceramic substrate used to produce the Hall Generator is very brittle. Use the leads to move the Hall generator. Do not handle the substrate. The strength of the lead-to-substrate bond is about 7 ounces, so avoid tension on the leads and especially avoid bending them close to the substrate. The Hall Generator is also susceptible to bending and thermal stresses.

C2.4   POLARITY

If the control current enters the red lead (with $+I_C$ connected to the positive terminal of the current supply), and the magnetic field direction is as shown in Figure C-2, a positive Hall voltage will be generated at the blue lead ($+V_H$). Reversing either the current or the magnetic field will reverse the output voltage.

C2.5   LEAD CONFIGURATIONS

All Hall generators (except Models HGCA-3020 and HGCT-3020) have 34 AWG solid copper with poly-nylon insulation and have the same lead configuration as follows:

Red = $+I_C$
Green = $-I_C$ } Input (Control Current)

Blue = $+V_H$
Clear = $-V_H$ } Output (Hall Voltage)

The Model HGCA-3020 and HGCT-3020 Hall generators have 34 AWG stranded copper with Teflon® insulation and have the following lead configuration:

Red = $+I_C$
Black = $-I_C$ } Input (Control Current)

Blue = $+V_H$
Yellow = $-V_H$ } Output (Hall Voltage)

C3.0   HALL GENERATOR GENERIC HOOKUP

The Hall voltage leads may also 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. In this case, a separate precision current source (Lake Shore Model 120CS or equivalent) is necessary. See Figure C-3.

>   **CAUTION:** The four Hall generator leads connect to four points on a sheet of
>   semiconductor material having different potentials. No two leads can be connected
>   together without adversely affecting operation. Therefore, the current source and the
>   output indicator cannot have a common connection, but must be isolated from each
>   other. One, the other, but not both, may be grounded.

>   **CAUTION:** Do not exceed the maximum continuous control current given in the
>   specifications.

The Hall generator 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.
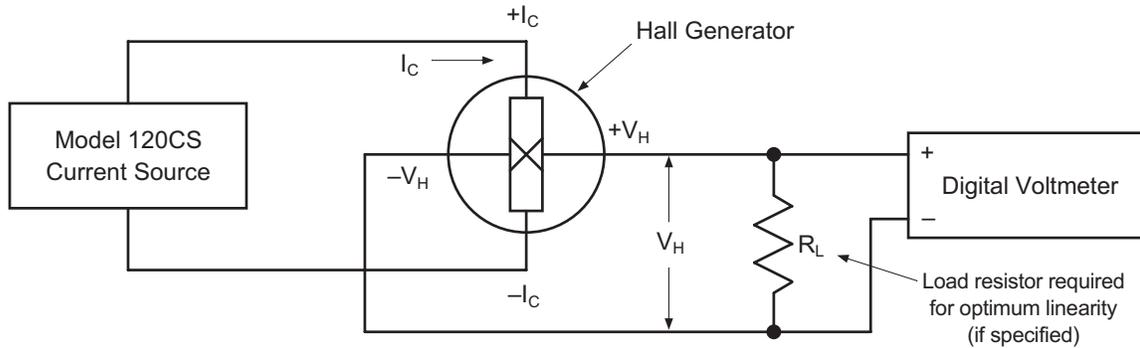
Figure C-3. Typical Hall Generator Hookup

C4.0   USING A HALL GENERATOR WITH THE MODEL 450

To hookup a Hall generator you must use a Lake Shore Model MCBL-6 Cable Assembly. The cable is 200 cm (79 inches) long with a DA-15 connector on one end and four leads on the other. The Hall generator is a 4-lead device. The 4 leads are labeled +Ic (Red), –Ic (Black or Green), +VH (Blue), and –VH (Yellow), corresponding to the 4 leads on all the Hall generators.

The Model 450 has an input impedance of 420 Ω. Therefore, the actual sensitivity at the gaussmeter input will be less than the value given with the Hall generator due to drop in the leads and cable. This fact is important because a sensitivity value is supposed to be loaded into the cable PROM to set calibration. We recommend that the customer always check accuracy against a reference field rather than use the sensitivity value sent with the bare Hall generator. Because Lake Shore has no control of the conditions beyond the cable, the customer must accept responsibility for accuracy and compatibility.

Finally, Manganin wire is not usually acceptable for cryogenic installations. The resistance of Manganin wire is often too high. In cryogenic applications, Hall generators are normally connected using twisted pairs of copper wire such as 34 gauge, Teflon insulated. There are two reasons for this:

1. The gaussmeter current source is normally limited in compliance voltage. The Model 450 should not drive a load (Hall generator, Wires in cryostat, and probe cable) greater than 50 Ω. In fact, for best performance, the load should be less than 30 Ω.

2. Because the Model 450 input impedance is 420 Ω, there is a voltage drop due to lead resistance in series with the gaussmeter input. The Lake Shore Hall generator sensitivity given on the data sheet is basically with no lead resistance. See Figure C-4.
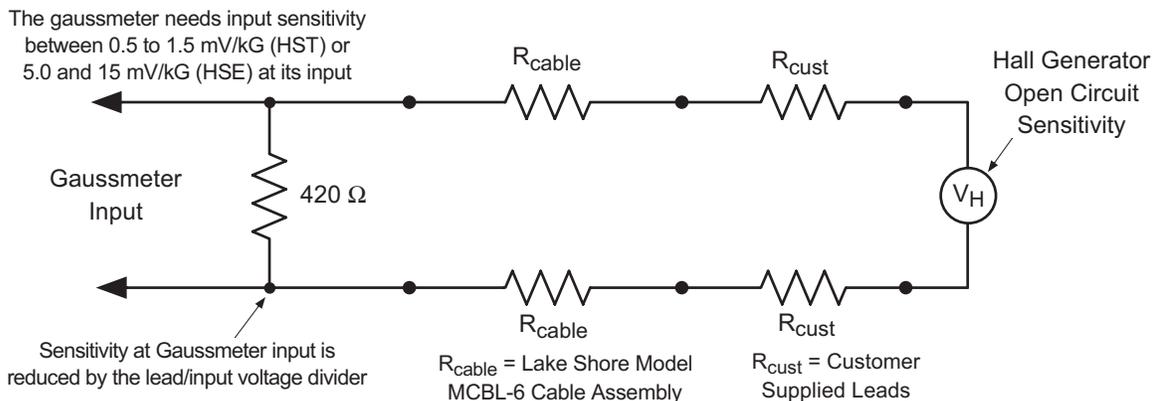
Figure C-4. Hall Generator Input Impedance

C5.0   SPECIFICATIONS

This section covers three types of Hall generators available from Lake Shore: HGCA & HGCT Series Cryogenic Hall generators (Figures C-5 and C-6) with specifications (Table C-1), HGA Series Axial Hall generators (Figures C-5 and C-7) with specifications (Table C-2), and HGT Series Transverse Hall generators (Figures C-8 thru C-10) with specifications (Table C-3).

0.25 in. diameter

0.20 in.

10 in. (min.)

+B

0.105 in.

0.20 in. diameter

C-421-C-5.eps
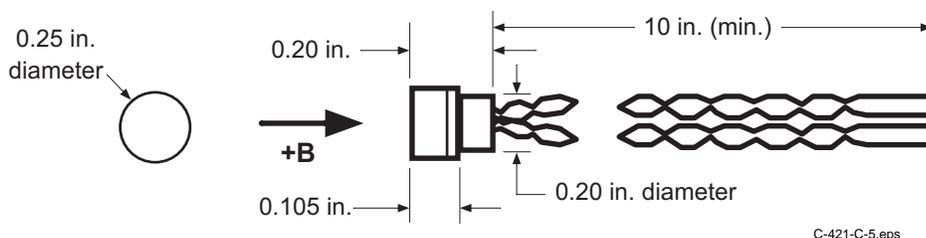
Figure C-5. Axial Hall Generator HGA-3010, HGA-3030, and HGCA-3020 Dimensions

0.63 in.

10 in. (min.) (Lead Length)

0.180 in.

0.240 in. (max.)

+B

0.043 in. (max.)

Protective Ceramic Case

Center of Active Area

C-421-C-6.eps
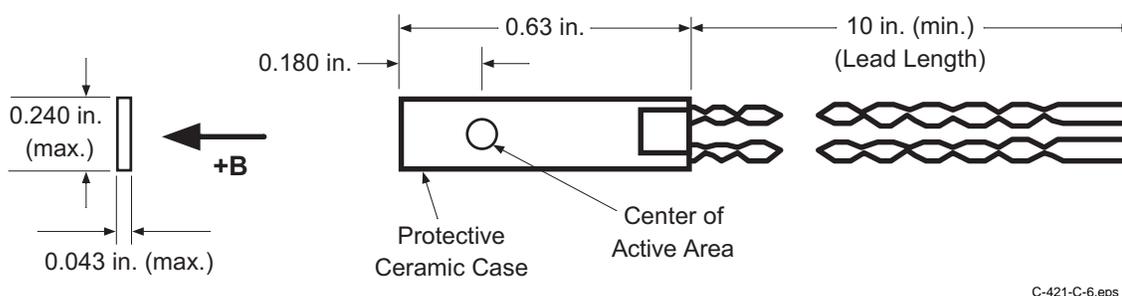
Figure C-6. Transverse Hall Generator HGT-3010, HGT-3030, and HGCT-3020 Dimensions

Table C-1. Cryogenic Hall Generator Specifications

Cryogenic	HGCA-3020	HGCT-3020
Description	Cryogenic axial; phenolic package	Cryogenic transverse; ceramic package
Active area (approximate)	0.030 inch diameter circle	0.040 inch diameter circle
Input resistance (approximate)	1 ohm	1 ohm
Output resistance (approximate)	1 ohm	1 ohm
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	0.55 to 1.05 mV/kG
Maximum linearity error (sensitivity vs. field)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)	±1.0% RDG (-30 to +30 kG) ±2.0% RDG (-150 to +150 kG)
Zero field offset voltage (I_C = nominal control current)	±200 µV (max.)	±200 µV (max.)
Operating temperature range	4.2 K to 375 K	4.2 K to 375 K
Mean temperature coefficient of magnetic sensitivity	±0.01%/K (approx.)	±0.01%/K (approx.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/K (max.)	±0.4 µV/K (max.)
Mean temperature coefficient of resistance	±0.6%/K (max.)	±0.6%/K (max.)
Leads	34 AWG copper w/Teflon insulation	34 AWG copper w/Teflon insulation
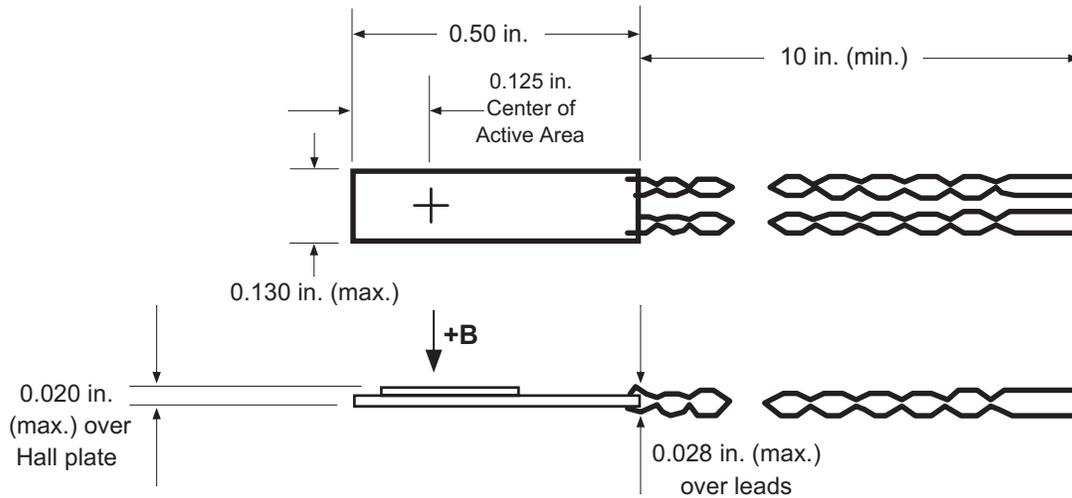
C-421-C-7.eps

Figure C-7. Transverse Hall Generator HGT-1010 Dimensions

Table C-2. Axial Hall Generator Specifications

Axial	HGA-3010	HGA-3030
Description	Instrumentation quality axial; low temperature coefficient; phenolic package	Instrumentation quality axial; phenolic package
Active area (approximate)	0.030 inch diameter circle	0.030 inch diameter circle
Input resistance (approximate)	1 ohm	2 ohms
Output resistance (approximate)	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±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)	±50 µV (max.)	±75 µV (max.)
Operating temperature range	−40 to +100 °C	−40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	±0.005%/°C (max.)	−0.04%/°C (max.)
Mean temperature coefficient of offset (I_C = nominal control current)	±0.4 µV/°C (max.)	±0.3 µV/°C (max.)
Mean temperature coefficient of resistance	±0.15%/°C (approx.)	+0.18%/°C (approx.)
Leads	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

Table C-3. Transverse Hall Generator Specifications

Transverse	HGT-1010	HGT-3010	HGT-3030
Description	General purpose transverse; 0.020 inch thick	Instrumentation quality transverse; low temperature coefficient; ceramic package	Instrumentation quality transverse ceramic package
Active area (approximate)	0.040 inch diameter circle	0.040 inch diameter circle	0.040 inch diameter circle
Input resistance (approx.)	2 ohms	1 ohm	2 ohms
Output resistance (approx.)	2 ohms	1 ohm	2 ohms
Nominal control current (I_{CN})	100 mA	100 mA	100 mA
Maximum continuous current (non-heat sinked)	300 mA	300 mA	300 mA
Magnetic sensitivity (I_C = nominal control current)	7.5 to 12.5 mV/kG	0.55 to 1.05 mV/kG	6.0 to 10.0 mV/kG
Maximum linearity error (sensitivity versus field)	±1.0% 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.	±50 µV max.	±75 µV max.
Operating temperature range	−40 to +100 °C	−40 to +100 °C	−40 to +100 °C
Mean temperature coefficient of magnetic sensitivity	−0.08%/°C max.	±0.005%/°C max.	−0.04%/°C max.
Mean temperature coefficient of offset (I_C = nominal control current)	±1 µV/°C max.)	±0.4 µV/°C max.	±0.3 µV/°C
Mean temperature coefficient of resistance	±0.18%/°C approx.	±0.15%/°C approx.	+0.18%/°C approx.
Leads	34 AWG copper with poly-nylon insulation.	34 AWG copper with poly-nylon insulation	34 AWG copper with poly-nylon insulation

C6.0   HALLCAL.EXE PROGRAM

The HALLCAL.EXE program was developed by Lake Shore Cryotronics, Inc. to allow the interfacing of customer attached Hall generators to the Model 450 Gaussmeter. (Please refer to the Software License Agreement behind the title page of this manual.) This program is provided with the purchase of a Model MCBL-6 or -20 Cable Assembly. Because of the many intricacies involved with proper calibration, the Customer must accept responsibility for the measurement accuracy.

Requirements:
- Lake Shore Model 450 Gaussmeter (connected via RS-232 to the computer in the COM1 port).
- Lake Shore Model MCBL-6 or -20 Cable Assembly.
- IBM or compatible CPU.
- Hall generator meeting the sensitivity ranges given below.
- Calibration or sensitivity constant and serial number of the Hall generator.

Operation:
1. Set the Lake Shore Model 450 Gaussmeter to 300 Baud. Refer Paragraph 3.11 of this User's Manual on how to set the Gaussmeter to communicate at 300 Baud.

2. Insert the 3.5-inch disk and type in the default drive (**A:** or **B:**).

3. Type in **HALLCAL**. This will execute the HALLCAL.EXE program.

4. The program will prompt for the Probe serial number. Any combination of 6 letters or number can be entered. Press **Enter** when this is accomplished.

5. The program will prompt for the probe type (0 or 1).
   Enter "**0**" for Hall generators with sensitivities between 5.5 and 10.5 mV/kG (@ 100 mA current).
   Enter "**1**" for Hall generators with sensitivities between 0.55 and 1.05 mV/kG (@ 100 mA current).

6. The program will prompt for the "Calibration Constant." Enter the magnetic sensitivity in mV/kG at a control current of 100 mA. Remember to account for the 420 Ω input impedance of the Gaussmeter when calculating the proper load resistor to install.

7. The program will display all the values entered along with designated F keys:

F1	Probe Serial Number	ABC123
F2	Probe Type	0
F3	Calibration Constant	X.XXX
F10	Program Probe	
Esc	Exit Program	

8. At this time, if any of the parameters need to be changed, just press the appropriate F key and type in the new value. When everything appears correct, press F10 to program the probe.

9. It takes about 20 seconds to program the probe. After the probe is programmed, press the **Esc** key to exit the program.