OPERATING INSTRUCTION MANUAL

FOR THE

MODEL LM-500
CRYOGENIC LIQUID
LEVEL MONITOR

CRYOMAGNETICS, INC.
INNOVATIVE SUPERCONDUCTING MAGNET SOLUTIONS

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WARNING!
DO NOT ATTEMPT TO OPERATE THIS EQUIPMENT BEFORE YOU HAVE THOROUGHLY READ THIS INSTRUCTION MANUAL.

CE

MANUFACTURER'S DECLARATION OF CONFORMITY

According to ISO / IEC Guide 22 and EN45014

Manufacturer's Name: Cryomagnetics, Inc.

Manufacturer's Address: 1006 Alvin Weinberg Drive
Oak Ridge, TN 37830

Declares. the product

Product Name: Liquid Cryogen Level Monitor
Model Number: LM-500
Product Options: All Options

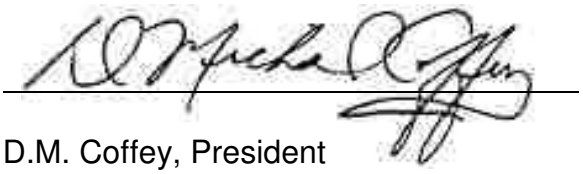
Conforms to the following Product Specifications:

Safety: EN61010-1 (95)
EN61326-1 (97)

EMC: EN61326-1 (97) Electrical Equipment for Measurement, Control and Lab use – EMC Requirements
EN61000-4-2 (95) Electrostatic Discharge Immunity Test
EN61000-4-3 (96) Radiated Electromagnetic Fields
EN61000-4-4 (95) Electrical Fast Transient/Burst
EN61000-4-5 (95) Amendment A-Surge Immunity Test
EN61000-4-6 (96) Amendment A-Immunity to Conducted Disturbances
EN61000-4-11 (94) Voltage Dips, Short Interruptions and Voltage Variations

Application of Council Directives:

The product complies with the requirements of the Low Voltage Directive 73/23/EEC as amended by 93/68/EEC and the EMC Directive 89/336/EEC as amended by 93/68/EEC.



D.M. Coffey, President
Cryomagnetics, Inc
Oak Ridge Tennessee May 27th, 2004

TABLE OF CONTENTS

1.0 Introduction

The LM-500 Liquid Cryogen Level Monitor is the most advanced instrument to monitor cryogenic liquids available today. Its versatile architecture allows configuration to virtually any cryogenic fluid. This includes liquid helium, liquid nitrogen, LNG, and many other cryogenic fluids using an appropriate sensing element.

With the 2-Sensor option, the instrument has two independent input channels that are factory configurable to either the same or different liquid types. The unit is compatible with liquid helium level sensors based upon industry standard niobium-titanium superconducting elements. Virtually all liquid helium sensor manufacturers use this technology, so the LM-500 can be used with most existing equipment. Flexible calibration procedures allow the use of two, three, or four wire configured liquid helium sensors.

Capacitive sensors are used to monitor liquid nitrogen, LNG, and other cryogenic fluids. As with liquid helium sensors, the LM-500 can monitor many manufacturer's capacitive sensors due to advanced circuit design.

The LM-500 has user-adjustable high and low setpoints that may be used to control automated refill cycles. With the 2-Sensor option, independent setpoints can be adjusted for each channel. This allows simultaneous control of two liquid cryogen systems with a single LM-500. Also included is a fully adjustable audible alarm. Most commonly set below the low setpoint, the audible alarm can be used to alert the user to a problem with the refill cycle. A separate audible alarm setpoint is included with the 2-Sensor option.

Unique features of the LM-500 include a sensor deicing cycle and filament burnout protection for liquid helium systems. This insures reliable, accurate level readings even under the most adverse cryogenic conditions. Computer control via RS-232 is available in the standard configuration. Remote control via the latest IEEE-488.2 command set is available as an option. LabVIEW® virtual instrument drivers are available to allow computer control via a familiar, intuitive interface. A wide variety of other options are also available that allow the instrument to be upgraded and tailored to your particular requirements.

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2.0 Factory Calibrations, Installed Options and Certification

LM-500 Serial Number: _____

Input Voltage: 100 VAC: _____ 115 VAC: _____ 230 VAC: _____

Input Channel 1:

Type: LHe _____ LN2 _____ Other: _____

Calibration: Sensor Manufacturer / Serial No: _____

Sensor Length: _____

Characteristic Resistance/Voltage: _____

Lead Resistance: _____

Control Output: TTL: _____ Open Collector: _____ Other: _____

Input Channel 2 (Option 3): Not Installed: _____

Type: LHe _____ LN2 _____ Other: _____

Calibration: Sensor Manufacturer / Serial No: _____

Sensor Length: _____

Characteristic Resistance/Voltage: _____

Lead Resistance: _____

Control Output: TTL: _____ Open Collector: _____ Other: _____

Analog Output (Option 1): Not Installed: _____

Type: 0-1 Volt: _____ 4-20mA: _____

Computer Interface Installed: RS-232: __X__ IEEE-488.2 (Option 2): _

Notes: _____

_____

_____

_____

_____

Certified: _____

Date: _____

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3.0 Setup

The LM-500 is delivered to you fully tested and ready to operate. This includes sensor calibration if Cryomagnetics supplied the sensor(s) with the instrument. Calibration will also be complete if the active sensing length of an existing sensor(s) was specified at the time of order.

3.1 Line Voltage and Fuse

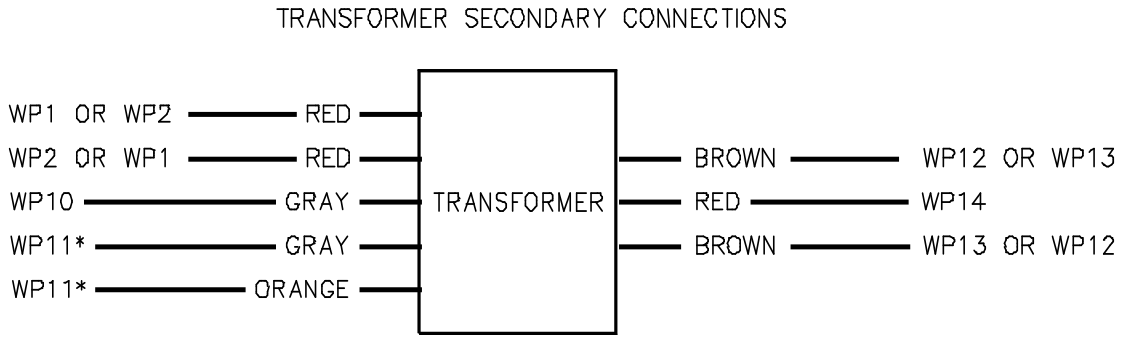
Unless otherwise specified, the LM-500 is configured for operation using 115 VAC +/- 10%, 50/60 Hz input power. The serial number tag on the rear panel of the unit indicates the factory voltage setting.

The line voltage setting can be changed to 100 or 230 VAC if desired. Always disconnect the power cord from the unit prior to opening the case. To open the LM-500, remove the two screws from the rear panel of the unit. Also remove the screws on the RS-232 and Sensor(s)/IO connectors. The rear panel can then be pulled back and the cover of the LM-500 can be slid off. Figure 3.0 indicates the changes in circuit board jumpers inside the unit used to make a change in line voltage.

Figure 3.0 - Line Voltage Jumper Settings

Transformer Primary Jumpers

Line Voltage	JP1	JP2	JP3	**JP4**
100V, 115V	Short	Open	Short	Open
200V, 230V	Open	Short	Open	Short



* For almost all configurations of the LM-500, the gray connection to WP11 is used and the orange lead is not connected. The orange lead is connected to WP11 instead of the gray ONLY if the unit is to be used with 100V/50Hz or 200V/50Hz power AND with liquid helium level sensors having an active sensing length of more than 80 cm.

The fuse for the LM-500 is mounted on the main circuit board inside the unit. Should the fuse need to be changed, open the LM-500 as described above. Locate the fuse - it is a cylindrical device labeled F1 and can be found on the right side of the unit near the main transformer. Replace the fuse only with another fuse of the same type. Use only Wickmann part number 19374-035-K (250V, 0.25A, time lag). Never replace the fuse with a wire.

3.2 Connecting Sensors

Sensors connect to the LM-500 through the rear panel DB-15F connector labeled “Sensor(s)/IO”. This connector provides service not only to the sensors, but also to the automatic refill signals generated by the LM-500 and the 4-20mA analog output signal. Figure 3.1 indicates the pin designations for the Sensor(s)/IO connector.

********** **IMPORTANT** **********

1) Connections should NEVER be made directly to the connector on the rear panel. Always solder to a mating connector that is not attached to the unit. Connections should be double-checked for accuracy prior to attaching to the LM-500 and powering the unit ON since liquid helium level sensors are driven by high voltages (up to 100 volts DC). These high voltages could damage liquid nitrogen sensors or other sensors (such as temperature sensors or hall probes) should these be accidentally connected.

2) NEVER connect/disconnect the sensors with the LM-500 powered ON.

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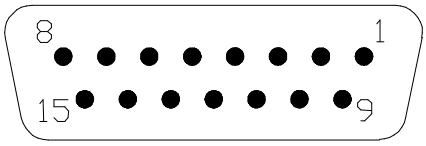
Figure 3.1 - Sensor Connector Wiring - DB-15F



View Facing Rear Panel Connector

Pin #	Function: LHe / LN2	Pin #	Function: LHe / LN2
1	Sensor 1: I+ / VCC (+10.6V)	9	Sensor 2 (Optional): I+ / VCC (+10.6V)
2	Sensor 1: I- / GND	10	Sensor 2 (Optional): I- / GND
3	Sensor 1: V+ / Vsensor	11	Sensor 2 (Optional): V+ / Vsensor
4	Sensor 1: V- / GND	12	Sensor 2 (Optional): V- / GND
5	Analog Output (Optional) 4-20 mA I-	13	Sensor 2 (Optional): Control Output
6	Analog Output (Optional) 4-20 mA I+	14	Sensor 1: Control Output
7	Analog Output (Optional) Sensor Select	15	GND
8	N/C		

Cryomagnetics, Inc. liquid helium level sensors have four (4) lead wires and use either #30 AWG Teflon insulated lead wires or color coded phosphor-bronze lead wires (either option may be specified when the sensor is ordered). The standard color codes for lead wires is shown in Figure 3.2.

Figure 3.2 - LHe Level Sensor Color Codes

Lead Function	Teflon Color	Phosphor-Bronze Color
I+	Red	Clear
I–	Black	Black
V+	Blue	Yellow
V–	Yellow	Green

Some liquid helium level sensors made by Cryomagnetics may have only 2 or 3 lead wires. If the sensor has 3 lead wires, the I- and V- leads are typically combined into a single black lead. If the sensor has 2 lead wires, the I- and V- leads are combined into a single black lead and the V+ lead is not used. The V+ connection at the input to the LM-500 should be connected to the I+ terminal in this case.

Cabling between the liquid helium level sensor and the LM-500 should be of appropriate size such that high voltage drop across the I+ and I- leads does not occur. It is recommended that cables up to 5 meters in length be #18 AWG wire minimum. Cables from 5 to 15 meters in length should be #16 AWG minimum, and cables from 15 to 30 meters should be #14 AWG minimum. Unshielded cable may be used where no significant use of SCR-controlled equipment or intense electrostatic field sources are present. Otherwise, it is recommended that shielded cable be used.

3.3 LHe Sensor Calibration

Calibration of liquid helium level sensors is performed through the front panel keypad of the LM-500. Calibration can not be performed through the LM-500 computer interfaces.

To calibrate a sensor, power ON the LM-500 (the sensor does not need to be connected). If the 2-sensor option is installed, use the UP or DOWN arrow keys to highlight the sensor channel to be calibrated and press the MENU key. Again use the UP or DOWN arrow keys to select CAL from the opening menu. When CAL is highlighted, the LM-500 will show the present calibration settings for the sensor on the second line. In particular, the unit displays the sensor's active sensing length, characteristic resistance, and the lead resistance. Press ENTER to access the calibration values.

The LM-500 indicates "Ch# Sensor Length:" on the first line of the display, and the present setting for the sensor length on the second line. The sensor length should be set to the actual length of the sensing filament in the sensor. This is usually the overall length of the sensor less any dead space on the ends of the sensor. Cryomagnetics' sensors typically have 1 cm of dead space on each end. If the unit is to be used with a Cryomagnetics' sensor that can not be accessed to measure the active sensing length, the value can be determined by measuring the resistance of the sensing filament. Cryomagnetics' sensors typically have a characteristic resistance at room temperature of about 5.46 ohms/cm (or 4.55 ohms/cm at 20 Kelvin). The sensing length may be adjusted by using the UP and DOWN arrow keys. Press ENTER to accept and save the displayed value, or MENU to exit without saving the value.

Next, the LM-500 will indicate "Sensor # Resistance" on the first line of the display, and the present setting of the characteristic resistance of the superconductive filament in ohms/unit length on the second line. Use the UP or DOWN arrow keys to adjust the setting of the characteristic resistance for the sensor (use the characteristic resistance at 20K, not at room temperature). Press ENTER to accept and save the value, or MENU to exit without saving.

Finally, the LM-500 will indicate "Ch# Lead Resistance" on the first line of the display, and the

present setting for the lead wire resistance on the second line. The lead resistance should be set to zero if a 4-wire sensor is being used. If a 2 or 3 wire sensor is being used, the resistance of the leads can be entered and will be removed from the sensed value. For a 2-wire sensor the lead resistance will be the measured resistance from the I+/V+ lead to the I-/V- lead, less the resistance of the active sensing filament (4.55 ohms/cm * active sensing length in cm for Cryomagnetics' sensors). For a 3-wire sensor the lead resistance will usually be the measured value of resistance between the V+ lead and the I- lead, less the resistance of the active sensing filament, divided by two (since you only need to subtract out the lead resistance of the I- lead, not both the I- and V+ leads). To change the lead resistance setting, use the UP and DOWN arrow keys to adjust the value. Press ENTER to accept and save the value, or MENU to exit without saving.

3.4 LN_2 Sensor Calibration

Liquid nitrogen sensors are calibrated through the LM-500 menus in a manner that is similar to liquid helium level sensors. However, since LN_2 sensors are capacitive and return a small voltage signal to the LM-500, characteristic resistances are not used. Instead, voltages that are measured at the empty and full points are entered directly. Calibration of liquid nitrogen level sensors is performed through the front panel keypad of the LM-500. Calibration can not be performed through the LM-500 computer interfaces.

To calibrate a sensor, power ON the LM-500 (the sensor does not need to be connected). If the 2-sensor option is installed, use the UP or DOWN arrow keys to highlight the sensor channel to be calibrated and press the MENU key. Again use the UP or DOWN arrow keys to select CAL from the opening menu. When CAL is highlighted, the LM-500 will show the sensor's active sensing length on the second line. Press ENTER to access the calibration values.

The LM-500 indicates "LN2 Calibration" on the first line of the display, and calibration options "Length Zero Full" on the second line. Access the Length parameter by pressing the ENTER key with Length selected. The LM-500 indicates "Ch# Sensor Length:" on the first line of the display, and the present setting for the sensor length on the second line. The sensor length should be set to the actual length of the sensing portion of the sensor. This is usually the overall length of the sensor less any dead space on the ends of the sensor. Cryomagnetics' sensors typically have 1.5 cm of dead space on each end. The sensing length may be adjusted by using the UP and DOWN arrow keys. Press ENTER to accept and save the displayed value, or MENU to exit without saving the value. The options of "Length Zero Full" will be again be presented.

If the instrument does not indicate 0.0 when the LN2 is empty and the sensor is at LN2 temperature,

the "Zero" setting needs to be corrected. This may be done selecting "Zero" using the UP, DOWN, and Enter keys. The LM-500 will indicate ”Zero Point Cal” on the first line of the display, and "Measure Adjust" options on the second line. If the sensor is connected and the LN2 is near empty, select Measure to automatically measure and reset the zero point. If the zero calibration point was inadvertently changed, the original value may be entered manually by selecting the "Adjust" option. If the sensor and instrument were factory calibrated, the value entered at factory may be found on page 2 of the manual. Use the UP or DOWN arrow keys to adjust the setting to the correct voltage (use the value obtained when the sensor is cold and in an atmosphere of nitrogen gas – not at room temperature and in air). Press ENTER to accept and save the value, or MENU to exit without saving.

If the instrument does not indicate the full sensor length when the LN2 is full, the "Full" setting needs to be corrected. This may be done selecting "Full" using the UP, DOWN, and Enter keys. The LM-500 will indicate ”Full Scale Cal” on the first line of the display, and "Measure Adjust" options on the second line. If the sensor is connected and the LN2 is full, select Measure to automatically measure and reset the full point. If the full calibration point was inadvertently changed, the original value may be entered manually by selecting the "Adjust" option. If the sensor and instrument were factory calibrated, the value entered at factory may be found on page 2 of the manual. Use the UP or DOWN arrow keys to adjust the setting to the correct value. Press ENTER to accept and save the value, or MENU to exit without saving.

The audible alarm and auto refill limits should be reset to the desired levels after any calibration changes.

3.5 Factory Calibration

The LM-500 Factory Calibration is used to establish sensor excitation levels, hardware calibration, and in the case of an LN2 channel, automate sensor calibration. If these procedures are not carefully performed the instrument may not function properly.

********** **WARNING** **********

Dangerous voltages and currents are used in this procedure.

Proper care must be exercised to ensure safety of personnel and equipment.

Load resistors and/or Sensors must be attached to perform the calibration in most cases.

Power MUST be removed while making ALL connections.

****

The factory calibration menu is invoked by holding the MENU and ENTER keys while power is applied to the unit. The display will show

```
Instrument Cal
>Abort< Ch1 Ch2
```

or,

```
Instrument Cal
>Abort< Ch1 Ch2 Anlg
```

if the analog output option is installed. If the analog output is installed, it *must* be recalibrated after the Ch1 factory calibration is performed. Use the UP and DOWN keys to select the calibration to be performed, and press ENTER to begin the calibration.

3.5.1 Factory Calibration of a Liquid Helium Channel

Factory calibration of a liquid helium channel requires a known calibration resistor to be connected. Since the calibration is performed at a constant current of 70 mA, the wattage of the resistor must be considered. 25 ohms at 1/4 watt or 100 ohms at 1 watt are acceptable values. Connect I+/V+ to one terminal of the resistor, and I-/V- to the other terminal. Once all sensor connections have been made, enter the factory calibration menu as described in section 3.5 above.

Select the appropriate sensor channel using the up or down arrow keys and press ENTER. The value of the LM-500's internal current sense resistor will be displayed. The value should not need to be changed. Press ENTER to accept the value of the current sense resistor.

The value of the calibration resistor will next be displayed. Use the up or down arrow keys to make this display the known resistance of the calibration resistor attached above and press Enter to accept the value.

The LM-500 now will display:

```
Attach Cal Resistor
<Enter> when ready
```

Ignore this message (since the cal resistor should already be attached), and press ENTER to begin calibration. The subsequent prompts allow the sensor length, sensor sensitivity, and lead resistance

to be set. The procedure for setting these values is provided in Section 3.3. Note that these values may also be also set in the standard calibration menu.

3.5.2 Factory Calibration of a Liquid Nitrogen Channel

Factory calibration of a liquid nitrogen channel requires the sensor to be connected and operated in known levels of liquid nitrogen. When the channel is selected from the factory calibration menu and ENTER is pressed the value of the LM-500's internal current sense resistor will be displayed. The value should not need to be changed. Press ENTER to accept the value of the current sense resistor.

The display will show:

```
Attach Sensor (80°K)
 <Enter> when ready
```

At this point the LN2 sensor should be immersed in LN2 to ensure that it is cold. Press ENTER to initiate the calibration. The LM-500 applies power to the oscillator (about 10.6 volts) and a timer gives the system approximately one minute to thermally and electrically stabilize. No actual readings are taken during this period. When the stabilizing delay is complete, the LM-500 display will indicate:

```
Position Sensor
<Enter> when ready
```

The LN2 sensor should be raised out of the liquid in preparation for setting the zero level calibration point. If possible, leave the 1 cm dead space at the bottom of the sensor in the LN2 to ensure that the sensor remains cold. The sensor must be suspended by the cable since any contact with the sensor itself will affect the zero calibration. Press ENTER and continue to maintain the 1 cm level for a few seconds (until the reading is complete).

The display will now show:

```
Ch 2 Sensor Output
    4.373 Volts
```

The voltage may be adjusted to match the sensor output by using the UP/DOWN arrows and accepting the final value by pressing ENTER.

The active sensor length will be displayed, and may be adjusted if needed by using the UP/DOWN arrows and pressing ENTER when done:

```
Ch 2 Sensor Length:
▲▼     50.0 cm
```

Now the sensor should be lowered into a bath of LN2. Using the up and down arrow keys, enter the overall active length of the sensor and press Enter. The LM-500 will indicate:

```
  Ch 2 LN2 Level:
▲▼     50.0 cm
```

Using the up and down arrow keys, set this value to the level of LN2 currently on the sensor. This feature allows the sensor to be calibrated in a known level of LN2 that is less than the overall sensor length. When the correct level is displayed, press Enter. The display will show:

```
Attach Sensor in LN2
 <Enter> when ready
```

Ignore this message (since the sensor is already attached). Press ENTER. The LM-500 will take a final reading, which completes the calibration.

The LN2 level used to calibrate the sensor should be measured carefully to avoid errors. Preferably, the level should be at or near the top of the sensor. Calibrating with low LN2 can cause small errors in the calibration to be amplified when the sensor is operated near full scale.

3.5.3 Factory Calibration of the Analog Output Option

The LM-500's Analog Output must be recalibrated whenever the Ch 1 factory calibration is changed. In preparation for calibrating the analog output, the sensor(s) must be connected to the LM-500. If the Analog Output is configured to for 0-1 Volt Output, no load is required at the analog output. If the Analog Output is configured to be a 4-20mA Output, either a load resistor of less than 600 ohms or the actual current loop itself must be attached to pins 5 and 6 of the rear panel DB15 connector (current must be able to flow in order for the calibration to be made). The value of the resistor is not important.

Select ANLG on the Factory Calibration Menu and press Enter. The Analog Output calibration is automatic and will be completed in about 3 seconds.

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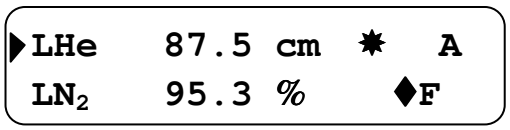
4.0 Operation and Menus

Setup of the LM-500 can be performed either through the front panel keypad and simple menu instructions or through remote computer interface (RS-232 or IEEE-488.2). Calibration is only supported through the front panel keypad. In the following sections there are detailed descriptions of how to recalibrate for different sensor lengths, set the audible alarm, and configure the controller functions.

Before connecting any level sensors or other cabling to the LM-500, connect the power cord provided with your LM-500 to an appropriate power source. Power the instrument ON and familiarize yourself with the display. If your LM-500 is configured for dual sensor inputs, the first line of the display will indicate Sensor #1 and the second line will indicate Sensor #2. If your LM-500 is configured for a single sensor input, the display will only indicate one level.



Symbols to the right of the liquid level provide an indication of the status of the sensor channel:

- ✸ Indicates a sample is in progress for a liquid helium level sensor.
- ♦ Indicates the limits are exceeded for the channel.
- **F** Indicates a fill cycle is in progress for the channel (Flashing indicates the fill cycle timed out rather than completed with the high level being achieved.)
- **A** Indicates the level is below the alarm level.

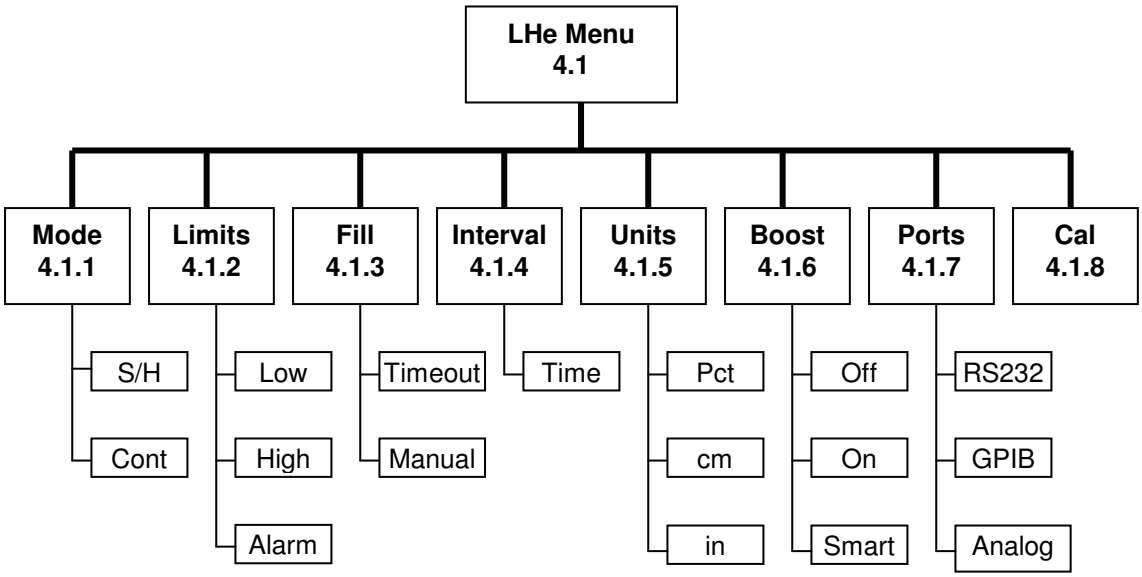
A liquid helium level channel may indicate the words "Open" or "BO Protect" instead of a level. Either indication will immediately abort further attempts to sense the liquid helium level until the MENU is entered and the mode is changed from DISABLED. "Open" will appear if no current flows when a reading is being taken, indicating that the sensor is not connected, or a connection is broken in the current path. "BO Protect" will appear if the LHe sensor resistance is measured at more than 130 percent of the sensor in gas, which prevents sensor burnout, should the sensor be energized in a vacuum.

For dual input units, an arrow is displayed to the left of the Sensor #1 or Sensor #2 display line. Using the UP or DOWN arrow keys on the front panel, this arrow can be toggled between the two display lines (sensors). To change the calibration, set alarm points, set computer communication parameters, set up the level units, or any other user-settable options, you must first set the arrow so it points to the appropriate sensor and the press the MENU key. Depending upon whether the

selected sensor is a liquid helium level sensor or a liquid nitrogen level sensor, different menu options will appear.

4.1 Liquid Helium Level Monitor Menu Options

There are several user-adjustable options available for liquid helium level monitoring. The following diagram indicates options and the menu headings under which they are found.



4.1.1 Mode

Under the Mode menu item, the user can select either Sample/Hold or Continuous operational mode. This item appears first in the menu list since it may be changed frequently in a system that is left in Sample/Hold mode normally, but is switched to Continuous mode during liquid helium refills. Pressing ENTER while “Mode” is selected toggles the unit between Sample/Hold and Continuous modes. The display will indicate the selected mode.

4.1.2 Limits

The LM-500 has an internal audible alarm that can be set to activate when the liquid helium falls below a user-settable threshold. It also has an external “auto-refill” signal that can be used to automatically maintain liquid helium level between high and low limits (using the appropriate transfer hardware). The set points for the high and low limits and the audible alarm are set in the “Limits” menu. Both the alarm and refill functions give front panel display indications when they are activated - “A” appears when an alarm indication is present, and “F” appears when the unit’s controller output signal is active. The audible alarm can be silenced by pressing any front panel key on the LM-500; however, the visual indication of the alarm condition, “A” on the display, is

maintained until the liquid level is read by the LM-500 and is found to be above the alarm level set point. The visual indication can also be removed manually if the user enters the menu system and then exits again. Separate indicators are displayed for each channel if the 2-Sensor option is installed.

For additional information on interfacing the LM-500 for automatic refill, please refer to section 5.5 and Appendix B.

4.1.3 Fill

The Fill menu item displays the fill timeout value, and allows a fill cycle to be started manually. With "Fill" selected, press ENTER to display the options Timeout and Auto. Select Timeout to change the fill timeout value, or set it to zero to disable fill timeout. Select Auto to toggle to the Start fill option. Pressing ENTER with Start displayed will start a fill cycle when the menu is exited regardless of level. The fill cycle will end when the level reaches the high limit, when the fill timeout expires, or when MENU is selected.

4.1.4 Interval

The Interval (Intvl) menu item allows the user to select the interval of time between readings of the liquid helium level sensor in Sample/Hold mode. With “Intvl” selected, press ENTER to bring up the interval setting display. Then use the UP or DOWN arrow keys to bring the sample interval to the desired time. Press ENTER again when the correct time is displayed, or MENU to escape without changing the interval.

4.1.5 Units

The Units menu item allows the user to set the display units of the LM-500 for this particular channel. Available options are percent (%), centimeters (cm), or inches (in). Note that sensor lengths under the Calibrate menu item must be entered in either centimeters or inches - depending upon the setting of the units. If percent is the unit of display for the LM-500, calibration data must be entered in centimeters.

4.1.6 Boost

The “Boost” menu item allows the user to set the sensor de-ice mode of the LM-500 on this particular channel according to the system’s requirements. Options under this item are:

OFF Current to the sensor is never boosted to a higher setting to clear contaminants on the sensing filament.

ON — Current to the sensor is briefly boosted to a higher setting at the beginning of each liquid level reading to clear contaminants on the sensing filament.

SMART — Current to the sensor is only boosted to a higher setting at the beginning of a liquid level reading to clear contaminants if the sensor has not been activated within the past five minutes of operation.

4.1.7 Ports

The Ports menu item allows the user to set the analog output mode of the LM-500 (if this option is installed), select the computer interface which is active (RS-232 or IEEE-488.2 - if installed), and to set up the parameters of the computer interface such as baud rate, address, etc. When the Ports menu item is highlighted, the current setting of the analog and computer interfaces are displayed on the second line. To change any of the Port options, press enter when “Ports” is highlighted. Then select the option that is to be changed:

RS-232 — Baud rate may be set to 9600, 4800, 2400, or 1200. Factory default is 9600.

IEEE-488.2 — Device address may be selected from 0 - 31. Factory default is 0.

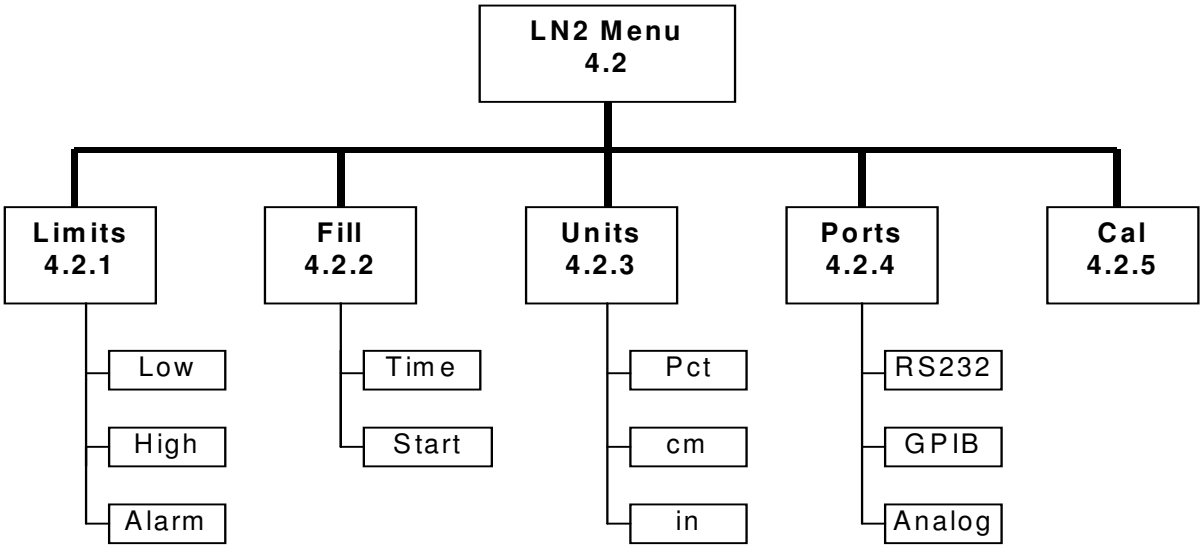
AO — The sensor input channel controlling the analog output port is selected. The analog output of the LM-500 may be configured to be proportional to the level reading on Channel 1, Channel 2, or Remote. The Remote setting allows the user to supply a digital signal to the LM-500 to select which channel is controlling the analog output. This allows the user to monitor both channels without computer commands.

4.1.8 Calibrate

Under the Calibrate (Cal) menu item, the user can set the parameters of the sensor being used on this channel. When “Cal” is highlighted, a summary of the present sensor settings is shown on the second line of the display. The units used by the LM-500 (cm or inches) for calibration is set with the Units menu item. Pressing Enter while “Cal” is highlighted allows the user to set sensor length, sensitivity, and lead resistance. Refer to section 3.3 for LHe sensor calibration procedures.

4.2 Liquid Nitrogen Level Monitor Menu Options:

There are several user-adjustable options available for liquid nitrogen level monitoring. The following diagram indicates options and the menu headings under which they are found.



4.2.1 Limits

In the Limits menu, the user can adjust the (A)larm set point for the sensor as well as the (L)ow and (H)igh set points. Typically, the alarm is used to generate an audible alarm and digital signal output should the liquid level fall below the alarm set point. The low and high set points can be used in a similar manner, or they can be used in conjunction with each other to drive an automatic refill system. See section 5.5 for information on interfacing the LM-500 with an automatic liquid nitrogen refill system.

4.2.2 Fill

The Fill menu item displays the fill timeout value, and allows a fill cycle to be started manually. With "Fill" selected, press ENTER to display the options Timeout and Auto. Select Timeout to change the fill timeout value, or set it to zero to disable fill timeout. Select Auto to toggle to the Start fill option. Pressing ENTER with Start displayed will start a fill cycle when the menu is exited regardless of level. The fill cycle will end when the level reaches the high limit, when the fill timeout expires, or when MENU is selected.

4.2.3 Units

The “Units” menu item allows the user to set the display units of this channel of the LM-500. Available options are percent (%), centimeters (cm), or inches (in). Note that sensor lengths under the “Cal” menu item must be entered in either centimeters or inches - depending upon the setting of the units.

4.2.4 Ports

The Ports menu item allows the user to set configure the I/O of the LM-500. When the Ports menu item is highlighted, the current setting of the analog and computer interfaces are displayed on the second line. See section 4.1.7 for further information about setting port options.

4.2.5 Calibrate

Under the Calibrate (Cal) menu item, the user can set the parameters of the sensor being used. When Cal is highlighted, a summary of the present sensor settings is shown on the second line of the display. Pressing Enter while Cal is highlighted allows the user to set the sensor length, characteristic voltage of the sensor, and zero offset. Refer to section 3.4 for calibration procedures.

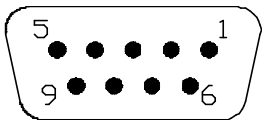
5.0 Interfacing

The LM-500 comes standard with an RS-232 computer interface. All front panel functions, except calibration functions, may be accessed using the corresponding command string over the RS-232 port. In addition, an IEEE-488.2 port is available as an option. This port conforms to the IEEE-488.2-1992 standard.

5.1 RS-232 Computer Interface

An RS-232 computer interface port is provided as standard equipment on all LM-500s. The port accessed through the DB-9F connector on the rear panel of the instrument. The interface is factory configured for 9600 baud, 8 data bits, 1 stop bit, and no parity. Figure 5.0 indicates the proper pin designations for the port. Figure 5.1 details available RS-232 port commands.

Figure 5.0 - RS-232 Port Connector Wiring



View Facing Rear Panel Connector

Pin #	LM-500 Pin Function
1, 4, 6, 7, 8, 9	N/C
2	RS-232 Transmit
3	RS-232 Receive
5	Ground

Commands available to the LM-500 operator over the RS-232 computer interface are given in Appendix A. The commands available through RS-232 are identical to those available through IEEE-488.2; however, some commands may be IEEE-488.2 specific and may not provide responses consistent with the RS-232 interface.

Command strings are normally limited to 30 characters when the RS-232 interface is used. A <RETURN> will be generated internally when lines longer than the maximum are encountered, and any valid commands in the received line will be processed. An output buffer of 32 characters is

used although longer responses can be successfully generated. All remote commands are case insensitive, allowing upper or lower case to be used without affecting operation of the commands.

When the RS-232 interface is selected all commands sent to the instrument will be echoed including the terminating ASCII <RETURN> character, followed by a <NEWLINE> character when command processing is complete.

5.2 IEEE-488.2 Computer Interface

The LM-500 may have an optional IEEE-488.2 computer interface (Option 2). The LM-500 implements SH1, AH1, T6, L4, SR1, RL0, PP0, DC1, DT0, C0, and E1 options. The commands are compliant with the IEEE-488.2 standard.

Reference: IEEE Standard Codes, Formats, Protocols, and Common Commands (IEEE Std 488.2-1992) provides a detailed description of the IEEE common commands (identifiable in the command list by the asterisk as the first character.)

The command list and structure is identical to the RS-232 command set. Reference Appendix A for a detailed description.

5.3 Analog Output

An analog output from the LM-500 is available as an option (Option 1). This output can be specified at the time of purchase to be either 4-20mA or 0-1V. If the 4-20 mA option is installed, the signal is found on the LM-500 rear panel DB-15F connector, pins 5 and 6 (see Figure 3.1). If the 0-1V analog output option is installed, the signal is found on the LM-500 rear panel BNC connector. In either case, the analog output signal is linear and proportional to the sensor reading. If the 2-Sensor option is installed, the sensor having control of the analog output may be selected through the LM-500 rear panel DB-15F, pin 7 (see Figure 3.1). This is a TTL compatible (0-5V nominal) input. A low level on this pin selects Sensor 1, and a high level or an open connection selects Sensor 2.

5.4 Audible Alarm

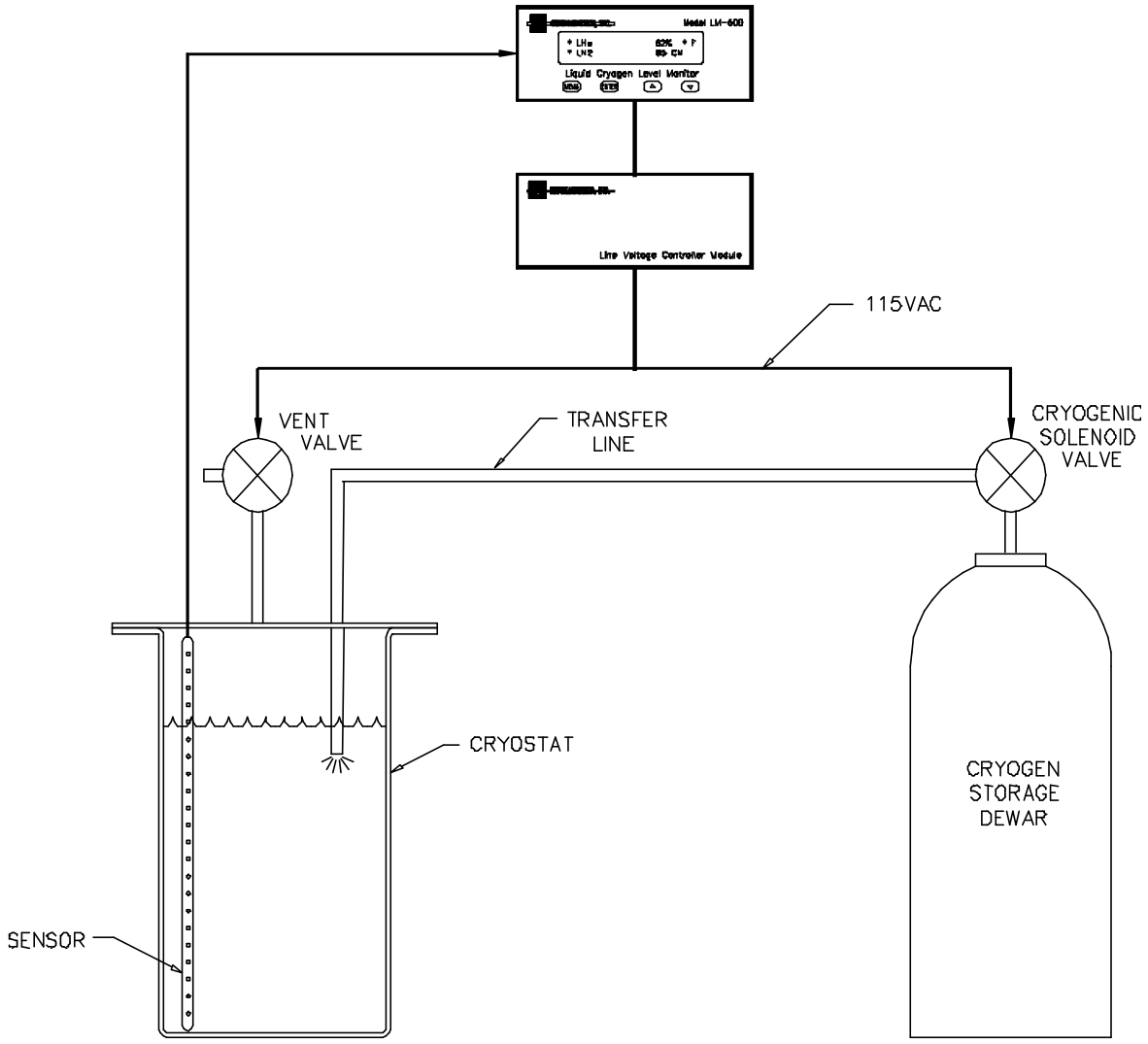
A user-adjustable audible alarm is standard on the LM-500. The alarm may be set through the front panel menu system (see sections 4.1.2 and 4.2.1). The alarm gives the user an audible indication if the measured cryogen level fall below the alarm set point. If the 2-Sensor option is installed, the audible alarm will activate if either sensor input falls below its respective set point. Once the alarm is activated, it may be silenced by any front panel keystroke. It will only be reactivated after a normal reading (i.e., one above the alarm setpoint) is detected by the LM-500,

followed by another reading in which an alarm condition again exists. The audible alarm may be disabled by setting it to 0.0.

5.5 Automatic Refill

The LM-500 in its standard configuration is capable of controlling an automatic liquid cryogen refill system. Since many different types of valves, transfer lines and cryogen handling systems are possible, additional interfaces are necessary to implement the refill system. In particular, Figure 5.2 shows a typical automatic liquid cryogen refill system. Note that the system consists not only of the LM-500, but also a Line Voltage Controller Module (Option 5), a cryogen transfer line, a solenoid valve, the level sensor, and any additional venting/plumbing needed to handle off-gas.

Figure 5.2
Typical Automatic Cryogen Refill System



In an automatic refill system, the LM-500 monitors the cryogen liquid level in the cryostat. If that level is determined to fall below the “low limit” setpoint, the LM-500 activates the automatic refill control output which opens a vent valve on the cryostat and a solenoid valve on the storage dewar beginning a cryogen transfer. The LM-500 output remains activated (holding the valves open) until it detects that the cryogen level in the cryostat has risen above the “high limit” setpoint. Once the liquid level reaches the high limit, the control output is deactivated closing both valves. Thus the LM-500 maintains the liquid level between minimum and maximum levels. An auxiliary timeout may be set to abort cryogen transfers that run longer than the operator feels is appropriate. The feature helps minimize overflow of a system having an error in its calibration or prevention of transferring warm gas for lengthy periods of time in the event that the source dewar empties before the high limit is reached. If your LM-500 has the 2-Sensor option is installed (Option 3), two totally independent cryogenic systems can be under automatic refill control by a single LM-500.

The control output(s) of the LM-500 may be set to be either “open collector” or “0-5V”. Refer to Section 2.0 of this manual for the factory settings of your particular LM-500. Figure 3.1 indicates the output pins designated to carry the Control Output signals, and Figure 5.3 indicates the jumper settings to change the configuration.

Figure 5.3
Control Output Format Setting

Sensor / Jumper	TTL Compatible	Open Collector
Sensor 1 / JP22	Short	Open
Sensor 2 / JP20	Short	Open

If the output(s) are to be used for automatic refill (and will consequently be driving a solenoid valve or relay), the output(s) will typically be configured as open collector. If other equipment (e.g., a computer) is simply monitoring the control output(s), the output(s) should be configured as TTL Compatible (0-5V).

When the LM-500 is used in conjunction with Option 5, the Line Voltage Controller Module, as shown in Figure 5.2, the unit is capable of driving solenoid valves requiring 115V/230V AC. Option 5 provides the user with two independent channels with fused and opto-isolated line voltage outputs. Refer to Appendix B for a technical description of Option 5.

In order for the automatic refill to operate properly, several precautions should be taken in setting up the system:

1. The Cryogen Storage Dewar should have a regulated pressure maintained which is compatible with the Cryogenic Solenoid Valve, Transfer Line, Cryostat and any equipment installed within the Cryostat (such as a superconducting magnet or a variable temperature insert). For most systems, the Cryogen Storage Dewar should be held at about 2-3 PSI above the pressure in the Cryostat. If the Cryogen Storage Dewar has a very high pressure inside when the refill cycle is begun, some system components could be damaged by the surge in pressure that occurs when transfer is begun.

2. The Vent Valve in some systems can be bypassed if there is adequate venting available from the Cryostat through other pressure relief valves. Again, care should be taken that venting through a fixed pressure relief valve does not cause excessively high back pressure in the Cryostat. Also, when an automatic refill cycle is completed, one must be sure the cryostat is sealed properly with appropriate and working pressure relief valves. Refill cycles usually result in significant frost at the vent port of the Cryostat. This can frequently result in a pop-off valve becoming frozen in the open position and may allow air or water to be drawn into the Cryostat resulting in damage.

3. If the wiring between the LM-500, Line Voltage Controller Module, Valves, and/or Sensors is long and in an electrically noisy environment, false signals can be picked up by the LM-500 causing a spurious refill cycle to start. In general, any cabling over 5 meters long should be shielded cables to avoid this problem, although even shorter cables may require shielded lines in some cases.

4. The control output(s) of the LM-500 may be disabled by setting the low limit(s) to 0.0.

5. The Timeout setting of the LM-500 should be set to a value which the user is confident is beyond the time needed for a worst-case cryogen transfer, but no further. Should the Cryogen Storage Dewar run out of liquid during a refill cycle, this feature will stop the transfer rather than let it run all night long blowing warm gas into the Cryostat.

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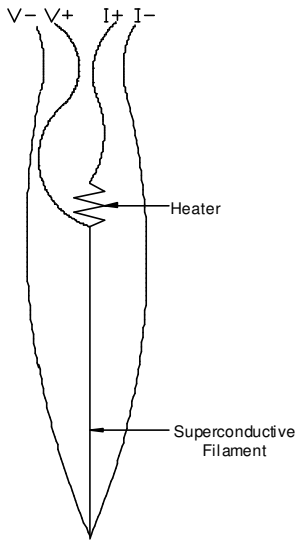
6.0 Theory of Operation

Depending upon how your LM-500 is configured, it may be compatible with superconductive filament liquid helium level sensors, capacitive sensors used for liquid nitrogen, LNG, etc., or a combination of the two. It can be configured for single sensor input or dual sensor inputs. Since liquid helium level sensors and capacitive sensors operate on completely different principles, the unit must be factory configured to the options chosen. Changing the sensor configuration of an LM-500 from LHe to LN_2 sensor inputs or vice versa is possible by returning the unit to Cryomagnetics. Consult the factory if this is necessary.

6.1 Liquid Helium Level Sensing (Superconductive Filament Probes)

If at least one input of the LM-500 is configured for liquid helium level sensors, the unit may be used with 2, 3 or 4 wire superconductive filament level sensors for monitoring liquid helium (an industry standard). These sensors use a single filament of NbTi as the level-sensing element. The sensor has a small heater installed near the top of the filament. When a current is passed from I+ to I-, that is, through the heater and superconductive filament, the top of the filament is forced into the resistive state by the heater. The normal zone of the filament propagates down the length of the filament until it encounters the liquid helium surface. Unable to propagate through the liquid, the normal zone stops. By activating the sensors with a constant current, the voltage measured across the filament is proportional to the length of filament that is in the helium gas. The portion of the filament in the liquid remains superconducting, and therefore has no voltage developed across it. The LM-500 measures the voltage across the filament and converts it, according to the instrument's calibration, into a liquid level which is then displayed.



Sensors operating in a 3-wire configuration typically combine the leads I- and V- into a single lead. Doing so adds some lead resistance to the liquid level measurement that would show up as errors in the reading in most helium level monitors. The LM-500, however, has provisions for subtracting out lead resistance in 3-wire sensing systems.

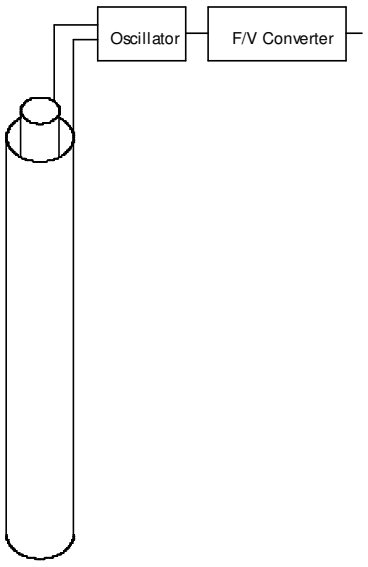
Likewise, sensors operating with only 2 wires combine I+/V+ into a single lead, and I-/V- into a single lead. Therefore two wire sensors have not only the resistive error induced by two leads, but also the error induced by the heater in the sensor. The LM-500 can easily subtract out all of these

errors to give a stable, accurate reading of liquid helium level.

The LM-500 contains circuitry allowing it to sample a liquid helium level sensor at a predetermined interval or on demand. Sampling the liquid helium level minimizes the amount of heat input to the cryogenic system through the sensor - thereby minimizing cryogen boil-off. During a sampling period, the helium level sensor is activated only long enough to obtain a valid reading of the helium level. The sensor is then turned off and the instrument display is updated and held until the next sample time. The LM-500 configured for liquid helium level monitoring also provides a unique sensor deicing cycle within the sensor-reading period. Deicing, which may be necessary if the liquid helium environment has become corrupt from impurities, prevents false readings of liquid level should the sensing filament become contaminated with ice. During the de-ice portion of the sensor sampling, the sensor's current is briefly pulsed to a higher than normal level to clear any ice blockages which may have formed on the sensing filament. This insures an accurate reading of the liquid level even when refilling the cryostat. The sensor deicing part of the sampling cycle can be disabled if desired.

6.2 Liquid Nitrogen Level Sensing (Capacitive Probes)

If one or both channels of the LM-500 is configured for capacitive liquid level sensors (such as liquid nitrogen sensors), the unit is configured to provide a supply voltage to the sensor and receive back an analog voltage from the sensor that is proportional to liquid level. Capacitive sensors are typically based upon a sensing element comprised of two parallel conductors (usually stainless steel tubes) separated by a space which is open to the cryogenic fluid. The sensor uses the difference in dielectric constant between the liquid and gas phases of the fluid to determine the liquid level. Sensors usually consist of the parallel conductors - which are part of a tuned oscillator circuit - and an “oscillator” used to convert the oscillation frequency of the sensor to a voltage proportional to the capacitance of the sensor. For these types of sensors, the LM-500 continuously energizes the sensor (since this does not represent a significant heat load on the cryogenic system), and continuously updates the display according to the analog signal it receives back from the sensor.



6.3 LM-500 Circuit Description

The LM-500 is a 68HC11 microprocessor-based instrument. This microprocessor has built-in EEPROM that is used to hold factory calibration and configuration data, as well as user entered

calibration and setup information. Consequently, it is not possible to simply change the processor with another 68HC11. The unit will not work properly with a new processor until the factory has initialized it.

The processor controls virtually all aspects of the LM-500 including the display, keypad, a precision constant current or constant voltage source (depending upon what type of sensor the instrument is configured for), and the high stability, 21-bit analog-to-digital converter used to monitor sensor voltages. Due to the flexibility and stability of the LM-500's circuits, very high resolution and accuracy is achieved.

The LM-500's display is a bright, vacuum fluorescent unit having high contrast. It is capable of full alphanumerics and can clearly be read from a significant distance.

In units configured for use as liquid helium level monitors, high voltages are possible in the output stage. Typically, helium level sensors will have characteristic resistances of the sensing element of about 4.5 ohms/cm and optimally run at about 70 mA. Therefore, it is not unusual for a sensor to have as much as 50 volts DC or more across it while the sensor is active. Great care must be taken to avoid shock if any changes are being made inside the unit.

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7.0 Limited Warranty Policy

Cryomagnetics, Inc. warrants its products to be free from defects in materials and workmanship. This warranty shall be effective for one (1) year after the date of shipment from Cryomagnetics. Cryomagnetics reserves the right to elect to repair, replace, or give credit for the purchase price of any product subject to warranty adjustment. Return of all products for warranty adjustment shall be FOB Oak Ridge, TN, and must have prior authorization for such return from an authorized Cryomagnetics, Inc. representative.

This warranty shall not apply to any product which has been determined by Cryomagnetics, Inc. inspection to have become defective due to abuse, mishandling, accident, alteration, improper installation or other causes. Cryomagnetics, Inc. products are designed for use by knowledgeable, competent technical personnel.

In any event, the liability of Cryomagnetics, Inc. is strictly limited to the purchase price of the equipment supplied by Cryomagnetics, Inc. Cryomagnetics, Inc. shall not assume liability for any consequential damages associated with use or misuse of its equipment.

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Appendix A

Computer Interface Command Reference

Commands available over the computer interface are separated into commands that are IEEE 488.2 specific, commands that are inhibited when the operator menu is accessed, and commands that are always available. All command mnemonics that elicit a response from the instrument end with a question (?) character. The general command format is as follows:

<Subcommand1>;<subcommand2>;<subcommand3><RETURN>

where a subcommand is formatted

<Command Mnemonic><SPACE><Parameter>

Example:

*IDN?;CHAN 2;UNITS CM;UNITS?<RETURN>

Semicolons separate responses to each subcommand. The above example would return:

*IDN?;CHAN 2;UNITS CM;UNITS?<RETURN><LINEFEED>
Cryomagnetics,LM-500,2002,2.00;cm<RETURN><LINEFEED>

where the serial number is 2002 and the firmware version number is 2.00.

Error Handling and Command Availability

The ERROR command allows error messages to be enabled or disabled when the RS-232 interface is used. The IEEE-488.2 status mechanisms may always be used to determine if an error occurred processing a command, and the category of the error. Some commands are unavailable if an operator at the instrument is accessing the instrument menu. If a command available only in operate mode is received while the menus are being accessed, a device dependent error is reported in the Extended Status Register (ESR), and the message "Blocked by menu" will be returned if error reporting is enabled when using the RS-232 interface. If commands that are specific to a Liquid Helium Level Sensor are addressed to a Liquid Nitrogen channel, a device dependent error is reported in the ESR, and message "Parameter error" will be returned if error reporting is enabled when using the RS-232 interface.

The following table lists the LM-500 commands, shows the LM-500 mode and channel where the command may be used, and provides a short command description. Command details are provided in the reference that follows.

Command	Available	Description
ALARM	Operate	Set audible alarm threshold
ALARM?	Operate	Query audible alarm threshold
BOOST	LHe Operate	Set Liquid Helium Level Meter BOOST mode
BOOST?	LHe Operate	Query Liquid Helium Level Meter BOOST mode
CHAN	Operate	Select instrument channel for computer commands
CHAN?	Operate	Query selected channel
ERROR	Operate	Set error response mode for RS-232 interface
ERROR?	Always	Query error response mode
FILL	Operate	Start automated refill
FILL?	Always	Query automated refill status/elapsed fill time
HIGH	Operate	Set high threshold for automated refill completion
HIGH?	Operate	Query high threshold for automated refill completion
INTVL	LHe Operate	Set Liquid Helium Level Meter sample interval
INTVL?	LHe Operate	Query Liquid Helium Level Meter sample interval
LNGTH?	Operate	Query sensor length
LOW	Operate	Set low threshold for automated refill activation
LOW?	Operate	Query low threshold for automated refill activation
MEAS	Operate	Start measurement on selected channel
MEAS?	Operate	Query last completed measurement on selected channel
MODE	LHe Operate	Set Liquid Helium Level Meter sample mode
MODE?	LHe Operate	Query Liquid Helium Level Meter sample mode
OUT	Operate	Select channel for analog output
OUT?	Operate	Query selected channel for analog output
STAT?	Always	Query instrument status
TYPE?	Operate	Query channel type for selected channel
UNITS	Operate	Select units for selected channel
UNITS?	Operate	Query selected units for selected channel
Command	**Available**	**Description**
*CLS	Always	Clear Status Command
*ESE	Always	Standard Event Status Enable Command
*ESE?	Always	Standard Event Status Enable Query

*ESR?	Always	Standard Event Status Register Query
*IDN?	Always	Identification Query
*OPC	Always	Operation Complete Command
*OPC?	Always	Operation Complete Query
*RST	Always	Reset Command
*SRE	Always	Service Request Enable Command
*SRE?	Always	Service Request Enable Query
*STB?	Always	Read Status Byte Query
*TST?	Always	Self-Test Query
*WAI	Operate	Wait-to Continue Command

Command Reference

This section describes how each LM-500 command is used and provides a cross-reference to related commands. The command syntax sections show required elements enclosed in <angle brackets> and optional parameters enclosed in [square brackets]. All numbers are decimal (base 10).

ALARM Set audible alarm threshold

Availability: Operate Mode

Command Syntax: ALARM [Alarm Level]

Example: ALARM 65.0

Default Parameter: 0.0 (Off) **Parameter Range:** 0 to Sensor Length

Description: The **ALARM** command sets the threshold for the audible alarm in the present units for the selected channel. If the liquid level falls below the threshold the audible alarm will sound. The alarm will be disabled if the threshold is set to 0.

Related Commands: ALARM?, CHAN, CHAN?, LNGTH?, UNITS, UNITS?

ALARM? Query audible alarm threshold

Availability: Operate Mode

Command Syntax: ALARM?

Response: <Alarm Level> <Units>

Response Example: 15.0 cm **Response Range:** 0 to Sensor Length

Description: The **ALARM?** query returns the audible alarm threshold in the present units for the selected channel. If the liquid level falls below the threshold the audible alarm will sound. The alarm is disabled if the threshold is set to 0.

Related Commands: ALARM, CHAN, CHAN?, LNGTH?, UNITS, UNITS?

BOOST Set Liquid Helium Level Meter BOOST mode

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: BOOST <Boost Mode>

Example: BOOST SMART

Parameter Range: OFF, ON, SMART

Description: The **BOOST** command sets the operating mode for the boost portion of a sensor read cycle. BOOST OFF will eliminate the boost portion of the read cycle, BOOST ON enables the boost portion on every read cycle, and BOOST SMART enables a boost cycle if no readings have been taken in the previous 5 minutes.

Related Commands: BOOST?, CHAN, CHAN?

BOOST? Query Liquid Helium Level Meter BOOST mode

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: BOOST?

Response: <Boost Mode>

Response Example: Smart **Response Range:** Off, On, or Smart

Description: The **BOOST?** query returns the operating mode for the boost portion of a sensor read cycle. BOOST OFF will eliminate the boost portion of the read cycle, BOOST ON enables the boost portion on every read cycle, and BOOST SMART enables a boost cycle if no readings have been taken in the previous 5 minutes.

Related Commands: BOOST, CHAN, CHAN?

CHAN Select instrument channel for computer commands

Availability: Operate Mode

Command Syntax: CHAN <Selected Channel>

Example: CHAN 2

Parameter Range: 1 or 2

Description: The CHAN command selects the default channel for future computer commands. The default channel is set to 1 when power is applied or when the *RST command is sent.

Related Commands: ALARM, ALARM?, BOOST, BOOST?, CHAN?, FILL, FILL?, HIGH, HIGH?, INTVL, INTVL?, LNGTH?, LOW, LOW?, MODE, MODE?, MEAS, MEAS?, TYPE?, UNITS, UNITS?, *RST

CHAN? Query selected channel

Availability: Operate Mode

Command Syntax: CHAN?

Response: <Channel number>

Response Example: 1 **Response Range:** 1 or 2

Description: The **CHAN?** query returns the default channel for future computer commands. The default channel is set to 1 when power is applied or when the *RST command is sent.

Related Commands: ALARM, ALARM?, BOOST, BOOST?, CHAN, FILL, FILL?, HIGH, HIGH?, INTVL, INTVL?, LNGTH?, LOW, LOW?, MODE, MODE?, MEAS, MEAS?, TYPE?, UNITS, UNITS?, *RST

ERROR Set error response mode for RS-232 interface

Availability: Operate Mode

Command Syntax: ERROR <Error Mode>

Example: ERROR 1

Parameter Range: 0 or 1 (0 - disable error reporting, 1 - enable error reporting)

Description: The **ERROR** command enables or disables error messages when the RS-232 interfaced is used. It is much easier to handle errors under program control when using the RS-232 interface if error messages are disabled, but it is desirable to enable error messages if a terminal program is used to interactively control and query the LM-500.

Related Commands: ERROR?

ERROR? Query error response mode

Availability: Always

Command Syntax: ERROR?

Response: <Error Mode>

Response Example: 0 **Response Range:** 0 or 1

Description: The **ERROR?** query returns the selected error reporting mode.

Related Commands: ERROR

FILL Start automated refill

Availability: Operate Mode

Command Syntax: FILL [Channel]

Example: FILL 2

Default Parameter: Default Channel (See CHAN) **Parameter Range:** 1 to 2

Description: The **FILL** command starts a refill on the selected channel if refill is not active, if the

LOW limit is not set to zero, and if a refill timeout has not occurred. The LM-500 will start sampling the refill channel as in continuous mode until the HIGH limit is exceeded, the timeout set in the FILL menu is exceeded, a *RST command is received, or MENU is selected on the LM-500 front panel. If refill is inhibited by the refill timeout having been exceeded, the *RST command can be sent to allow a FILL command to start an automatic refill.

Related Commands: CHAN, CHAN?, FILL?, LOW, LOW?, HIGH, HIGH?, MODE, MODE?, *RST

FILL? Query automated refill status/elapsed fill time

Availability: Always

Command Syntax: FILL? [Channel]

Example: FILL? 2

Default Parameter: Default Channel (See CHAN) **Parameter Range:** 1 to 2

Response: <Mode> or <Refill Time>

Response Examples: Off
15 min
Timeout

Description: The **FILL?** query returns the refill status if refill is not active, or the time in minutes since refill started if the refill is active. "Off" indicates that a refill timeout has not occurred. "Timeout" indicates that the HIGH limit was not reached before the maximum refill time was exceeded, and that refill is inhibited until the operator resets the refill timeout by selecting MENU on the LM-500, or a *RST is entered via the computer interface. The timeout can be inhibited by setting the value to zero in the fill menu for the channel.

Related Commands: CHAN, CHAN?, FILL, LOW, LOW?, HIGH, HIGH?, MODE, MODE?, *RST

HIGH Set high threshold for automated refill completion

Availability: Operate Mode

Command Syntax: HIGH [Level]

Example: HIGH 65.0

Default Parameter: 0.0 **Parameter Range:** 0 to Sensor Length

Description: The **HIGH** command sets the high threshold for automated refill completion. The present units for the selected channel are implied. A refill cycle is started when a reading is taken that is below the LOW limit. A refill cycle is completed when a reading is taken that is above the HIGH limit, or when the refill timeout configured in the FILL menu is exceeded. A sensor is sampled as in continuous mode during refill, but when the HIGH limit is reach the selected sample interval will be used for future readings.

Related Commands: CHAN, CHAN?, FILL, FILL?, HIGH?, LNGTH?, LOW, LOW?, MODE, MODE?

HIGH? Query high threshold for automated refill completion

Availability: Operate Mode

Command Syntax: HIGH?

Response: <High Level> <Units>

Response Example: 65.0 cm **Response Range:** 0.0 to Sensor Length

Description: The **HIGH?** query returns the high threshold for automated refill completion in the present units for the selected channel.

Related Commands: CHAN, CHAN?, FILL, FILL?, HIGH, LNGTH?, LOW, LOW?

INTVL Set Liquid Helium Level Meter sample interval

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: INTVL [Sample Interval ([HH[:MM[:SS]]]]

Example: INTVL 24:00:00

Default Parameter: 0 (Sample Continuously) **Parameter Range:** 00:00:00 to 99:59:59

Description: The **INTVL** command sets the time between samples for the selected Liquid Helium Level Meter channel. Time is in hours, minutes, and seconds.

Related Commands: CHAN, CHAN?, INTVL?

INTVL? Query Liquid Helium Level Meter sample interval

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: INTVL?

Response: HH:MM:SS

Response Example: 23:59:59 **Response Range:** 00:00:00 to 99:59:59

Description: The **INTVL?** query returns the time between samples for the selected Liquid Helium Level Meter channel. Time is in hours, minutes, and seconds.

Related Commands: CHAN, CHAN?, INTVL

LNGTH? Query sensor length

Availability: Operate Mode

Command Syntax: LNGTH?

Response: <Active Sensor Length> <Units>

Response Example: 120.0 cm **Response Range:** 0.0 to Sensor Length

Description: The **LNGTH?** query returns the active sensor length in the present units for the selected channel. The length is returned in centimeters if *percent* is the present unit selection.

Related Commands: ALARM, LOW, HIGH, UNITS, UNITS?

LOW Set low threshold for automated refill activation

Availability: Operate Mode

Command Syntax: LOW [Level]

Example: LOW 45.0

Default Parameter: 0.0 **Parameter Range:** 0 to Sensor Length

Description: The **LOW** command sets the low threshold for automated refill activation. The present units for the selected channel are implied. A refill cycle is started when a reading is taken that is below the LOW limit, and the sensor will be sampled as in Continuous mode until the High limit is reached. A refill cycle is completed when a reading is taken that is above the HIGH limit, or when the refill timeout configured in the FILL menu is exceeded.

Related Commands: CHAN, CHAN?, FILL, FILL?, HIGH, HIGH?, LNGTH?, LOW?, MODE, MODE?

LOW? Query low threshold for automated refill activation

Availability: Operate Mode

Command Syntax: LOW?

Response: <Low Level> <Units>

Response Example: 45.0 % **Response Range:** 0.0 to Sensor Length

Description: The **LOW?** query returns the low threshold for automated refill activation in the present units for the selected channel.

Related Commands: CHAN, CHAN?, FILL, FILL?, HIGH, HIGH?, LNGTH?, LOW

MEAS Start measurement on selected channel

Availability: Operate Mode

Command Syntax: MEAS [Channel #]

Example: MEAS 2

Default Parameter: Default Channel (See CHAN) **Parameter Range:** 1 to 2

Description: The MEAS command starts a measurement on the selected channel. The DATA READY bit for the selected channel will be set in the status byte returned by the *STB? command when the measurement is complete.

Related Commands: CHAN, CHAN?, MEAS?, *STB?

MEAS? Query last completed measurement on selected channel

Availability: Operate Mode

Command Syntax: MEAS? [Channel #]

Example: MEAS? 2

Default Parameter: Default Channel (See CHAN) **Parameter Range:** 1 to 2

Response: <Measured Level> <Units>

Response Example: 15.0 cm

Description: The **MEAS?** query returns latest reading in the present units for the selected channel. If a reading for the selected channel is in progress, the previous reading is returned.

Related Commands: CHAN, CHAN?, MEAS, *STB?

MODE Set Liquid Helium Level Meter sample mode

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: MODE <Sample Mode>

Example: MODE S

Default Parameter: 0.0 (Off) **Parameter Range:** S or C

Description: The **MODE** command sets the sample mode for the selected channel. In *Sample/Hold* mode the measurements are taken when a MEAS command is sent via the computer interface, the <Enter> button is pressed on the front panel, or when the delay between samples set by the INTVL command expires. The interval timer is reset on each measurement, regardless of source of the measurement request. In *Continuous* mode measurements are taken as frequently as possible. The channel will also operate as in continuous mode any time a refill cycle has been activated by the level dropping below the low threshold until the refill cycle is completed by the HIGH threshold being exceeded or a *RST command.

Related Commands: CHAN, CHAN?, FILL, FILL?, INTVL, INTVL?, MODE?

MODE? Query Liquid Helium Level Meter sample mode

Availability: Liquid Helium Level Channel in Operate Mode

Command Syntax: MODE?

Response: <Sample Mode>

Response Examples: Sample/Hold
Continuous
Disabled

Description: The **MODE?** query returns the sample mode for the previously selected channel. The sample mode may have been set by a MODE command, the front panel menu, or set to *Disabled* by the LM-500 if an open sensor was detected. Once the mode is set to *Disabled* it will remain *Disabled* until changed by the front panel or the MODE command.

Related Commands: CHAN, CHAN?, INTVL, INTVL?, MODE

OUT Select channel for analog output

Availability: Operate Mode with Dual Channel Analog Output Option

Command Syntax: OUT <Selection>

Example: OUT 2

Parameter Range: 0, 1, 2

Description: The **OUT** command sets the channel to be placed on the analog output port. If <0> is selected the digital input select (remote select) will be used to select the channel. Otherwise <1> or <2> selects the respective channel.

Related Commands: OUT?

OUT? Query selected channel for analog output

Availability: Operate Mode with Dual Channel Analog Output Option

Command Syntax: OUT?

Response: <Select Value>

Response Example: 0

Description: The **OUT?** command returns the channel placed on the analog output port, or 0 if the digital input select (remote select) is used to select the channel.

Related Commands: OUT

STAT? Query instrument detailed status

Availability: Always

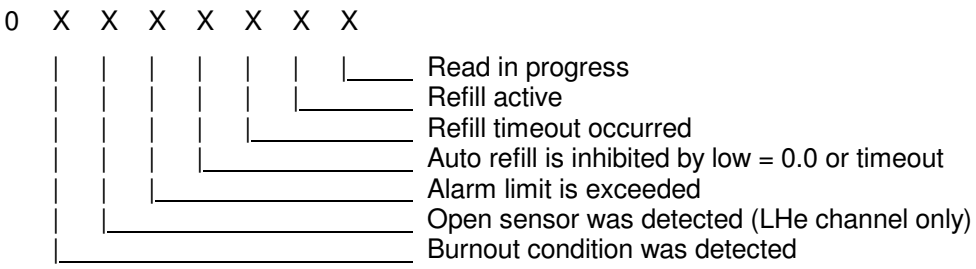
Command Syntax: STAT?

Response: <Ch 1 Detailed Status>,<Ch 2 Detailed Status>,<Menu Mode>

Response Example: 8,3,0 **Response Range:** 0,0,0 to 127,127,1

Description: The **STAT?** query returns detailed instrument status as decimal values, and the status of local menu selection. When an operator selects the Menu, the instrument is taken out of operate mode, and <Menu Mode> is returned as 1. <Menu Mode> is returned as 0 when in operate mode. Channel detailed status is returned as a decimal number where each bit indicates a status condition of the channel. The meaning of each bit when set to one is shown:

Channel Detailed Status:



Related Commands: *STB?

TYPE? Query channel type for selected channel

Availability: Operate Mode

Command Syntax: TYPE? [Channel]

Example: TYPE? 2

Default Parameter: <Default Channel> **Parameter Range:** 1 or 2

Response: <Channel Type>

Response Example: 1 **Response Range:** 0 or 1

Description: The **TYPE?** query returns a code for the channel type of the designated channel, or the channel type of the default channel set by the CHAN command if a channel is not specified. 0 denotes a liquid helium level sensor and 1 denotes a liquid nitrogen level sensor.

Related Commands: CHAN, CHAN?

UNITS Select units for selected channel

Availability: Operate Mode

Command Syntax: UNITS <Unit Selection>

Example: UNITS CM

Parameter Range: CM, IN, PERCENT, or %

Description: The **UNITS** command sets the units to be used for all input and display operations for the default channel selected by a prior CHAN command. Units may be set to centimeters, inches, or percentage of sensor length.

Related Commands: ALARM, ALARM?, CHAN, CHAN?, HIGH, HIGH?, LNGTH?, LOW, LOW?, MEAS, MEAS?, UNITS?

UNITS? Query selected units for selected channel

Availability: Operate Mode

Command Syntax: UNITS?

Parameter Range: CM, IN, PERCENT, or %

Response: <Selected Units>

Response Example: cm **Response Range:** cm, in, or %

Description: The **UNITS?** command returns the units used for all input and display operations for the default channel selected by a prior CHAN command. Units may be set to centimeters, inches, or percentage of sensor length.

Related Commands: ALARM, ALARM?, CHAN, CHAN?, HIGH, HIGH?, LNGTH?, LOW, LOW?, MEAS, MEAS?, UNITS

***CLS** Clear Status Command

Availability: Always

Command Syntax: *CLS

Description: The ***CLS** command operates per IEEE Std 488.2-1992 by clearing the Standard Event Status Register (ESR) and resetting the MAV bit in the Status Byte Register (STB).

Related Commands: None

***ESE** Standard Event Status Enable Command

Availability: Always

Command Syntax: *ESE <mask>

Example: *ESE 255

Default Parameter: 0 **Parameter Range:** 0 to 255

Description: The ***ESE** command operates per IEEE Std 488.2-1992 by setting the specified mask into the Standard Event Status Enable Register (ESE).

Related Commands: *ESE?

***ESE?** Standard Event Status Enable Query

Availability: Always

Command Syntax: *ESE?

Response: <ESE Mask>

Response Example: 255 **Response Range:** 0 to 255

Description: The ***ESE?** command operates per IEEE Std 488.2-1992 by returning the mask set in the Standard Event Status Enable Register (ESE) by a prior *ESE command.

Related Commands: *ESE

***ESR?** Standard Event Status Register Query

Availability: Always

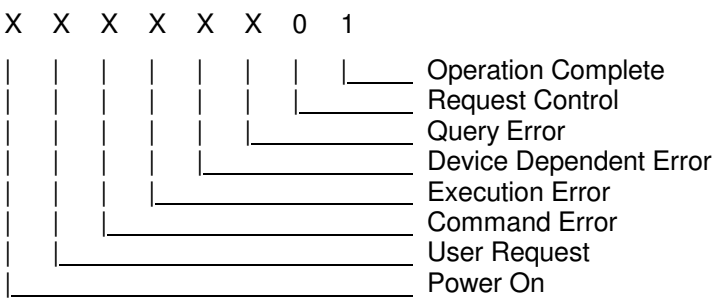
Command Syntax: *ESR?

Response: <Standard Event Status Register>

Response Example: 128 **Response Range:** 0 to 255

Description: The ***ESR?** command operates per IEEE Std 488.2-1992 by returning the contents of the Standard Event Status Register and then clearing the register.

Status Byte Bit Allocations:



Related Commands: *ESE, *ESE?

***IDN?** Identification Query

Availability: Always

Command Syntax: *IDN?

Response: <Manufacturer>,<Model>,<Serial #>,<Firmware Level>

Response Example: Cryomagnetics,LM-500,2002,2.00

Serial # Range: 2000 to 9999 **Firmware Level Range:** 1.00 to 9.99

Description: The ***IDN?** command operates per IEEE Std 488.2-1992 by returning the LM-500 manufacturer, model, serial number and firmware level.

Related Commands: None

***OPC** Operation Complete Command

Availability: Always

Command Syntax: *OPC

Description: The ***OPC** command operates per IEEE Std 488.2-1992 by placing the Operation Complete message in the Standard Event Status Register (ESR). The LM-500 processes each command as it is received and does not defer any commands for later processing.

Related Commands: *OPC?

***OPC?** Operation Complete Query

Availability: Always

Command Syntax: *OPC?

Description: The ***OPC** command operates per IEEE Std 488.2-1992 by placing an ASCII character "1" in the output queue since the LM-500 does not defer any commands for later

processing.

Related Commands: *OPC

***RST** Reset Command

Availability: Always

Command Syntax: *RST

Description: The ***RST** command operates per IEEE Std 488.2-1992 by returning the LM-500 to its power up configuration. This selects channel 1 as the default channel, terminates any refill sequence in progress, and clears any refill timeouts that may have occurred.

Related Commands: None

***SRE** Service Request Enable Command

Availability: Always

Command Syntax: *SRE <mask>

Example: *SRE 255

Default Parameter: 0 **Parameter Range:** 0 to 255

Description: The ***SRE** command operates per IEEE Std 488.2-1992 by setting the specified mask into the Service Request Enable Register (SRE).

Related Commands: *SRE?

***SRE?** Service Request Enable Query

Availability: Always

Command Syntax: *SRE?

Response: <SRE Mask>

Response Example: 255 **Response Range:** 0 to 255

Description: The ***SRE?** command operates per IEEE Std 488.2-1992 by returning the mask set in the Service Request Enable Register (SRE) by a prior *SRE command.

Related Commands: *SRE

***STB?** Read Status Byte Query

Availability: Always

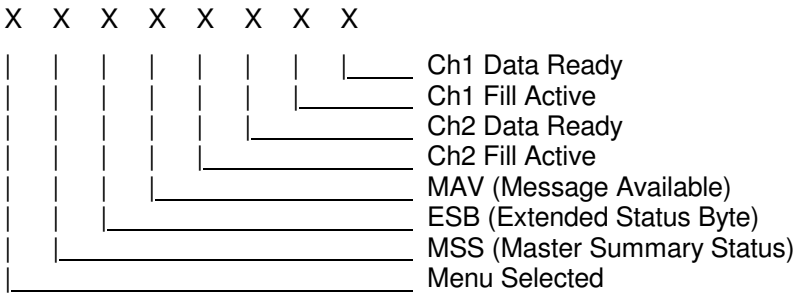
Command Syntax: *STB?

Response: <Status Byte>

Response Example: 65 **Response Range:** 0 to 255

Description: The ***STB?** command operates per IEEE Std 488.2-1992 by returning the Status Byte.

Status Byte Bit Allocations:



*** TST?** Self-Test Query

Availability: Always

Command Syntax: *TST?

Response: <Self test status>

Response Example: 1 **Response Range:** 1

Description: The ***TST?** command operates per IEEE Std 488.2-1992 by returning the self-test status. Explicit tests are not performed in response to this command, but a 1 is returned for compliance with the specification.

Related Commands: None

*** WAI** Wait-to-Continue Command

Availability: Always

Command Syntax: *WAI

Description: The ***WAI?** command operates per IEEE Std 488.2-1992 by accepting the command without generating an error. Since the LM-500 only implements sequential commands the no-operation-pending flag is always TRUE.

Related Commands: OPC, *OPC?

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Appendix B

Line Voltage Controller Module – Option 5

Overview

The Line Voltage Controller Module enables the LM-500 to control one or two 115/230 VAC loads up to 1 Amp each using the LM-500 Low and High setpoints. Section 5.5, Automatic Refill, describes operation of the LM-500 in automatic refill applications. The outputs are labeled channel 1 and channel 2, and are controlled by the respective channels of the LM-500.

Connections

An interconnection cable is provided with the Line Voltage Controller Module to connect the LM-500 to the Line Voltage Controller Module and to the sensors. The DB-15M connector attaches to the LM-500, the DB-9F attaches to the Line Voltage Controller Output Module. Individual sensor connectors on the cable for channel 1 and channel 2 are labeled. Output connections are standard 115V or 230V output sockets as specified per order.

DB-9M Pinout

Pin 1 - Channel 1 control input (0V - enabled, open - disabled)
Pin 3 - Channel 2 control input (0V - enabled, open - disabled)
Pin 6 - +15V input (10 ma max)
Pin 9 - Ground

Fuses

Each output is individually fused on the rear panel of the module with a user replaceable 2 amp 250VAC fuse. Slow blow fuses should not be used.

Theory of Operation

The 'hot' side of each output is individually switched using an opto-isolated solid state switch rated for 20-500Hz operation. These switches exhibit a 1 mA off-state leakage current, which will be observed as 90-100 VAC if the output is checked with a voltmeter with no load attached to the output.

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