OPERATING INSTRUCTION MANUAL
FOR THE
4G
MAGNET POWER SUPPLY

Issue Date: 02/17/2010
Rev. 9.0

WARNING!
DO NOT ATTEMPT TO OPERATE THIS EQUIPMENT BEFORE YOU HAVE THOROUGHLY READ THIS INSTRUCTION MANUAL.
CE
MANUFACTURER'S DECLARATION OF CONFORMITY
In accordance with ISO/IEC 17050-1

Manufacturer's Name: Cryomagnetics, Inc.
Manufacturer's Address: 1006 Alvin Weinberg Drive
Oak Ridge, TN 37830

Declares the product
Product Name: 4G Superconducting Magnet Power Supply
Model Numbers: 4G-50, 4G-100, 4G-150, 4G-200, 4G-50-50, 4G-100-50, 4G-100-100
Product Options: All Options

Conforms to the following Product Specifications:

Safety: EN61010-1, 1993, Amendment 2
EN61326

EMC:
EN55011 Conducted Emissions
EN55011 Radiated Emissions
EN61000-4-2 ESD Air Discharge, 1kV, 2kV, 4kV
EN61000-4-2 ESD Contact Discharge, 2kV, 4kV, 8kV
EN61000-4-3 Radiated Immunity 10V/m
EN61000-4-4, EFT 500V, 1kV, 2kV
IEC 1000-4-5:1995 Surge 500V, 1kV L-L
500V, 1kV, 2kV L-G
EN61000-4-6 Conducted Immunity 10V rms
EN61000-4-8 Power Frequency Magnetic Field
EN61000-4-11 Voltage Dips and Interrupts

Application of Council Directives:
The product complies with the requirements of the Low Voltage Directive

D.M. Coffey, President
Cryomagnetics, Inc
Oak Ridge Tennessee  February 16, 2009
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Symbols and Abbreviations

Warning – Danger of electrical shock

Protective Earth Ground

A  Amperes
°C  degrees centigrade
°F  degrees Fahrenheit
Hz  Hertz
kg  kilograms
kG  kilogauss
mA  milliamperes
mV  millivolts
T  Tesla
1. Introduction to the Cryomagnetics Model 4G Superconducting Magnet Power Supply

1.1. Description
The 4G Superconducting Magnet Power Supply is an advanced instrument designed specifically for powering superconducting magnets. It is a true four-quadrant power supply – meaning it is capable of operating with positive current / positive voltage (sourcing power), positive current / negative voltage (sinking power), negative current / positive voltage (sinking power), and negative current / negative voltage (sourcing power). The supply allows the user to generate smooth sweeps through zero current for performing hysteresis loop experiments or other research requiring smooth magnetic field reversal.

The 4G is available in several configurations. It may have one or two power modules, and the power modules may be independent or paralleled internal to the supply. Power modules are available as 50A or 100A units. This architecture allows the 4G to be configured as a single 50A, 100A, 150A, or 200A unit. It also allows it to be configured as a dual 50A or dual 100A unit. The dual units may be paralleled externally by the user to provide the full current capability to a single load, but this requires some special operational considerations. All 4G units are capable of delivering up to ±10 volts of output voltage. An easy-to-use menu system is provided to allow the operator to set the supply up using the parameters of his/her particular magnet. Most of the supply operating parameters may be changed or queried through the USB and IEEE-488 interfaces.

Power supplies used for energizing superconducting magnets have unique requirements placed upon them. The supplies are used to source energy to magnets which can have a wide range of inductance (mH to thousands of henries). In addition, the magnet load can range from a nearly pure resistance to a nearly pure inductance – and everything in between. This places demands on the supply that are far beyond what a typical power supply used for bench top electronics would see. The supply will experience the challenges of sinking energy when a magnet is discharging every day. At the same time, the potential exists for either the magnet or power supply to be damaged in the event of a power failure or magnet quench. The 4G's advanced circuitry enables it to take virtually any scenario encountered in superconducting magnet operation in stride. The quiet switch-mode design of the 4G makes it a low noise, highly efficient supply – and one that is proven stable even on the most sensitive superconducting magnets. Versatile programmability allows the user to specify several different sweep rates for different current ranges of the magnet – making it possible to sweep a magnet slower in a particular range if it is more sensitive there, without user intervention.
1.2. Features

The 4G has a wide range of features available:

- True Four-Quadrant Operation. The supply can provide positive or negative output current along with either polarity voltage. This gives it the ability to smoothly sweep through zero current without the need for current reversing switches or pauses.

- User – Friendly Menus. The 4G has intuitive menus to display and enter operating parameters. It can be set up in a matter of minutes and changes during daily operation are simple and quick.

- Easy to Read Display. The high quality 5 1/4” color LCD can be read at a glance. The current is displayed in a large font that can be read even from across the lab.
- ±10 Volt / ±50A, 100A, 150A, 200A High Stability Output(s). The 4G provides quiet, stable output power thanks to its low noise switch-mode design and precision current monitoring and control circuits.

- Power Fail Magnet Discharge. Should a power failure occur during operation of the magnet, the supply converts to a "Power Fail" mode wherein it begins to discharge the magnet at a low voltage. If power is restored, the user can intervene to stop the discharge and re-energize the magnet if desired. "Power Fail" mode is a convenient feature of the 4G since it enables the user to simply turn OFF the power switch for the unit at the end of the day.

- Independent Upper and Lower Current Limit Set points. Independent current limits allow sweeping between two set points without having to re-enter the menu and constantly change limit settings.

- PID-Controlled Sweeping. A PID inside the power supply’s control circuits allows smooth sweeping between set points without the need for or dependence on voltage taps across the magnet.

- Changeable Settings During Sweep. The menu system can be entered at virtually any time during operation of the supply to change parameters. While in the menu, the display continues to update the user as to the status of the supply/magnet.


- LabVIEW™ drivers. Virtual Instrument drivers compatible with National Instruments LabVIEW™ are available for Cryomagnetics’ instrumentation through Cryomagnetics’ website.

- Built-in Persistent Switch Heater Supply. A power supply for energizing a persistent switch is built into the 4G.

- Remote Shut-down Input. A signal can be provided by the user to the 4G which commands it to discharge (Zero) the magnet. This can be used to lock out operation of the magnet when helium gets too low or when some other user-defined event occurs.

- Quench Detection and Protection. The 4G is fully protected from damage due to quench. In
addition, if a quench is detected the 4G will give an audible and visual indication of the quench. The current readings leading up to the quench can be displayed on the unit’s front panel. Since quench detection is activated on observed current transients, it must be disabled if automatic recovery is desired from abnormal conditions such as those encountered in several of the CE qualification tests. These tests include electrical fast transient and electrostatic discharge.
1.3. Specifications

Common Specifications

<table>
<thead>
<tr>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Output:</td>
<td>See model specific spec</td>
</tr>
<tr>
<td>Output Power</td>
<td>See model specific spec</td>
</tr>
<tr>
<td>Ripple and noise</td>
<td>20 uA rms</td>
</tr>
<tr>
<td>Stability (drift) at 25 ± 1°C:</td>
<td>± 3mA / °C</td>
</tr>
<tr>
<td>Display Resolution:</td>
<td>0.1 mA</td>
</tr>
<tr>
<td>Display Update Rate:</td>
<td>~ 500ms Intervals.</td>
</tr>
<tr>
<td>Output Current Setability:</td>
<td>0.1 mA</td>
</tr>
<tr>
<td>Sweep Rate Resolution:</td>
<td>0.1 mA/sec</td>
</tr>
<tr>
<td>Source effect (line regulation for any line change within the rated line voltage):</td>
<td>0.005% Imax</td>
</tr>
<tr>
<td>Load effect (load regulation for a load change equal to max. voltage in constant current mode or max. current in constant voltage mode):</td>
<td>0.01% Imax</td>
</tr>
<tr>
<td>Output Protection:</td>
<td>Protected from damage due to quench</td>
</tr>
<tr>
<td>Persistent Switch Heater</td>
<td>0-125mA</td>
</tr>
<tr>
<td>AC Input:</td>
<td>220-230V a.c., 50-60 Hz, 16A max</td>
</tr>
<tr>
<td>Circuit Breakers:</td>
<td>16A, 240V a.c., slow blow</td>
</tr>
<tr>
<td>Operating Temperature:</td>
<td>15 °C to 35 °C</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>10% to 95%, non-condensing</td>
</tr>
<tr>
<td>Over-Temperature Protection:</td>
<td>Unit will limit discharge power to prevent overheating.</td>
</tr>
<tr>
<td>Overall Dimensions (excluding front handles):</td>
<td>483 mm W X 133 mm H X 533 mm D</td>
</tr>
<tr>
<td>USB interface:</td>
<td>USB 1.1/2.0 Full-Speed</td>
</tr>
<tr>
<td>Ethernet:</td>
<td>IEEE-802.3 10/100 BASE-T</td>
</tr>
<tr>
<td>Shut-down Input:</td>
<td>+5V, +24V, or switch closure signaling</td>
</tr>
</tbody>
</table>

Model Specific Specifications

<table>
<thead>
<tr>
<th>Max Current</th>
<th>Max Output Power</th>
<th>Weight (lbs/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G-100</td>
<td>100A</td>
<td>1000W</td>
</tr>
<tr>
<td>4G-200</td>
<td>200A</td>
<td>2000W</td>
</tr>
<tr>
<td>4G-100/100</td>
<td>100A/100A</td>
<td>1000W/1000W</td>
</tr>
</tbody>
</table>

The 4G is designed to operate per the specifications in this table and the instructions provided in this manual. Other use may impair the safety protections provided by the equipment.
2. Installation
The following section outlines information concerning the installation and setup of the 4G supply. As with any equipment purchase, the user is strongly encouraged to inspect the power supply for shipping damage immediately upon receipt. Proper power and ground connections should be made using the appropriate codes and practices. Should the 4G require return to the factory due to shipping damage or for servicing, contact Cryomagnetics or an authorized service representative for instructions and a return authorization number.

The 4G is delivered to you fully tested, calibrated, and ready to operate. This includes configuring appropriate setup values if the supply is purchased with a magnet system.

2.1. Line Voltage and Fuses
The 4G is fused for operation using 220-230 V a.c., 50-60 Hz input power by a 16A circuit breaker incorporated in the power entry module. Never use an ungrounded power cord for line power.

It is strongly recommended that AC power provided to the 4G be protected with a Ground Fault Interrupter (GFI) and a surge suppressor. If the unit is operating in an area subject to power failures or brownouts, the user may wish to install an Uninterruptible Power Supply (UPS) (sine wave) to minimize the chance of inadvertently discharging or quenching the magnet due to line effects.

If the 4G is powered from a line voltage less than 220V the output power available will be reduced. The maximum power available from each power output module may be calculated by

\[
\text{Output Power Available} = (1200-(200-V_{\text{in}})\times7.42) - 3\times I_{\text{out}}
\]

where \(V_{\text{in}}\) is the AC input line voltage and \(I_{\text{out}}\) is the DC output current.

Operation at a reduced voltage greater than 90V a.c. can be achieved if both of the above constraints are observed.

2.2. Mounting
The 4G is compatible with all standard 19-inch wide rack cabinets. Due to the instrument’s weight, it is recommended that rails be located beneath the supply to prevent bending of the supply mounting brackets. Adequate ventilation is essential to the 4G. An unobstructed air path should be available at the ventilation slots in the rear and side panels of the instrument and at the fan outlets to avoid overheating.

2.3. Environment
The 4G is designed for operation in free air, non-condensing atmospheres within a temperature range of 15 to 35C (59 to 95F). It has been designed primarily for laboratory use – so harsh environments of dust or corrosive materials could result in eventual damage. A filtered enclosure is recommended for operation under these conditions.

2.4. Terminal Strip Connections
The rear panel terminal strip of the 4G provides service for all analog input and output signals for the 4G. The terminal strip is shown in Figure and Table outlines the definition and function of each terminal pair. A cover is provided to prevent electrostatic discharge damage to the electrical connections. A terminal strip is present for each installed power module.

![Figure 3. Rear Panel Terminal Strip](image)

<table>
<thead>
<tr>
<th>Terminal #</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pers Sw +</td>
<td>Persistent Switch Heater Power Supply Output</td>
</tr>
<tr>
<td>2</td>
<td>Pers Sw -</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mag.Vin +</td>
<td>Magnet Voltage Taps – Input Signal to 4G from Magnet (optional)</td>
</tr>
<tr>
<td>4</td>
<td>Mag.Vin -</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ground</td>
<td>Ground connections for I/O Cable and Output Cable shields</td>
</tr>
<tr>
<td>6</td>
<td>Ground</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Terminal Functions

Before making connections to the rear panel terminal strip, make sure the power to the 4G is OFF. Shield cables must be used with shields connected to terminal 6 for CE compliance. Make all connections using the appropriate wire size. The terminal strip is designed to accept AWG 24 – 12 (0.2 – 2.5 mm² stranded or 0.2 – 0.4 mm² solid) conductor. The ends should be stripped bare 7mm. All connections should be isolated from instrument ground and from each other.

2.5. Power Output Terminals
The high current output terminals are located on the rear panel and are labeled I(+) and I(-). Make
sure the 4G power is OFF before attaching the terminals to the magnet power leads. Care should be taken in attaching power leads for the magnet to insure solid contact is made using a ¼-20 bolt with nut to each terminal. Although quench protection is built into the 4G to prevent the occurrence of high voltages, the magnet leads should NEVER be disconnected when current is present. Potentially lethal voltage can easily occur due to the high inductance of superconducting magnets.

CAUTION – RISK OF ELECTRIC SHOCK

Note: Ferrite beads (Fair-Rite P/N 0444177081) must be installed on the output cables for compliance with CE standards for RF conducted immunity. Cables must be shielded with shields connected to terminal 6 of the terminal block.

2.6. Maintenance

The 4G should be inspected periodically to verify that all connections are secure, fans operate properly, and that the ventilation openings are clear.

If cleaning is required, disconnect the power cord and clean the unit with a soft cloth dampened with water.

The 4G does not contain user serviceable parts. If repairs should be required, contact the factory for a repair authorization number, and return to the factory for service to ensure the integrity of the unit is maintained.
3. Setup and Operation

The 4G is designed specifically for operation with superconducting magnets. Before using the supply to energize a magnet; however, certain parameters specific to the superconducting magnet being used, the charge rate(s) desired during field sweep, and the operating current limit(s) should be set through the menu system. The following procedure is recommended.

3.1. Setting Magnet Parameters

The first thing the user should set up is the magnet parameters. If this is a dual unit, select SUPPLY A or SUPPLY B first. In the sweep menu, press [SETUP], then [MAGNET]. The display will show the Magnet Parameters. If a persistent heater is being used, Persistent Heater Present should be set to Yes. If the magnet to be energized is currently at zero field, the Persistent Mode Current should be set to 0.0000A. If the magnet is already in persistent mode at some other known current, this current can be entered instead. Be sure the polarity of the magnet current is entered correctly.

The maximum safe operating current for the magnet should be entered in the Maximum Current Rating parameter position. The supply will not allow output current to exceed this value. Should the user enter a Sweep Limit setting exceeding this value (in the Limits menu), the supply will only sweep to the Maximum Current Rating value and indicate MAG LIMIT REACHED on the display.

The Gauss/Amp Ratio of the magnet may be entered in the Magnet Parameters setup if desired. The 4G only uses this parameter if the Display Units is set to Field rather than Amperes. Consequently setting this parameter is not essential.

If the magnet to be energized is equipped with a persistent mode switch, the heater current necessary to activate it should be entered in the Persistent Switch Heater (mA) field. The persistent switch heater power supply is capable of up to 125 mA of output current at up to 12V compliance.

If quench detection is desired, set Quench Detection to On.

Set the magnet's nominal inductance into the Inductance (H) parameter. If the supply was shipped with a magnet, this field should already be set.

When done with the magnet parameters, press EXIT, then SAVE.
3.2. Setting Charge Rates

The charge rate(s) for energizing the magnet should be entered through the Rates menu. The 4G allows the user to set up to five different charge rates to be used in five current ranges, plus a fast rate. This allows the user to specify a slower rate for a magnet when it is near its maximum rated field.

From the sweep menu, press [SETUP], then [RATES]. Using the inductance of the magnet as a guide, set the desired rates keeping in mind that the best (smoothest) sweeps of the magnet are achieved when 1V margin is maintained relative to the supply's voltage limit setting. The charging voltage of the magnet is computed by \( V = L \frac{di}{dt} \), where the value of \( \frac{di}{dt} \) is the desired sweep rate in amperes per second indicated in the Rates menu.

Once the rates and their respective current ranges have been set, press [EXIT] then [SAVE] to accept the changes, or [DISCARD] to abort and ignore all changes. If the message 'VALUE TOO LOW' appears, the cursor will be on a 'To' field that is lower than the start of the range. It must be greater.

3.3. Setting Limits

The desired operating current for the magnet is set in the Limits menu. The 4G allows the user to enter two different limits – an upper and a lower – to enable smooth sweeps between two points. Either or both of the upper and lower current limits may be positive or negative current values as long as the upper is more positive than the lower.

From the sweep menu, select [SETUP] then [LIMITS]. Use the arrow keys to select the appropriate current limit and then enter the desired value. If changes to the voltage limit are desired, this can be entered now, too.

If alarm operation is desired, change the Alarm HI Limit and Alarm LO Limit to the desired values. This will result in alarm messages on the display when these values are exceeded. If the optional relay outputs are in use, they can be enabled or disabled with the Alarm Relay Bypass setting. If set to On, the outputs remain closed all the time.

When an alarm occurs, it is reset either automatically (when the current falls back within limits) or require a button press. To automatically reset them, set Alarm Relay Autoreset to On.

Once the settings are made, press [EXIT] and [SAVE] to accept the changes (or [DISCARD] to abort and ignore the changes).
3.4. **Energizing the Magnet**

Once the magnet parameters, charge rates, and limits have been set, the supply is ready to energize the magnet. From the supply sweep menu, energize the persistent switch heater supply by pressing [PERS HTR] then [CONFIRM HTR ON]. Pressing either [CANCEL] or [ESC] will cancel turning the heater on. Wait for a few seconds or whatever time is required by the magnet's persistent switch before beginning the field sweep.

Press [HI LIMIT] to begin energizing the magnet in the direction of the upper current limit. Alternatively, the operator can press [LO LIMIT] to begin energizing the magnet in the direction of the lower current limit. Once the appropriate current limit is reached, the 4G will hold that current.

To place the magnet into persistent mode, turn off the persistent switch heater supply by pressing [PERS HTR] then [CONFIRM HTR OFF]. Pressing either [CANCEL] or [ESC] will cancel turning the heater off. Wait a few seconds or whatever time is required by the magnet's persistent switch before zeroing the current in the leads.

Once the magnet is in persistent mode, the current in the leads may be brought back to zero by pressing the [Zero] key.

**IMPORTANT**

*Be sure to zero the supply by pressing the [ZERO] key.*

*Pressing [LO LIMIT] will result in the supply sweeping to the lower current limit rather than to zero.*

Watch the magnet voltage while the supply begins to sweep toward zero to verify that the magnet has indeed entered persistent mode. If no voltage is detected, press [Shift-ZERO] to bring the supply back to zero output current at the fast sweep rate. When the supply reaches zero output current, it automatically switches to Standby mode.

3.5. **Discharging the Magnet**

To discharge a magnet that is in persistent mode, press the [Shift-HI LIMIT] or [Shift-LO LIMIT] to quickly bring the supply output current back to the current left in the magnet. Be sure to bring the current back in the proper polarity as was left in the magnet.
When current limit is reached, the supply will stabilize and hold that current. From the main supply sweep menu, energize the persistent switch heater supply by pressing [PERS HTR] then [CONFIRM HTR ON]. To cancel turning the heater on press either [CANCEL] or [ESC]. Wait for a few seconds (or whatever time is required by the magnet’s persistent switch) before beginning the field sweep.

Once the persistent switch is warm, sweep the magnet current back to zero by pressing the [ZERO] key. Watch the magnet voltage to verify that the magnet is beginning to discharge. When the supply reaches zero output current, it will automatically change to Standby mode. Turn off the persistent switch heater supply by pressing [PERS HTR] then [CONFIRM HTR OFF].

To sweep to the opposite current limit rather than zero, press the appropriate [HI LIMIT] or [LO LIMIT] key rather than the [ZERO] key. The supply will smoothly sweep through zero and on to the other current limit.

3.6. Fast Sweeping
To invoke the fast sweep rate, press and hold SHIFT, and then select the desired sweep function.

Note that fast sweeping is only available under certain conditions in order to avoid accidental exposure of the superconducting magnet to excessive voltage and rapid current changes. For fast sweeping to be enabled:

- The Persistent Heater Present parameter in the MAGNET menu must be set to Yes.
- The persistent switch heater must be OFF.

If the above conditions are not met, fast sweep operation will be disabled (the keys will gray out when SHIFT is pressed).

3.7. Power Fail Mode
Should there be a loss of line power during energizing or discharging of the superconducting magnet, the 4G will automatically switch to Power Fail Mode. In Power Fail Mode, the magnet is put into a slow self-discharge by limiting the voltage at the power supply output terminals to about 0.9V.

If line power is restored, the 4G will continue to discharge the magnet at 0.9V unless the user intervenes. Upon return of line power, the supply displays a message PASSIVE DISCHARGE if it detects current in the magnet, and will continue slowly discharging the magnet. It is not necessary to fully discharge the magnet if this occurs. Pressing [PAUSE] will stop the self-discharge by entering RECOVERY mode, and when complete will allow normal operation to be resumed.
3.8. Magnet Quench

The 4G has magnet quench detection built-in. In the event a magnet quench is detected, QUENCH DETECTED will be displayed and the supply will switch to Standby mode, removing power from the output. If the Quench Alarm (in the General menu) has been set to Yes, the unit emits a steady tone. Pressing any key will silence the tone. In the quench state, there are two keys available: QUENCH RESET and QUENCH DATA. QUENCH DATA will show the last few dozen current readings leading up to the quench. QUENCH RESET clears the quench state and puts the supply into STANDBY. If a quench should be falsely detected, the power supply will display PASSIVE DISCHARGE, and the magnet will be discharged as described in the Power Fail Mode.
4. Displays and Menus
Setup and operation of the 4G may be performed either through the front panel keypad and simple menu instructions or through a remote computer interface (USB or IEEE-488.2). The following sections contain descriptions of how to configure and operate the 4G through the front panel.

The 4G Superconducting Magnet Power Supply is available in single or dual power module configurations. With few exceptions, in dual power module configurations, the two modules operate independently and have separate settings. The displays vary slightly between a single and dual module unit. Unless otherwise specified, menu descriptions apply equally to both modules.

Before connecting a magnet or other cabling to the 4G, connect the power cord provided with your 4G to an appropriate power source. Power the instrument ON and familiarize yourself with the display and keypad.

4.1. Normal Operating Displays
The normal operating displays of the 4G are shown in Figures 2 through 4.

4.1.1. Single Supply

![Normal Operating Display, Single Supply](image)

Figure 4. Normal Operating Display, Single Supply
Figure 5. Normal Operating Display, Single Supply, Continued
4.1.2.  Dual Supply

Figure 6. Normal Operating Display, Dual Supply
4.1.3. Display Field Descriptions

Module Name
This field displays which power module's data is being shown.

Module Sweep Status
The Module Sweep Status field indicates the present supply activity. **Standby** indicates that the power supply output module is disabled and not developing power. **Sweeping to HI LIMIT** indicates that the supply output current is being swept to the upper sweep limit. **Sweeping to LO LIMIT** indicates that the supply output current is being swept to the lower sweep limit. **-Paused-** indicates that the sweep function is not active, and that the supply is maintaining or converging to a constant output current. **Sweeping to ZERO** indicates the supply is discharging the magnet.

When the Sweep Status is **Sweeping to HI LIMIT** or **Sweeping to LO LIMIT** the sweep will continue until the respective upper or lower current limit is reached. When Zeroing, the Sweep Mode of the supply will automatically change to **Standby** when zero current and zero voltage is reached.

Indicators that may appear in the Module Sweep Status field are:
- Standby
- -Paused-
- Sweeping to HI LIMIT
- Sweeping to LO LIMIT
- Sweeping to ZERO
- Sweeping to MAGNET
- Swp FAST to HI LIMIT
- Swp FAST to LO LIMIT
- Swp FAST to ZERO
- Swp FAST to MAGNET

In addition, Module Sweep Status can indicate several module exceptions:
- QUENCH DETECTED
- PASSIVE DISCHARGE
- RECOVERING
- SHUTDOWN COMMAND (rear shutdown input activated)
- OFFLINE (indicates a problem with the module)
Module User Label
The Module User Label is a 16-character alpha-numeric label that is user-settable. This field may be set using a command through the 4G’s USB, Ethernet, or GPIB interface.

Module Output Current
This field indicates the output current or field (amperes shown) sensed in the output leads.

Module Output Voltage
This field indicates the output voltage at the output terminals of the power supply module. Note that it may differ from magnet voltage due to voltage drop in the magnet power leads. This voltage will be clamped to the voltage limit setting in the LIMITS menu.

Magnet Voltage
This field indicates the voltage sensed at the Mag. Vin terminals on the rear panel.

Magnet Current
The magnet current is displayed in this field in the selected units. The magnet current will track the Module Output Current if either:

- There is no persistent switch heater (a setting in the Magnet menu)
- There is a persistent switch heater and it is on.

If a persistent switch heater exists and it is off (magnet is in the persistent mode), this value is either:

- The Module Output Current existing when the heater was turned off
- A value entered by the user when the heater was off.

The magnet current will indicate zero if a quench is detected.

Persistent Switch Heater Status
This field is shown if there is a persistent switch heater present (a setting in the Magnet menu). The values it can show are:

- OFF
- ON
- FAIL No switch heater current detected (check connections).

High Sweep Limit
The target current for a sweep-to-high limit command. This value is entered in the LIMITS menu. If
this value exceeds the Maximum Current Rating (set in the Magnet menu), the supply will only
sweep up to the maximum rating and indicate **MAG LIMIT REACHED**.

**Low Sweep Limit**
The target current for a sweep-to-low limit command. This value is entered in the LIMITS screen. If
this value exceeds the Maximum Current Rating (set in the Magnet menu), the supply will only
sweep down to the maximum rating and indicate **MAG LIMIT REACHED**.

**Output Voltage Limit**
The module will not allow the output voltage to exceed this value. It is set in the LIMITS menu.

**Local / Remote** (not shown in pictures)
The *Local* indication shows that operator has pressed the *Local* button, and that the remote
interfaces (USB, Ethernet or GPIB) cannot control the supply until the operator presses the *Local*
button again. The *Remote* indication shows that a remote interface is controlling the supply, and
that all buttons except the *Local* button are disabled.

**Display Units**
The operator may select Amperes or Field to display the output current.

4.2. **Key Pad Operation**
The keypad layout is shown in Figure 5. The six unlabeled (soft) keys next to the display are not
shown. Most keys on the keypad are used only for menu navigation and parameter entry.
Figure 7. Keypad Layout

The [Local] key is used to put the 4G in local mode, locking out remote commands. [Local] is the only button active when in REMOTE mode. [ESC] is used to back out of a parameter change and restore the previous value, and if not editing a parameter, behaves the same as the [Exit] key in menus. [Enter] is used to accept parameter changes and parallels the function of the SAVE soft-key in menus. [Shift] is used in conjunction with the sweep soft-keys to command a fast sweep mode. See Notes about Sweeping.

4.3. Menus

The menus of the 4G are designed for to minimize the number of keystrokes required, while at the same time being intuitive for system operators.

4.3.1. Organization

The menus have the following overall organization:
4.3.2. General Menu Features

There are two types of parameters in the menus: Numerical and list. Numerical parameters are entered via the keypad 0-9, decimal point, and the change sign key. When starting an entry on a numerical parameter, the field is cleared and changed to a yellow background, and a SAVE soft-key function appears. After you enter the desired value, you must press SAVE to keep your entry, or ESC to abort the change (which restores the old value) before you can exit the field.

List parameters are selected by using the CHANGE soft-key, which appears when the cursor is on a list parameter. You press CHANGE to cycle through all the possible values for the field. Like numerical parameters, the field turns yellow during changing, and you must either SAVE the new setting or ESC to restore the old before you can exit the field.

Parameter changes made in any menu are not effective until you exit the menu and choose SAVE at the prompt.

All setup menus share a common upper half where the status of the module(s) is shown in real time. Example:

![General Setup Menu](image)
4.3.3. **Limits Menu**

The Limits menu is used to set the sweep limits and voltage limit.

![Limits Menu](image)

**Figure 10. Limits Menu**

**High and Low Sweep Limits**

These are the target sweep limits for the sweep up and sweep down functions. They may be set to anything within the capability of the installed module(s), but the module(s) still obey the Maximum Current Rating setting in the Magnet menu.

**Voltage Limit**

The voltage limit is used to set the maximum or minimum output voltage that will appear at the power supply output terminals during charge or discharge. Note that the voltage at the magnet will be either more or less due to the direction of current in the current leads and the lead resistance.

**Alarm HI and LO Limits**

The output current is compared to these values, and if they are exceeded, alarm messages appear on the monitor displays. If you have the optional alarm outputs installed, these will go open upon
an alarm condition. If you do not desire alarm messages, set these to a high value or to the maximum capability of the module.

**Alarm Relay Bypass**
If you have the optional alarm outputs installed, and you do not desire these to open under any condition, set Alarm Relay Bypass to ON. The outputs will always be closed as long as the 4G is powered on.

**Alarm Relay Autoreset**
This parameter is not shown in the picture; you must scroll down to it. There are two ways to reset alarms: Automatically, when the current falls under the alarm limits, and manually, by soft-keys provided on the display. Set Alarm Relay Autoreset to On if you want it done automatically, Off if you want manual resets.
4.3.4. Rates Menu

The Rates menu is used to set the sweep ranges and rates.

![Rates Menu](image)

**Figure 11. Rates MenuCurrent Ranges**

Five current ranges may be defined by setting the upper current limits (the To field) for each. Start at the top and work down. As you enter a value for an upper limit of a range, it is automatically copied to the beginning of the next range. The upper limit must be greater than the beginning of the range, or you will get a 'VALUE TOO LOW' error when you try to exit.

**Sweep Rates**

Sweep rates may be set for each current range. This allows sweep rates to be automatically reduced at high fields and increased at low fields if desired.

**Fast Mode**

Fast mode sweep rate is used when sweep up fast [Shift-HI LIMIT], sweep down fast [Shift-LO LIMIT], or [Shift-Zero] is selected. These modes are selected by holding the shift key and pressing the appropriate sweep button. Fast mode is only available when the persistent switch heater option is enabled and the heater is turned off.
4.3.5. Magnet Menu

The Magnet menu should be the first menu configured when preparing the supply for use.

![Magnet Parameters Menu](image)

**Figure 12. Magnet Parameters Menu**

**Display Units**

The Units menu item allows the user to set the display units of the 4G. Available options are Amperes and Field. The Fields displays will autorange between Gauss, Kilogauss, and Tesla. Once the system of units is selected, the 4G uses that system of units for displaying the output current, magnet current, and limits.

**Persistent Heater Present**

This tells the 4G whether or not a persistent switch heater is present. If not, you will not have the capability to use fast sweeps, and the Persistent Mode Current and Persistent Switch Heater parameters will be unavailable.
**Persistent Mode Current**
Persistent mode current displays the present magnet current if it is in persistent mode and it was last used with the supply. This field may be edited, in case the magnet was placed in persistent mode using a different power supply, or if a magnet quenches while the power supply is turned off.

**Persistent Switch Heater Current**
The persistent switch heater current can be set from 1 to 125 mA. The switch heater is not turned on until it is selected in the operating display or via a remote interface command.

**Maximum Current Rating**
This is the maximum current that the supply may output, regardless of the settings in the upper or lower current limits, or the maximum current set the current ranges in the Rates menu. It would normally be set to the magnet's maximum safe operating limit.

**Gauss to Amp Ratio**
This is entered in units of gauss per ampere. It is used to display the magnetic field instead of output current if Field is selected in the Display Units menu item. It may be set as a whole number ranging from 1 to 3000.

**Quench Detection**
The supply monitors the output current when quench detect is enabled. If a rapid decrease is detected it assumes that a quench has occurred, and the supply is immediately placed in standby. At this point the supply stops delivering any current to the magnet system, which in turn protects the magnet's quench protection system. The Quench Detection setting allows this feature to be disabled.

**Inductance**
Set this to the nominal inductance of your magnet. It is used to set PID parameters for the sweep algorithm. If a low resistance persistent switch is used in parallel with the magnet, a lower value than the actual magnet inductance may provide faster settling times without inducing overshoot.
4.3.6. **General Menu**

The General menu is used to select computer interface parameters and other parameters common to either one or two module units.

![General Power Supply Setup Menu](image)

**Figure 13. General Power Supply Setup Menu**

**Interface**

The Interface field displays the computer interface. Available interfaces are GPIB, USB, and Ethernet. Power must be cycled for it to take effect.

**GPIB Device ID**

The GPIB device ID may be set from 0 to 30. Power must be cycled for it to take effect.

**Baud Rate**

This controls the baud rate used for the USB virtual COM port. It may be set to 9600, 19200, 38400, 57600, and 115200. It does not require power cycling to become effective.
**IP Address**
Sets the IP address for the Ethernet.

**Subnet Mask (not shown)**
Sets the Subnet mask for the Ethernet.

**Port**
Sets the port for the Ethernet.

**Quench Alarm**
If quench detection is enabled, this allows control over the audible alert. It can be set to Silent or Steady. When the alarm is activated, pressing any key will silence it.

**Key Click (not shown)**
This provides audible feedback when pressing keys.
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5. Interfacing
The 4G provides USB, IEEE-488.2, and Ethernet computer interfaces. Front panel functions may be accessed using command strings over the selected interface. Commands available to the 4G operator over the computer interfaces are given in Appendix B. The commands available through USB and Ethernet 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 USB and Ethernet interfaces. The command set includes Local, Remote, and RWLock which are not applicable to IEEE-488.2.

Command strings are normally limited to 60 characters when the USB and Ethernet interfaces are used. A \textit{<RETURN>} will be generated internally when any line longer than the maximum is encountered, and any valid commands in the received line prior to the internally generated \textit{<RETURN>} will be processed. An output buffer of 62 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 USB interface is selected, all commands sent to the instrument will be echoed including the terminating ASCII \textit{<RETURN>} character, followed by a \textit{<NEWLINE>} character when command processing is complete.

5.1. USB Computer Interface
The USB port is accessed through the USB Type B connector on the rear panel of the instrument. To use the USB interface, you must install a virtual com port on the PC, which then treats the USB interface as a traditional RS-232 interface. The virtual com port driver is available from Cryomagnetics or from WWW.FTDICHIP.COM. The 4G must be configured for the same baud rate as your virtual com port (See the GENERAL setup menu).

5.2. IEEE-488.2 Computer Interface
The 4G has an IEEE-488.2 computer interface. The 4G implements SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT0, C0, and E1 options. The commands are compliant with the IEEE-488.2 standard. The connector is identified on the rear panel of the instrument.

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.)
5.3. **Ethernet Interface**

The 4G has a IEEE-802.3 10/100 BASE-T Ethernet interface that supports a socket connection. The IP address, subnet mask, and port address are set in the General Menu (paragraph 4.3.6.)

The Ethernet Interface is supported by the LabVIEW VISA driver which uses a Resource string such as tcpip0::192.168.0.254::4444::socket, where 192.168.0.254 is the IP address and 4444 is the port address entered in the General Menu.
6. Theory of Operation

The 4G is a 4 quadrant power supply with glitch free bi-directional output capability and programmable voltage limiting in both polarities.

6.1. Circuit Description

The 4G front panel is a microprocessor based unit that handles all display, keyboard, and persistent switch heater operation, and all communications with the outside world, including the power modules. User data is stored in non-volatile memory external to the processor.

The power modules are microprocessor-based units that only communicate with the front panel. The microprocessor has built-in EEPROM that is used to hold factory calibration. Consequently, it is not possible to simply change the processor with another. The unit will not work properly with a new processor until it has been initialized by the factory.

Output current is set by a 20 bit digital-to-analog converter controlled by a software PID algorithm updated at a 15Hz rate. A 24 bit sigma-delta analog-to-digital converter is used to sense the output current. The programmable current sweep rate is digitally implemented in the PID algorithm.

The 4G’s display is a bright, full-color 5 1/4” LCD display. It is capable of graphics and full alphanumerics. Both voltage and current can easily be read from a significant distance.
7. **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.
Appendix A

Factory Calibrations and Certification

Notes: ________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________ 

Certified: ____________________________________________________________

Date: ______________________________
Appendix B

Computer Interface Command Reference

Commands available over the computer interface are identified by availability. Commands that are available only when the operational display is active are noted as "Operate", commands that require remote mode are noted as "Remote". All queries and IEEE-488.2 specific commands are always available, regardless of whether the state is Local, Remote, or unassigned. Commands that are IEEE 488.2 specific can be recognized by an asterisk (*) as the first character. All command mnemonics that elicit a response from the instrument (referred to as queries) end with a question (?) character. A general command format is as follows:

```
<subcommand1>;<subcommand2>;<subcommand3><RETURN>
```

where a subcommand is formatted

```
<Command Mnemonic><SPACE><Parameter>
```

Example:

```
*IDN?;*ESE 12;*ESE?<RETURN>
```

Responses to each subcommand are separated by semicolons. The above example would return:

```
Cryomagnetics,4G,2239,1.14,245;12 <RETURN><LINEFEED>
```

where the serial number is 2239 and the firmware version number is 1.14,245.

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 the instrument menu is being accessed by an operator at the instrument, or if the instrument is in LOCAL mode. If a command available only in operate mode is received while the menus are being accessed, or if a command available only in remote mode is received while not in remote mode, a device dependent error is reported in the Extended Status Register(ESR), and the message "Command blocked" will be returned if error reporting is enabled when using the RS-232 interface.

The following table lists the CS-4 commands, shows the modes where the command may be used and provides a short command description. Command details are provided in the reference that
Table 2. Computer Interface Command Summary

<table>
<thead>
<tr>
<th>Command</th>
<th>Available</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAN</td>
<td>Remote</td>
<td>Select module for subsequent commands (Dual Supply only)</td>
<td>43</td>
</tr>
<tr>
<td>CHAN?</td>
<td>Always</td>
<td>Query module selection (Dual Supply only)</td>
<td>44</td>
</tr>
<tr>
<td>ERROR</td>
<td>Remote</td>
<td>Set error response mode for RS-232 interface</td>
<td>44</td>
</tr>
<tr>
<td>ERROR?</td>
<td>Always</td>
<td>Query error response mode</td>
<td>44</td>
</tr>
<tr>
<td>IMAG</td>
<td>Remote</td>
<td>Set magnet persistent current</td>
<td>45</td>
</tr>
<tr>
<td>IMAG?</td>
<td>Always</td>
<td>Query magnet current</td>
<td>45</td>
</tr>
<tr>
<td>IOUT?</td>
<td>Always</td>
<td>Query power supply output current</td>
<td>45</td>
</tr>
<tr>
<td>LLIM</td>
<td>Remote</td>
<td>Set low current sweep limit</td>
<td>46</td>
</tr>
<tr>
<td>LLIM?</td>
<td>Always</td>
<td>Query current sweep limit</td>
<td>46</td>
</tr>
<tr>
<td>LOCAL</td>
<td>Always</td>
<td>Return control to front panel (RS-232 Only)</td>
<td>46</td>
</tr>
<tr>
<td>MODE?</td>
<td>Always</td>
<td>Query selected operating mode</td>
<td>46</td>
</tr>
<tr>
<td>NAME</td>
<td>Remote</td>
<td>Set magnet coil name</td>
<td>47</td>
</tr>
<tr>
<td>NAME?</td>
<td>Always</td>
<td>Query magnet coil name</td>
<td>47</td>
</tr>
<tr>
<td>PSHTR</td>
<td>Remote</td>
<td>Control persistent switch heater</td>
<td>47</td>
</tr>
<tr>
<td>PSHTR?</td>
<td>Always</td>
<td>Query persistent switch heater state</td>
<td>47</td>
</tr>
<tr>
<td>QRESET</td>
<td>Remote</td>
<td>Reset quench condition</td>
<td>48</td>
</tr>
<tr>
<td>RANGE</td>
<td>Remote</td>
<td>Set range limit for sweep rate boundary</td>
<td>48</td>
</tr>
<tr>
<td>RANGE?</td>
<td>Always</td>
<td>Query range limit for sweep rate boundary</td>
<td>48</td>
</tr>
<tr>
<td>RATE</td>
<td>Remote</td>
<td>Set sweep rate for selected sweep range</td>
<td>49</td>
</tr>
<tr>
<td>RATE?</td>
<td>Always</td>
<td>Query sweep rate for selected sweep range</td>
<td>49</td>
</tr>
<tr>
<td>REMOTE</td>
<td>Operate</td>
<td>Select remote operation (RS-232 Only)</td>
<td>49</td>
</tr>
<tr>
<td>RWLOCK</td>
<td>Operate</td>
<td>Select remote operation with front panel lock (RS-232 Only)</td>
<td>50</td>
</tr>
<tr>
<td>SHIM</td>
<td>Remote</td>
<td>Select shim to be queried or changed (shim option only)</td>
<td>50</td>
</tr>
<tr>
<td>SHIM?</td>
<td>Always</td>
<td>Query shim selection (shim option only)</td>
<td>50</td>
</tr>
<tr>
<td>SLIM?</td>
<td>Always</td>
<td>Query current limit for selected shim (shim option only)</td>
<td>51</td>
</tr>
<tr>
<td>SLIM</td>
<td>Remote</td>
<td>Set current limit for selected shim (shim option only)</td>
<td>51</td>
</tr>
<tr>
<td>SWEEP</td>
<td>Remote</td>
<td>Start output current sweep</td>
<td>51</td>
</tr>
<tr>
<td>SWEEP?</td>
<td>Always</td>
<td>Query sweep mode</td>
<td>52</td>
</tr>
<tr>
<td>ULIM</td>
<td>Remote</td>
<td>Set current sweep upper limit</td>
<td>52</td>
</tr>
<tr>
<td>ULIM?</td>
<td>Always</td>
<td>Query current sweep upper limit</td>
<td>52</td>
</tr>
<tr>
<td>UNITS</td>
<td>Remote</td>
<td>Select units</td>
<td>52</td>
</tr>
<tr>
<td>UNITS?</td>
<td>Always</td>
<td>Query selected units</td>
<td>53</td>
</tr>
<tr>
<td>Command</td>
<td>Availability</td>
<td>Description</td>
<td>Related Commands</td>
</tr>
<tr>
<td>---------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>CHAN?</td>
<td>Always</td>
<td>Query the currently selected module</td>
<td>CHAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>CHAN?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The CHAN? query returns the power module currently selected for remote commands. It returns 1 or 2. A command error is returned if only one module is installed.</td>
<td></td>
</tr>
</tbody>
</table>

Command Reference

This section describes how each 4G 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).
CHAN Set the module for subsequent remote commands
Availability: Remote Mode
Command Syntax: CHAN [module number]
Example: CHAN 2
Default Parameter: none Parameter Range: 1 to 2
Description: The CHAN command selects the module for subsequent remote commands. A command error is returned if only one module is installed.
Related Commands: CHAN?

ERROR Set error response mode for USB interface
Availability: Remote 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 USB interface is used. It is much easier to handle errors under program control when using the USB 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 4G.
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
**IMAG?**  
Query magnet current (or magnetic field strength)

**Availability:** Always

**Command Syntax:** IMAG?

**Response:** <Magnet Current> <Units>

**Response Example:** 87.9350 A

**Description:** The IMAG? query returns the magnet current (or magnetic field strength) in the present units. If the persistent switch heater is ON the magnet current returned will be the same as the power supply output current. If the persistent switch heater is off, the magnet current will be the value of the power supply output current when the persistent switch heater was last turned off. The magnet current will be set to zero if the power supply detects a quench. If in SHIM mode, the IMAG? query reports the present current of the shim selected by the SHIM command in Amps. If the optional Shim ID is provided while in shim mode, the present current of the specified shim will be reported.

**Related Commands:** UNITS, UNITS?

---

**IMAG**  
Sets the magnet current (or magnetic field strength).

**Availability:** Remote Mode

**Command Syntax:** IMAG [value]

Example:
- IMAG 47.1123
- IMAG X2 -13.4571 (shim mode only)

**Default Parameter:** 0.0  
**Parameter Range:** ±Maximum Magnet Current

**Description:** The IMAG command sets the magnet current shown on the display. The supply must be in standby or a command error will be returned. The value must be supplied in the selected units - amperes or field (kG). If Shim Mode is enabled, the persistent mode current displayed for the named shim is set if the shim parameter is provided.

**Related Commands:** IMAG?

---

**IOUT?**  
Query power supply output current

**Availability:** Always

**Command Syntax:** IOUT?

**Response:** <Output Current> <Units>

**Response Example:** 87.935 A

**Description:** The IOUT? query returns the power supply output current (or magnetic field strength) in the present units.

**Related Commands:** UNITS, UNITS?
**LLIM**  
Set current sweep lower limit  
**Availability:** Remote Mode  
**Command Syntax:** LLIM [Limit]  
**Example:** LLIM 20.1250  
**Default Parameter:** 0.0  
**Parameter Range:** ±Maximum Magnet Current  
**Description:** The LLIM command sets the current limit used when the next SWEEP DOWN command is issued. The value must be supplied in the selected units - amperes or field (kG). An error will be returned if this value is greater than the upper sweep limit.  
**Related Commands:** LLIM?, ULIM, ULIM?, SWEEP, SWEEP?, UNITS, UNITS?

---

**LLIM?**  
Query current sweep lower limit  
**Availability:** Always  
**Command Syntax:** LLIM?  
**Response:** <Limit> <Units>  
**Response Example:** 20.1250 A  
**Response Range:** ±Maximum Magnet Current  
**Description:** The LLIM? query returns the current limit used with the SWEEP DOWN command. It is issued in the selected units - amperes or field (kG).  
**Related Commands:** LLIM, ULIM, ULIM?, SWEEP, SWEEP?, UNITS, UNITS?

---

**LOCAL**  
Return control to front panel  
**Availability:** Always (USB and Ethernet Only)  
**Command Syntax:** LOCAL  
**Description:** The LOCAL command returns control the front panel keypad after remote control has been selected by the REMOTE or RWLOCK commands.  
**Related Commands:** REMOTE, RWLOCK

---

**MODE?**  
Query selected operating mode  
**Availability:** Always  
**Command Syntax:** MODE?  
**Response:** <Operating Mode>  
**Response Example:** Manual  
**Response Range:** Shim or Manual  
**Description:** The MODE? command returns the present operating mode.  
**Related Commands:** MODE
NAME

Sets the name of the coil (magnet) on the display.

Availability: Remote Mode

Command Syntax: NAME <name string>

Example: NAME GUN COIL

Default Parameter: None  Parameter Range: 0 to 16 characters

Description: The NAME command sets the name of the currently selected module for display. Upper and lower case is accepted, however the string is converted to upper case.

Related Commands: NAME?

NAME?

Query the name of the currently selected coil (magnet)

Availability: Always

Command Syntax: NAME?

Response: 0 to 16 characters

Description: The NAME? query returns the name of the currently selected module.

Related Commands: NAME

PSHTR

Control persistent switch heater

Availability: Remote Mode

Command Syntax: PSHTR <State>

Example: PSHTR ON

Default Parameter: None  Parameter Range: On or Off

Description: The PSHTR command turns the persistent switch heater on or off. Note that the switch heater current can only be set in the Magnet Menu using the keypad. This command should normally be used only when the supply output is stable and matched to the magnet current. If in Shim Mode, the heater for the selected shim is controlled instead of the main switch heater.

Related Commands: PSHTR?

PSHTR?

Query persistent switch heater state

Availability: Always

Command Syntax: PSHTR?

Response: 0 or 1

Description: The PSHTR? query returns 1 if the switch heater is ON or 0 if the switch heater is OFF. If in Shim Mode, the status of the switch heater for the selected shim is returned.

Related Commands: PSHTR

QRESET

Reset Quench Condition
Availability: Remote Mode
Command Syntax: QRESET
Description: The QRESET command resets a power supply quench condition and returns the supply to STANDBY.
Related Commands: None

---

RANGE
Set range limit for sweep rate boundary
Availability: Remote
Command Syntax: RANGE <Select> <Limit>
Example: RANGE 0 25.0
Default Parameter: None Parameter Ranges:
  Range Selection: 0 to 4
  Limit: 0 to Max Supply Current
Description: The RANGE command sets the upper limit for a charge rate range in amps. Range 0 starts at zero and ends at the limit provided. Range 1 starts at the Range 0 limit and ends at the Range 1 limit provided. Range 2 starts at the Range 1 limit and ends at the Range 2 limit provided. Range 3 starts at the Range 2 limit and ends at the Range 3 limit provided. Range 4 starts at the Range 3 limit and ends at the supply output capacity.
Related Commands: RANGE?, RATE, RATE?

---

RANGE?
Query range limit for sweep rate boundary
Availability: Always
Command Syntax: RANGE? <Select>
Example: RANGE? 1 Parameter Range: 0 to 4
Response: <Limit>
Response Example: 75.000 Response Range: 0 to Max Magnet Current
Description: The RANGE? query returns the upper limit for a charge rate range in amps. See RANGE for further details.
Related Commands: RANGE, RATE, RATE?
RATE

Set sweep rate for selected sweep range

Availability: Remote

Command Syntax: RATE <Range> <Sweep Rate>

Example: RATE 0 0.250

Default Parameter: None

Parameter Ranges:
Range Selection: 0 to 5
Limit: 0 to Max Magnet Current

Description: The RATE command sets the charge rate in amps/second for a selected range. A range parameter of 0, 1, 2, 3, and 4 will select Range 1, 2, 3, 4, or 5 sweep rates as displayed in the Rates Menu. A range parameter of 5 selects the Fast mode sweep rate.

Related Commands: RANGE, RANGE?, RATE?

RATE?

Query range limit for sweep rate boundary

Availability: Always

Command Syntax: RATE? <Range>

Example: RATE? 1 Parameter Range: 0 to 5

Response: <Rate>

Response Example: 0.125 Response Range: 0 to Max Magnet Current

Description: The RATE? command queries the charge rate in amps/second for a selected range. A range parameter of 0 to 4 will select Range 1 through 5 sweep rates as displayed in the Rates Menu. A range parameter of 5 queries the Fast mode sweep rate.

Related Commands: RANGE, RANGE?, RATE

REMOTE

Select remote operation

Availability: Operate (USB Only)

Command Syntax: REMOTE

Description: The REMOTE command takes control of the 4G via the remote interface. All buttons on the front panel are disabled except the Local button. This command will be rejected if the menu system is being accessed via the front panel or if LOCAL has been selected via the Local button on the front panel. Pressing the Local button again when the menu is not selected will allow this command to be executed. This command is only necessary for USB operation since the IEEE-488 interface provides for bus level control of the Remote and Lock controls.

Related Commands: LOCAL, RWLOCK
**RWLOCK**
Select remote operation

**Availability:** Operate (USB Only)

**Command Syntax:** RWLOCK

**Description:** The REMOTE command takes control of the 4G via the remote interface. All buttons on the front panel are disabled except the Local button. This command will be rejected if the menu system is being accessed via the front panel or if LOCAL has been selected via the Local button on the front panel. Pressing the Local button again when the menu is not selected will allow this command to be executed. This command is only necessary for USB operation since the IEEE-488 interface provides for bus level control of the Remote and Lock controls.

**Related Commands:** LOCAL, RWLOCK

---

**SHIM**
Select SHIM to be controlled or queried

**Availability:** Remote Mode (Shim mode only)

**Command Syntax:** SHIM [Enable or Disable] <Selection>

**Examples:**
- SHIM Z4  SHIM Enable All
- SHIM Enable Z3  SHIM Disable All
- SHIM Disable Z3

**Default Parameter:** None

**Parameter Range:** Z, Z2, Z3, Z4, X, Y, ZX, ZY, C2, S2, Z2X, Z2Y

**Description:** The SHIM command selects a shim to be controlled or queried. It also allows selected shims or all shims to be disabled or enabled. The command is only valid when operating in SHIM mode. The switch heater must be off when making a shim selection.

**Related Commands:** IMAG?, SHIM?, SLIM, SLIM?

---

**SHIM?**
Query SHIM selection

**Availability:** Always (Shim mode only)

**Command Syntax:** SHIM? [Query selection]

**Response:** <Shim selection> <Enabled or Disabled>

**Response Example:** ZX Enabled

**Response Range:** Z, Z2, Z3, Z4, X, Y, ZX, ZY, C2, S2, Z2X, Z2Y

**Description:** The SHIM? command identifies the shim selected to be controlled or queried, and reports the enable/disable status. If the optional Shim ID is provided as a parameter, the command reports the enable/disable status of the specified shim. The command is only valid when operating in SHIM mode.

**Related Commands:** IMAG?, SHIM, SLIM, SLIM?
**SLIM**

Set current limit for selected shim

**Availability:** Remote Mode (Shim mode only)

**Command Syntax:** SLIM <Limit>

**Example:** SLIM –5.837

**Default Parameter:** 0.0  
**Parameter Range:** ±30.000

**Description:** The **SLIM** command sets the current limit for the selected shim. The command is only valid when operating in SHIM mode with the persistent switch heater off. The maximum value for the current limit is set in the setup screen of the main menu when in Manual mode. The **SWEEP** command is used to sweep the power supply to the target current of the selected shim.

**Related Commands:** IMAG?, SHIM?, SLIM, SLIM?, SWEEP

---

**SLIM?**

Query current limit for selected shim

**Availability:** Always (Shim mode only)

**Command Syntax:** SLIM?

**Response:** <Limit> A

**Response Example:** 5.923 A  
**Response Range:** ±30A (See 4.3.5.4)

**Description:** The **SLIM?** Query returns the current limit used when the next **SWEEP UP** or **SWEEP DOWN** command is issued.

**Related Commands:** IMAG?, SHIM, SLIM, SLIM?, SWEEP

---

**SWEEP**

Start output current sweep

**Availability:** Remote Mode

**Command Syntax:** SWEEP <Sweep Mode> [fast or slow]

**Examples:**

SWEEP UP

SWEEP UP FAST

**Default Parameter:** None  
**Parameter Range:** UP, DOWN, PAUSE, or ZERO

**Shim Mode Only:** LIMIT

**Description:** The **SWEEP** command causes the power supply to sweep the output current from the present current to the specified limit at the applicable charge rate set by the range and rate commands. If the FAST parameter is given, the fast mode rate will be used instead of a rate selected from the output current range. SLOW is required to change from fast sweep. **SWEEP UP** sweeps to the Upper limit, **SWEEP DOWN** sweeps to the Lower limit, and **SWEEP ZERO** discharges the supply. If in Shim Mode, **SWEEP LIMIT** sweeps to the shim target current.

**Related Commands:** LLIM, LLIM?, SLIM, SLIM?, SWEEP?, ULIM, ULIM?, UNITS, UNITS?
**SWEEP?**

Query sweep mode

**Availability:** Always

**Command Syntax:** SWEEP?

**Response:** <Mode> [fast]

**Response Example:** sweep up fast

**Response Range:** sweep up, sweep down, sweep paused, or zeroing

**Description:** The **SWEEP?** query returns the present sweep mode. If sweep is not active then 'sweep paused' is returned.

**Related Commands:** LLIM, LLIM?, SLIM, SLIM?, SWEEP, ULIM, ULIM?, UNITS, UNITS?

---

**ULIM**

Set current sweep upper limit

**Availability:** Remote Mode

**Command Syntax:** ULIM [Limit]

**Example:** ULIM 65.327

**Default Parameter:** 0.0

**Parameter Range:** ±Maximum Supply Current

**Description:** The **ULIM** command sets the current limit used when the next **SWEEP UP** command is issued. The value must be supplied in the selected units - amperes or field (kG). An error will be returned if this value is less than the lower sweep limit.

**Related Commands:** LLIM, LLIM?, SWEEP, SWEEP?, ULIM, ULIM?, UNITS, UNITS?

---

**ULIM?**

Query current sweep upper limit

**Availability:** Always

**Command Syntax:** ULIM?

**Response:** <Limit> <Units>

**Response Example:** 65.327 A

**Response Range:** ±Maximum Supply Current

**Description:** The **ULIM?** query returns the current limit used for the **SWEEP UP** command. It is issued in the selected units - amperes or field (kG).

**Related Commands:** LLIM, LLIM?, SWEEP, SWEEP?, ULIM, ULIM?, UNITS, UNITS?

---

**UNITS**

Select units

**Availability:** Remote Mode

**Command Syntax:** UNITS <Unit Selection>

**Example:** UNITS A

**Parameter Range:** A, G

**Description:** The **UNITS** command sets the units to be used for all input and display operations. Units may be set to Amps or Gauss. The unit will autorange to display Gauss, Kilogauss or Tesla.

**Related Commands:** IMAG?, IOUT?, LLIM, LLIM?, ULIM, ULIM?, UNITS?
**UNITS?**

Query selected units

**Availability:** Always

**Command Syntax:** UNITS?

**Response:** <Selected Units>

**Response Example:** G  
**Response Range:** A, G

**Description:** The UNITS? command returns the units used for all input and display operations.

**Related Commands:** IMAG?, IOUT?, LLIM, LLIM?, ULIM, ULIM?, UNITS

---

**VLIM**

Set voltage limit

**Availability:** Remote Mode

**Command Syntax:** VLIM <Voltage Limit>

**Example:** VLIM 5.0  
**Parameter Range:** 0.0 to 10.0

**Description:** The VLIM command sets the power supply output voltage limit to the voltage provided.

**Related Commands:** VLIM?, VMAG?, VOUT?

---

**VLIM?**

Query voltage limit

**Availability:** Always

**Command Syntax:** VLIM?

**Response:** <Voltage Limit>

**Response Example:** 4.75 V  
**Response Range:** 0 to 10.00

**Description:** The VLIM? command returns the power supply output voltage limit.

**Related Commands:** VLIM, VMAG?, VOUT?

---

**VMAG?**

Query magnet voltage

**Availability:** Always

**Command Syntax:** VMAG?

**Response:** <Magnet Voltage>

**Response Example:** 4.75 V  
**Response Range:** -10.00 to +10.00

**Description:** The VMAG? command returns the present magnet voltage.

**Related Commands:** VLIM, VLIM?, VOUT?
VOUT?  Query output voltage
Availability:  Always
Command Syntax:  VOUT?
Response:  <Output Voltage>
Response Example:  4.75 V  Response Range:  -12.80 to +12.80
Description:  The VOUT? command returns the present power supply output voltage.
Related Commands:  VLIM, VLIM?, VMAG?

*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. The User Request bit is set any time the Local or Menu buttons on the front panel are depressed. The remaining bits are defined in the referenced standard.

Status Byte Bit Allocations:

<table>
<thead>
<tr>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
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<th>0</th>
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<td></td>
<td></td>
<td>User Request</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Power On</td>
</tr>
</tbody>
</table>

Related Commands:  
*ESE, *ESE?

---

*IDN?  
Identification Query

Availability:  
Always

Command Syntax:  
*IDN?

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

Response Example:  
Cryomagnetics,4G,2239,1.02,208

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 4G manufacturer, model, serial number, firmware level and build 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 4G 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 4G 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 but does not change the power supply operation due to safety concerns.
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.

<table>
<thead>
<tr>
<th>Status Byte Bit Allocations:</th>
</tr>
</thead>
<tbody>
<tr>
<td>X X X X X X X X</td>
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<td></td>
</tr>
</tbody>
</table>

*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 4G only implements sequential commands the no-operation-pending flag is always TRUE.

Related Commands:  OPC, *OP
Appendix C

Calibration

There are currently no calibrations of the 4G power supply that can be made by the user. Should calibration of the supply be required, please contact Cryomagnetics for assistance.
Appendix D

Shut-down Input

The rear panel Shut-down input can be configured to accept a +5V signal, +24V signal, or a contact closure to put the supply into shutdown. During shutdown, the output power modules sweep to zero current at the programmed rate, and commands that affect module operation (sweep, limits changes, etc.) are inhibited, both on the keyboard and computer interfaces. The status words SHUTDOWN COMMAND will show on the display as long as the input is active. When deactivated, the commands are re-enabled, however the modules will continue to sweep the current to zero at the programmed rate unless intervened.

To configure the interface, disconnect the power and remove the top cover of the 4G by removing six screws from the top cover (the center front screw is not currently attached internally), and the three screws from the lip of the cover in the rear.

Locate the communication module on the rear panel of the unit. On it are four 3-pin headers labeled H1 through H4, each with two possible positions – ON and OFF. Use the following matrix to configure the interface, by moving the shorting jumpers to the correct positions. Jumpers not labeled ON must be in the OFF position, or left off altogether.

<table>
<thead>
<tr>
<th></th>
<th>24V MODE</th>
<th>5V MODE</th>
<th>SWITCH MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>H2</td>
<td>ON</td>
<td>ON</td>
<td></td>
</tr>
<tr>
<td>H3</td>
<td></td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>H4</td>
<td></td>
<td></td>
<td>ON</td>
</tr>
</tbody>
</table>

Table 3. Shutdown Input Configuration

CAUTION: Configurations other than the above could damage the board.

Shut Down Input Electrical Specifications:

5V - Polarity insensitive, optically isolated, approx. 10mA drawn from 5V source.

24V - Polarity insensitive, optically isolated, approx. 10mA drawn from 24V source.

Switch Contact - Non-isolated, 4.3V open circuit, approx. 10mA passed through the switch.

Positive terminal is on the left.
Appendix E

Paralleling Power Modules

The 4G Dual consists of two independent power supplies with a common front panel and power input module. The dual 100A unit has been tested with the outputs connected in parallel to provide a 200A output capability. This appendix address issues specific to operation in parallel.

Connect one current lead of the load to each module, then connect the remaining modules’ terminals together as follows:

Figure 14. Parallel Supply Connections

This balances the lead resistance seen by each module, and will provide better current sharing if wall power is lost and the magnet is discharged in the power fail mode.

Now set the lower limit on one supply to 0.0A, and sweep it to the low limit to bring it on-line at zero amps. Then set the upper limit on the second supply, and sweep it to its high limit. The supplies can be swept together or staggered, but in either case, you must set up the charge rates on each according to that configuration, keeping in mind what each supply is putting out at what time, so the magnet sees the proper combined charge rate vs current.

If the supplies are swept together, it is better not to pause both supplies at the same time, since interaction may be seen.

When discharging, both supplies should be swept to a limit of 0.0A rather than using the sweep-to-zero function. This is because both supplies need to be active at 0.0A before entering standby.
After reaching zero, both supplies can be swept-to-zero to enter standby.
Appendix F

Revision History

FRONT PANEL Firmware

Panel ver. 1.14 Build 247 – 02/16/10

Released Shim option support.

Panel ver. 1.13 Build 241 – 09/30/09

Rebuilt with a new compiler release to eliminate a GPIB related build problem in ver 1.12.

Panel ver. 1.12 Build 240 – 08/12/09

Send Rate, Range, and Voltage Limits to the power module when updated remotely.

Panel ver. 1.11 Build 238 – 06/02/09

Support Field-to-Current ratios from 0.001 to 3000.0. Fixed communication issue with power module. Extended watchdog to 4.5 seconds to tolerate LCD panel delays.

Panel ver. 1.10 Build 236 – 01/02/09

Reconfigure FPGA on EEPROM read failure to eliminate power cycling the 4G after a gyrotron arc.

Panel ver. 1.10 Build 235 – 12/17/08

Added watchdog logic for module communications, panel communications and fan control tasks. Fixed a reentrancy problem and module communication problem. Requires module firmware of R1.16.

Panel ver. 1.02 Build 208 initial release.

Hardware Revisions

Beginning with panel PCB version 3, the unit may have the panel software updated without removing the top cover. To do this, press and hold <Shift> and the top soft key while applying power to the unit. The Current Present in Leads indicators will be bright yellow while in the programming mode. Follow the panel firmware upgrade instructions minus removing the cover and positioning the jumper. To exit the programming mode, power the unit down.
POWER MODULE REVISIONS

Power Module Rev 2.05 – 02/12/10
  Modified Master/Slave logic to allow recovery from power failures and to pause with high inductive load. Enhanced recovery logic for both 100A and 200A configurations.

Power Module Rev 2.04 – 11/18/09
  Modified thermal limiting logic to allow higher discharge rates.

Power Module Rev 2.03 – 07/18/08
  Further refinements for sweep convergence. Upgraded range and inductance commands for master/slave configuration.

Power Module Rev 2.02 – 01/24/09
  Shutdown Vicor on unsafe temperature. Includes master/slave support for 200A.

Power Module Rev 1.16 – 07/18/08
  Tuned sweep algorithm when on voltage limit.
Appendix G

Firmware Upgrading

Upgrades may be done to either the main operating firmware and/or the power module firmware.

To upgrade the main operating firmware, first obtain the upgrade files from Cryomagnetics. You will need:
- New firmware binary file.
- The Flashit programming software.
- FTDI virtual COM port software (if not already installed)

Tools needed:
- Phillips head screwdriver.
- USB cable.

Leave the unit powered off until you complete these first two steps.

Remove the top cover. It is secured by five screws on the top and three screws on the cover's lip in the rear of the unit.

Locate the circuit board attached to the instrument's front panel. At the top near the center is a small slide switch labeled PROG and RUN. Place this switch in the PROG position.

Power ON the unit. The display will show the Cryomagnetics logo but otherwise will be blank.

If you already have the FTDI virtual COM port drivers installed on your PC: When the 4G Supply is connected to the computer's USB port, the computer will enumerate it as a new COM port without running the Found New Hardware wizard. In that case, just go to the control panel/hardware manager and note what COM port it is assigned to.

If you do not have the FTDI virtual COM port drivers installed on your PC: The 4G Supply requires FTDI virtual COM port drivers on the PC to communicate. If they are not installed on your PC, when the 4G is connected to the computer's USB port the PC will begin running the Found New Hardware wizard.
On a new install, do the following. These steps were written for Windows XP:

1) Connect the 4G to the computer via the USB cable.
2) The computer should find the new hardware.

Select No, not this time, then click Next >.

Tell the wizard to Install from a list or specific location (Advanced) and click Next >
Browse to the folder containing the virtual COM port software and then click Next >

The first step is completed when you press Finish.
At this point the wizard will run a second time.
Follow the same steps as before.

Select Install from a list of specific location (Advanced), then click Next >

Browse to the folder containing the virtual COM port files, then click Next >
Click Finish to complete the COM port driver installation.
Setting up 4G Supply Communications:
To set up communications between your PC and the 4G Supply, open Control Panel and note which COM port was assigned when the 4G was connected.

You can right-click the COM port to change the assignment if necessary.

Note: The FLASHIT program may not be able to find COM port if the ports are not contiguous. For example, if you have COM1 and COM2, and the 4G enumerates as a COM4, FLASHIT may not see it. This is an open issue.
Installing FlashIt.

The FlashIt program is required on your PC to install new firmware into the 4G Supply. To install the program, run the _____ installation software.

Select Next >, then accept the EULA.
It is recommended that you use the default install file location, then click Next >
Install the program and run it.
When Flashlt starts up, it attempts to find the 4G (Rabbit processor) on its selected COM port. If it is successful, the above details are shown. If not, you get the below.
Go to Options and select Detect. The program will search all available COM ports for the 4G. If that is unsuccessful, go to Options, Serial, and select the 4G's COM port.

At this point you should be connected to the 4G. Click on the Folder Icon. Browse for the 4G binary file and select it.
Press the center button to begin the upload.

When complete, the following is displayed. You may now exit FlashIt.

Done. 161579 bytes written and verified.

100%
Turn off the 4G. Put the Program/Run switch into the RUN position. Replace the top cover.

When you power the unit on, you will see a software upgrade message on the 4G if the software version number is higher than the previous. The unit is configuring memory with added parameters. Existing parameters are not affected. You will need to review the new parameters for your application.

It is also permissible to DOWNGRADE to a lower version. In this case, you will get a warning saying SOFTWARE ROLLBACK TO vX.XX SOME SETTINGS WILL BE LOST. <ENTER> TO CONTINUE

Press ENTER to continue with the downgrade. If you do not desire to downgrade, turn the unit off without continuing and reinstall the previous version. If you press continue, the parameters that do not exist in the downgrade version will be lost.
Upgrading power module firmware

Connect the 4G to the USB port, and open a terminal program on the PC. Set the port to that of the 4G. Set the port to 115200 baud, 8 bits, 1 stop bit, no parity. Make sure the program is not set to automatically add characters such as line feeds to the outgoing string. It may be useful to turn on local echo as the modules do not echo characters.

From the main menu on the 4G, enter the following code: <decimal point>48295511. If this is a dual unit, you will have to select a supply first to get to SETUP. A single unit has the SETUP key on the main menu.

Select GENERAL.

You should now be on the Power Module Connection Manager screen. Select the module you want to upgrade. Even on the single module units, this selection must be made.

Press LOAD. If the module is functioning, you should see 'Direct USB load mode entered' at the bottom.

In the terminal program, type ver?<return>. You should get a response similar to 1.13 1.09. The first number is the active firmware version, and the second number is the backup version.

If the two numbers are different, it is recommended that you back up the current version, by typing vback<return>. This copies the current version into the backup location. This way, if the new version fails to load, or there are issues with the new version, you can fall back to the older one.

Type vload<return>
There is no response.

Locate the upgrade file for the module. Open the 'Send File' dialog of your terminal program and browse to the file and send it. When it is done, type ver?<return> If the load was successful, you will now see the new version listed first.

If your terminal program does not have a proper file send function, you can open the upgrade file with a text editor, copy the contents, and paste them into the terminal window.
Press EXIT on the front panel. The supply will now restart with the new version operational.

If there is no response to ver?<return> after sending the file, or ver?<return> returns 0 in the first position, the load has failed. Press NORMAL on the front panel, ignore any error message, then press LOAD again. Either repeat the load process or type vrestore<return>. vrestore<return> will activate the old firmware.
Appendix H
Shim Supply Option

H.1. Overview
The Shim Supply Option for the 4G Power Supply is a hardware and software upgrade that provides the user with the capability to control up to 12 independent superconducting shim coils in addition to the main superconducting magnet. Typical applications for this option are high homogeneity ICR or NMR magnets that incorporate superconducting shims to adjust and optimize central field shape.

Superconducting shim coils are, in effect, complete and self-contained superconducting magnets. Each consists of its own set of windings, its own persistent switch, and its own quench protection circuits. The coils are used to superimpose known magnetic field gradients over the homogeneous region of a magnet to correct for error components. Figure H.1 shows schematically a typical magnet with four superconducting shims (Z, Z₂, X, and Y). These shims are typically referred to as “first order shims”, although technically Z₂ generates a second order effect.

Figure 15 - Superconducting Magnet with Shims

A comprehensive overview of superconducting shims and shimming is beyond the scope of this Appendix. Considerable documentation exists that describes in detail the various inhomogeneities.
in magnetic fields and how to correct them. The purpose of this Appendix is to give a description of how the Shim Supply Option for the 4G Power Supply works, how to connect the Shim Supply Option to a magnet system, how to set up the supply, and how to operate the supply in SHIM mode.

H.2. Shim Option Description
The 4G power supply shim supply option allows the operator to use the 4G for energizing and discharging multiple superconducting shim coils. The option provides the following features:

a) 12 persistent switch heater output channels.
b) Polarity selection to allow shim multiplexing.
c) 0 – 100mA heater current range.
d) +/- 30 amp output current range.
e) Automatic shim dumping during main coil energizing/discharging.
f) Independent shim heater enable/disable.

The shim supply option provides the operator with 12 persistent switch heater output channels that are independently controllable through the menus of the 4G. The heater outputs may be configured in either “standard” or “multiplexed” arrangement. In the “standard” arrangement, each output channel corresponds to its own shim persistent switch heater. A common return (ground) line is used for all switches. This configuration is directly compatible with Figure H.1 above.

Some superconducting magnet systems utilize a multiplexed heater arrangement to reduce the number of heater wires necessary to operate the shims. A multiplexed heater arrangement is shown schematically in Figure H.2. Using a simple diode arrangement inside the magnet system, the number of heater wires is reduced by switching polarity of the heater signal to select the appropriate shim. For instance, positive output current on the Z/Z2 line activates the heater on the Z shim, while negative output current activates the heater on the Z2 shim. For multiplexed shim heater systems, the 4G Shim Supply Option offers the flexibility to be configured according to the user’s needs. Shims may be mapped to any of the outputs, and may have either positive or negative polarity.
When the 4G Shim Supply Option is activated, the 4G uses its main current outputs to set the shim coil current. In shim mode the supply is software limited to a maximum current output. The current limit for each shim, the persistent switch heater current for each shim, and its overall status (enabled or disabled) is controlled through the menu system via the front panel keys.

While the 4G is operating in Manual Mode (the standard mode used when energizing the main superconducting magnet), the Shim Supply Option will periodically activate the persistent switch heater of each enabled shim coil for a few seconds to “dump” any current that has been induced in the coil due to coupling (mutual inductance) between the main coil and the shim coil. Without periodic dumping of current induced in superconducting shim coils, current would build to values sufficient to quench the shim coil and possibly the main coil.

Once the main coil has been energized, the user typically will change from Manual Mode to Shim Mode with the 4G. In most systems, changing from main coil energizing to shim coil energizing requires the user to change to a different set of current leads.
H.3. Setup

The 4G shim supply option is designed for ease of use and to allow the user to set shim coils using a minimum of keystrokes. It provides considerable flexibility in setup and operation. There are built-in interlocks that reduce the risk of accidental dumping of a shim or quenching of a coil. However, it is still necessary for the operator to be familiar and experienced with shimming to reduce the chance of errors. It is highly recommended that the operator familiarize himself with the operation of the 4G shim supply option PRIOR to connecting it to an operating superconducting magnet.

H.3.1. MANUAL Mode

Mutual inductance coupling between shim coils and the main superconducting coil is inevitable. Due to this coupling, if the main coil is energized or discharged while the shim coils are in persistent mode, significant current can be induced in the shim coils. If this current is not periodically “dumped” during the main coil charge cycle, it can build to the point where a quench of the shim coil and/or the main coil occurs.

The 4G shim supply option is designed to periodically scan through the shims installed in the system to dump the current induced in them during main coil charge or discharge. Dumping a shim coil involves activating the persistent switch heater on the shim coil for a period of several seconds. By effectively quenching the persistent switch, the loop is “opened” and any current induced in the coil is converted to heat and is dissipated. While dumping shim coils it is usually a good idea to connect a low resistance (~ 5 ohms) load across the main current leads on the shim coils to prevent large voltage spikes from occurring.

The 4G shim option will step through each of the 12 shim coil heater outputs in the system. The unit activates each heater for approximately 6 seconds – long enough for the persistent switch to change to its “normal” state. Scanning of the shim coil heaters to dump them during main coil energizing or discharge may be inhibited by activating the global inhibit command while in manual mode.

H.3.2. SHIM Mode

The “Shim Mode” setting in the General Menu of the 4G is used to toggle the supply between MANUAL and SHIM modes. The user must have the 4G in an idle (STANDBY) state before a change from MANUAL to SHIM mode will be allowed. Likewise, returning from SHIM mode to MANUAL mode will be allowed only if all shims in the system are either dumped or disabled and the supply is in an idle (STANDBY) state. The “Shim Mode” setting only appears in the General Menu when these conditions are met.
The main operating display of the 4G while in SHIM mode is similar to the main operating display in MANUAL mode. When in SHIM mode, the selected shim coil appears in the top right corner of the display, and the status of the enabled shims appears below the main portion of the display with the selected shim highlighted. The display indicates the present status of all enabled shim coils in the system.

![SHIM Mode Operating Display](image)

When operating in SHIM mode as indicated in Figure H.4, the [Down] or [Shift-Up] softkey may be used to select the desired shim. Disabled shims do not appear in the list. If the currently selected shim is active (persistent switch heater ON), changing to another shim is inhibited. While in the Shim Mode Operating Display, the selected shim is the only shim enabled for control and adjustment. The selected shim's persistent switch may be activated, the shim may be swept up to the indicated current limit, the persistent switch heater may be turned off, and the supply may be swept back to zero output current leaving the shim in persistent mode at the desired current. All operations are identical to those found in the operation of the main superconducting magnet in MANUAL mode. Refer to paragraph H.4 for detailed operating instructions.

### H.3.3. Setup Menu

Pressing the [Setup] softkey activates the Shim Setup Menu. This display shows the limit current and present current setting for each shim, the output channel and polarity, the enable status, and the programmed heater current. This menu gives access to the General Menu and Info Menu described in the main section of the manual, and gives access to the Shim Edit menu.
H.3.4. Edit Menu

The Shim Edit Menu is invoked by pressing the [Edit] softkey in the Shim Setup Menu. The Shim Edit Menu is indicated in Figure H.6. Target Current, Present Current, Output Channel and Polarity, Enable/Disable, and Persistent Switch Heater Current are fields that may be edited. The [Down], [Shift-Up], [Right], and [Shift-Left] softkeys may be used to select the desired field.

If the shim name field is selected, the order the shims appear on the display may be changed by pressing [Move], [Up] or [Shift-Down], and finally [Change] to complete the action. A move may be cancelled by pressing the [ESC] key on the keypad.

When a field is selected for editing by the arrow keys, the desired value is entered on the keypad. The change is accepted by pressing the [Save] softkey, or cancelled by pressing the [ESC] key. A shim is enabled or disabled by selecting the field and toggling the value with the [Change] softkey, and accepting the result with the [Save] softkey.
The “Limit” field is the current limit that will be used when operating the shim coil.

The “Setting” field is the value of current the 4G believes has been left in the shim coil when it was last put into persistent mode. This is an editable field since it is possible for a quench of the shim to occur without the 4G detecting it. If this happens, the user may manually reset the present current value to zero.

The “Chan” field allows the user to map the shim to a specified output channel and with a specified polarity. Valid output channels are 1 through 12 with either + or – polarity. If the user attempts to exit the Edit Menu with more than one shim set to a channel/polarity already occupied by another shim, the changes in the edit session cannot be saved. The changes may only be discarded, or the edit session may be continued to correct the errors.

The “Heater” field allows a particular shim coil to be enabled or disabled. This may be used when the particular shim is not present in the system, or when the user wishes to disable it to lock it down and prevent dumping of the shim during main coil field changes.

The “I-Htr” field is the persistent switch heater current for the particular shim. This current may be anywhere from 0 to 100 milliamps. The current value, along with the channel polarity, determines the polarity and magnitude of the persistent switch heater current applied to the specified channel when the shim is selected. If only six shim outputs are used, the heater current is allowed to be set
up to 150 milliamps, which requires two shim outputs to be wired in parallel. The paired outputs must be 1/7, 2/8, 3/9, 4/10, 5/11, and 6/12. The firmware assumes the outputs are paralleled if a current greater than 100 milliamps is entered for the switch heater current.

H.3.5. Hardware Connections
Connection of the 4G Shim Option to the shim coil persistent switch heaters is done through a DB-15 connector on the rear panel of the supply. Main output current to the shim coils is provided through the high current output terminals. Figure H.7 indicates wiring assignments.

Figure 20 - Superconducting Shim Persistent Switch Heater Connections

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Function</th>
<th>Pin #</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Channel 1</td>
<td>9</td>
<td>Channel 7</td>
</tr>
<tr>
<td>2</td>
<td>Channel 2</td>
<td>10</td>
<td>Channel 8</td>
</tr>
<tr>
<td>3</td>
<td>Channel 3</td>
<td>11</td>
<td>Channel 9</td>
</tr>
<tr>
<td>4</td>
<td>Channel 4</td>
<td>12</td>
<td>Channel 10</td>
</tr>
<tr>
<td>5</td>
<td>Channel 5</td>
<td>13</td>
<td>Channel 11</td>
</tr>
<tr>
<td>6</td>
<td>Channel 6</td>
<td>14</td>
<td>Channel 12</td>
</tr>
<tr>
<td>7</td>
<td>Common</td>
<td>15</td>
<td>Common</td>
</tr>
<tr>
<td>8</td>
<td>Common</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H.4. Operation
Once the shims have been set up through the menus of the 4G and all connections are made to the persistent switch heaters and main current leads, the system is ready to operate. The 4G power supply shim supply option is intuitive and designed for ease of use.

H.4.1. Energizing Shims
When starting with fully dumped shims and with the 4G in SHIM mode (main operating display as indicated in Figure H.4), the user will typically perform the following sequence of events to set the selected shim.

Procedure for Initial Setting of Shim Coil Currents
a) Use the [Down] or [Shift-Up] softkey to select the first shim to be set.
   b) Press the [Pers Htr] softkey and [Confirm Htr On] softkey to confirm and turn ON the persistent switch heater.
   c) Wait about 10 seconds for the persistent switch to warm.
d) Press the [Limit] softkey to begin energizing the shim coil. The 4G will begin sweeping in
the direction of the requested current limit. Once the limit is reached, the 4G will hold that
current.

e) Press the [Pers Htr] softkey and [Confirm Htr Off] softkey to confirm and turn OFF the
persistent switch heater.

f) Wait about 10 seconds for the persistent switch to cool.

g) Press the [Zero] key to bring the current in the power leads back to zero. [Shift-Zero] may
be used to more quickly return to zero if desired.

After completing the sequence, the operator will use the [Up] or [Shift-Down] softkey to change to
the next shim coil. The procedure will be repeated to set this shim coil current. Likewise all other
shims are set. Once a first pass setting of each shim coil has been made, typically a second pass
is made through the shims to minimize the effects of mutual inductance coupling from shim-to-shim.
In the second and subsequent passes, the procedure is as follows:

Procedure for Resetting Shim Coil Currents

a) Use the [Up] or [Shift-Down] softkey to select the desired shim.

b) Press the limit or shim softkey to bring the current in the power leads back to the current
limit (the same value that was left in the shim coil). Alternatively, the [Shift-Limit] or [Shift-
Shim] softkey may be used to fast sweep back to the shim current.

c) Press the [Pers Htr] softkey and [Confirm Htr On] softkey to confirm and turn ON the
persistent switch heater.

d) Wait about 10 seconds for the persistent switch to warm and the current in the shim to
stabilize at the current limit.

e) Press the [Pers Htr] softkey and [Confirm Htr Off] softkey to confirm and turn OFF the
persistent switch heater.

f) Wait about 10 seconds for the persistent switch to cool.

g) At this point, the shim is in persistent mode and the operator has two options – 1) press the
[Zero] softkey (or [Shift-Zero]) softkey to bring the current in the power leads back to zero,
or 2) use the [Down] or [Shift-Up] softkey to proceed directly to setting the next shim. It is
not necessary to sweep the output current of the supply to zero prior to moving on to the
next shim.

This process (b through f) should be repeated for each shim.
H.4.2. Discharging Shims

The 4G requires that all shims be either disabled or discharged before it will allow the user to change back to Manual mode for control of the main magnet. If only a minor change in main coil current is desired (e.g., to fine tune Z0), the user may want to leave the currents in the shim coils while the change in main coil current is made. To do this, each shim coil that is not set at zero current must be disabled as described in section H.3.4.

To discharge a shim coil to zero current, the following sequence is typically followed:

a) Use the [Up] or [Shift-Down] softkey to select the desired shim.
b) Press the [Limit] or [Shim] softkey to bring the current in the power leads back to the current limit (the same value that was left in the shim coil). Alternatively, the [Shift-Limit] or [Shift-Shim] softkey may be used to fast sweep back to the current limit or shim current.
c) Press the [Pers Htr] softkey and [Confirm Htr On] softkey to confirm and turn ON the persistent switch heater.
d) Wait about 10 seconds for the persistent switch to warm.
e) Press the [Zero] key to sweep the current in the shim coil back to zero.
f) After the current stabilizes at zero and the 4G enters STANDBY mode, press the [Pers Htr] softkey and [Confirm Htr Off] softkey to confirm and turn OFF the persistent switch heater.
g) Wait about 10 seconds for the persistent switch to cool.
h) Go to step “a” to select the next shim and repeat the process for each shim.

After zeroing or disabling each shim coil, the user may change the 4G back to Manual mode if desired.

<table>
<thead>
<tr>
<th>CAUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>When changing the 4G back to MANUAL mode, be aware that the supply's firmware safety limit (typically +/- 30 amps) is no longer enabled. The 4G becomes capable of sourcing its full output current rating (e.g. 100 amps for a 4G-100). Most shim coils are not designed to handle high currents and could be quenched and/or damaged by them. Be sure to change the 4G’s power leads back to the main coil’s current terminals when changing back to MANUAL mode to avoid damaging the system.</td>
</tr>
</tbody>
</table>