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i. SAFETY REQUIREMENTS

The following general safety precautions must be observed whenever operating, servicing, or repairing this instrument. Failure to comply with these precautions violates safety standards of design, manufacture, and intended use of the instrument. Quantum Design Inc. assumes no liability for the customer's failure to comply with these requirements. This is a Safety Class 1 instrument.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet International Electrotechnical Commission (IEC) safety standards.

KEEP INSTRUMENT DRY

To help minimize the possibility of electrical fire or shock hazards, do not expose this instrument to rain or excessive moisture; it was not designed to be water or splash proof.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a flagrant safety hazard.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

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

ii. WARRANTY AND REMEDIES

QUANTUM DESIGN WARRANTY AGREEMENT

This agreement has been entered into by and between Quantum Design Inc., ("Quantum") and the undersigned purchaser/licensee ("Purchaser") with respect to the sale of hardware and/or the license of software by Quantum to Purchaser.

1. Warranty. Quantum warrants that, for a period of one (1) year from the date of delivery to Purchaser, the hardware, instrumentation and/or equipment manufactured or designed by Quantum will be, under normal use, free from defects in material and workmanship. Quantum further warrants that the hardware, instrumentation, equipment and/or software manufactured or designed by Quantum will perform, under normal use, substantially in accordance with the specifications contained in published sales literature, data sheets and operating manuals. Quantum does not warrant that the operation of any software program will be uninterrupted or error-free.

Quantum agrees to assign to Purchaser whatever rights Quantum may have under any warranty, express or implied, of any supplier or manufacturer of components used by Quantum but not manufactured or designed by Quantum.

Quantum's entire liability and Purchaser's exclusive remedy under this warranty will be to repair, or at Quantum's option, to replace, without charge, any product or component manufactured or designed by Quantum which proves to be defective within the scope of this warranty. In the event Quantum is unable to repair or replace such a defective product or component within a reasonable time after receipt thereof, Quantum shall refund to Purchaser the original purchase price of the defective product or component. If the loss of use of a component manufactured or designed by Quantum substantially impairs the use of the product, and Quantum is unable to repair the defect, Quantum shall refund to Purchaser the original purchase price of the product.

All warranty claims must be made in writing to Quantum within the warranty period. Purchaser shall not make any returns to Quantum without receiving prior authorization from Quantum, as evidenced by a return authorization number. Any authorized returns must be made to Quantum's factory or to an authorized service center within thirty (30) days after discovery of a defect or nonconformity. The return shipping to Quantum shall be at the risk and expense of Purchaser.

Products which are returned should be properly shipped to minimize further damage, and insured at their original purchase price. All returns to Purchaser shall be at the risk and expense of Quantum.

EXCEPT FOR THE ABOVE EXPRESS LIMITED WARRANTIES, QUANTUM MAKES NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, IN ANY OTHER PROVISION OF THIS AGREEMENT OR IN ANY OTHER COMMUNICATION, STATEMENT OR REPRESENTATION, WHETHER ORAL OR WRITTEN, MADE BY ANY AGENT, DISTRIBUTOR, REPRESENTATIVE OR EMPLOYEE OF QUANTUM, UNLESS MADE IN WRITING, EXECUTED BY AN AUTHORIZED QUANTUM EMPLOYEE, AND EXPRESSLY DESIGNATED AS A "WARRANTY".

2. Conflict of Terms. In the event that the terms and conditions of this Agreement conflict with the terms or conditions of any other agreement or representations between Quantum and Purchaser with respect to the purchase of the products, the terms of this Agreement shall be deemed to control.

3. Controlling Law. Except to the extent that this Agreement is governed by the laws of the United States, this Agreement shall be governed, interpreted and enforced in accordance with the laws of the State of California, and the parties specifically elect to exclude applicability of the Convention on Contracts for the International Sale of Goods.

4. Limitation of Liability. REGARDLESS OF THE FORM OF THE ACTION AND WHETHER IN CONTRACT OR IN TORT, QUANTUM SHALL IN NO EVENT BE LIABLE TO PURCHASER (a) FOR ANY EXEMPLARY, SPECIAL, CONSEQUENTIAL OR INCIDENTAL DAMAGES, INCLUDING BUT NOT LIMITED TO LOSS OF BUSINESS OR PROFITS, LOSS OF USE, OR LOSS OF DATA, NOR (b) FOR ANY OTHER DAMAGES WHICH EXCEED THE PURCHASE PRICE PAID BY PURCHASER TO QUANTUM.

iii. ASSISTANCE AND MAINTENANCE AGREEMENTS

Product maintenance agreements and other customer assistance agreements are available for Quantum Design products. For any assistance, contact Quantum Design Inc or its designated representatives.

Current address, telephone, FAX, and E-Mail information is provided at the back of this manual for your convenience in contacting Quantum Design or our company's representative for your area.

iv. PREFACE

This manual covers the Quantum Design dc SQUID System. This system comprises the Model 5000 dc SQUID Controller and up to eight input channels. Each channel is made up of four components which plug together: a Model 5000 multiCARD which plugs into the back of the controller, a microPREAMP which mounts on the helium cryostat and whose cable extends back to the multiCARD, a flexible Probe which extends into the cryogenic environment, and a SQUID Sensor which mounts into the bottom end of the Probe.

The Model 5000 provides complete control of up to eight SQUID sensors, allowing the user to individually set bias currents, offsets, feedback ranges, gains, filters, reset levels, test signals, noise suppression, and other special functions. An automated tuning capability is also provided.

The graphic front panel display provides extensive instrument status and channel information in both tabular and bar-graph formats selectable by the user. The front panel keys provide a manual method for setting up the instrument and displaying information. For fully remote operation, both an IEEE-488 and an RS-232 interface have also been provided.

The output voltages of the SQUID channels are all available at one common connector on the rear panel for the user who wishes to do his own analog or digital processing. In addition, any channel can be multiplexed to a BNC connector on the front panel for test and diagnostic purposes. Additional low-pass and notch filtering is available for this Monitor Output.

In addition to its analog outputs, the Model 5000 also has the capability of digitizing, filtering, and transmitting channel data through the IEEE-488 and RS-232 interfaces to a system computer. High performance hardware is provided which can support acquisition and transmission of 16-bit data at up to 48K samples-per-second though the IEEE-488 port.

The Model 5000 can also operate a superconducting-wire style helium level sensor, providing the user with regularly updated level information as well as a convenient display to use while filling the cryostat.

V. OVERVIEW

This manual contains six chapters which describe the installation, use, and characteristics of the Quantum Design dc SQUID System based on the Model 5000 controller.

OPERATOR'S GUIDE - Chapter 1 is intended to give the user a familiarity with the hardware and software features of the instrument. It is organized to present these features in a tutorial manner.

MANUAL OPERATION REFERENCE - Chapter 2 is a more formal listing of all the hardware and software items which comprise the system. It is organized as a reference document and provides more details about any particular hardware or software item.

REMOTE OPERATION - Chapter 3 describes the use of the two external control ports and the specifics of the commands which can be sent over them.

DATA ACQUISITION - Chapter 4 discusses the architecture of the data processing done in the Model 5000, and shows how to select combinations of acquisition parameters which will provide data having the desired characteristics.

INSTALLATION - Chapter 5 discusses the physical, thermal, and electrical requirements for connecting together the Controller, multiCARD, microPREAMP, Flexible Probe, and SQUID Sensor.

SPECIFICATIONS - Chapter 6 presents an extensive listing of specifications as well as supplemental characteristics to assist the user in evaluating and optimizing the performance of the overall system.

1 OPERATOR'S GUIDE

This chapter is intended to give the user an overview of the instrument and introduce the user to many of the hardware and software features which are available. Topics are presented in the order in which they might be encountered in a typical session of using the instrument. This chapter is not intended to be exhaustive either in the range of topics covered or the depth of that coverage. Please refer to chapters 2 thru 5 for additional details about specific controls, menu items, commands, and specifications.

1.1 Before Turning On the System

If the Model 5000 unit is being used in your facility for the first time it is most important to verify that the line voltage switch on the back panel is set correctly for your local voltage. The main fuse must also be selected to match the voltage switch setting for safe and reliable operation. Voltage and fuse ratings are printed on the instrument.

***** CAUTION *****

INCORRECT SWITCH SETTINGS OR FUSE SELECTIONS ARE LIKELY TO CAUSE DAMAGE TO THE EQUIPMENT!

The Model 5000 is designed as a Class I instrument, meaning that safe operation depends on the chassis being properly grounded. This is normally accomplished through the ground wire in the line cord. It is therefore necessary to ensure that the outlet which powers the instrument is correctly grounded. If the outlet itself is not grounded, then a three-contact to two-contact adapter must be used and the green lead on the adapter must be securely connected to a safety electrical ground.

***** WARNING *****

FAILURE TO PROPERLY GROUND THE INSTRUMENT CAN CAUSE INJURY OR DEATH TO THE USER!

In order to actually use the system as a SQUID Controller, it will be necessary to have at least one Model 5000 multiCARD and microPREAMP connected to a functional SQUID sensor through a Quantum Design Flexible DC SQUID Probe (or its functional equivalent). Directions for installing and connecting probes and sensors are given in Chapter 5, sections 5.5, 5.6, 5.7.

It is quite permissible to turn on the Model 5000 without any multiCARD installed or microPREAMP connected. In this configuration it will still perform power-on self tests and you may examine or change any of the menu items available on the front panel. You might wish to set the real-time clock or change the IEEE-488 address under these conditions. It would, of course, be unreasonable to try tuning a SQUID channel under these conditions.

1.2 Turning On the System

After observing the cautions, warnings, and advice of the previous section, turn on the power by pressing the button marked POWER on the front panel. The back-lighting of the display screen should be visible if the ambient light level is not excessive (i.e. outdoors in bright sun). If the back-light does not appear to be functioning at all, check the power line fuse and verify that the outlet is "live." If you still cannot get the back-light to appear, there may be a problem with the power supply. Use the information at the back of this manual to contact Quantum Design for assistance.

By adjusting the contrast knob on the front panel it should be possible to obtain an easily readable character display. If this is not possible, use the information at the back of this manual to contact Quantum Design for assistance.

The initial display reports the results of various internal self tests. These include RAM function, program integrity, data integrity, timer function and I/O port operation. If any of these tests fails, the instrument will remain in this initial display. Use the information at the back of this manual to contact Quantum Design for assistance.

Next, the instrument checks to see if the SQUID channels, enabled according to the nonvolatile RAM, match the actual hardware configuration. The Model 5000 can determine whether a specified multiCARD is installed as well as whether its associated microPREAMP is connected. Any inconsistencies will be reported on the screen for your consideration. If you wish to operate the instrument under these conditions, press the ESC button to continue.

The first "real" display after the power-on procedure will be the Channel Status Display. You can always return to this display by pressing the STATUS button. There may be anywhere from zero to eight channels presented on this display, depending on which ones have been enabled in the Channel Installation Menu.

1.3 Selecting Status Displays

There are two distinct status screens which may be displayed. The Channel Status is the primary one and is always displayed after the power-on procedure. The Helium Level Status screen, if enabled, may be obtained by pressing the STATUS button a second time after the Channel Status Display is presented. Further presses of the STATUS button will toggle between these displays. If the STATUS button is pressed when some other display is present, the instrument will return to the Channel Status display.

It is not possible to change the basic configuration of the system from the status displays. They are intended to provide just what their name implies - status. It is possible, however, to do several things from the Channel Status Display which affect the output of the Monitor BNC. You can change which channel is being multiplexed to the Monitor Output BNC on the front panel, you can change the Monitor Filter, and you can reset channels. Use the left and right direction keys to select the channel and the INCR or DECR keys to change the filter. Use the numeric keys to select which channel to reset. A quick press of the numeric key will cause a momentary reset. Holding the key down longer will cause the channel to be placed into chronic reset. The period [.] key is used for resetting all channels which have been enabled for group reset. Refer to the menu item "GR ENABLE" for details of this feature.

1.4 Selecting Output Displays

Pressing the OUTPUT button at any time will cause the outputs of the SQUID channels to be presented either in tabular or graphical format. Toggling between these formats is done by pressing the OUTPUT button additional times. The Output Displays work very much as the Status displays do; please refer back to section 1.3 for details. The up and down direction keys can be used to select which channel is switched to the front panel Monitor Output in this display.

These output displays will not present any useful information, however, unless the SQUID sensors are working and have been properly tuned. If this has not yet been done, please refer to the next section for instructions on performing this tuning.

1.5 Auto-Tuning SQUID Channels

Under normal conditions, it should be possible to obtain excellent tuning results from the Model 5000's automatic tuning algorithm. This is invoked by pressing the TUNE button and selecting the channels which are to participate in the tuning procedure. Only channels which have been enabled can be selected for tuning. You may also elect to apply a heating cycle to each SQUID sensor before it is tuned. This cycle consists of heating the SQUID above its transition temperature for a few seconds and then letting it cool again. This has the effect of removing "trapped flux" from in and around the Josephson junctions. Although the exact mechanisms are not well understood, it appears that electromagnetic transients may cause flux lines to be trapped in the SQUID sensor. This reduces the critical current of one (or both) of the Josephson junctions. SQUIDs in this condition generally have inferior signal and noise characteristics.

Once you have chosen the channel and heater options, press the TUNE (or ENTER) key to begin the process. To save time all channels are tuned simultaneously. This is possible because the architecture of the Model 5000 allows any set of multiCARDs to be simultaneously selected and controlled. A bar-graph display presents the progress and result of the tuning algorithm. If any channels fail to give a good tuning response the software will remain in the Tuning Result Display and flag the problem channels with a flashing symbol.

If you wish, you may also remain in the Tuning Result Display by pressing the ENTER key before the program returns to its pre-tuneup display. You need to do this if you want to adjust the Gain and/or Modulation controls on the multiCARDs. These potentiometers are available for screwdriver adjustment on the rear panel of each Model 5000 multiCARD through holes above and below the 15-Pin "D" shell connector. These controls should not have to be changed once a given channel has been fully tuned and adjusted. Even if you switch Quantum Design SQUID sensors around to different channels, it should not be necessary to adjust these controls. If you are attempting to use SQUID sensors from other sources, then these potentiometers may have to readjusted substantially to optimize performance.

The criterion for setting the MOD or modulation potentiometer is to turn the 4-turn control fully counter-clockwise and then turn it clockwise until the bar-graph display shows the FIRST maximum response for the channel. Unless you have long arms and good dexterity, it may be useful to have a mirror available so that you can see the display at the same time you are adjusting the controls.

The gain inside the feedback loop, FB-GAIN, is increased by rotating the potentiometer clockwise until the bar graph reaches approximately mid-scale. If the full 50KHz bandwidth is not required, then this gain can be reduced somewhat to improve the system's response to very short transients.

For additional information on setting these potentiometers, please refer to section 1.10 which covers manual tuning of SQUID sensors.

1.6 Selecting Output Signals

As we have already discussed, the Monitor Output connector on the front of the unit can be switched between the available channels by using the four direction keys when you are in the Status or Output screens. There is another group of screens which is reached by pressing the CONFIG button and selecting from the main Configuration Menu. The left and right direction keys will select the channel for the Monitor Output when in the Channel Response display. If you select "Individual Channel Configuration" from the main menu, then the channel which you choose to configure will be the one switched to the

Monitor BNC. The principle is that the Monitor is freely switched to whichever channel the user appears to be working with at the moment. From the Channel Response display it is also possible to change the Monitor Filter setting.

We have provided a pair of pins on the rear panel ANALOG OUTPUT connector which also carry the Monitor Output signal. This feature might be useful if, for example, you wish to have a dedicated CRT display available and prefer not to have cables connected to the front panel. Note that the Monitor Filter only affects the signals appearing at these two Monitor Output points. It does not affect any data acquisition or digitizing functions.

1.7 Setting Individual Ranges, Gains, Bandwidths

Press the CONFIG button and then select the menu item "Channel Response." This screen will allow you to see the status of all the active channels and set several of the parameters which affect the response of the channel.

The RANGE item allows you to determine how many flux quanta will be represented by a full scale swing of the channel output voltage (±5V). The choices are ±5, ±50, and ±500 quanta. There is also a 5S range; the "S" stands for "Stable" or for "Slow". In this range, the open-loop bandwidth is reduced to about 1KHz which can improve stability against "flux jumps" in the presence of short electro-magnetic transients.

The GAIN item allows you to select some additional out-of-loop gain for the signal before is presented to the Butterworth filters and the A/D converter. The choices are 1X, 2X, 5X, and 10X. If you are not using one of the filters, then the gain stage is not in the signal path, and the effective gain is 1X by default.

The FILTER item allows one to select a 1KHz, 2KHz, 4KHz, or 16KHz three-pole analog Butterworth filter for the SQUID output channel. You can also bypass all filtering and gain on the multiCARD and look at the "raw" output of the flux-locked-loop circuit. This is done by selecting OUT for this item.

Toggling TEST to ON causes a sawtooth signal to be injected into the SQUID's modulation coil. This signal is several quanta in amplitude and is at a few hundred Hertz. It can be useful in determining the proper operation of a channel.

Channels can be placed into (and removed from) chronic reset by toggling the RESET item for that channel.

Last but not least, this is the menu in which the Monitor Filter can be modified. The bottom item on this screen, Monitor Filter selection, allows the user to cycle through five combinations of low-pass and notch filters to be applied to signals before they appear at the Monitor Output BNC. Remember that this filtering is only applied to the Monitor Output and does not affect the eight Analog Outputs on the rear panel or the inputs to the A/D Converter.

1.8 Setting Global Channel Parameters

Press the CONFIG button and select the second item, "Global Channel Configuration." This screen is convenient when all the channels are being set-up identically. In addition to the display parameters already discussed in the previous section, this screen gives the user more intimate access to the operation of the SQUID sensor. If all active channels do not have a particular parameter in the same state, then that item will display dashes instead of an explicit value. Toggling such a "mixed state" will bring all channels into a homogeneous state.

By changing YAMS to ON you can apply a.c. (reversing) current bias to the Josephson Junctions. Such a.c. Biasing can dramatically reduce the effects of junction fluctuations on 1/f noise in some types of SQUID sensors. Although the Quantum Design SQUID has intrinsically good 1/f performance, this biasing capability has been included to handle special situations and also to serve as a diagnostic tool. Note that if a.c. biasing is used, then the SKEW must be adjusted to reduce the amplitude of transients at the reversing frequency (1935 Hz).

All channels can be enabled to respond to a Group Reset by toggling the GR ENA item to ON. Channels which have GR ENA on will be reset when the period key [.] is pressed or a Group Reset command is received through one of the control ports.

The NULL item selects how the channel responds to either an external or internally generated reset. If NULL is OFF, then no auto-zero is ever performed. If it is set to MANual, then the software will attempt to bring the output of a channel to zero voltage only after an external reset is received. If AUTO is specified, then the software will attempt to zero the channel output after any reset, internal or external.

The DISCRiminator item allows one to globally set the trip voltage for resetting the SQUID channels. A reset is generated when the magnitude of the output voltage reaches the value of DISCR. Setting DISCR identically to zero will disable automatic resetting completely for all channels when set from this global menu.

All heaters located in the SQUID Sensor Assemblies can be directly turned on from the HEATER item. Once turned on, they will remain ON until the user explicitly turns them OFF or leaves the menu. Care should be taken with the HEATER function, since it puts a significant amount of power into the liquid helium bath. There should be no reason to leave heaters on for more than a couple of minutes.

1.9 Setting Individual SQUID Configurations

Press the CONFIG button and select the third item, "Individual Channel Configuration" to get into this screen. The most detailed control of the operating parameters for an individual channel can be obtained from here. It is possible to tune a channel manually and analyze performance under open loop conditions in this menu. Training a novice to skillfully use this menu is beyond the scope of this section. More experienced users should consult section 2.4 for a detailed description of the various parameters. One typical use of this menu is to perform a manual tune-up of a SQUID sensor as described in section 1.10.

1.10 Manual Tuning Techniques

It should not be necessary to perform SQUID tuning manually under normal operating conditions, however the procedure may be a useful diagnostic tool. If extremely large signals are being applied to the SQUID signal coils or if a particular tuning optimum is being sought, then manual tuning may be indicated. If you need to use a.c. bias for 1/f noise reduction then you should also consult the next section for information on setting the SKEW parameter. The procedure described here is approximately the same one which the Model 5000 uses when performing an Auto-Tune.

Before attempting to tune a channel be certain that the channel is physically installed, the cables are all connected, and the SQUID sensor is cold. Consult sections 5.5 through 5.7 for instructions on physically installing the multiCard, microPREAMP, and SQUID Probe.

Begin tuning by going into the Individual Channel Configuration screen for that particular channel number and setting the following menu items as follows:

Menu Item	Value
RESET	ON
TEST	ON
YAMS	OFF
SELECT	TUNE
HEATER	OFF
BIAS	0

The other parameters may be left in their original states. Tuning may now be performed by increasing the BIAS value and observing the response on the bar-graph display at the top of the screen. The goal is to find the value of BIAS which results in strong peak on the bar-graph. If more than one peak is seen, the one occurring at the lowest bias should be chosen. This should also be the largest peak. Use the INCR, DECR, and FAST buttons to control the value of the bias current.

If the modulation amplitude has already been set for this SQUID sensor, then it should not be necessary to adjust the MOD potentiometer on the back of the multiCARD. If the MOD pot must be adjusted, use a small straight-blade screwdriver and rotate it counter-clockwise several turns; this should turn off the modulation. Now rotate the screwdriver clockwise slowly until the first peak is found. This is the correct setting and should not be changed unless the SQUID sensor is changed for the particular channel.

The potentiometer labeled FB-GAIN (also at the rear of the multiCARD) may now be adjusted. This pot should be set so that the bar-graph reads about 3 volts. Values below 2 volts will give a reduced bandwidth for locked loop operation whereas values above 4 volts may make the feedback loop jittery.

Choosing the TUNE option for the SELECT menu item causes the peak amplitude of the SQUID "triangle" pattern to be displayed. If an oscilloscope is available, it is possible to observe the "triangle" display directly. Choose the DETECT option for SELECT and connect the 'scope to the Monitor Output BNC Connector. This method of observing the SQUID gives the most insight into its operation. Try turning off the TEST signal and using the OFFSET control to adjust the flux in the SQUID loop. If the signal coil of the SQUID is grounded or the input coil is well shielded, then it is possible to measure the white or 1/f noise of the system in this open-loop operating mode. Use the OFFSET control to set the DETECT signal to zero volts and measure the noise spectral density at the Monitor Output. This noise voltage can be converted to flux quanta by determining the open loop gain in units of volts-per-quantum.

1.11 Using 1/f Noise Reduction - YAMS

Noise reduction of the SQUID junctions <u>may</u> be obtained by driving them with a.c. current, although Quantum Design SQUIDS do not usually exhibit excessive 1/f energy. Before attempting to use a.c. bias, tune the SQUID ~~either~~ using either automatic or manual methods. Then turn the YAMS menu item to ON and look at the DETECT signal by connecting an oscilloscope to the Monitor Output Connector. With RESET ON and TEST OFF, adjust the OFFSET control to make the output voltage approximately zero, then adjust the SKEW control to minimize the size of the 1953 Hz chopping signal. Several minima may be found, but the minimum obtained with the smallest SKEW is probably the correct one. Quantum Design SQUIDS will usually show the proper minimum with a value of SKEW between -5% and +5%. The proper minimum can be verified by changing the BIAS value somewhat and observing that the 1953 Hz chopping signal does not increase noticeably.

Even if a.c. biasing is not turned on, there may be subtle improvements in d.c. performance of the SQUID sensor when the SKEW value is set correctly. This is because junction bias currents do not couple into the SQUID loop, creating potential drift or noise sources.

It has been our experience that the optimum SKEW setting remains constant for a particular Quantum Design SQUID sensor unless its operating temperature changes significantly or one junction suffers a reduced critical current due to flux trapping.

1.12 Using Analog Output Signals

As we have described in section [1.6], SQUID output signals can be obtained either from the front panel Monitor BNC or the rear panel Analog Interface Connector. It is possible to obtain single-ended or differential outputs for each channel from the 26 pin Interface Connector. The Monitor Output signal, with it's additional low-pass filtering capability, is also presented on two pins of this connector. Please refer to Appendix D for the pin assignments and layout.

The normal range of output voltages for standard locked-loop operation is ±5 volts. Under atypical conditions, up to ±13 volts may be present at any of analog output pins; any device connected to the Model 5000 analog outputs should be able to handle this voltage safely. The analog output impedance is approximately 100 ohms, but it is strongly recommended that only high impedance loads (>0.5 Meg ohm) be used to reduce voltage drops, ground loops, and cross-talk problems.

When more than one SQUID channel is installed and operating, a small high-frequency "glitch" may be noticed on the analog output signals. This is caused by the mulitplexer which feeds the system A/D converter. Because it is synchronized with the digitizing process, this noise does not affect the digital data which is returned from the Model 5000. It does, however, create noise at the multiplexing frequency and its harmonics. Under normal operation (ARM state off) this will be 2400 Hz divided by the number of installed channels.

Since channel multiplexing is done only in the screens which require SQUID data to be updated, these glitches may be suppressed by displaying the Configuration Menu, Channel Response, or Global Channel Configuration screens. Note, however, that automatic resets will not occur in these screens since the SQUID outputs are not being monitored.

1.13 Using Remote Operation

This section is intended to provide only a brief introduction to remote operation of the Model 5000; there is extensive information provided in chapter 3 and in Appendices B, C, and D. It is necessary to understand the hardware, protocol, and language of the particular interface before remote operation can be established, and remote operation must be established before useful data acquisition can be performed.

Remote operation is done either through the RS-232 serial port or the IEEE-488 parallel port (also called GPIB). The GPIB interface is much faster and more flexible than the RS-232, but it does require that special hardware be available in the computer which will control the system.

The serial port, on the other hand, can be connected to any type of workstation or PC with nothing more than a three wire cable and a couple of "D" shell connectors. This cable must be wired so that the Model 5000 and the computer are sending and receiving data on complementary pins. Also, the communication parameters such as Baud rate, parity, data bits, and stop bits must be set correctly before any information can be exchanged. In this regard, the RS-232 "standard" is far less standard than the GPIB.

It is possible to configure both the RS-232 and the GPIB ports from the front panel as well as by remote action. In fact one can send commands over the GPIB interface which configures the RS-232 interface.

To configure the ports from the front panel, go to the Main Configuration Menu and select the System Setup option. From the System Setup Menu, select either the IEEE-488 Port or the RS-232 Port option. All parameters in the RS-232 Setup Screen must be correct before any information can be exchanged. In the IEEE-488 Setup Screen only the ADDRESS item is critical for establishing communication. The other items are used for specifying how the Model 5000 will behave when specific events occur and how messages will be terminated.

1.14 Configuring Data Acquisition

This section is only intended to introduce the user to the Data Acquisition Screen. There is a detailed description of the menu items themselves in chapter 2 and a discussion of their usage in chapter 4.

The parameters used for data acquisition can be set from the front panel by pressing CONF to get into the Main Configuration Menu. From there select Data Acquisition to get into the desired screen. In this screen you can select which channels are to be read (CHANNEL SET), how many times they will be read after each trigger (REP FACTR), how fast they will be read (CONV RATE), and when the readings are to start (TRIG MODE). Additional menu items such as FLTR MODE, BW FACTOR, and DEC FACTOR determine what digital processing is done to the data before it is sent through the communication port. The DATA TYPE item specifies how to format the data before sending it.

Finally, the ARM STATE item is used to tell the Model 5000 to actually load all these acquisition parameters into hardware and enter a special acquisition mode. In this mode, normal screen displays and communication capabilities may be unavailable since the instrument has to support all the user's data acquisition specifications. If any problems occur, such as data overflowing the user's computer program, the Model 5000 automatically drops out of the ARM STATE and resumes normal operation. It can also be taken out of the ARM STATE from the front panel or by a remote command.

1.15 Operating the Level Meter

Before the level meter can be used, it must be set up and calibrated. This is done in the Helium Level Sensor Screen, available through the System Setup item in Main Configuration Menu. If the HE MONITOR item is enabled, the level meter will be turned on each hour (on the hour) and read. The reading will be presented at the bottom of the Status Display Screen. If the HE DISPLAY item is enabled, the user can toggle between the normal Status Display Screen and a Helium Level Screen by repeatedly pressing the STATUS button. This screen provides continuous information on the helium level and rate of change, both of which are useful when filling the cryostat.

Calibration of the Level Sensor can only be done when the cryostat is less than 50% full. The best accuracy is obtained when the cryostat is cold but empty, since the entire superconducting wire is just above its transition temperature under these conditions. Move the cursor to the PRESENT LEVEL item and enter the percentage of helium which you believe to be in the cryostat. The instrument calculates and stores the voltage which would correspond to an empty condition and then displays that calibration value for your information.

1.16 Miscellaneous Utilities

There are two additional screens which are available from the System Setup Menu. These are the Timing Functions screen and the Channel Installation screen. The Timing screen can be used to set the "real time" clock (RTC) and to separately change the width of the reset pulses used for the 5S feedback range and for the other ranges. The Installation screen is used to tell the Model 5000 which channels are to be displayed in the Status, Output, and Configure screens. This list would normally include only those channels which are actually installed and working, however no harm is caused if nonexistent channels are displayed.

2 MANUAL OPERATION REFERENCE

This chapter describes all of the controls, displays, and connectors available on the Model 5000. Although the front panel may appear relatively simple compared to an instrument such as a full-featured oscilloscope, this is deceptive. There are numerous menu and data displays available which provide great flexibility to the user. Section 2.4 in this chapter describes the items found on these displays.

2.1 Front Panel Features

The controls and displays listed in the following paragraphs are the primary interface to the Model 5000 when it is used under manual control. If the instrument is used on the benchtop, the tilt-bail will raise the front panel to a more convenient angle both for viewing the LCD and for operating the buttons. If it must be rack-mounted, try to avoid installing the unit too low. Is is quite awkward to use in this condition.

Display

The LCD provides both text and graphic monochrome displays. In text mode the display shows 8 lines of 40 characters. It is backlighted by an electroluminescent (EL) panel to provide better viewing under low-light conditions. Under bright ambient light, the EL illumination will not be noticeable nor will it be necessary. Under high glare conditions, it may be desirable to attach a small sheet of anti-reflective material over the display to improve readability. We do not recommend polarized or tinted materials designed for CRT displays, however, as they reduce the transmitted light.

Contrast Knob

This is a 1-turn potentiometer located to the left of the display. It is used to optimize the readability of data on the LCD display. When the power is on, it should be possible to vary the appearance of the display from completely clear to completely dark by adjusting this knob to its extremes.

The optimum setting of the knob depends strongly on the vertical viewing angle of the display, as with most LCD's. It also depends somewhat on the temperature of the display.

Power Switch

The power switch, located at the left side of the display, is an alternate action pushbutton. The front panel button remotely actuates a switch inside the power supply enclosure which connects and disconnects both sides of the AC line. The switch is not illuminated, nor does it serve as a circuit breaker.

Menu Keys

These four keys are located immediately to the left of the LCD. Pressing one of them causes the specified display or menu to immediately appear. They allow the user to quickly return from a low-level menu to one of the four top level displays. This is in contrast to some user interfaces which require the operator to "escape" one step at a time back up to the highest level display. Note: When in the process of automatic SQUID tuning, all keys (including these) are temporarily disabled.

STATUS

This key presents a non-editable table of information describing the state of all active SQUID channels. It is possible to change which channel is presented at the Monitor Connector and how it is filtered from this menu. If the mode has been enabled, it is also possible to toggle to a helium level display by pressing this key a second time.

OUTPUT

This key toggles the user between two types of display of the SQUID outputs. One is a tabular display which allows the user to see the output voltage with high resolution. The other display is a bar graph of the channels' output voltages expressed as a fraction of their ±5 volt full scale. This display is good for visualizing the response of the SQUID channels to some stimulus; passing a sample past a pickup loop array would be one example.

TUNE

This key puts the user into a tuning menu which allows him to select the channels which are to be tuned and whether they are to be heated above their transition temperature to remove trapped flux and circulating currents. If no channels are selected for tuning, the program will just set up the channels for tuning and wait for the user to adjust the MOD and FB GAIN potentiometers.

CONFIG

This key takes the user to the top-level of a configuration menu tree. These menus provide a method of setting up the detailed operation of the SQUID sensors, the communications, the data acquisition, the level meter, the system clock and various other utility functions. Pressing any of the four Menu keys will immediately "pop" you out of this tree structure.

Control Keys

These nine keys are used to move between menus, within menus, and to change items in menus. All editing which does not require the explicit use of numeric entry can be done with these keys.

Cursor Motion

The four cursor motion keys are arranged in the convenient inverted "T" configuration. In the Status and Output displays they are used to select which channel is presented at the Monitor BNC. In the CONFIGguration menus they are used to select which item is to be edited. Wrap-around is always provided when the cursor is moved past the last item in a row or column.

Increment-Decrement

The INCR and DECR keys are used to change the values of menu items. Some items have a set of several choices which can be cycled through with these two keys. Other items take a numerical value. For these items it may be useful to use the INCR and DECR keys along with the FAST key. This allows the user to make large changes in the numerical values quickly. The FAST key used alone has no effect; it functions only as a "Shift" or "Alt" key.

Enter

This key has various actions depending on what the user is doing. If the cursor is on the name of a sub-menu, you are placed into that menu. If you have been pressing numeric keys to create a value for a menu item, then that value is loaded into the item. In the Tune menu it causes the auto-tuning procedure to begin.

Escape

The exact action of this key depends on the context where it is used. Generally, it has the effect of getting you safely out of whatever you are doing. It can move you one level up in a menu tree or abort numeric input.

Numeric Keys

Number Keys

The keys 0-9 can be used for general numeric input. The subset of numbers 1-8 can be used in various menus to toggle SQUID channels into or out of participation in some activity - tuning or resetting for example.

Decimal Point Key

In addition to its normal use in constructing numeric values, this key can be used to issue a Group Reset command when in the Status and Output menus.

Plus/Minus Key

In addition to its normal use in constructing numeric values, this key is used in special situations to toggle a system variable when other keys are not available. A prompt on the display will instruct the operator in its use.

Remote Indicator

This Green LED to the right of the numeric keypad signifies that the instrument has been put into "remote" operation by a GPIB controller. See section 1.13 for more information about the remote mode.

Reset Indicator

This Red LED on the right side of the numeric keypad blinks whenever any channel is internally or externally reset. It also remains lighted when any channel is held in chronic reset.

Monitor Jack

This BNC connector provides an analog output signal from one selected SQUID channel. It has a 100 ohm output impedance and has a nominal output voltage range of ±5 volts. Under abnormal conditions, however, up to ±15 volts may appear at this connector.

2.2 Rear Panel Features

The rear of the instrument is dominated by various connectors. Note that two distinct types of connectors may appear similar at first glance. The 15-Pin connectors for the multiCARDS and the 26-Pin connector for the Analog Output are both designed around a "DA-15" shell size. The Analog Output connector, however, has three rows of terminals instead of the more common two rows.

Power Connector

The instrument uses a standard 3-Contact IEC connector suitable for operation up to 240 VAC. This connector also incorporates a fuse holder which can be configured for either one or two fuses, depending on local standards and conventions. See section 5.3 for additional information.

Voltage Selector

This switch allows the Model 5000 to operate over a very wide range of input voltages with maximum efficiency and reliability. Use a small screwdriver blade to move this switch to the appropriate voltage range.

GPIB Connector

This is the standard 24-Pin ribbon connector used to implement the IEEE-488 standard. The jack-screw hardware is metric.

RS-232 Connector

This connector is configured so that a 9-Pin "D" Male-Female cable can be used to attach the Model 5000 directly to an AT type computer. See Appendix D for information of the specific pin functions.

Analog Output Connector

This is a 26-Pin connector housed in a "DA-15" size shell. These "1.5 Density" connectors are not as readily available as the standard density versions, so a mating plug has been included for your convenience. The pin assignments are given in Appendix D.

Level Sensor Connector

This is a small 4-Pin circular connector made by Lemo. Quantum Design has adopted it as a standard for driving superconducting level meters. We have included a cable with this connector already wired for your convenience. See Appendix D for the pin assignments and color code of the cable.

multiCARDs

From one to eight multiCARDS can be installed into the Model 5000. There are two screws which mount the rear plate of the multiCARD to the card cage; these should be securely tightened for reliable operation.

Modulation Amplitude Pot

This 4-Turn potentiometer is accessible through a small hole at the bottom of the rear plate. Modulation amplitude is increased by clockwise rotation of the potentiometer. This pot is set correctly when the SQUID sensor is at the first maximum of its response. See sections 1.10 and 5.5 for further information regarding the use of this control.

Feedback Gain Pot

This 4-Turn potentiometer is accessible through a small hole at the top of the rear plate. The open-loop gain can be changed by a factor of 5 by adjusting this pot. See sections 1.10 and 5.5 for further information regarding the use of this control.

microPreamp Connector

This standard 15-Pin "D" shell connector attaches to the passive end of the microPREAMP cable. The jack screws should always be tight for reliable operation.

2.3 Internal Adjustments

There are several screwdriver adjustable trimpots which can be reached by removing the top cover of the instrument. Remove the retaining screws in the cover and slide it off to the rear. The potentiometers are located along the top edge of the masterBOARD and are accessible through a slot in the card cage.

There are NO adjustments in either the Power Supply or CPU enclosures. In addition, voltages up to 400V are present in the Power Supply enclosure.

***** WARNING *****

UNDER CERTAIN FAULT CONDITIONS, THESE HIGH VOLTAGES MAY PERSIST FOR A LONG TIME AFTER POWER HAS BEEN REMOVED FROM THE INSTRUMENT.

Notch Frequency Pots

There are three ADJACENT pots used to adjust the notch filter. From FRONT to REAR of the instrument, these set the frequency of the line Fundamental, Third Harmonic, and Second Harmonic. In the U.S., for example, they would control 60, 180, and 120 Hertz in that order. The pots can be set by introducing a signal into the SQUID sensor at each of these frequencies (or 50, 100, 150 Hertz in Europe) and observing the amplitude of the output. It should be possible to obtain at least 40dB of rejection for the power line and its first two overtones. If large changes are made to one pot setting, you should go back and re-optimize the other two since there is a small amount of interaction.

Level Meter Current Pot

This potentiometer is located to the rear of the three notch filter potentiometers. Adjust this by placing a sensing resistor (typically 100 ohms, ½ Watt) or ammeter across pins 1 and 2 of the 4-Pin Lemo connector at the rear of the masterBoard. Adjust for 70 mA or whatever current (up to 100 mA) your level meter requires for activation.

2.4 Menu Item and Screen Descriptions

AMP

The amplifier which feeds the anti-alias filters (see FILTER) can be configured to have gains of 1X, 2X, 5X, and 10X. The desired value is selected by scrolling through the four choices using the INCR and DECR keys. When the filters are being used, the AMP gain corresponds to the value reported by the menu item GAIN.

ARM STATE

The ARM STATE can be either ON or OFF. The desired state is selected by toggling between the two choices with either the INCR or DECR keys. This command affects the system in several ways. When the ARM STATE is ON, the primary focus of the CPU is to support the specified data conversion, filtering, and transfer requirements. The Data Acquisition parameters which you have loaded (such as CHAN LIST, CONV RATE, and FLTR MODE) do not take effect until the ARM STATE is turned ON. Until this happens, the default parameters suitable for updating the LCD display are in effect. The updating of the front panel displays and scanning of the keys will be done only as a secondary task when ARM STATE is ON, and only the channels which are in he Channel List will be updated. Auto-reset is not implemented when the ARM STATE is ON.

When the ARM STATE is on, the instrument is either waiting for a trigger or actively acquiring and transmitting data. Consequently, the control computer should not be sending unrelated commands to the instrument. A typical sequence would be to arm the Model 5000, send a trigger, and start listening. Or, if the trigger mode is MANUAL, the control computer could look at the Data Ready byte in the Status Word to determine whether it should start listening; this test would avoid hanging up the controller if the trigger did not occur.

If there is any problem in data transfer, or any acquisition parameters are changed while the ARM STATE is ON, the Controller will immediately set the ARM STATE back to OFF.

BIAS

The BIAS control sets the AC or DC bias current to the SQUID sensor, expressed as a percentage of full scale. When using the front-panel controls, the BIAS is set between 0% and 100% either by ramping it with the INCR and DECR keys, or by directly entering a value with the numeric keys.

BW FACTOR

When using front-panel controls, the BW FACTOR is set either by ramping with the INCR and DECR keys, or by directly entering a value with the numeric keys. This parameter affects the cutoff frequency for all of the 6-pole Butterworth lowpass filters. Since these filters are implemented digitally, the action of the filter is expressed as a dimensionless ratio describing how much the bandwidth has been reduced. Specifically, it sets the ratio of the input data Nyquist frequency to the output 3dB frequency. The acceptable values for the BW FACTOR are from 1.0 (no filtering action) up to 9999.99.

Channel Response [SCREEN]

This display is reached by pressing the CONFIG button and selecting the menu item Channel Response. The screen allows the user to individually set most of the common parameters for any channel. These include RANGE, GAIN, FILTER, TEST, and RESET. The MONITOR FILTER can also be changed from here.

Channel Status [SCREEN]

This display is obtained by pressing the STATUS key once. It gives the user a high-level report on the state of the instrument. No parameters can be changed from this menu, however the user can select the channel whose output is to be presented at the Monitor Output BNC.

CHANNEL SET

When using the front panel controls, the channel list is defined by pressing a numeric key to toggle a particular channel into or out of the active mode for data acquisition. The decimal point key can be used to toggle all channels simultaneously.

The active channels are read and reported in ascending numerical order. The REP FACTOR command controls the number of times the active channels are read for each triggering of the A/D converter module. The number of active channels times the REP FACTOR must be less than or equal to the size of the hardware FIFOs which store the list of channels and the digitized readings: 500 entries.

CHANNEL

In menus which show the status or output of multiple channels, there will be a marker showing which of the eight possible channels has been electronically switched to the Monitor BNC Connector on the front panel, and the monitor pins on the rear panel analog output connector. The active channel can be instantly changed by moving this marker to a different channel using one of the four direction keys. In some situations, the channel number may also be entered using one of the numeric keys.

CONV RATE

This item selects the A/D Conversion Rate to be 6KSP, 12KSP, 24KSP, or 48KSP. The desired value is selected by scrolling through the four choices using the INCR and DECR keys.

Data Acquisition [SCREEN]

This display is reached by pressing the CONFIG button and selecting the fourth menu item, Data Acquisition and Processing. This screen allows the user to examine and change the modes and parameters of data acquisition, processing and transmission. It is anticipated that this menu will be used primarily for diagnostic purposes. It is more natural to perform this configuration through one of the communication ports, since there must be an interface established for the reception of this data anyway. The items which can be set from this menu include ARM STATE, BW FACTOR, CHANNEL SET, CONV RATE, DATA TYPE, DEC FACTOR, FILTR MODE, REP FACTOR, and TRIG MODE.

DATA TYPE

This item selects between ASCII and IEEE formats for data transmission. A third choice, NONE, is also available for diagnostic purposes. The desired state is selected by toggling among the choices with the INCR or DECR key. The ASCII format uses an exponential number format of 6 significant digits. Numbers in a record are delimited by comma-space. Records are terminated by a semicolon and an End-Of-String (EOS) character, if one has been specified. An End-Or-Interrupt (EOI) may also be sent along with the last byte during GPIB communications, if this has been enabled. Both of these options can be selected from the IEEE-488 Setup Screen.

The IEEE format is the standard 4-byte binary form used for floating point numbers. This is faster because conversion is not required at either end and the number of bytes which must be transmitted is reduced by a factor of almost three.

When the NONE option is selected, data acquisition and filtering is performed normally, but no data is sent to an output port. Instead, the REMOTE LED is briefly flashed whenever a string of data would have been sent to an output port. This can be very instructive when setting up an acquisition and filtering configuration since you can see when data transmission would begin and what the rate would be without regard to communication issues. This mode would also be useful when verifying external triggering of the A/D converter.

Note that when the FILTR MODE is set to RAW, then a third data format is automatically used regardless of the DATA TYPE command. This is a 2-byte integer just as taken from the A/D converter FIFO's. At the end of a block of data, a 2-byte check-sum is computed and sent. For GPIB communications, EOI may sent along with the second byte (LSB) of the checksum if this has been enabled.

DEC FACTOR

This item allows the user to specify the ratio between the number of readings input to the filter compared to the number which are output. For example a decimation factor of 5 would mean that only one out of every 5 output values is actually sent to the port.

DISCR

The Discriminator value determines the point at which a particular SQUID channel is to be reset by the computer. A voltage between 0.00 and +5.00 may be selected either by using the INCR and DECR keys or by entering the number directly from the numeric keypad. The voltage comparison is performed on the signal after it has been digitized, so bandwidth and gain settings must be considered. Setting the discriminator to 0.0 disables the automatic reset function for the channel.

***** NOTE *****

NOTE THAT SETTING A VALUE WHICH CORRESPONDS TO LESS THAN ONE FLUX QUANTUM (BUT IS NOT EXACTLY ZERO) MAY CAUSE THE CHANNEL TO CONTINUOUSLY PERFORM AUTO-RESETS.

The output of each channel is compared against its DISCR value approximately 60 times/second. A momentary reset is asserted if the magnitude of the output voltage is larger than the specified reset voltage. A service request may also be sent over the GPIB if it has been enabled.

When data acquisition and transfer has been armed, the microprocessor will disable the auto-reset function if the data rates are determined to be too high to support the overhead of this activity. This situation is indicated in the Data Acquisition Menu.

EOS VALUE

This item specifies the ASCII value of the terminator character which is sent after the last byte of the GPIB message, assuming the EOS character has been enabled with the SEND EOS item. The terminator can have any decimal value, but is typically a linefeed character.

FILTER

There are five bandwidth choices: four butterworth filters or no filtering. The butterworth filters on the multiCARD are 3-pole designs set at 1KHz, 2KHz, 4KHz, and 16KHz. The desired filtering is selected by scrolling through the five choices using the INCR and DECR keys.

If no filtering is selected, then the effective bandwidth is approximately 50KHz. The 50KHz option exceeds the Nyquist bandwidth for the on-board A/D converter substantially, and is therefore intended for external processing by the user. In this unfiltered mode, the 1x-2x-5x-10x gain stage is also bypassed on the multiCARD

FLTR MODE

This item determines how data is to be digitally filtered before being sent through the GPIB or RS-232 ports. There are three modes: RAW, AVG, BUTTRW. The desired mode is selected by scrolling through the three choices using the INCR and DECR keys. The RAW mode can only be used with GPIB communications because of data rate limitations in serial communications.

When in the AVG or BUTTRW modes, data is formatted according to the DTYP command, but in the RAW mode a 2-byte integer is used. This integer is in exactly the same format as the data taken from the A/D converter FIFO's. In this RAW mode, a value of $0000 corresponds to -5 volts, $8000 corresponds to zero voltage, and $FFFF corresponds to +5v. At the end of a block of data, a 2-byte check-sum is computed and added to the data stream. End-Or-Interrupt (EOI) is sent with the second byte (lsB) of the checksum.

GAIN

This menu item displays and sets the out-of-loop gain for a channel. When the anti-alias filters are not in the signal path, this gain is always unity (1X). This is the "raw" analog signal mode, which puts the minimum amount of circuitry between the output connectors and the SQUID feedback loop. When one of the anti-alias filters (1KHz - 16KHz) is being used, this gain can be set to 1X, 2X, 5X, or 10X. It is the same as the hardware-level menu item AMP under this condition.

Global Channel Configuration

This display is reached by pressing the CONFIG button and selecting the second menu item. The screen is particularly useful when all channels are being configured identically. It allows the user to globally set many of the available SQUID parameters such as RANGE, GAIN, FILTER, TEST, YAMS, RESET, GR ENA, NULL, DISCR, and HEATER. The parameters which are not available on this screen would not make sense to set globally, such as SKEW or OFFSET. See the Individual Channel Configuration screen for access to these parameters.

GR ENABLE

This menu item toggles Group Reset Enable between enabled and disabled for the current SQUID channel. Channels which have been enabled will perform a momentary reset whenever the period [.] key is pressed from a STATUS or OUTPUT menu or when a Group Reset command is sent to the instrument. Note that channels which have been in chronic reset would be taken out of the reset condition after responding to a momentary Group Reset.

HE CALIBRATE

This item allows the user to calibrate the level meter by specifying how full the cryostat is at the moment. The value should be a percentage between 0% and 50%. The instrument then performs a reading and sets the level meter calibration to give the specified value. A one point calibration is valid since this type of level sensor is inherently linear. The most accurate calibration will be with a cold but empty cryostat. Calibration with the cryostat full is not possible since the sensor always reads zero voltage under this condition regardless of its length.

HE DISPLAY

This menu item enables the The STATUS key to display an alternate Status Display for the helium level sensor. This display, if enabled will appear alternately with the Channel Status display when the STATUS button is repeatedly pressed. HE ENABLE can be either ON or OFF. The desired state is selected by toggling between the two choices with the INCR or DECR key. Note that there is no remote command for changing HE ENABLE since the desired display can be presented using the DISPLAY command. See the Command Reference section for details.

HE MONITOR

The HE MONITOR can be either ON or OFF. The desired state is selected by toggling between the two choices with the INCR or DECR key. When the Helium MONITOR is on, the instrument turns on the level sensor for a few seconds every hour and reads the level. The result is displayed in the Status Display as a percentage between 0% and 100%. The level sensor must have been previously calibrated for the readings to be valid.

HEATER

This menu item toggles the heater ON or OFF for the current SQUID channel. It is the responsibility of the operator to turn the heaters OFF after a suitable period of time. The bias current should be set to zero before activating the heater to avoid trapping flux in the junctions during heater operation.

NOTE: Heaters must be physically installed before this command will have any effect. See section 5.11 for details.

Helium Level [SCREEN]

This display is available from the Configuration Menu through the Utility Menu. It is used to calibrate the level sensor and enable automatic updating of the helium level using the HE CALIBRATE and HE MONITOR items.

Helium Level Sensor [SCREEN]

This display is obtained by pressing the STATUS key a second time. It presents a continuous report on the liquid helium level as well as the rate of change in percent/minute, which is a useful parameter when transferring helium into the cryostat. If the helium level has not increased after 2 minutes, the instrument will give a short warning beep to signal that the cryostat may be full or that the transfer has stalled.

When you leave this menu, the helium level meter will automatically be turned off. After 60 minutes this display will terminate automatically and the instrument will return to showing the Channel Status. Since the level meter dissipates a significant amount of power into the cryostat when it is active, the 60 minute limit ensures that the level meter will not inadvertently be left on continuously.

IEEE-488 Port [SCREEN]

This display is reached from the System Setup menu by selecting the first menu item, IEEE-488 Port. The screen allows the user to define the characteristics of IEEE-488 (GPIB) port communications. The instruments primary address, the EOS value, and the usage of EOI may all be specified from here.

Individual Channel Configuration [SCREEN]

This display is reached by pressing the CONFIG button and selecting the third menu item, Individual Channel Configuration. This is a screen which allows the experienced user to have complete control over the functions available on the multiCARD. In addition to the controls available on other menus, this screen allows the user to turn on YAMS (a.c. biasing), control the OFFSET current, set the BIAS and SKEW levels, and SELECT several special diagnostic modes.

Channel Installation [SCREEN]

This display allows the user to activate channels by installing them into the software. Channels listed as "Active" in this menu indicate those channels which are currently installed. Channels listed as "Found" are those for which the physical presence of a multiCARD has been detected in the slot corresponding to the channel. The channels to be installed or de-installed are specified by pressing numeric keys to toggle them into or out of operation. The decimal point key can be used to toggle all channels simultaneously. De-installed channels are not considered to exist for purposes of tuning, display, or configuration: they will not appear in any other screens.

If "RESTORE FACTORY DEFAULTS" is enabled from this menu, then the entire state of the machine will be overwritten upon the next cycling of the power to the controller. This state includes the GPIB address and serial port baud rate, as well as all low level SQUID tuning functions. When this function is disabled, the controller will remember its previous settings upon a cycling of the power.

MONITOR FILTER

There are six combinations of low-pass and notch filtering which can be applied to the signal before it is presented at the front-panel BNC connecter and the monitor pins on the rear-panel "Analog Output" connector. The choices are 1Hz, 10Hz, 100Hz+Notch, 100Hz, Notch, and None. The desired value is selected by scrolling through the six choices using the INCR and DECR keys.

The low pass filters are a 2-pole butterworth design. The notch filter has rejection notches at the line frequency as well as its second and third harmonics. The filter is factory tuned for either 50 or 60 Hz operation depending on the location of the user. It is possible for this selection to be changed in the field by a competent technician.

NULL

This item allows the user to select if and when the instrument tries to null the output of a channel to zero volts by use of the offset D/A converter after a momentary reset. The options are OFF, MAN, and AUTO. The desired value is selected by scrolling through the three choices using the INCR and DECR keys. If OFF is selected, the value in the offset D/A converter is left unchanged. If MAN is selected, the offset D/A converter is adjusted only after a manual or externally generated reset. If AUTO is selected, the adjustment will also occur after an internal reset caused when the channel exceeds the discriminator voltage.

OFFSET

When using front-panel controls, the OFFSET is set between 0% and 100% either by ramping it with the INCR and DECR keys, or by directly entering a value with the numeric keys. The specified offset current is injected into the indicated channel. The full output, 100%, corresponds to a current of 3.6 microamps into the SQUID modulation coil (or about 2 flux quanta). This command is typically used to null the output of a SQUID channel so that additional gain can be applied without suffering amplifier saturation.

RANGE

The four feedback ranges which are available are 5S, 5, 50, and 500. The desired value is selected by scrolling through the four choices using the INCR and DECR keys. These numbers represent the approximate number of flux quanta for a zero to full-scale excursion on the specified range. The peak-to-peak excursion is twice this number, with a corresponding voltage range of ±5V. The 5S range has a bandwidth of about 1KHz and a correspondingly low slew-rate. It is characterized as being very stable against short transients which might cause a faster feedback system to respond incorrectly (flux jump).

We have chosen a voltage range of ±5 volts instead of the usual ±10 volts for several reasons. Slew rate and distortion problems with low-power op-amps, leakage and non-linearity of FET switches, and greater compliance voltage for current sourcing are some of the issues. The system's A/D converter is also designed for a ±5 volt range.

REP FACTOR

This item tells the CPU how many times to repeat loading the channel list into the control FIFO. When using front-panel controls, the REP FACTOR is set either by ramping it with the INCR and DECR keys, or by directly entering a value with the numeric keys. In Filter Modes other than high-speed binary, the REP FACTOR tells how many readings to average for each "on" channel once the converter has been triggered. The product of the REP FACTOR and the number of channels in the channel list will exceed 500. See CHANNEL SET item.

RESET

The RESET state for a channel can be either ON or OFF. The desired state is selected by toggling between the two choices with either the INCR or DECR keys. Note that from the Display Menus, the numeric keys can be pressed briefly to issue a momentary reset for a channel. If the channel had been held in chronic reset, this has the effect of taking the it out of reset. If the numeric key is held down longer, the channel is placed into chronic reset.

The period [.] key functions as a group reset from the Display Menus, causing a momentary reset to be sent to all channels for which group reset has been enabled (see GR ENABLE item).

SELECT

This item, available only in the Individual Channel Configuration screens, is an expanded version of the FILTER item available in some other menus. In addition to selecting the five filter settings, SELECT allows the user access to a DETECtor signal for observing the "triangle" tuning pattern and a TUNE signal which is essentially the amplitude of the triangle pattern. There is also a SENSE signal which drops from 5 volts to 4.5 volts when the microPREAMP for the channel is connected. These three extra signals are used internally by the software to perform tuning operations and to detect the presence of hardware, and are available to the experienced user for diagnostics.

SEND EOI

This item enables or disables the assertion of the GPIB EOI (End-Or-Identify) line when the last byte of a message is being sent.

SEND EOS

This item enables or disables the sending of an End-Of-String termination character after the last byte of a message. If EOI is enabled, it is asserted along with this terminator. The terminator can have any decimal value, but is typically a linefeed character. (See EOS VALUE item).

Serial Port [SCREEN]

This display is reached from the System Setup menu by selecting the second menu item: Serial Port. This screen allows the user to define the characteristics of the RS-232 serial communication port. The basic parameters such as BAUD RATE, STOP BITS, DATA BITS, and PARITY may be set from here. The user may also specify whether the instrument will follow an XON/XOFF PROTOCOL.

There are two special strings which may also be specified in this screen. They are the serial port service request string and the line terminating string. Up to 4 characters may be defined for each of these strings. The user should first enter the number of characters to be sent (0-4) using the SRQ CHAR COUNT or TERM CHAR COUNT items. Then the decimal ASCII values for each desired character should be entered into the fields to the right of the SRQ CHARS or TERM CHARS prompts. Note that only the characters enabled by the CHAR COUNT item will be displayed in the CHARS fields.

The line terminating string is appended to all normal responses from the Model 5000 and would typically consist of line-feed and/or carriage-return characters. Note, however, that the line terminating string is NOT appended to the service request string. This SRQ string can either be composed of standard printing characters or special control characters which could be detected by the host computer's serial input handling routine. This latter technique would make it possible to conveniently implement an interrupt driven SRQ capability though the serial port interface.

SKEW

This item is used to set the skew factor for an individual channel. When using front-panel controls, the SKEW is set between -100% and +100% either by ramping it with the INCR and DECR keys, or by directly entering a value with the numeric keys. A value of less than ±10% is typical for a properly operating SQUID with symmetric junctions and no significant "flux trapping."

System Setup [SCREEN]

This display is reached by pressing the CONFIG button and selecting the last menu item, System Setup. The screen is itself a menu which breaks system parameters into related groups. From here you can configure the IEEE-488 or RS-232 ports, Install Channels, or set the Time and Date. When you press the number of your choice or position the cursor at your choice and press ENTER, the appropriate screen will be displayed.

TEST

The TEST signal can be either ON or OFF for an individual channel. The desired state is selected by toggling between the two choices with the INCR or DECR key.

This signal is a sawtooth voltage at a frequency of about one hundred hertz which sweeps the SQUID sensor through about 10 flux quanta. It is useful for tuning the SQUID as well as observing its operation in locked loop mode.

Timing Functions [SCREEN]

The on board real time clock may be set from this menu.

The durations of the SQUID reset pulses may also be set from this menu.

TRIG MODE

This item selects the method of starting the conversion process. The possible choices are MAN, EXT, LINE, and CONT. The desired mode is selected by scrolling through the four choices using the INCR and DECR keys.

In the MANual mode, conversion is initiated by pressing the period [.] key when the cursor is at this menu item. In the EXTernal mode, conversion is initiated by sending a Group Execute Trigger command over the IEEE-488 interface or the TRIG command over either interface. In the LINE mode, triggering will be synchronized to zero crossings of the a.c. power supply line. The CONTinuous mode does not wait for any triggering event, but immediately begins conversion and continues as long as no overflows occur in any data buffers. The MANual mode can be used to effectively turn off triggering since the instrument will wait for a manual key-press.

YAMS

YAMS can be either ON or OFF for a specific channel. The desired state is selected by toggling between the two choices with either the INCR or DECR key. The bias current applied to the SQUID sensor will be a constant d.c. value if YAMS is turned off. It will switch direction at a 2KHz rate when YAMS is on.

This a.c. bias mode, called YAMS, is used for 1/f noise reduction. This is one of many methods proposed to suppress noise due to fluctuations in junction parameters. Its main advantage is that it can easily be turned off if it is not required.

3 REMOTE OPERATION

This chapter describes how to operate the Model 5000 through its two control ports. There are sections devoted to the unique aspects of each port as well as a section presenting the command language - which is essentially common to both. For a tabular listing all the commands the user should refer to Appendix A.

3.1 IEEE-488 OPERATION

General Description the Interface

This interface is also known as the General Purpose Interface Bus (GPIB). Due to its remarkable power and complexity, a full description of the IEEE-488 standard is far beyond the scope of this manual. There are several books and articles available which describe this interface and its applications, and for the very serious user there are the official IEEE documents which define the standard (IEEE Standard Digital Interface for Programmable Instrumentation, ANSI/IEEE Std 488.1-1987 and IEEE Standard Codes, Formats, Protocols, And Common Commands ANSI/IEEE Std 488.2-1987). If you have already used a GPIB system, however, the information contained in this chapter should be sufficient for you to interface to the Model 5000.

The IEEE specification permits up to 15 devices to be connected together by passive cables. These cables have stacking 24-pin ribbon connectors at each end and are up to 3 meters long. The total length of cable allowed in a system is 20 meters.

Information is sent in a byte-serial, 8-bit parallel data format. Bytes are transferred asynchronously using a "3-wire handshake" which allows instruments having very different speeds to operate together easily. Each instrument on the bus must have a unique address (or addresses). Specific devices can be addressed to talk or listen on the bus. Only one talker may be active at a time, but up to 14 listeners may be active simultaneously.

The IEEE specification limits data rates to one megabyte per second, but rates are usually lower depending on the length of cables in a system and the capability of the slowest device. The Model 5000 can sustain transmission rates of up to about 200 kilobytes per second when sending raw binary data from the digitizer.

In most GPIB systems there is one controller, often a personal computer or engineering workstation. Since the Model 5000 does not support a "Listen Only" or "Talk Only" mode, there must be a device capable of performing the controller function present in the system.

Model 5000 Capability

The Model 5000 supports a functional subset of the IEEE Standard 488.1-1987. Table 3.1 describes the codes and functions which are available. These codes and the terminology used in this table are defined by the Standard, but they basically mean that this device can talk, listen, respond to serial polls, and receive triggers. It cannot act as a controller, respond to parallel polls, or talk/listen without being addressed. It uses high speed line drivers wherever permitted.

Table 3.1 - IEEE-488 Capability

Code	Function
SH1	Complete Source Handshake capability
AH1	Complete Acceptor Handshake capability
T6	Basic Talker; unaddress if MLA
TE0	No Extended Talker capability
L4	Basic Listener; unaddress if MTA
LE0	No Extended Listener capability
SR1	Complete Service Request capability
RL1	Complete Remote/Local capability
PP0	No Parallel Pole capability
DC1	Complete Device Clear capability
DT1	Complete Device Trigger capability
C0	No Controller capability
E2	Tri-state drivers used where possible

Bus Addresses

The Model 5000 can be configured to have one address in the range from 0 to 15 for talking and listening. The address is set from the front panel by pressing the CONF key and selecting the System Setup then IEEE-488 menus. The address is stored in nonvolatile memory, so this process should only have to be done when a particular GPIB system is initially configured.

Bus Messages

The GPIB system operates in two distinct modes which are selected by the state of the ATN ("Attention") line. When ATN is asserted the system is in Command Mode, otherwise it is in Data Mode. In Command Mode, devices can be addressed or unaddresed as talkers or listeners. Also, in this mode, Interface Messages can be sent to instruments to do such things as trigger them, clear them, or handle their service requests. Table 3.2 lists the Interface Messages (and their three-letter mnemonics) to which the Model 5000 can respond.

Table 3.2 - Interface Messages

Message	Description of Model 5000 Response
INTERFACE CLEAR (IFC)	Halts all GPIB activity and unaddresses all devices on bus.
DEVICE CLEAR (DCL)	If addressed, clears all I/O buffers and registers, resets GPIB hardware, and aborts any data acquisition process.
LOCAL LOCKOUT (LLO)	Disables the [ESC] or [ENTER] key from returning the instrument to local control once it has been placed into the remote state.
CLEAR LOCKOUT/ SET LOCAL (REN false)	Takes ALL devices on bus out of LOCAL LOCKOUT. Returns unit to front panel control. Simply making the REN line false sends this command. Unplugging the GPIB cable has the same effect.
REMOTE (REN and MLA)	Directs an instrument to take instructions from the bus. The REMOTE LED is lighted and the front panel is disabled. If LOCAL LOCKOUT is not active then pressing the [ESC] or [ENTER] button returns the instrument to local control.
GO TO LOCAL (GTL)	Returns the instrument to front panel control. LOCAL LOCKOUT is not cleared by this command. It has the same effect as pressing [ESC] if LOCAL LOCKOUT is not active.
SERIAL POLL (SPE/SPD)	These command the addressed device to send its Status Word. Various operating conditions of the instrument are encoded in the 8 bits of this word.
GROUP EXE TRIGGER (GET)	When the Model 5000 has its ARM STATE active, and the trigger mode is set to EXT, this command starts the A/D converter.

When the bus is in the data mode, information and instructions can be sent between instruments on the bus. Instructions which are sent when in this mode are called Device Dependent Commands. They typically consist of a mnemonic followed by one or more parameters. These mnemonics and their parameters are listed alphabetically and described in section 3.3.

Common Commands, IEEE-488.2 Standard

The Model 5000 follows the IEEE-488.2 standard which requires that the instrument be able to respond to a set of specified "common" commands. Each of these commands or queries starts with an asterisk and must end with a terminating semicolon. They perform generically useful functions such as resetting the instrument, checking its status, and indicating triggered operations. Although normally associated with the GPIB protocol, these commands may also be sent over the Serial Port. They are listed and described fully in section 3.3. Note that in some cases, we have provided an alternative to the common command in our suite of device specific commands.

Local/Remote Modes

The Model 5000 is placed into Remote Mode when it is addressed by the system controller. It is possible that the controller may leave the Model 5000 under remote control after communication is finished. When in Remote Mode, the REMOTE LED is lighted, and normal front panel operation is inhibited. The instrument can be returned to Local Mode from the front panel by pressing either the [ESC] or [ENTER] keys unless the controller has sent the LOCAL LOCKOUT (LLO) message. If LOCAL LOCKOUT has been sent, front panel control can only be re-established by having the system controller send the GO TO LOCAL (GTL) message or by physically unplugging the GPIB cable.

Service Requests

The SRQ (service request) line is one of the five bus management lines (along with EOI, REN, IFC, and ATN). It is used by the instrument to request attention from the controller. When the Model 5000 issues an SRQ, it also sets bit six in the Status Byte. Bit six is the "Requesting Service" bit and is sometimes called the status bit.

When the controller detects an SRQ, it can serially poll each device on the bus to determine which one(s) are requesting attention. Each device responds by sending its Status Byte. After the Model 5000 responds to a Serial Poll, it clears bit six along with the SRQ line. Any bit in the Status Byte may be enabled to initiate a service request. This is done by setting the corresponding bit in the Service Request Enable Register (SRER), using the Service Request Enable (SRE) command with the weighted binary value of the enabled bits as its parameter. The current value of the SRER can be read using the SRE? command.

The Status Word

The Status Word for the Model 5000 is sent whenever the device is addressed in a Serial Poll. The eight bits of this word are used to encode various conditions existing in the instrument. These are Described in Table 3.3.

Table 3.3 - GPIB Status Word

Bit #	Value	Description of Condition
0	1	Enabled Command Error
1	2	Enabled Execution Error
2	4	Enabled Internal Error
3	8	Enabled SQUID Reset Event
4	16	Enabled Message Available
5	32	Enabled Standard Event
6	64	Device Requesting Service (RQS)
7	128	Device Status Change

Bits 4 - 6 in this Status Word conform to the requirements of IEEE 488.2 for standard codes and formats. Bits 0 - 2 are used to report different categories of errors to the system controller. Bit 7 will be set whenever an enabled system state changes. There are a large number of status conditions which the Model 5000 keeps track of. By enabling specific ones, the sophisticated user can closely monitor just those conditions in which he is interested.

Bit 3 is dedicated to reporting resets triggered by discriminator on any active SQUID channels. The direction of the reset is also encoded, permitting the user to count and track the net changes in each channel.

3.2 RS-232 OPERATION

General Description of the Interface

This interface provides bi-directional communication to a typical serial port on a PC or workstation. It is provided for those who do not have the need or capability to establish a GPIB interface to the Model 5000. In our experience, there are far more difficulties in establishing reliable two-way communications between serial devices than are encountered with the parallel GPIB. The serial interface is also about 500 times slower than the GPIB. Nevertheless, a serial interface may be perfectly adequate for some situations and the required hardware is already present in any PC.

Almost all of the Device Control Commands which are available in the IEEE-488 interface are available with exactly the same syntax for the RS-232 interface. The Common Commands and Status Reporting Commands are also available, but the Service Request function is handled differently due to the hardware limitations inherent in a serial interface. We have tried to the extent possible to approximate the functions available in the GPIB, but an obvious limitation is that the computer can only communicate with one device per port.

When using the RS-232 interface, all data sent to the Model 5000 must be in ASCII format and all data which it sends out is in ASCII format. High-speed transfer of binary "raw" data is not supported with this interface since its inherent speed is too slow to make it useful.

Communication Protocol

Communication parameters can be set up from the front panel. Use the CONFIG key to enter the System Configuration Menu; from there, select System Setup, and then the RS-232 menu item. To set up the RS-232 interface, you must select the appropriate Baud rate, number of data bits, number of stop bits, and the parity. A typical configuration would be 9600 Baud, 8 data bits, 1 stop bit , no parity. The Model 5000 uses a 9-pin female connector for this interface, but only the data lines and ground line are required. Pin 9 is used to bring external triggers into the instrument, so it should definitely not be connected to any serial communication line. Figure 3.1 shows the pin numbers and functions for both this instrument and the IBM PC-AT (using the 9-pin connector).

Function	Model 5000 Pin	IBM PC-AT Pin
"DCD" -12V Out >	1	1
"RXD" Data Out >	2	2
"TXD" Data In <	3	3
"DTR" N/U In <	4	4
"GND" Ground	5	5
"DSR" -12V Out >	6	6
"RTS" N/U In <	7	7
"CTS" -12V Out >	8	8
TRIG. Neg Edge <	9	N/C

Figure 3.1

As with any serial communication, the maximum Baud rate can be limited by the length of the cable, but there should be no problem at 9600 Baud with up to 100 feet of cable. It is good practice to use a cable with either a foil or braid shield.

Device Clear, Serial Port

It is possible to send a command similar to the GPIB "Device Clear" by using the RS-232 "Break" signal. The effect of this break signal is to clear the input and output buffers of the serial port, abort any data acquisition operation, and reset the Xon/Xoff handshake status to "both sides flow." It does not affect the state of the GPIB interface nor does it clear any GPIB data or status registers.

Requesting Service

Since the RS-232 interface does not have a dedicated line and an established protocol for letting an instrument request service, it was necessary for us to provide a suitable procedure. The method we have chosen is based on techniques used by other instrument manufacturers. By using the "Serial Port Service Request String" [SSPS] command, you can define a string of up to 4 characters which is to be sent by the Model 5000 whenever a Service Request would have been sent over the GPIB port. Please see the COMMAND REFERENCE section for full descriptions of the SSPS and the SSPS? commands.

If you do not want the Model 5000 to send unexpected characters over the serial port, you can determine if the instrument needs service by polling it. This is done be sending the *STB? query and testing whether bit 6 (with a binary weighting of 64) has been set in the returned ASCII coded integer. This testing can be done by reading the returned string into a variable of type "Byte", performing the bitwise AND function with $40, then checking for a non-zero result.

3.3 COMMAND REFERENCE

This section contains the mnemonic commands and their parameters for operating the Model 5000 from a remote computer by way of the GPIB or RS-232 port. The general format of a command is: [mnemonic command] [parameter(s)] [terminator";"].

If the mnemonic command ends with a question mark "?", it is a Query and will generate a response from the Model 5000 if the command does not generate a command error (see appendix C).

All commands must end with a terminating semicolon or a command error will be generated.

Parameters sent to the Model 5000 can be of type real or integer for many of its commands. The 5000 follows the IEEE 488.2 standard which states devices are to be "EASY Listeners". This means that if the parameter is to be of one type and another type is sent, the sent parameter is to be converted into the correct type, if possible. If a channel number of 7.5 is sent to the model 5000, the value will be rounded to the nearest whole number of 8. Scientific notation and hexadecimal numbers are also excepted and converted to the correct type. It is recommended however that the host computer send the correct type to avoid confusion. For example, a channel number of 7.4999 will be rounded down to 7 but 7.5 will be rounded up to 8.

If the command has more than one parameter, the parameters are to be separated by a comma or by one or more spaces. Some commands like TIME have optional parameters that may or may not be sent depending on if they need changing. These parameters are indicated by being inside the [] syntax in this manual.

The parameter syntax is as follows unless otherwise stated:

{ch#}

This parameter indicates which channel the command is to be directed to. The legal range is determined by the installed channels but will be a number from 1 to 8. Some commands allow a channel number of "0" representing "send command to all installed channels". Example "RSET 0,1;" would lock all channels into reset.

{boolean} or {xxxx-flag} Where xxxx may be a flag name.

These types of parameters are used to modify a flag in the controller. A zero generally means FALSE, OFF or DISABLED while a non zero means TRUE, ON or ENABLED. While any non zero value will work for TRUE, it is recommended that a value of 1 be used for clarity. Example: "SEOS 1;" = enable EOS control.

{integer}

This parameter should be a WHOLE number within the limit of the command. If an exponential value is sent, it is converted first into a floating point number and then rounded to the nearest integer. Example: "BIAS 1, 250;"

{real}

This parameter should be a REAL or floating point number. Example: "BWRF 21.23"

{string}

Strings do not need any format characters like the quote. They are a string of characters or numbers terminated with the semicolon. If more than one semicolon is sent, the string ends with the first semicolon and the following characters are processed as the next command.

{ASCII-code}

This parameter represents the ASCII value of the character you wish to send. Example: "SPSS 13,10;" = set serial pole service string to Carriage Return, Line Feed. See an ASCII conversation chart for more information.

{xxxx-code} Where xxxx may be filter, gain, range, rate, etc.

These codes are integers who's range is set by the command. They represent modes or switches that don't directly translate into a flag or integer. For example, the DFMD command sets the digital filter mode to RAW, AVERAGE, or BUTTERWORTH with {filter-code} values of 1,2 and 3, respectively.

{BWSB}

Binary Weighted Sum of Bits - The BWSB is an ASCII decimal number between 0 and 255 representing which channels are to be acted on by the command. If the bit is "0", then the channel number 1, etc. The following table shows the principle. The BWSB is the sum of the values which represent each channel.

CHANNEL	VALUE
1	1
2	2
3	4
4	8
5	16
6	32
7	64
8	128

Example: "CHSS 175;" scan channels 8,6,4,3,2, and 1. "CHSS $AF;" is the same command in hex.

Other parameter descriptions are command dependent and are explained with it.

***CAL?;**

Has the Model 5000 do an A/D calibration and returns an error flag stating the results. A zero indicates a good calibration. This command will not get the response for about 1 second while the calibration is in progress.

***CLS;**

This command clears all error classes and the status byte and clears the SQR line on the GPIB. This command is usually preceded with a low level device clear command to put the Model 5000 into an idle state. All error/failure information will be cleared with this command.

***ESE (0-255);**

The standard event status enable command is followed by an enable mask to enable or disable the generation of a service request for the events flagged by this register. A duplicate device command "ISE" can also be used for this purpose.

***ESE?;**

Returns the current enable mask. The device command "ISE? 5;" will also return the same mask value.

***ESR?;**

Returns and clears the standard event status register to the host computer. The device command "ISR? 5;" has a duplicate function.

***IDN?;**

Returns the identification string: "QUANTUM DESIGN, 5000 DC SQUID CONTROLLER, 0, 0;"

***OPC;**

This command will set the operation complete flag in the standard event register when it is processed and all multitasking processes are completed. At this time only the helium update is multitasked, all other processes are sequential, meaning they will be completed before the next command is executed. Since the Model 5000 has an input command queue, this command or the "*OPC?;" can be used to tell where the controller is in its command parsing and whether or not the controller is ready to accept more commands.

***RST;**

Resets the Model 5000 to a power on state. Since the controller remembers its power down state, this command will not change most of the system's parameters but will have the system go through its power on self test. The controller will be off line for about 2 to 3 seconds during these tests.

***SRB?;**

Reads the status byte query without changing it. Returns the same response as a GPIB serial pole without resetting the SRQ line.

***SRE (0-256);**

Sets the service request enable mask. A value of zero disables all error/status classes from generating service request.

***TRG;**

Triggers the A/D section if it is armed and the trigger mode is set to external.

***TST?;**

Returns the error class 3 register without clearing it. A non zero value indicates that an internal error has occurred. The device command "ISR? 2;" will return the same information but will also clear the register.

***WAI;**

The wait command will hold the parser until the operation complete register is clear. Then the next command will be parsed. At this time, unless a helium update is in progress, the *WAI; command will have no effect on the controller.

ADCR {rate-code};

A/D Converter Rate Command - Specifies the A/D Conversion Rate to be 6KSP, 12KSP, 24KSP, or 48KSP depending on the value of the code parameter, which ranges from 1 to 4 respectively. The rate is actually set when the ARM STATE is turned ON.

ADCR?;

A/D Converter Rate Query - Returns a code from 1 to 4 indicating the rate at which the converter will run when ARM STATE is turned ON; see ADCR.

AMPG {ch#} {gain-code};

Amplifier Gain Command - The amplifier which feeds the anti-alias filters (see SELS command) can be configured to have gains of 1X, 2X, 5X, and 10X. These are set by codes 1 thru

4 respectively. When the filters are being used, the AMPG gain corresponds to the value reported by the menu item GAIN. Global action for channel #0 is supported.

AMPG? (ch#);

Amplifier Gain Query - Returns a code from 1 to 4 indicating the gain setting of the specified channel; see AMPG.

ARMS {boolean};

Arm State Command - This command affects the system in several ways. When the Arm State is set to ON by the parameter being one, the primary focus of the CPU is to support the user specified data conversion, filtering, and transfer requirements. The Data Acquisition parameters which the user has loaded (such as CHSS, ADCR, and DFMD) do not take effect until the Arm State is turned on. Until this happens, the default parameters suitable for updating the LCD display are in effect. The updating of the front panel displays and scanning of the keys will be done only as a secondary task when Arm State is On, and only the channels which are in the Channel List will be updated. Auto-reset is not implemented when ARM STATE is ON.

When the ARM STATE is on, the instrument is either waiting for a trigger or actively acquiring and transmitting data. Consequently, the control computer should not be sending unrelated commands to the instrument. A typical sequence would be to arm the Model 5000, send a trigger, and start listening. Or, if the trigger mode is MANUAL, the control computer could look at the Data Ready byte in the Status Word to determine whether it should start listening; this test will avoid hanging up the controller if the trigger does not occur.

If there is any problem in data transfer while the Arm State is On, the Controller will immediately set the Arm State back to Off.

ARMS?;

Arm State Query - Returns a boolean indicating whether the Arm State is On or Off; see ARMS.

BCSF {boolean};

Binary Check Sum Flag - When set, this flag tells the binary transmission control to keep a running check sum of the data from the RAW data type acquisition and to send this two byte value at the end of the binary block. A zero value parameter disables the check sum feature.

BCSF?;

Binary Check Sum Flag Query - Returns the state of the Binary check sum flag.

BIAS {ch#} {integer};

Bias Current Command - This sets the level of bias current to the SQUID sensor. The second parameter can have values between 0 and 255, corresponding to bias values from 0 to about 20 microamps. The YAMS command determines whether the bias current is be a.c. or d.c.. Global action for channel #0 is supported, however it is not obvious why this would be useful except to set all bias currents to zero.

BIAS? {ch#};

Bias Current Query - Returns a value between 0 and 255 indicating the level of SQUID bias current in the specified channel; see BIAS.

BWRF {real};

Bandwidth Reduction Factor Command - This command affects the cutoff frequency for all of the 6-pole Butterworth low-pass filters. Since these filters are implemented digitally, the action of the filter is expressed as a dimensionless ratio describing how much the bandwidth has been reduced. Specifically, it sets the ratio of the input data Nyquist frequency to the output 3dB frequency. The acceptable parameter values for this command are from 1.0 (no filtering action) up to 9999.99.

BWRF?;

Bandwidth Reduction Factor Query - Returns a value between 1 and 9999.99 indicating the Bandwidth Reduction Factor; see BWRF.

CESE;
CESE?;

Command Error State Enable Command/query - same as ISE 0. See ISE.

CESR?;

Command Error State Register Query - same as ISR 0. See ISR.

CHAN {ch#};

Monitor Channel Select Command - This command selects which of the installed SQUID channel outputs is switched to the Monitor Connector on the front panel. If an uninstalled channel number is selected, the command will be ignored and a command error flag set.

CHAN?;

Monitor Output Channel Query - Returns the number, 1 thru 8, of the SQUID channel which is currently switched to the Monitor Connector.

CHIM {ch#} {string};

Channel Image Command - Allows the user to set all the parameters for a specified channel with one command. At this revision there are 10 parameters which have to be set to completely specify the operation of a SQUID channel. The string needed as the second parameter of this command is obtained from the CHIM? query and may be up to 80 characters long. In order to maintain flexibility in expanding the capabilities of the Model 5000, we are not explicitly defining the elements of this string; it should be created only by using the CHIM? query and then sent back, unmodified, when the user wants to restore the specified channel to a known condition.

The setup string generated from one channel can be sent to other channels, but since this would also copy the BIAS, OFFSET, and SKEW values it will normally be inappropriate to use the command in this manner.

CHIM? {ch#};

Channel Image Query - Generates and returns the character string which can be used later by the CHIM command to restore a channel to its current state.

CHSS {BWSB};

Channel Scan Set Command - This command sets which channels are to be actively scanned in a data acquisition procedure based on whether they are represented in the BWSB parameter.

The active channels are read and reported in ascending numerical order. The REP FACTR command controls the number of times the channel set is read for each triggering of the A/D converter module. The number of active channels times the REP FACTR will be less than or equal to the size of the hardware FIFOs which store the list of channels and the digitized readings: 500 entries.

CHSS?;

Channel Scan Set Query - Returns a Binary Weighted Sum of Bits indicating which channels will be read when the Arm State is turned on and conversion is triggered; see CHSS.

CONV {boolean};

A/D Converter Control Command - This command is used to disable or re-enable normal operation of the instrument's A/D converter. When the converter is running with more than one SQUID channel installed, it produces a low-level signal in the output of the SQUID channels at the converter's sampling frequency. This does not affect the digital data which is returned from the Model 5000, but it does introduce some high frequency noise into the analog data. This noise may be suppressed by sending the CONV command with a parameter of 0. When the converter is disabled, the bar graphs and the numeric display of the SQUID output data are frozen. Automatic resetting is also inoperative.

Note that this command will be temporarily overridden if the converter is required to support data acquisition in the ARM state, a manually requested output null, or a tuning operation. This command is reset to normal when the power is cycled.

CONV?;

Converter Control Query - Returns a 1 if normal operation of the A/D converter is enabled (default), otherwise returns a 0. See CONV.

DATE {month} [{date} {year}];

Set Real Time Clock's Date - This command modifies the controller's internal date. The date and year parameters are optional and will not be changed if a new value is not sent. The year parameter consists only of the last two digits.

DATE?;

Real Time Clock's Date Query - Returns the current value of the controller's date in the format: (month),(date),(last digits of year);

DECF {integer};

Decimation Factor Command - This command determines the ratio between the number of readings input to the filter compared to the number which are output. For example a DEC FACTOR of 5 would mean that only one of every 5 output values is actually sent to the port. The valid range of values for this command is 1 though 9999.

DECF?;

Decimation Factor Query - Returns the Decimation Factor which will be used when the Arm State is turned On; see DECF.

DFMD {filter-code#};

Digital Filter Mode Command - This command selects the way data is digitally filtered before being sent through the GPIB or RS-232 ports. There are three modes: RAW, AVG, and BUTTRW which are selected by codes 1 through 3 respectively.

The RAW mode can only be used with GPIB communications because of data rate limitations in the RS-232 serial interface.

When in the AVG or BUTTRW modes, data is formatted according to the DTYP command, but in the RAW mode a 2-byte integer is used. This integer is in exactly the same format as the data taken from the A/D converter FIFO's. In this RAW mode, a value of $0000 corresponds to -5 volts, $8000 corresponds zero voltage, an optional $FFFF corresponds to +5v. At the end of a block of data, a 2-byte check-sum is computed and added to the data stream if specified by the BCSF command. End-Or-Interrupt (EOI) is sent along with the second (lsB) of the checksum.

DFMD?;

Digital Filter Mode Query - Returns the code for the digital filtering mode which will be used when the Arm State is turned on; see DFMD.

DISC {ch#} {trip-voltage};

Discriminator Volts Command - The discriminator value determines the point at which a particular SQUID channel is to be reset by the computer. A voltage between 0.00 and +5.00 may be entered. The voltage comparison is performed on the signal after it has been digitized, so bandwidth and gain settings must be considered. Setting the discriminator to 0.0 disables the automatic reset function for the channel. Note that setting a value which corresponds to less than one flux quantum (but is not exactly zero) may cause the channel to continuously perform auto-resets.

The output of each channel is compared against its DISCR value approximately 60 times/second. A momentary reset is asserted if the magnitude of the output voltage is greater than the specified reset voltage. A service request may also be sent over the GPIB if it has been enabled.

When data acquisition and transfer has been armed, the microprocessor will disable the auto-reset function. This situation is indicated in the Data Acquisition Menu.

DISC? {ch#};

Discriminator Volts Query - Returns the discriminator voltage set for the specified channel; see DISC.

DISP {screen-code};

This command allows the user to remotely select one of the STATUS or DISPLAY screens to appear on the front panel. The four available options are No Display, Status Display, Bar-graph Display, and Tabular Display. These are represented by codes 0 thru 3 respectively. Note that a code of zero turns off the front panel display on the Model 5000.

DTYP {type-code} [flux_quanta_flag];

Data Type Command - This command selects between ASCII and IEEE formats for data transmission depending on whether the code number is 1 or 2 respectively. A code of 3 selects the NONE option which disables sending of data to the output port. This may be used for diagnostic purposes.

The ASCII format uses an exponential number format of 6 significant digits. Records are terminated by a semicolon and an End-Of-String (EOS) character if one has been specified. An End-Or-Interrupt (EOI) may also be sent along with the last byte during GPIB communications, if this has been enabled. Options can be selected from the IEEE-488 Setup Screen.

The IEEE format is the standard 4-byte binary form used for floating point numbers. This is faster because conversion is not required at either end and the number of bytes which must be transmitted is reduced by a factor of almost three.

Note that when the FILTR MODE is set to RAW, a 2-byte integer format is automatically used regardless of the DTYP command. See the DFMD command for a description of this format.

Normally the return values will have already been scaled by the range and gain of the channel to represent the channel's flux quanta. If you wish to deactivate this flux quanta conversion, the optional flux_quanta_flag can be set to 0. The return values will then be in a range of -5.00 to +5.00.

DTYP? [flux_quanta_flag];

Data Type Query - If the optional flag is not specified or is 0, then a value of 1, 2, or 3 will be returned depending on whether ASCII, IEEE, or NONE formats have been selected. If the flag is non zero, then the state of the flux_quanta conversion flag is returned. See DTYP.

ECHO {port number} {string};

Echo "String" Out A Port - Transmits the user's string out either the Serial (port number = 1) or the GPIB port (2). This feature is used primarily for testing. All printable characters from the parameter separator to the semicolon are converted to upper case in order to become the output string. If a non printable character or a semicolon is desired in the output string, the character's ASCII value can be specified along with a leading backslash (\) char followed by a base 10 number ranging from 1 to 255.

EESE;
EESE?;

Execution Error Status Enable Command/query - same as ISE 1. See ISE.

EESR?;

Execution Error Status Register Query - same as ISR 1. See ISR.

EOSV {ASCII-value};

EOS Value Command - Sets the value of the End-Of-String character. Any value is legal, but a typical choice would be 10 for a linefeed. Sending of the character is enabled with the SEOS command.

EOSV?;

EOS Value Query - Returns the ASCII value of the designated EOS character. See EOSV.

GODF {format-code};

General Output Data Format - Specifies how numeric output queries are to be formatted. A format-code of "1" specifies numbers are to be sent in base 10 format. "2" specifies an output format of hex (base 16) with a leading '$' character. "3" is also hex but with a leading '0x'. "4" specifies a binary (base 2) format with a leading '#' character. This command has no affect on floating point numbers or on data acquisition formats set by "DTYP".

GODF?;

General Output Data Format Query - Returns the format currently in uses. See GODF.

GREN {ch#} {boolean};

Group Reset Enable - Group reset is enabled or disabled for the specified channel depending on the value of the second parameter. Channels are numbered 1 thru 8. If a channel is enabled, then the GRST command will cause this channel to participate in the group reset activity.

GREN? {ch#};

Group Reset Enable Query - Reports whether the specified channel will participate in group resets; see GREN.

GRST {boolean};

If the parameter is TRUE (1), the channels for which group reset is enabled are held in reset. If FALSE, a momentary reset is issued to the enabled channels. This momentary reset will have the effect of taking a channel out of a chronic reset condition.

HCAL {percentage};

Helium Calibration Command - Tells the instrument that the cryostat is filled to the percentage given in the parameter. This value should be between zero and 50. The instrument then performs a reading and calibrates it to the specified value. A one point calibration is valid, since this type of helium level sensor is inherently linear. The most accurate calibration will be with a cold but empty cryostat. Calibration with the cryostat full is not possible since the sensor always reads zero voltage. If the cold but empty voltage point is already known, then use the HZER command.

HEAT {ch#} {boolean};

Heater Activation Command - The heater for the specified channel is turned ON or OFF as specified by the second parameter. Channel 0 causes global activation of the heaters. It is the responsibility of the user to turn off the heaters after a suitable period of time.

NOTE: Heaters must be physically installed before this command can have any effect. See section 5.11 for details.

HEAT? {ch#};

Heater Activation Query - Returns 1 if the heater is on for the specified channel and 0 otherwise.

HLEV [stay_on_flag];

Helium Level Command - If the stay_on_flag is not specified, the instrument will turn on the level sensor for a few seconds, read the level, and make the result available for reading. The result will be a real number between 0 and 100 corresponding to the percentage of helium in the cryostat. The level sensor must have been previously calibrated for the reading to be valid.

The level sensor can be locked on by specifying the stay_on_flag as 1. Each helium level query (HLEV?) will do an immediate helium level read and return the resulting percentage with the fresh flag = 2 showing the meter is still in the stay_on mode. If a HLEV? query is not received within 60 seconds, a timer will turn off the meter heater causing the fresh flag to return to a 1 value.

A value of "0" for the stay_on_flag will immediately deactivate the meter heater.

HLEV?;

Helium Level Query - Returns two integers. The first is the most recent percentage reading for the helium level sensor. The second is a fresh_flag indicating age of this percentage.

The fresh_flag may be 0 if the percentage is over an hour old or an update is in progress but the percentage is not available yet. A value of 1 for the fresh_flag indicates the percentage is under an hour old.

A value of 2 indicates the helium meter is in the "Stay_on" mode and the percentage was read immediately due to this query command. The time the DC5000 takes to return the responses in this mode may be up to 1 second depending on how long it takes to quiz the hardware. This query will also reset a timer so the meter will stay on for another 60 seconds before timing out. When using the Stay_on mode, adequate time to let the helium meter warm up should be given between the "HLEV 1;" command and the first "HLEV?" query or the percentage response will not be correct. This mode would most likely be used during a helium transfer to continuously monitor the level without having the meter turn on and off.

A procedure for forcing a new level measurement would be to send the HLEV; command without a flag and then keep sending the HLEV? query until the fresh flag returned as a 1.

HMON {boolean};

Helium Level Monitor Command - This command turns on or off the hourly updating of the helium level display depending on the value of the boolean parameter. A value of 1 turns it on, while 0 turns it off.

HMON?;

Helium Level Monitor Query - Returns a 1 or 0 indicating whether hourly updating of the helium level display has been enabled or disabled.

HZER {new voltage};

Helium Zero Reference command - Sets the zero voltage reference point used to calculate the current helium level percentage. This real number between 0.0 to 30.0 volts is normally figured out by the DC5000 when the user specifies the current helium percentage. However, if the cold empty voltage of the helium meter is known and the user does not wish to wait for the helium level to be between 0 to 50%, this command allows the point used in the point/slope calculation to be specified. A HLEV command may be needed to update the current level using this new voltage.

HZER?;

Helium Zero Reference Query - Returns a real number representing the helium zero reference voltage. This reference is the voltage of the helium level meter when the cryostat is empty but still cold. The level sensor must have been previously calibrated for the value to be valid.

IESE;
IESE?;

Internal Error Status Enable Command/query - same as ISE 2. See ISE.

IESR?;

Internal Error Status Register Query - same as ISR 2. See ISR.

INST {ch#} {boolean};

Install Channel Command - Either installs or uninstalls the specified channel depending on the value of the boolean parameter. A value of 1 installs the channel and a value of 0 uninstalls it. An installed channel exists for purposes of tuning, display, and configuration. A channel may be installed without a multiCARD physically present in the slot corresponding to the designated channel.

INST?;

Install Channel Query - Returns a Binary Weighted Sum of Bits (BWSB) indicating which channels have been installed. The BWSB is an ASCII decimal number between 0 and 255 which represents which channels are installed. If a bit in the binary representation of the number is "1" then that channel is installed. If the bit is "0" then the channel is not installed, et cetera. The following table shows the principle. The BWSB is the sum of the values which represent each channel.

CHANNEL	VALUE
1	1
2	2
3	4
4	8
5	16
6	32
7	64
8	128

ISE {class} {enable_mask}

Indexed Status Enable Command - enables the generation of a Service Request when the corresponding class/register bit is set. Valid class numbers and duplicate commands are described in the ISR? query description. The bits within each class are described in Appendix C. The enable_mask is a BWSB type integer whose range runs from 0 {mask all} to 65535 {allow all bits in this class to generate a service request}. An entire class may be disabled by using the *SRE command with its BWSB parameter bit set to a 0.

ISE? {class}

Indexed Status Enable Query - Returns the current enable mask for the class specified. See the ISE and ISR? commands.

ISR? {class}

Indexed Status Register Query - Returns a BWSB type integer indicating the errors, events or status changes for the class specified. This command clears the class afterwards so the next query will have fresh data. Each bit will generate a service request on its CLEAR to SET transisition if its corresponding enable_mask has been set (ISE) and the class is enable (*SRE). Valid class numbers and duplicate commands are:

```
[CESE] 0 = Command Error Class
[EESE] 1 = Execution Error Class
[IESE] 2 = Internal Error Class {also by *TST? but not
           cleared}
[SQSE] 3 = SQUID Reset Event
       4 = Data Ready Class {normally not read with ISR}
[*ESE] 5 = Standard Event Class
       6 = {not used - reserved for GPIB}
[SDSE] 7 = Status Change Summary [not used - reserved}
```

See Appendix C for the bit and class descriptions.

LINE?;

Line Frequency Query - Returns the power line frequency as measured in a 2 second period and rounded to the nearest integer Hertz. Normally this value would fall within ±1 Hertz of either 60 or 50 depending on the user's location.

MONF {filter-code};

Monitor Filter Command - There are several combinations of low-pass and notch filtering which can be applied to the signal before it is presented at the front-panel BNC connecter and the monitor pins on the rear-panel "Analog Output" connector. The low pass filters are 2-pole Butterworth design. The notch filter has rejection notches at the line frequency as well as its second and third harmonics. The filter is factory tuned for either 50 or 60 Hz operation depending on the location of the user. It is possible for this selection to be changed in the field by a competent technician.

The code# parameter selects combinations of low-pass and notch filtering according to the following table. Note that some combinations would not be useful and are therefore not included.

CODE#	FILTERS
1	NONE
2	NOTCH ONLY
3	100HZ
4	100HZ+NOTCH
5	10HZ
6	1HZ

MONF?;

Monitor Filter Query - Returns the code for the currently active monitor filter combination; see MONF.

NULL {ch#} {null-code};

Nulling Mode Command - This command allows the user to determine when the instrument is to null the output of a channel to zero volts by use of the offset D/A converter after a momentary reset. The options are OFF, MAN, and AUTO which are selected by codes 1 thru 3 respectively. Global action for channel zero is supported. If OFF is selected, the value in the offset D/A converter is left unchanged. If MANual is selected, then the offset D/A converter is adjusted only after a manual or externally generated reset. If AUTO is selected, then adjustment will also occur after an internal reset generated when the channel exceeds the discriminator voltage.

NULL? {ch#};

Nulling Mode Query - Returns the value of the Null Code for the specified channel; see NULL.

OBOF {boolean};

Output Buffer Overwrite Flag - This flag determines how the controller will handle a second query when the first query is still in the output buffer. When this flag is set (1), the second query will cause the output buffer to be reset before it's response is added. Otherwise, the second query will be appended to the end of the first query after the semicolon. This flag has no affect on the RS-232 system or on the data acquisition output buffer control.

OBOF?;

Output Buffer Overwrite Flag Query - Returns the state of the output buffer overwrite flag. See OBOF.

OFST {ch#} {integer};

Offset Current Command - Using this command an offset current can be injected into the specified channel. The value of the second parameter can range from zero to 4095, corresponding to a 12-bit resolution. The full output, 4095, corresponds to a current of 3.6 microamps into the SQUID modulation coil (or about 2 flux quanta). Global action for channel zero is supported.

This command is typically used to null the output of a SQUID channel so that additional gain can be applied without causing saturation in amplifier or filter stages.

OFST? {ch#};

Offset Current Query - Returns the offset current being applied to the specified channel; see OFST.

REPF {integer};

Repeat Factor Command - This command tells the CPU how many times to repeat loading the channel list into the control FIFO. In Filter Modes other than high-speed binary, the REP FACTR tells how many readings to average for each "on" channel once the converter has been triggered. The maximum value for this parameter depends on the size of the channel list; see CHSS command.

REPF?;

Repeat Factor Query - Returns the repeat factor which will be used when the Arm State is turned on; see REPF.

REV?;

Revision Number Query - Returns a string containing the revision number and the date in the following form: "Revision Number: 1.00, Date: Apr 03 1991".

RNGE {ch#} {range-code};

Feedback Range Command - The four feedback ranges which can be selected by this command are 5S, 5, 50, and 500. These numbers represent the approximate number of flux quanta for a zero to full-scale excursion on the specified range. The peak-to-peak value is twice this number with a corresponding voltage range of ±5V. The 5S range has a bandwidth of about

1KHz and a correspondingly low slew-rate. It is characterized as being very stable against short transients which might cause a faster feedback system to respond incorrectly (flux jump). The ranges are selected by codes 1 thru 4 respectively. Global action for channel zero is supported.

We have chosen a voltage range of ±5 volts instead of the usual ±10 volts for several reasons. Slew rate and distortion problems with low-power op-amps, leakage and non-linearity of FET switches, and greater compliance voltage for current sourcing are some of the issues. The system's A/D converter is also designed for a ±5 volt range.

RNGE? {ch#};

Feedback Range Query - Returns the feedback range code for the specific channel; see RNGE.

RSET {ch#} {boolean};

SQUID Channel Reset Command - If the second parameter is TRUE, this command holds the specified channel in reset. If the parameter is FALSE, a momentary reset is issued to the specified channel. The momentary reset will have the effect of taking a channel out of a chronic reset condition. If the channel number is zero, then a global reset is issued, and the operation just described is performed on all channels regardless of whether group reset is enabled. See also GR RESET.

RSET? {ch#};

SQUID Channel Reset Query - This query returns a 1 if the specified channel is in a chronic reset condition, and a 0 otherwise. Momentary resets are not detected; see RSET.

RSWD {slow_fast_select} {hold_time};

Reset Pause Width command - Changes the time a channel is held in reset when a momentary reset command is executed. The slow_fast_select parameter selects which delay time to modify. A 1 selects the fast reset time while 2 selects the slow reset time used with range "5S". The hold_time is in milliseconds ranging from 1 to 1000.

RSWD? {slow_fast_select};

Reset Pause Width Query - Returns the current reset delay time used for momentary resets. The slow_fast_select picks which time to return. See RWSD command.

SDSE;
SDSE?;

Summary Device Status Enable Command/query - same as ISE 7. See ISE.

SDSR?;

Summary Device Status Register Query - same as ISR 7. See ISR. This Register catches the changes of the Indexed Device Status Register array which at this time is mostly not implemented or described.

SELS {ch#} {source-code};

Signal Source Select Command - There are five bandwidth choices for each channel: four Butterworth filter settings or no filtering. In addition to these normal outputs, one can select three diagnostic outputs: Detector, Tune, and Sense. The Butterworth filters on the multiCARD are 3-pole filters set at 16KHz, 4KHz, 2KHz, and 1KHz selected by codes 1 thru 4 respectively. If you select no filtering (code 5), the effective bandwidth is about 50KHz. The 50KHz bandwidth exceeds the Nyquist bandwidth for the on-board A/D converter substantially, and is therefore intended for external processing by the user. Note that the 1x-2x-5x-10x gain stage is only active when one of the Butterworth filters is being used (codes 1 thru 4). For all other output choices, it is bypassed so that the effective gain is 1X.

The Detector output (code 6) allows one to observe the "triangle" pattern when in open loop mode. The TUNE output (code 7) is a peak-detected version of the Detector output and may be useful for tuning operations. The SENSE output (code 8) is +5 volts if a multiCARD is present for the channel but the microPREAMP is not plugged in; it drops to 4.5 volts when the microPREAMP is installed. It is near zero volts if no multiCARD is installed. These diagnostic outputs can be viewed at the Monitor Connector just as the normal channel outputs are. Global action for channel zero is supported.

SELS? {ch#};

Signal Source Select Command - Returns the code of the signal source for the specified channel; see SELS.

SEOI {boolean};

Send EOI Command - If the parameter is TRUE, the EOI line will be asserted along with the last byte in a string. This will be the EOS character if one is enabled, otherwise it will be the terminating semicolon.

SEOI?;

Send EOI Query - Returns a 1 if sending of EOI has been enabled, 0 otherwise. See SEOI.

SEOS {boolean};

Send EOS Character - If the parameter is TRUE, this enables sending an End-Of-String character after the terminating semicolon. The ASCII value of the character which is sent can be specified by the EOSV command. This character may be useful when reading data into application programs. For example, if the EOS is a linefeed, then Pascal programs can use one "Readln" command to obtain a full block of data.

SEOS?;

Send EOS Query - Returns a 1 if sending of an EOS character has been enabled, 0 otherwise. See SEOS.

SKEW {channel#} {integer};

The skew factor is set for the specified channel. The value can range from -127 to 128. A value near zero is typical. Global action for channel zero is supported.

SPMD {baud-rate} [{parity-code} {data-bits} {stop-bits} {use_Xon}];

Serial Port Mode Command - Sets up the communication parameters for the serial port. The baud-rate can be 300, 1200, 2400, 4800, 9600, 19200, or 38400. The rest of the parameters are optional and will not change unless specified. The parity-code is 0 for "None", 1 for "Odd" and 2 for "Even". The data-bits parameter can be 7 or 8, and the stop-bits can be 1 or 2. The use_Xon parameter is a flag with a value of 0 for "OFF" and 1 for "ON" specifying the uses of the Xon protocol { ^S and ^Q }. The form of this command is similar to that used in IBM PC DOS except that the parity must be given as a numeric code rather than a letter, and the additional use_Xon flag.

SPMD?;

Serial Port Mode Query - Returns a string describing the configuration of the serial port using the same format as described in the SPMD command.

SPSS {ASCII-code} [{ASCII-code} {ASCII-code} {ASCII-code}];

Serial Port Service Request String - This feature is for serial port error handling. When enabled and an event or error occurs that would normally generate a GPIB service request, a user defined character string of up to 4 characters is transmitted out the serial port. Every enabled error bit {set by ISE or the equivalent} in each enabled class {set by *SRE command} can generate a serial request string with the exception being the DATA ready class. The error or event must be cleared {ISR? or equivalent command} to re-enable the serial request for that event. A value of -1 in the first parameter turns off this feature. Any other value is interpreted as the ASCII value of the first char in the serial request string. The other 3 parameters are optional and may contain the break char (ASCII zero) if desired. If the serial port terminator string {SPTS} has been enabled, it's affect will be appended to the end of the serial request string. This feature has no affect on GPIB commutations.

SPSS?;

Serial Port Service Request String Query - Returns the ASCII values of the service request string's characters. The number of returned values is equal to the number of characters in the string. A -1 indicates that the feature is disabled.

SPTS {ASCII-value} [{ASCII-value} {ASCII-value} {ASCII-value}];

Serial Port Terminator String - This command is used to add termination characters after the semicolon on most query responses. The termination string functions are similar to the EOS feature of the GPIB but only works with the serial port. An ASCII-value of -1 in the first parameter disables this termination control. The 2nd through 4th parameters are optional and will be appended to the query if specified.

SPTS?;

Serial Port Terminator String Query - Returns the value of the characters appended to each query. A -1 value indicates no termination characters are appended.

SQSE;
SQSE?;

SQUID Reset Status Enable Command/query - same as ISE 3. See ISE.

SQSR?;

SQUID Reset Status Register Query - same as ISR 3. See ISR>

TEST {ch#} {boolean};

Test Signal State Command - The test signal is turned on or off for the specified channel depending on the value of the second parameter. Global action for channel zero is supported. A boolean value of TRUE turns the test signal on.

This signal is a sawtooth voltage at a frequency of approximately one hundred hertz which sweeps the SQUID sensor through about 10 flux quanta. It is useful for tuning the SQUID as well as observing its operation in locked loop mode.

TEST? {ch#};

Test Signal State Query - Returns a 1 or 0 depending on whether the test signal is turned on for the specified channel; see TEST.

TIME {hour} [{minute} {seconds}];

Set Real time clock command - This command modifies the real time clock. The minutes and seconds parameters are optional and will not be changed if a new value is not sent. The hour parameter is to be in 24 hour format. The real time clock is used by the controller to determine when to update the helium level if the feature is enabled. The update occurs on the hour change. The real time clock continues to function on battery power when the main power is turned off.

TIME?;

Real Time Clock Query - Returns the current value of the real time clock in the format: (Hour),(Minute),(Second);

TMOD {trigger-code};

Trigger Mode Command - This command selects the method of starting the conversion process. The possible choices are MAN, LINE, EXT, and CONT for codes from 1 to 4 respectively. In the MANual mode, conversion is started by pressing the period [.] key when the cursor is at this menu item. When in the EXTernal mode conversion is started by sending a Group Execute Trigger command over the IEEE-488 interface or the TRIG command over either interface. In the LINE mode, triggering will be synchronized to zero crossings of the a.c. power supply line. The CONTinuous mode does not wait for any triggering event, but immediately begins conversion and continues as long as no overflows occur in any data buffers. The MAN mode can be used to effectively turn off triggering since the instrument will wait for a manual keypress.

TMOD?;

Trigger Mode Query - Returns the code for the triggering which will be used when the Arm State is turned on; see TMOD.

TUNE {BWSB} {heat-flag};

Tune Command - This causes the channels represented in the Binary Weighted Sum of Bits to be auto-tuned. Auto-tuning adjusts the BIAS current of the SQUID sensor to obtain a maximum amplitude of response from an input signal. In the present code revision it does not attempt to adjust the SKEW value to optimize performance when YAMS is activated.

It is assumed that the MOD and FB-GAIN potentiometers have already been set correctly for the particular SQUID sensors involved. These should not require re-adjustment when the SQUIDs are retuned.

TUNE? {ch#};

Tune Query - Returns the amplitude of the tuning peak for the specified channel. The value is reported in volts, ranging from 0 to 5. The nominal voltage for a channel is 3 ± 1. The bias current which is being used on the channel can be read with the BIAS? query.

VOUT? {ch#};

Channel Output Voltage Query - This command provides a minimal form of data acquisition suitable for diagnostic purposes. The channel voltage which had last been read for screen display purposes is placed into the GPIB output buffer for reading. The SELS command determines what is being reported: locked-loop output, detector output, tuning output, et cetera.

YAMS {ch#} {boolean};

YAMS Biasing State Command - The bias current applied to the SQUID sensor will be a constant d.c. value if the boolean parameter is FALSE. It will be reversed at a 1953 Hz rate if the parameter is TRUE. Global action for channel zero is supported.

This a.c. bias mode, called YAMS, is used for 1/f noise reduction. This is one of many methods proposed to suppress noise due to fluctuations in junction parameters. Its main advantage is that it can be easily and completely turned off when it is not required

YAMS? {ch#};

YAMS Biasing State Query - Returns a 1 or 0 indicating whether a.c. biasing has been enabled or disabled respectively for the specified channel; see YAMS.

4 DATA ACQUISITION

This chapter describes how to use the Model 5000's A/D conversion, digital filtering, and data transfer capabilities to provide a high performance data acquisition system.

4.1 General Architecture

The data acquisition function is shown schematically in Figure 4.1. Analog signals from up to 8 SQUID channels are routed to the input of the multiplexer which cycles among the channels that have been selected for digitizing. The channel list information is stored in hardware so that blocks of information can be digitized rapidly without direct intervention of the microprocessor. A block of data consists of repeated sets of data, where each set contains from 1 to 8 individual channel readings - one reading per channel, with readings made in channel-number order. The channel set is defined using the Channel Scan Set Command (CHSS) or by toggling individual channels on/off in the Data Acquisition Menu. The number of data sets in a block is specified by the Repeat Factor Command (REPF) or by the REP FACTR menu item. A block of data can contain up to 500 readings. For example it might contain readings on channels 1,2,5,7,8 repeated 100 times.

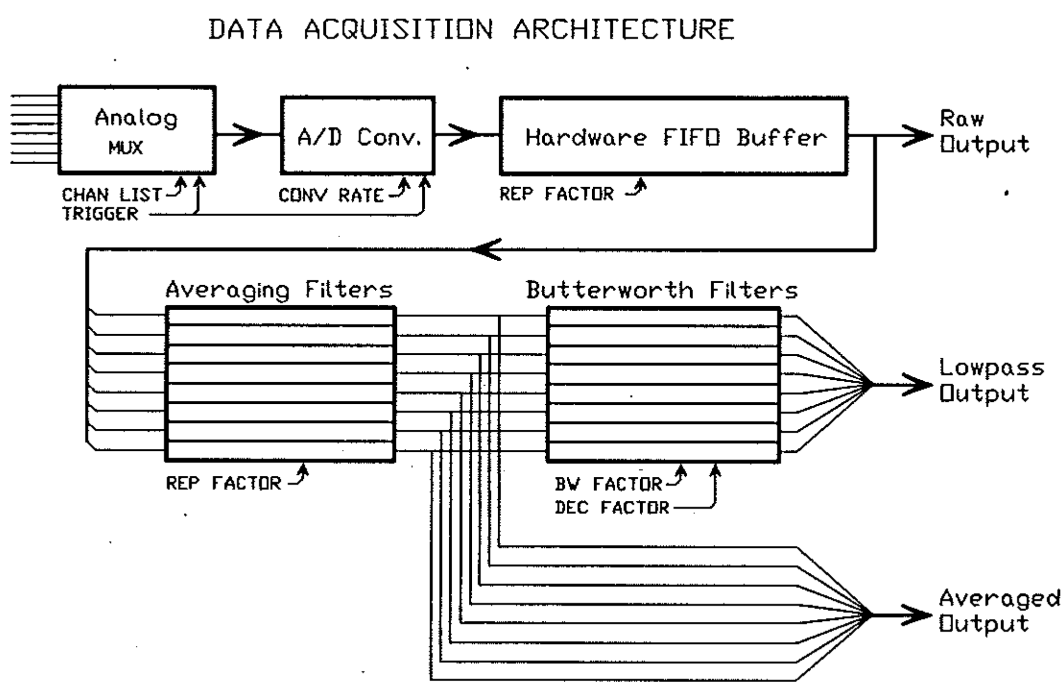


Figure 4.1

Data conversions are performed at a rate determined by a quartz crystal oscillator and a programmable dividing network. Rates of 6KHz, 12KHz, 24KHZ, and 48KHz can be selected using the A/D Conversion Rate Command (ADCR) or the AD RATE menu item. This range of rates was chosen to best utilize the performance of the A/D converter and multiplexer. These specific rates were chosen because they are convenient multiples of both 60 Hz and 50 Hz - a feature which can be used to greatly improve the rejection of power line noise as we discuss in section 4.6.

The A/D converter has 16-bits of resolution and uses the successive approximation technique. It also has a built-in microprocessor which allows it to calibrate itself on command, correcting any errors in the binary weighting of the bits, and providing remarkable linearity characteristics for the device. A failure of the converter to adequately correct its binary weighting is reported to the user in the Internal Error Status Register. These calibrations are performed at power-up and whenever a *CAL? query/command is issued.

When the converter finishes digitizing a voltage, the 16-bit result is pushed into an 18-bit wide by 512 word-deep FIFO buffer. The extra two bits are used internally for framing information. The FIFO will continue to accumulate data as long as the converter runs, causing an overflow unless it is unloaded regularly. The FIFO buffer can be unloaded through an interrupt process. As soon as the last reading in a block has been made, the main microprocessor is interrupted from its current task and begins transferring the 18-bit wide words into its main memory (RAM). This combination of a dedicated FIFO and fast RAM storage provides high performance and allows the microprocessor to perform complex filtering algorithms or data transfers while the converter is running unattended.

Once data has been loaded into RAM it may either be transmitted in binary form through the GPIB interface, or it may be split into separate channels and loaded into the Averaging Filters. These filters uniformly average all readings on a particular channel in each block. This averaging is performed in integer arithmetic, to enable the mircroprocessor to keep up with the A/D converter. The output of each Averaging Filter is a single value for each channel for each block of data. As you can see in Figure 4.2, the frequency response of the Averaging Filter is rather complicated; its main purpose is to reduce the effective data rate to a level which can be handled by a final filter such as the Low-pass Butterworth Filter. If desired, this averaged data can be sent out through either the GPIB or RS-232 interface without any further processing. This is the device's medium speed mode of operation.

The averaged data may also be used as input to a set of digital Butterworth filters to further reduce the effective bandwidth and provide a more typical frequency response than that of the Averaging Filters. The Butterworth filters are constructed with 6-poles and are derived from their analog counterparts by applying the bilinear transformation. They have an attenuation of 3dB at their cutoff frequency as shown in Figure 4.3. The filters provide a faster roll-off than

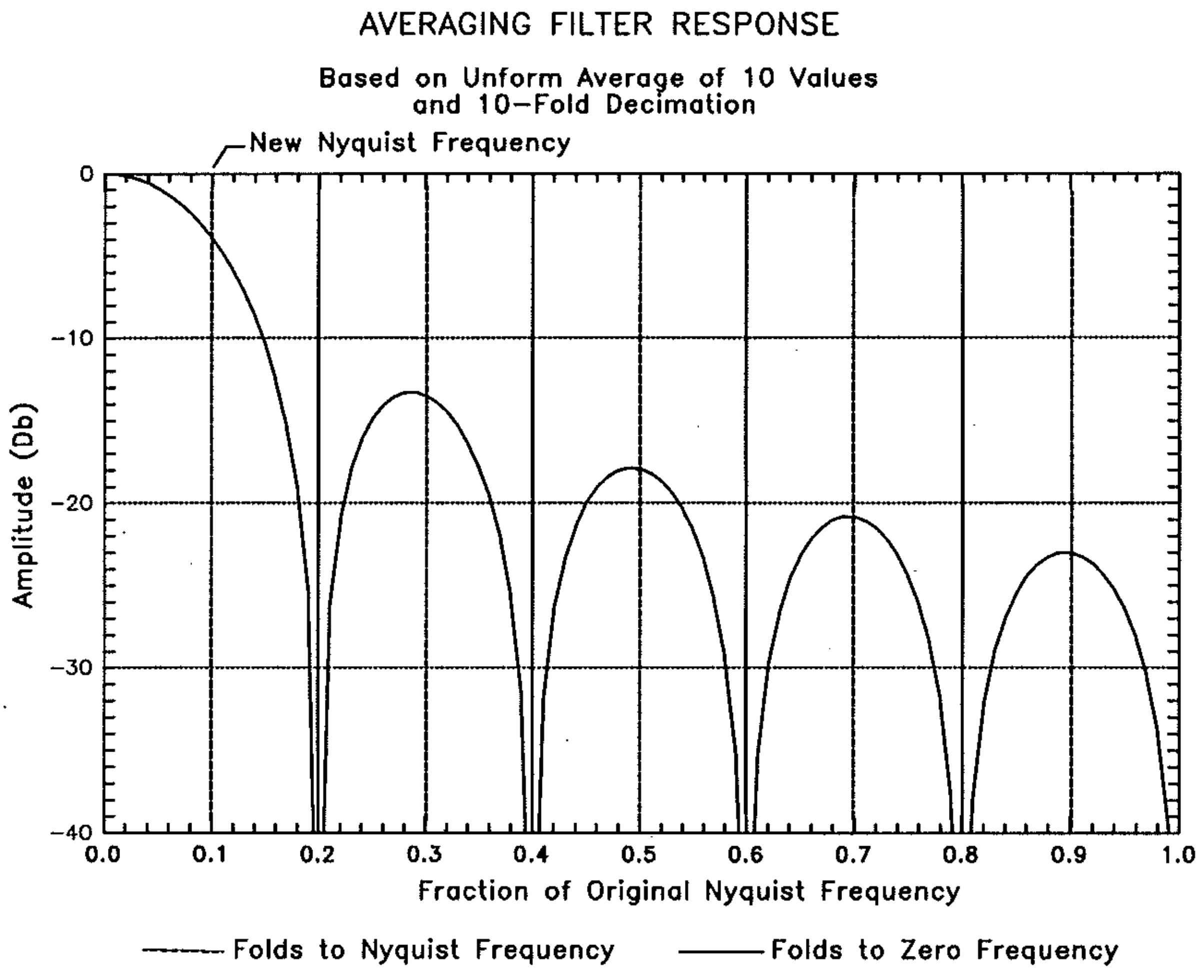


Figure 4.2

would be obtained from a corresponding analog filter since there is effectively zero response at the Nyquist frequency. The ratio between the Nyquist frequency of the input data and the 3dB frequency of the output data is specified by the BWRF command or by the BW FACTOR menu item. This factor must be greater than 1 for the filter to be realizable. The Decimation Factor Command (DECF) or the DEC FACTR menu item can be used to reduce the data rate of the filtered output through decimation. As we will discuss in section 4.4 the value for the Decimation Factor must be compatible with the Bandwidth Reduction Factor or you risk aliasing your data.

For improved dynamic range these filters use floating point arithmetic provided by the MC68882 coprocessor. Output can be in either ASCII or IEEE floating point format through the IEEE-488 interface or in ASCII format through the RS-232 interface.

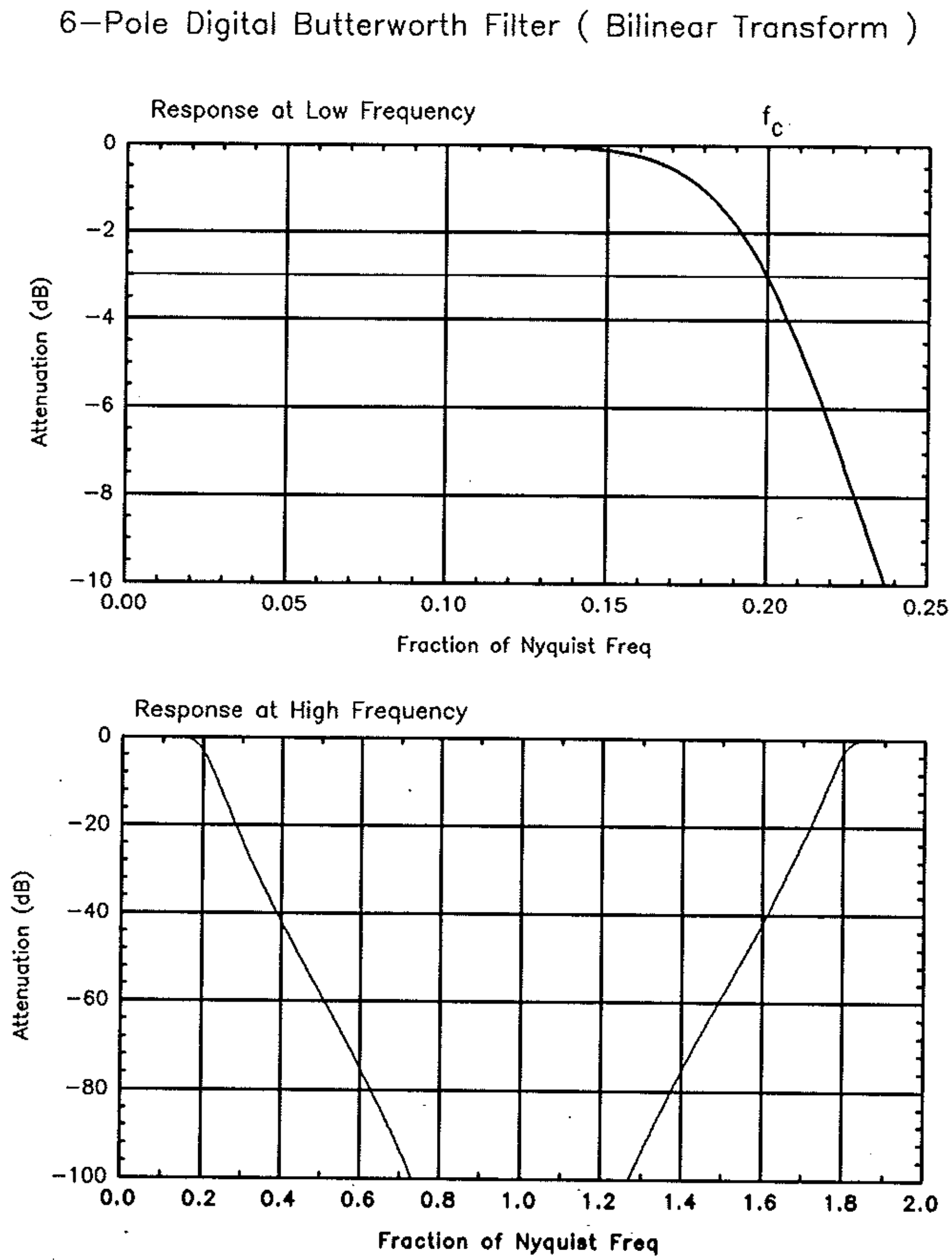


Figure 4.3

4.2 Acquisition Modes and States

As is evident from Figure 4.1, there are three points in the processing chain from which the output data can be obtained. These represent data in either the "Raw", "Averaged", or "Low-passed" condition. The Digital Filter Mode command (DFMD) or the FLTR Mode menu item is used to select which of these points is to be the source of the output data. Generally speaking, the Raw, Averaged, and Low-passed modes are used for high, medium, and low speed transmission respectively. See section 4.4 for further discussion.

When the Model 5000 receives commands to change data acquisition parameters (such as conversion rates or channel sets, they are stored in memory but the hardware is not reconfigured until the instrument is given a command to go into the Arm State (ARMS 1;). At this point all eight acquisition parameters are loaded and the system will begin taking data as soon as a trigger is received (or immediately if continuous triggering has been selected). The system will remain in the Arm State until it is turned off by another Arm State command (ARMS 0;), or until there is an error in the data acquisition or transmission process, or until a command is received to change one of the acquisition parameters. In other words, the system will remain in the Arm State until some unexpected event occurs which causes it to drop out of that state.

This implementation of the Arm State allows the Model 5000 to operate in its normal manner until the user is completely ready to collect data. As soon as the data collection is finished, the instrument can immediately return to maintaining its data displays, resetting channels, nulling outputs, etc.

In normal operation the Model 5000 continuously maintains the front panel display, updating all of the installed channels. When the ARM State is activated, the instrument switches to reading only those channels for which data is to be collected and processed. Note that when the unit is in this state and when it is collecting data, the front panel display will be updated only if the microprocessor can do so without interfering with the data collection and processing. Hence, the ARM State provides a logical method for switching the unit between two states - its normal operating mode where the front panel display is updated continuously and the data collection/processing mode in which data collection and processing take priority.

4.3 Triggering Options

There are four options for initiating data collection via the A/D converter after the instrument has been placed in the Arm State. They are Manual, External, Line and Continuous. As soon as a trigger is received, one block of data is taken; digital filtering is done and the system waits for another trigger.

Manual triggering requires that the period [.] button be pressed on the keyboard to start the converter.

When External triggering is selected, either a GPIB *TRG command or a high->low transition on pin 9 of the RS-232 connector will start the converter.

When Line triggering is selected, conversions start on a zero crossing of the ac power line.

If Continuous triggering is selected, the converter retriggers itself as soon as the last block of data has been digitized. In this mode the converter runs continuously as long as the user can receive data through one of the control ports fast enough to keep the data buffers from overflowing.

4.4 Conversion Rates and Aliasing

There are four analog filters provided on each SQUID multi-CARD. These 3-pole Butterworth filters can be used to attenuate signals above the Nyquist frequency for a particular acquisition configuration. The effective Nyquist frequency for a channel depends on the A/D converter rate as well as the number of channels which must share the converter. For a particular combination of A/D Converter Rate, number of active channels, and analog filter cutoff frequency, (f_C), there will be a certain attenuation at the Nyquist frequency. These relationships are shown in Figure 4.4.

It is not possible to categorically specify the attenuation needed at the Nyquist frequency, f_N, since it depends on the spectral content of your signal and noise. If most of the energy in the signal is below f_N and you are only trying to keep white noise from aliasing into your data then the configuration with 11 dB of attenuation at f_N may be adequate. On the other hand, if there are large signals near f_N it may be necessary to use a configuration with 45 dB of attenuation.

It should be carefully noted that signals slightly above f_N will fold to a frequency slightly below f_N. If you are going to do further low-pass filtering, aliasing near f_N may not be a concern. On the other hand, frequencies near $2f_N$ will alias to frequencies near dc. This would presumably be undesirable under most conditions. Fortunately, the 3-pole filter provides up to 18 dB more attenuation at the crucial frequency of $2f_N$.

Attenuation at Nyquist Frequency and Twice Nyquist Frequency (dB)					
# Active Channels	Filter f_c (KHz)	A/D Converter Rate			
		48KHz	24KHz	12KHz	6KH
1	1	83/101	65/83	47/65	29/47
	2	65/83	47/65	29/47	11/29
	4	47/65	29/47	11/29	1/11
	16	11/29	1/11	0/1	0/0
2	1	65/83	47/65	29/47	11/29
	2	47/65	29/47	11/29	1/11
	4	29/47	11/29	1/11	0/1
	16	1/11	0/1	0/0	0/0
3	1	54/72	36/54	18/36	3/18
	2	36/54	18/38	3/18	0/3
	4	18/36	3/18	0/3	0/0
	16	0/3	0/0	0/0	0/0
4	1	47/65	29/47	11/29	1/11
	2	29/47	11/29	1/11	0/1
	4	11/29	1/11	0/1	0/0
	16	0/1	0/0	0/0	0/0
5	1	41/59	23/41	6/23	0/6
	2	23/41	6/23	0/6	0/0
	4	6/23	0/6	0/0	0/0
	16	0/0	0/0	0/0	0/0
6	1	36/54	18/36	3/18	0/3
	2	18/36	3/18	0/3	0/0
	4	3/18	0/3	0/0	0/0
	16	0/0	0/0	0/0	0/0
7	1	32/50	14/32	1/14	0/1
	2	14/32	1/14	0/1	0/0
	4	1/14	0/1	0/0	0/0
	16	0/0	0/0	0/0	0/0
8	1	29/47	11/29	1/11	0/1
	2	11/29	1/11	0/1	0/0
	4	1/11	0/1	0/0	0/0
	16	0/0	0/0	0/0	0/0

Figure 4.4

4.5 Repeat Counts and Averaging

As described in section 4.1, the Repeat Factor (REPF) command is used to specify how many times the channel set is to be read for each block of data. Remember that each block read is initiated by a trigger event. After the last conversion in a block is completed, the acquisition hardware interrupts the microprocessor at a high priority level, and the microprocessor copies the data into RAM. It must then return from the interrupt and perform some "housekeeping" tasks. Since there is a significant overhead for the interrupt process (about 400us), it is more efficient if there are many pieces of data to copy. For example, when operating in the high-speed RAW mode at 48 KHz, there must be at least 80 entries in the channel list or the microprocessor will not be able to keep up with the A/D converter. Reading all 8 channels with a Repeat Factor of 10 would result in a data block of this length. This also assumes that the host computer can handshake bytes through the GPIB at a 200K/sec rate. If the channel list is too short for the operating conditions, the converter will slowly fill up the hardware FIFO until it overflows, and the instrument will drop out of the Arm State. In fact, one way to determine the minimum length of channel list is to shorten it until the system just fails to keep up.

When in the Averaging or Lowpass modes, similar considerations apply for determining the minimum channel list. Here, however, the problem is complicated by the wider choice of configurations. The number of different channels, the Data Type (ASCII or IEEE), and the Decimation Factor also affect the minimum channel length in these two modes. The use of ASCII format slows down operations both because there is significant time required to perform the conversion (200us) and because more bytes must be transmitted per reading, typically 12 versus 4. (Remember that with RS-232 communication, only the ASCII mode is available.) The number of different channels in the list will affect the speed because each channel represents one reading which must be loaded into the Butterworth filter and processed (which requires about 500us/channel). Likewise, the value of the Decimation Factor affects speed because it helps determine how many numbers must be converted to ASCII and transmitted via the GPIB. This is not as complex as it may appear at first glance. If you clearly understand what kind of data rate and bandwidth you need, some experimentation should yield a suitable set of acquisition parameters.

4.6 Rejecting Unwanted Frequencies

The Repeat Factor can be chosen to aggressively notch out certain frequencies such as power-line noise. Referring back to Figure 4.2, it is clear that there are a series of zeros in the transmission of the averaging filter which are located at a frequency corresponding to the reciprocal of the averaging period and its harmonics. The trick is to select the correct

Repeat Factor for a particular fundamental frequency, size of channel set, and A/D converter rate. Figure 4.5 shows some suitable values of REPF for power line rejection under various conditions. Note that the hardware FIFO is not large enough to reject 50/60 Hz noise when running at 48KHz.

Optimum Repeat Factor for Power Line Rejection				
Freq	# Chan.	24KHz	12KHz	6Khz
60Hz	1	400	200	100
	2	200	100	50
	3	133*	66*	33*
	4	100	50	25
	5	80	40	20
	6	66*	33*	16*
	7	57*	28*	14*
	8	50	25	12
50Hz	1	480	240	120
	2	240	120	60
	3	180	90	45
	4	120	60	30
	5	96	48	24
	6	90	45	22*
	7	68*	34	17*
	8	60	30	15

*Not exact values.

Figure 4.5

4.7 Low Pass Butterworth Filters

For relatively low data transfer rates, the digital Butterworth filter can provide the best frequency response characteristics available from the Model 5000. In Figure 4.3 we have already seen the characteristics of this filter for a Bandwidth Reduction Factor (BWRF) of 5.

This filter has a steeper roll-off (120dB/decade) than either the 3-pole analog filters (60dB/decade) or the uniform averaging filter (roughly 20dB/decade). Used together correctly, the Averaging and Butterworth filters can provide a steep roll-off plus excellent protection from aliased power-line noise.

The other parameter which defines the operation of the Butterworth filter is the Decimation Factor (DECF). A Decimation Factor of 2 means that <u>every other value</u> for a channel is thrown away. This count must be chosen to be compatible with the Bandwidth Reduction Factor, or signals and noise may be aliased into the new reduced bandwidth. The effective Nyquist frequency for acquisition is reduced from that of the averaging filter by a factor equal to the Decimation Factor. Refer to Figure 4.3 to see how much attenuation is obtained at the NEW Nyquist frequency (or other frequencies) for certain ratios of BWRF to DECF. This graph is drawn in terms of an input frequency f_N of one for generality; it must be scaled by the actual output f_N of the Averaging Filter which is feeding the Butterworth filter.

5 INSTALLATION

This chapter contains information for installing the Model 5000 and the components which comprise the SQUID channels. Connector and cable requirements for attaching to the IEEE-488, RS-232, and Analog Output ports are discussed. Repackaging and shipping information is also given if factory modifications or repairs should be required.

5.1 Initial Inspection

The Model 5000 and its associated components were carefully inspected for electrical and mechanical faults before shipment. It should have no scratches or dents and should be fully functional when received. To confirm this, inspect the unit for physical damage which may have occurred in transit. If any damage is apparent, promptly file a claim with the carrier, and notify the factory.

Verify that all the multiCARDs and microPREAMPs which were ordered have been included. Verify that all cables and supplied accessories (listed in section 5.3) have been included.

If the instrument appears to be undamaged, turn it on following the instructions in section 1.2, and verify that it passes its initial power-on tests. If the instrument fails to present a display or to pass its self tests, please contact Quantum Design or its representative. You should also refer to the warranty at the beginning of this manual.

5.2 Components and Accessories Supplied

The following items should have been enclosed in the shipping container:

A. One Model 5000 Main Chassis.

B. One masterBOARD (installed in card cage).

C. One to Eight multiCARDSs (installed in card cage).

D. One to Eight microPREAMPs with cables attached.

E. One Operator's Manual (this manual).

F. One 9-Pin Male-Female Serial Port Cable.

G. One 26-Pin "D" Shell Connector for Analog Port.

H. One 4-Pin Level Meter Cable with one Connector.

I. One 5.25" 360K Diskette with Application Software.

J. One Bag of Spare and Alternate Fuses.

K. One Line Cord.

Depending on the specifications of your purchase order, there may also be one or more of the following items enclosed:

A. Thin Film D.C. SQUID Sensor(s).

B. Flexible SQUID Probe(s)

If the Model 5000 was purchased as part of a complete system which included a Cryostat, and/or Insert Assembly, the SQUID Probes and Sensors will have been installed in the Insert Assembly before shipment. If a level meter was mounted in the Cryostat or Insert Assembly, then a complete cable will be provided.

5.3 Power Requirements

The Model 5000 can be operated from any single phase ac power source supplying between 100 V and 120 V or between 200 V and 240 V (-10% to +5%). The Voltage Selector Switch must be set correctly for either the High or Low range of input voltages. Also verify that the correct fuse(s) are installed for the voltage range which you are using. The fuse holder can be configured for either a single 1-1/4" fuse (American Convention) or two of the 20 mm fuses (European Convention). Whichever method is used, the ratings of the fuses must be correct for the operating voltage range selected.

The frequency range of the ac power line is 48Hz to 66Hz for proper operation of the power supply. For the best performance of power-line filtering, however, the frequency should be either 50.0 Hz or 60.0 Hz (±0.3%). The analog notch filter is factory set to the frequency appropriate for your location. If this is not the case, contact Quantum Design or see section 2.3 for instructions on adjusting the frequency of this notch.

5.4 Operating and Storage Environment

Temperature: The Model 5000 may be operated at ambient temperatures between 0°C and +40°C. All specifications apply within this temperature range.

Humidity: The Model 5000 may be operated in environments with relative humidity up to 90%, but it should be protected from temperature changes which could cause condensation within the instrument.

Altitude: The instrument can be operated at altitudes up to 4600 meters (15,000′).

Air Circulation: The Model 5000 uses a cooling fan which draws air in through the rear panel. The instrument should be mounted in such a manner that air can freely flow though this fan. The filter should be removed and cleaned in soapy water periodically or if it becomes clogged.

Storage: Provide a clean, dry environment between -20°C and +55°C. Relative humidity should be below 95% (non-condensing) and the altitude should be below 15,300 meters (50,000 feet).

5.5 multiCARD Installation

There must be a multiCARD installed into the card-cage for each SQUID channel which the Model 5000 is to control. To add an additional multiCARD, first select which channel number you wish to activate. Channels are numbered from RIGHT to LEFT as you face the rear panel; channel ONE is nearest the middle of the unit. Note that the masterBOARD is installed in a special position to the right of channel 1 and should not be removed.

Each multiCARD board requires a 1 MHz square wave clock signal to produce modulation to the SQUID, and to demodulate the signal from the SQUID sensor. Each multiCARD board has the clock capability onboard. This clock is enabled or disabled by the "W5" jumpers. All Model 5000 Controllers require that one of the installed multiCARD boards have its clock enabled by configuring the "W5" jumpers to the "Control" setting. This jumper setting taps the output stage of the multiCARD board's oscillator clock and directs it to a busline on the motherboard. All additional multiCARD boards must have their "W5" jumpers configured to the "slave" setting, which disables the multiCARD board's crystal controlled oscillator and connects a path from the "Control Clock" line on the motherboards bus. Model 5000 Controllers are shipped with the "Control Clock" multiCARD board installed in slot one. The system will operate with the "Control Clock" multiCARD installed in any of the eight slots. Channel assignment should have no effect on the basic operation of a SQUID sensor. A Model 5000 Controller must have one <u>and</u> <u>only</u> <u>one</u> "Control Clock" multiCARD board installed to operate.

If all installed multiCARD boards are set up as "Slave Clocks" the SQUID sensor(s) will have no modulation - (1) the SQUIDs will not tune and (2) the output signal will be a flat line. If two or more multiCARD boards are set up as "Control Clocks" the clock signals will interact on the "Control Clock" busline in a random manner - (1) the SQUID sensor will not tune and (2) the output signal will be erratic or railed.

Proceed by removing the dummy cover plate for the selected channel; take out the two #4-40 screws. Orient the multiCARD so that the components are facing to the LEFT and then slide it carefully into the plastic card guides (avoid snagging components on the corners of the card cage's mounting tabs). When the edge-fingers reach the connector, press firmly to seat the card. Re-install the #4-40 screws to secure the board and ground the shell of the connector. The screws serve an important function in attaching the connector shell electrically to the instrument's case ground rather than the multiCARD's ground plane. Please take care to install and properly tighten these screws.

When a multiCARD, microPREAMP, and SQUID sensor combination are first tuned, it is necessary to verify that the Modulation and FB Gain potentiometers are adjusted correctly. This can be done by performing a TUNE operation and then remaining in the tune menu (by pressing the ENTER key).

The Modulation pot should be turned fully off (counterclockwise 4 turns) and then back on until the first maximum is observed on the Tune display screen.

The FB Gain pot can now be set to give a tuning signal of about 3 volts. The precise value is not critical, and may be intentionally left lower than 3 volts to reduce the closed-loop bandwidth and improve stability under certain conditions. See sections 2.2 and 1.10 for related information.

5.6 microPREAMP Installation

The microPREAMP is an essential component for a SQUID channel. It looks like a simple cable with a 15-Pin "D" Shell connector on one end and a 9-Pin rack-type connector on the other end. The back-shell for the 9-Pin connector actually contains the active circuitry for the microPREAMP. To attach the microPREAMP to the Model 5000, simply plug the 15-Pin connector into the back of an available multiCARD. The 9-Pin (preamplifier) end of the cable is plugged into the top of a Quantum Design Flexible Probe or its electrical and mechanical equivalent. Note that the connector is NOT KEYED at this end except for the asymmetric pattern of the pins. Proper orientation can be determined by facing the labels on the two pieces in the same direction or by inspecting the pin patterns directly. Please use care with these connectors because they are not positively keyed. See section 5.7 for a description of the flexible probe connector and wiring.

It is very important that the jack-screws on both ends of this microPREAMP cable be securely tightened - the connection to the flexible probe is especially important. Although the housings of the microPREAMP and flexible probe connector are moisture resistant and the contacting surfaces have been plated, these parts should not be allowed to chronically condense moisture. Reliability will be enhanced if appropriate precautions are taken to avoid corrosion at electrical interfaces.

The microPREAMP has a high-impedance, low noise amplifier which may not be stable under open-circuit conditions; it should not be operated unless it is connected to a SQUID Assembly, but it is not required that the SQUID Assembly be cold.

***** CAUTION *****

DO NOT OPERATE THE MICROPREAMP UNLESS IT IS CONNECTED TO A SQUID. DO NOT CONNECT OR DISCONNECT THE SQUID WITH POWER APPLIED TO THE MICROPREAMP.

5.7 Flexible Probe Installation

One or more Flexible Probes can be mounted onto a rigid "Insert" which is then placed into the neck of a helium cryostat. The SQUID Sensor on the bottom end of the Flexible Probe is cooled to about 4°K by direct immersion in a bath of liquid helium. Input circuits to the SQUID, such as transformers or magnetometer pickup loops, also are cooled and become superconducting. This is the traditional arrangement for operating SQUID sensors.

Alternatively, the Flexible probe can be installed so that it penetrates directly into the vacuum space of the cryostat and places the SQUID sensors on the outside of the liquid helium chamber. This method has been used successfully in designs which require superconducting pickup loops to be placed within 2mm of a room temperature surface. This method requires considerable experience with cryogenic engineering SQUID applications. The main difficulty in this design is keeping the SQUID and its input circuits cold enough to function properly.

To simplify the task of making a vacuum penetration into the cryostat, we have made a leak-tight seal in the top connector of the Flexible Probe. We have also designed the circular connector at the bottom end of the probe so that it can be inserted through a 6.5mm (1/4") hole. If this hole is on a flat surface of the cryostat, then the top connector can be mounted with two screws and an "O" ring to form a vacuum tight feedthrough. See Appendix D for mounting dimensions for this connector.

The 10-pin female plug on the bottom of the flexible probe connects directly to the SQUID Sensor Assembly. The plug and Sensor are keyed for correct orientation, but care should be used since the pins and shells are fragile. The SQUID Sensor Assembly will normally be mounted into the Shield Assembly at the time the Flexible Probe plug is inserted.

The shielded SQUID housing at the bottom end of the Flexible Probe should be mounted securely to the cryostat insert or the outer wall of the helium chamber as appropriate. See Appendix D for mounting dimensions for this housing. Wherever it is mounted, attention should be paid to the following points:

A. The housing must be well enough connected to a cold surface that it will cool to less than about 6°K in a reasonable time.

B. Heat flow down the leads of the Flexible Probe must be intercepted well enough that it does not keep the SQUID sensor from cooling. The shield of the cable is made of phosphor-bronze as are most of the leads. One twisted pair of #38 wires is made from a high-conductivity copper alloy.

C. In Field Gradiometer applications, the superconducting Niobium shield of the housing must be mounted far enough away from the pickup loops to avoid distorting the field. It must also be rigid enough with respect to the loops to avoid causing vibration noise.

D. If optimum drift and 1/f noise performance is required, it may be necessary to cool the SQUID in a low ambient field ($H < .01 Gauss$) and ensure that its temperature remains very stable ($\Delta T < .001°K$).

5.8 SQUID Sensor Installation

The thin-film SQUID chip is mounted on a small, connectorized circuit board which provides both physical protection and electrical support functions. See Figure D.3 in Appendix D. This SQUID Assembly is, itself, mounted into a niobium and phosphor-bronze housing which provides mechanical support and electromagnetic shielding.

The SQUID Assembly can be removed from this housing by unscrewing the niobium shield tube, loosening the retaining screw in the phosphor bronze base, and pulling the circuit board straight out from the base.

***** CAUTION *****

IT IS IMPORTANT THAT THE CIRCUIT BOARD NOT BE BENT OR TWISTED AS IT IS INSTALLED OR REMOVED FROM THE SHIELD HOUSING. FAILURE TO OBSERVE THIS CAUTION MAY WEAKEN OR BREAK CONNECTIONS IN THE BOARD.

Superconducting input leads should be twisted and brought into the Shield Housing through the .078" o.d. brass tube in the housing's base. This brass tube is large enough to accommodate a .05" o.d. niobium or lead shield over the twisted wires. The stripped and sanded ends of the wires are connected to the SQUID input coil by placing them under the brass washers and gently tightening the two 0-80 brass screws. It is essential that the wires be placed UNDER the washers to obtain a superconducting connection.

The Niobium shield of the housing must be screwed down securely against the niobium flange on the SQUID assembly to obtain optimum magnetic shielding. If the shielding obtained in this manner is inadequate, then the user must consider using a lead foil bag wrapped around the Shield Housing.

Note that for the best possible 1/f spectrum, temperature coefficient, and vibration immunity one should cool the SQUID in low field (<10mG). This is usually accomplished by placing a mu-metal or permalloy shield over the niobium shield. The need for such a hi-permeability shield must be determined from overall system requirements

5.9 External Feedback Operation

The SQUID sensor is connected for "internal feedback" when it is shipped from the factory. This means that the feedback current is applied to the modulation coil in an attempt to balance flux induced by the signal coil. One disadvantage of this technique is that substantial currents are induced in the pickup loops during normal operation. An alternative technique is to apply the feedback current to a transformer whose secondary is in series with the pickup loops. In this way, the feedback signal will suppress current changes in the pickup loops. This method is more difficult to implement since it requires the design and construction of a superconducting transformer. In some applications, however, it may be justified.

If "external feedback" is required, the internal circuit must be broken by clipping both of the short wire jumpers located on the SQUID Assembly. See Figure D.3 in Appendix D. The external feedback signal is then available on the two pads located on the far end of the SQUID Assembly. The coupling in the feedback transformer should be adjusted so that a value of approximately 2uA/quantum is maintained. Substantial deviations from this value will affect the instrument's open loop gain causing either bandwidth or stability degradation.

5.10 Input Damping Network

When typical input circuits are attached to the SQUID sensor, we have found that the white noise performance can be significantly degraded unless a suitable R-C damping network is installed across the input terminals. The noise increase is most evident when large inductances (>2uH) are employed and appears to be caused by various resonances in the input coils. Similar effects have been seen by other researchers when working with tightly coupled thin-film SQUIDs.

We have provided a damping network comprising a 1000pF NPO chip capacitor in series with a 10 ohm thick-film resistor. This network is mounted directly across the input terminals of the SQUID. The components in the network are non-magnetic and have been assembled with tin-silver solder which is not superconducting at 4.2K. We recommend that this network be left in place unless there is a specific reason to remove it.

When operating with unusual input loads, it may be necessary to find other values or configurations for this damping network. Contact Quantum Design for additional information regarding the issue of damping networks.

5.11 Heater Operation

The purpose of the heater is to suppress superconductivity in the Josephson junctions, SQUID loop, and signal coil by raising them above their critical temperature of about 9K. This is usually done to eliminate magnetic flux lines which have become trapped in or around the junctions causing them to have reduced and unbalanced critical currents. This condition is often characterized by an abnormally low critical current for the SQUID or by an optimum SKEW value which is more than a few percent away from zero. When this occurs a heater cycle is indicated.

The heater may also be used to suppress large currents induced in the signal coil circuit. This condition can cause small non-linearities and hysteresis in the locked-loop response of the SQUID and should generally be avoided if possible.

We have provided a heater configuration which is appropriate for heating the SQUID junctions and input coil when the probe is immersed in liquid helium. This configuration comprises a 100 ohm resistor, R_{SQ}, mounted directly behind the SQUID chip and a 182 ohm current limiting resistor (R67) located on the multiCARD. There will also be about 25 ohms of resistance in the Flexible Probe. When the heater is energized by turning on transistor Q1, -15 volts is applied across these three resistances in series. The power dissipated in R_{SQ} is given by:

$$\text{Heater Power} = 255*R_{SQ}/(R67+25+R_{SQ})^2,$$

which is 0.24 Watts for the standard configuration. Note that current flowing from the -15 volt supply rail into R_{SQ} returns through the shield of the Flexible Probe. The screws holding the microPREAMP to the top of the Flexible Probe must therefore be secure.

For applications where the SQUID is not immersed in liquid, it may be desirable to reduce the amount of heat by increasing the value of R67. This resistor is mounted on forked terminals and is located near Q1. We have found that a power of 0.05 Watts is appropriate for probes operated in exchange gas. Even less heat may be required for probes which are cooled by conduction in a vacuum. In this last case, especially, excessive heat can result in a large temperature rise at the chip and a very long re-cooling time. The optional thermal cycle used in the tuning process provides 10 seconds for both the heating and cooling phases. It should be possible to select a power level which works with these values.

Note that the resistor R_{SQ} is a non-magnetic thick-film chip which we have found to be reliable at 4K. It is attached with a tin/silver solder which is not superconducting at 4.2 Kelvin. We have found that under typical operating conditions this resistor does not affect the white or 1/f noise of the sensor.

If heat needs to be applied elsewhere than at the SQUID chip, the leads which go to the R_{SQ} can be un-soldered from the circuit board and other leads can be connected to your custom heater. See Figure D.3 in Appendix D.

If you wish to suppress currents in an input circuit which is not directly connected to the SQUID signal coil, it may be necessary to make a heater of resistance wire and wrap it around the transformer or other element to be heated. Remember that there is significant d.c. current flowing in this heater, so it is helpful to wind the heater in a bi-filar manner to reduce magnetic coupling to the SQUID sensor.

5.12 Analog Output Connections

The connector on the back of the masterBOARD is a 26-Pin 1.5-Density "D" shell connector. It has the same size outer shell as the more common DA-15 connector, but uses three rows of pins. A mating connector, crimp pins, and backshell have been included with the Model 5000 for your convenience. If crimping is not desired, soldering is an acceptable alternative. Please refer to Appendix D for the pin assignments of this connector.

Note that pins are available for either differential or single-ended connections. Differential inputs are preferable when available. Good instrumentation practice suggests that differential pairs be twisted separately and that the cable be shielded overall. In differential mode, each side has a series impedance of 100 ohms. In single ended mode, the low side is referenced to the chassis at the front panel BNC connector.

The Monitor Output (available at the front panel BNC) may also be obtained at the Analog Output Connector. The D/A Output, shown in the connector wiring diagram, is not yet implemented in the software. When available, it will provide a 0-2.5 V utility signal with 8-bit resolution that may be useful as a marker for a data acquisition system or as a programmable test signal for a magnetometer system.

5.13 IEEE-488 Interface Connections

Properly designed and well shielded IEEE-488 (GPIB) cables are available from numerous sources; use only the connectors with metric (black) jackscrews. Make sure that the Model 5000 is configured at a suitable address before plugging the instrument into a system. To begin, try to send a simple query such as REV?, and read back the response string. If you are not able to establish communications with the instrument even at this low level, contact Quantum Design or its representative for assistance.

5.14 RS-232 Interface Connections

The 9-Pin "D" shell cable which is included with the Model 5000 can be connected directly to an IBM PC-AT type computer. These machines have a 9-Pin male connector and are configured as DCE (they transmit data on pin-3). They can be connected "pin-for-pin" to the Model 5000. Note that pin-9 is used as an external trigger input, so this should either be connected to the appropriate signal source or left unconnected.

5.15 Repackaging and Shipment

If possible, repackage the instrument in the original box using all the original packaging materials. If this is not possible use the following guidelines for packaging:

- Wrap the instrument in anti-static plastic and attach a tag indicating what type of service is required, the return address, and the serial number.

- Use a layer of shock absorbing material (such as foam) about 10cm (4") thick around all sides of the instrument to provide firm support and prevent motion within the container. Protect the buttons and display on the front panel from direct forces by placing packing against the front handles. Do NOT use styrene pellets for packaging as these do not adequately cushion the instrument and keep it from shifting in the carton. They also tend to generate large static charges which can damage electronic components.

- Use a strong shipping container such as a double-wall carton made from 350-pound test material. Seal container securely and mark it:

FRAGILE - ELECTRONIC INSTRUMENT

This may improve the chances for careful handling. The environmental requirements for shipping are the same as those for storage; see section 5.4 for details.

6 SPECIFICATIONS

The following specifications describe the instrument's warranted performance. Supplemental characteristics are intended to provide information useful in applying the instrument by giving typical, but non-warranted, performance specifications. Supplemental characteristics are denoted as "typical", "nominal", or "approximate."

6.1 Display

Text Capacity: 8 lines x 40 characters

Graphic Capacity: 64 x 240 pixels

Backlighting: Electro-luminescent

Contrast: Adjust by front panel pot

6.2 Keyboard

Key Type: Full travel, resilient contact

Number of Keys: 25

Marking: Vapor diffusion process

6.3 CPU System

CPU Type: MC68020FE

FPU Type: MC68882FN

Speed: 16MHz

Timing: Real Time Clock + 10 Timers

RAM: 32K Bytes, Battery Backed

ROM: 128K Bytes

Battery: Lithium, 750mAH

6.4 A/D Converter

Resolution: 16-Bits

Linearity (integral): 0.0015%

Rates: 6KHz, 12KHz, 24KHz, 48KHz

Channel FIFO: 8-Bits x 512 Bytes

Data FIFO: 16-Bits x 512 Words

6.5 multiCARD

Feedback Ranges: $5\Phi_0$/FS, $50\Phi_0$/FS, $500\Phi_0$/FS

Bandwidth, Locked Loop: Typically 50KHz; 500Hz on 5S range

Filter Type: 3-pole Butterworth

Filter Cutoff (3dB) Frequencies: 1KHz, 2KHz, 4KHz, 16KHz

Filter Gain Factors: 1X, 2X, 5X, 10X (±0.1%)

Test Signal: 100HZ sawtooth, $\pm 10\Phi_0$/FS

Input Signal from microPREAMP: 0.05V P-P typical at 500KHz center frequency

Bias Modes: Normal d.c. and 1953Hz a.c. (YAMS)

Bias Resolution: 8-bit

Skew Resolution: 8-bit

Offset Resolution: 12-bit

6.6 microPREAMP, when used with multiCARD

Cable Length: 4 Meters

Voltage Gain: 400 nominal

Power Requirements: +13V at 20mA nominal

Bias Current Range: 0 - ±50 μA

Modulation Current Range: 0 - 8 μA P-P

Offset Current Range: 0 - 3.6 μA

Skew Current Range: 0 - ±10% of bias current

6.7 Flexible Probe

Length: 1.2 Meters

Mounting Patterns: See Figure D.2 in Appendix D.

Cable Design: 5 pairs #38 Cu alloy in Ph-Br. shield+Teflon

Superconducting Shield: Niobium tube w/ welded end

6.8 SQUID Sensor

Operating Temperature: < 1k - 7k

Input Inductance: 1.9 μH Nominal

Input Sensitivity: 0.2 $\mu A/\Phi_0$

White Noise Density, Matched Input: $4\text{x}10^{-6}\ \Phi_0$ Typical

1/f Noise Knee, Shorted Input: 0.1Hz Typical

Modulation Coil Inductance: 0.07 μH Nominal

Modulation Coil Sensitivity: 1.5 $\mu A/\Phi_0$

SQUID Bias Current (Effective): 15 - 30 μA

Modulation Frequency: 500KHz nominal

Output Frequency Range, with transformer: 200KHz to 1MHz

Output Impedance, with transformer: 200ohms typical

Output Signal, with transformer: $400\mu V/\Phi_0$ typical

6.9 masterBOARD

Low-pass Filters: 1Hz, 10Hz, 100Hz 2-pole Butterworth

Notch Filter: 50Hz or 60 Hz plus 2nd and 3rd harmonics

Analog Signal Output Impedance: 200ohms, balanced

Utility Test Signal: 0 - 2.5V, 8-bit resolution

Level Meter Compliance Voltage: 28V

Level Meter Current Range: 0 - 100mA

Level Meter Resolution: 8-bit

6.10 IEEE-488 Interface

Implementation: IEEE Std. 488.2 nominal

Address Selection: By software to nonvolatile RAM

Hardware: Metric

Supports: SH1 AH1 T6 TE0 L4 LE0 SR1 RL1 PP0 DC1 DT1 C0 E2

6.11 RS-232 Interface

Configuration: DTE, Terminal (transmit on pin #2)

Baud Rates: 300, 1200, 2400, 4800, 9600, 19200, 38400

Data Bits: 7, 8

Stop Bits: 1, 2

Handshake: XON / XOFF

6.12 Storage Environment

Temperature: -20°C to 55°C

Relative Humidity: <95% (non-condensing)

Altitude: <4600 meters

6.13 Operating Environment

Temperature: 0°C to 40°C

Relative Humidity: <90% (non-condensing)

Altitude: <4600 meters

6.14 Power Requirements

Voltage, Low Range: 100/120VAC +5% -10% 48-65Hz

Voltage, High Range: 220/240VAC +5% -10% 48-65Hz

Power Consumption: 60 Watts maximum

6.15 Weight

Net Weight: 7 Kg nominal (one channel)

Shipping Weight: 10 Kg nominal (one channel)

6.16 Dimensions

Width: 43.2cm (17", full rack width)

Height: 8.9cm (3.5", 2 rack units)

Depth: 38cm (15")

APPENDICES

Appendix A. Screen Displays

The following pages show the appearance of the screen displays available on the Model 5000.

Channel Installation Screen

```
           Channel Installation
---------------------------------------

Active: 1   -   -   4   -   6   7   8
Found : 1   -   3   4   5   6   7   8


```

Status Display Screen

```
CHANNEL >1        3   4   5   6   7   8
----------------[H]-[X]----------------
Reset    ON       -  ON       -   -  ON
Range    5S     500  50       5  50  5
Gain    10X      1X  2X      1X  5X  1X
Filter   2K     OUT 12K     OUT  2K  2K
Test     ON      ON  -        -   -   -
  Monitor Filter:100HZ+Notch   LHe: 99%
```

Helium Level Status Screen

```
              Helium Level

Current Level:  34%

Fill Rate:  2% / Minute


```

Output Display Screen (Bar Graph)

```
 1________**|********|________|_________

>3__________|________|********|_________
 4__________|________O________|_________

 6__________|____*****|_______|_________
 7__________|________O________|_________
 8__________|________|********|_________
```

Output Display Screen (Tabular)

```
CH#  FILTER   VOLTS  CH#  FILTER   VOLTS
----------------------------------------
 1    2K   RS -0.0020| 5     4K RS -0.0042
                     | 6    OUT     1.0331
 3    OUT            | 7     2K     3.4313
 4    16K     -1.2215| 8     2K    -3.9834
----------------------------------------
      Monitor Filter: 100Hz+Notch
```

Tune Setup Screen

```
CH#       1         3    4         6    7    8
SELECT:             *    *         *    *    *

Use Heater Cycle: YES [+/-]

 ---Press [TUNE] or [ENTER] to Start---
   {Toggle channels by [NUMBER] or [.]
```

Tune Result Screen

```
                  1*****************____|30
 --Bad Tune--
 (on blinking     3**************_______|65
     channels)    4***********__________|48

 [ESC] to exit    6*************________|37
                  7***********__________|54
                  8**************_______|34
```

Configuration Menu

```
            Configuration Menu
 ---------------------------------------
  >1. Channel Response
   2. Global Channel Configuration
   3. Individual Channel Configuration
   4. Data Acquisition & Processing
   5. System Setup
```

Channel Response Screen

```
               Channel Response
---------1------[3]--4-------6---7---8-
RANGE       5        50  50      5S  5S  5S
GAIN       1X        1X  2X     10X  1X  1X
FILTER    16K      >OUT  1K      4K  4K  4K
TEST       ON         -   -       -  ON   -
RESET       -         -   -      ON   -   -
      MONITOR FILTER: 100Hz+Notch
```

Global Configuration Screen

```
   Global Channel Configuration
RANGE  :>   5S      RESET :   ON
GAIN   :    1X      GR ENA:  OFF
FILTER :    2K      NULL  :  MAN
TEST   :    *       DISCR :  4.9
YAMS   :    ON      HEATER:  OFF

  { * -> Channels are in a mixed state }
```

Individual Configuration Screen

```
CH >3 Voltage: 2.0031
---------|---------|*******--|---------
RESET :  ON SELECT:   SENSE RANGE : MAN
TEST  : OFF OFFSET:  89.14% AMP   : OFF
YAMS  : OFF BIAS  :    -45% NULL  : OFF
HEATER: OFF SKEW  :   -4.9% GR ENA:  ON
                            DISCR : 1.5
               {      }
```

Data Acquistion & Processing Screen

```
              Data Acquisition
ARM STATE: OFF
---------------------------------------
FLTR MODE : BUTTRW    BW FACTOR : 45.22
TRIG MODE : EXT       DEC FACTOR: 50
CONV RATE : 24KSP     DATA TYPE : ASCII
REP FACTR : 16
CHAN LIST : 1-34-678        {     }
```

System Setup Menu

```
              System Setup Menu
---------------------------------------
   1. IEEE-488 Port
   2. Serial Port
   3. Install Channels
   4. Timing Functions
   5. Helium Level Sensor
```

IEEE-488 Setup Screen

```
            IEEE-488 Setup
---------------------------------------
ADDRESS : >15           SEND EOS : NO
SEND EOI: YES           EOS VALUE: 10

OUTPUT BUFFER MODE: OVERWRITE
BINARY CHECK SUM   : ENABLE
```

Serial Port Setup Screen

```
              Serial Port Setup
----------------------------------------
BAUD RATE    :>9600  PARITY   : NONE
STOP BITS    : 1     SRQ CHAR COUNT : 1
DATA BITS    : 8     TERM CHAR COUNT: 2
SRQ CHARS    : 5      nu    nu    nu
TERM CHARS   : 3      10    nu    nu
XON PROTOCOL: ON
```

Helium Level Sensor Setup Screen

```
             Helium Level Sensor

HE MONITOR: ENABLE
HE DISPLAY: ENABLE
PRESENT LEVEL:  --% (Volts at 0%: 1.21)

                    {     }
```

Timing Functions Screen

```
                Timing Functions
---------------------------------------
 TIME: 17 :>05 :45  DATE: 12 - 15 - 91

   ------ Reset Pulse Width -----
  5S RANGE: 100 mS    OTHERS: 100 mS

                  {     }
```

Appendix B. Programming Summary

The following tables present a listing of each the remote control mnemonic along with the corresponding front panel menu item, if it exists. If parameters are required, their form and number is indicated. A short description is also given for each command (usually an expansion of the mnemonic).

Table B.1 - Common Commands Summary

MNEM-ONIC	PARAMETER FORMAT	DESCRIPTION / MNEMONIC EXPANSION
*CLS	(none)	Clear Status Command
*ESE	0-255	Std. Event Status Enable Cmnd
*ESE?	(none)	Std. Event Status Enable Query
*ESR?	(none)	Std. Event Status Register Query
*SRE	0-255	Service Request Enable Command
*SRE?	(none)	Service Request Enable Query
*STB?	(none)	Read Status Byte Query
*IDN?	(none)	Identification Query
*RST	(none)	Reset Command
*TST?	(none)	Self-Test Query
*CAL?	(none)	Calibration Query
*TRG	(none)	Trigger Command
*OPC	(none)	Operation Complete Command
*OPC?	(none)	Operation Complete Query
*WAI	(none)	Wait To Continue Command

Table B.2 - Status Reporting Commands Summary

MNEM-ONIC	PARAMETER FORMAT	DESCRIPTION / MNEMONIC EXPANSION
ISE	0-7, 0-65535	Indexed Status Enable Cmnd
ISE?	0-7	Indexed Status Enable Query
ISR?	0-7	Indexed Status Register Query
CESE	0-65535	Command Error Status Enable Cmnd
CESE?	(none)	Command Error Status Enable Query
CESR?	(none)	Command Error Status Register Query
EESE	0-65535	Execution Error Status Enable Cmnd
EESE?	(none)	Execution Error Status Enable Query
EESR?	(none)	Execution Error Status Register Query
IESE	0-65535	Internal Error Status Enable Cmnd
IESE?	(none)	Internal Error Status Enable Query
IESR?	(none)	Internal Error Status Register Cmnd
SQSE	0-65535	SQUID Reset Status Enable Cmnd
SQSE?	(none)	SQUID Reset Status Enable Query
SQSR?	(none)	SQUID Reset Status Register Query
SDSE	0-65535	Summary Device Status Enable Cmnd
SDSE?	(none)	Summary Device Status Enable Query
SDSR?	(none)	Summary Device Status Register Query
IDSR?	0-15	Indexed Device Status Register Query?

Table B.3 - Device Control Commands Summary

MNEM-ONIC	PARAMETER FORMAT	FRONT PANEL MENU ITEM	DESCRIPTION / MNEMONIC EXPANSION
ADCR	1-4	CONV RATE	A/D Converter Rate Cmnd
ADCR?	(none)	(n/a)	A/D Converter Rate Query
AMPG	ch#, 1-4	AMP	Amplifier Gain Cmnd
AMPG?	ch#	(n/a)	Amplifier Gain Query
ARMS	0-1	ARM STATE	Arm State Cmnd
ARMS?	(none)	(n/a)	Arm State Query
BCSF	0-1	(n/a)	Bin. Chksum Flag Cmnd
BCSF?	(none)	(n/a)	Bin. Chksum Flag Query
BIAS	ch#,0-255	BIAS	Bias Current Cmnd
BIAS?	ch#	(n/a)	Bias Current Query
BWRF	1.0-9999.99	BW FACTOR	BW Reduction Factor Cmnd
BWRF?	(none)	(n/a)	BW Reduction Factor Query
CHAN	ch#	CHANNEL	Monitor Output Chan Cmnd
CHAN?	(none)	(n/a)	Monitor Output Chan Query
CHIM	ch#,{str}	(n/a)	Channel Image Cmnd
CHIM?	ch#	(n/a)	Channel Image Query
CHSS	0-255	CHAN LIST	Channel Scan Set Cmnd
CHSS?	(none)	(n/a)	Channel Scan Set Query
DATA?	(none)	(n/a)	Acquired Data Query
DATE	mo,day,yr	DATE	Date Cmnd
DATE?	(none)	(n/a)	Date Query
DECF	1-9999	DEC FACTR	Decimation Factor Cmnd
DECF?	(none)	(n/a)	Decimation Factor Query
DFMD	1-3	FLTR MODE	Digital Filter Mode Cmnd
DFMD?	(none)	(n/a)	Digital Filter Mode Query
DISC	ch#, 0-5.0	DISCR	Discriminator Volts Cmnd

MNEM-ONIC	PARAMETER FORMAT	FRONT PANEL MENU ITEM	DESCRIPTION / MNEMONIC EXPANSION
DISC?	ch#	(n/a)	Discriminator Volts Query
DISP	0-4	(n/a)	Select Front Panel Display
DTYP	1-2	DATA TYPE	Data Type Cmnd
DTYP?	(none)	(n/a)	Data Type Query
ECHO	1-2,{str}	(n/a)	Echo String Cmnd
EOSV	0-255	EOS VALUE	EOS Terminator Value Cmnd
EOSV?	(none)	(n/a)	EOS Terminator Value Query
GODF	1-4	(n/a)	Output Data Format Cmnd
GREN	ch#, 0-1	GR ENABLE	Group Reset Enable Cmnd
GREN?	ch#	(n/a)	Group Reset Enable Query
GRST	0-1	[.] Key	Group Reset Command
HCAL	0-0.5	HE CALIBRATE	Calibrate Helium Level Sensor
HEAT	ch#, 0-1	HEATER	Heater State Command
HLEV	(none)	HE LEVEL	Helium Level Sensor Cmnd
HLEV?	(none)	(n/a)	Helium Level Sensor Query
HMON	0-1	HE MONITOR	Helium Level Monitor Cmnd
HMON?	(none)	(n/a)	Helium Level Monitor Query
INST	0-255	ACTIVE	Install Channel Cmnd
INST?	(none)	(n/a)	Install Channel Query
MONF	1-6	MONITOR FILTER	Monitor Filter Cmnd
MONF?	(none)	(n/a)	Monitor Filter Query
NULL	ch#, 1-3	NULL	Voltage Nulling Mode Cmnd
NULL?	ch#	(n/a)	Voltage Nulling Mode Query
OBOF	0-1	(n/a)	Out. Buffer Ovflow Cmnd
OBOF?	(none)	(n/a)	Out. Buffer Ovflow Cmnd
OFST	ch#,1-4095	OFFSET	Offset Current Cmnd
OFST?	ch#	(n/a)	Offset Current Query

MNEM-ONIC	PARAMETER FORMAT	FRONT PANEL MENU ITEM	DESCRIPTION / MNEMONIC EXPANSION
REPF	1-500 *	REP FACTR	Repeat Factor Cmnd
REPF?	(none)	(n/a)	Repeat Factor Query
REV?	(none)	(n/a)	Revision Number Query
RNGE	ch#, 1-4	RANGE	Feedback Range Query
RNGE?	ch#	(n/a)	Feedback Range Query
RSET	ch#, 0-1	RESET	Channel Reset Cmnd
RSET?	ch#	(n/a)	Channel Reset Query
SELS	ch#, 1-8	SELECT	Signal Source Select Cmnd
SELS?	ch#	(n/a)	Signal Source Select Query
SEOI	0-1	SEND EOI	Send End-Or-Interrupt Cmnd
SEOI?	(none)	(n/a)	Send End-Or-Interrupt Query
SEOS	0-1	SEND EOS	Send EOS Terminator Cmnd
SEOS?	(none)	(n/a)	Send EOS Terminator Query
SKEW	ch#, ±127	SKEW	Skew Factor Cmnd
SKEW?	ch#	(n/a)	Skew Factor Query
SPMD	(see ref.)	RS-232 MENU	Serial Port Mode Cmnd
SPMD?	(none)	(n/a)	Serial Port Mode Query
SPMP	(see ref.)	SERIAL PORT SETUP MENU	Serial Port Mode Cmnd
SPSS	(see ref.)	SRQ CHR VALS	Serial SRQ Str. Cmnd
SPSS?	(none)	(n/a)	Serial SRQ Str. Query
SPTS	(see ref.)	TERM CHR VALS	Serial Term Str. Cmnd
SPTS?	(none)	(n/a)	Serial Term Str. Query
TEST	ch#, 0-1	TEST	Test Signal State Cmnd
TEST?	ch#	(n/a)	Test Signal State Query

* This value depends on the number of channels specified in the CHSS command.

MNEM-ONIC	PARAMETER FORMAT	FRONT PANEL MENU ITEM	DESCRIPTION / MNEMONIC EXPANSION
TIME	hr,min,sec	TIME	Time Cmnd
TIME?	(none)	(n/a)	Time Query
TMOD	1-4	TRIG MODE	Trigger Mode Cmnd
TMOD?	(none)	(n/a)	Trigger Mode Query
TUNE	0-255, 1-2	TUNE MENU	Tune SQUIDs Cmnd
TUNE?	(none)	(n/a)	Tune SQUIDs Query
VOUT?	ch#	(n/a)	Channel Output Voltage Query
YAMS	ch#, 0-1	YAMS	YAMS Biasing State Cmnd
YAMS?	ch#	(n/a)	YAMS Biasing State Query

Appendix C. Error, Device, and Reset Status Registers

This appendix lists the contents of the Command Error Status Registers, Execution Error Status Registers, Internal Error Status Registers, Reset Status Registers, and Device State Status Registers.

Command Error Class - Status Word Bit #0, Value 1		
Bit #	Value	Description
0	1	Unknown Command Received
1	2	Unterminated Command String (;)
2	4	Wrong Number of Parameters
3	8	Illegal Parameter
4	16	Illegal Channel Number
5	32	Channel Not Installed
6	64	(not used)
7	128	Illegal Command when Arm State On

Execution Error Class - Status Word Bit #1, Value 2		
Bit #	Value	Description
0	1	Transmit Buffer Overflow
1	2	Receive Buffer Overflow
2	4	Unknown GPIB Error
3	8	No Listeners on GPIB
4	16	Timeout on GPIB
5	32	RS-232 Receiver Overflow
6	64	RS-232 Receiver Parity Error
7	128	RS-232 Receiver Framing Error
8	256	(not used)
9	512	(not used)
10	1024	(not used)
11	2048	(not used)
12	4096	List FIFO Overflow
13	8192	Data FIFO Overflow
14	16384	(not used)
15	32768	(not used)

Internal Error Class - Status Word Bit #2, Value 4		
Bit #	Value	Description
0	1	Missing Frame Bit in Data FIFO
1	2	A/D Converter Locked in Cal Mode
2	4	A/D Converter Will Not Trigger
3	8	MC68901 Register Error
4	16	MC68901 Timer Error
5	32	8254 Timer Error
6	64	LCD Not Responding
7	128	SQUID Bus Data Latch Error
8	256	GPIB Processor Internal Error
9	512	Real-Time-Clock Error
10	1024	Keyboard Error or Keypressed
11	2048	RAM Error Detected
12	4096	ROM error
13	8192	LINE Trigger Failure
14	16384	EXT Trigger Error
15	32768	Program Structure Error

SQUID Reset Event - Status Word Bit #3, Value 8		
Bit #	Value	Description
0	1	Channel 1 Reset From Plus Limit
1	2	Channel 1 Reset From Minus Limit
2	4	Channel 2 Reset From Plus Limit
3	8	Channel 2 Reset From Minus Limit
4	16	Channel 3 Reset From Plus Limit
5	32	Channel 3 Reset From Minus Limit
6	64	Channel 4 Reset From Plus Limit
7	128	Channel 4 Reset From Minus Limit
8	256	Channel 5 Reset From Plus Limit
9	512	Channel 5 Reset From Minus Limit
10	1024	Channel 6 Reset From Plus Limit
11	2048	Channel 6 Reset From Minus Limit
12	4096	Channel 7 Reset From Plus Limit
13	8192	Channel 7 Reset From Minus Limit
14	16384	Channel 8 Reset From Plus Limit
15	32768	Channel 8 Reset From Minus Limit

Data Ready Event - Status Word Bit #4, Value 16		
Bit #	Value	Description
0	1	ASCII Data Ready to Send
1	2	IEEE Data Ready to Send
2	4	Binary Integer Data Ready

Standard Event - Status Word Bit #5, Value 32		
Bit #	**Value**	**Description**
0	1	Operation Complete
1	2	Request Control (not used)
2	4	Query Error (not used)
3	8	Device Dependent Error (not used)
4	16	Execution Error (not used)
5	32	Command Error (not used)
6	64	User Request (not used)
7	128	Power On (pon)

Status Change Summary - Status Word Bit #7, Value 128		
Bit #	**Value**	**Description**
0	1	(n/a)
1	2	(n/a)
2	4	(n/a)
3	8	(n/a)
4	16	(n/a)
5	32	(n/a)
6	64	(n/a)
7	128	(n/a)
8	256	(n/a)
9	512	(n/a)
10	1024	(n/a)
11	2048	(n/a)
12	4096	(n/a)
13	8192	(n/a)
14	16384	(n/a)
15	32768	(n/a)

Appendix D. Connector Pinouts and Drawings

RS-232 Interface Connector - 9-Pin Female "D" Shell (DE-9S)

Model 5000 Function	Model 5000 Pin	IBM PC-AT Pin
"DCD" -12V Out >	1	1
"RXD" Data Out >	2	2
"TXD" Data In <	3	3
"DTR" N/U In >	4	4
"GND" Ground	5	5
"DSR" -12V Out >	6	6
"RTS" N/U In <	7	7
"CTS" -12V Out >	8	8
TRIG. Neg Edge <	9	N/C

multiBOARD - to - microPREAMP Connector - 15-Pin Female "D"

Function	Pin
Signal-A	1
Signal-B	9
Heater-A	2
Common	10
Feedback-A	3
Feedback-B	11
Reserved	4
Reserved	12
Bias-A	5
Bias-B	13
Power	6
Inner Shield	14
Modulation-A	7
Modulation-B	15
Case Ground	8

Analog Interface Connector - 26-Pin High Density Female "D"

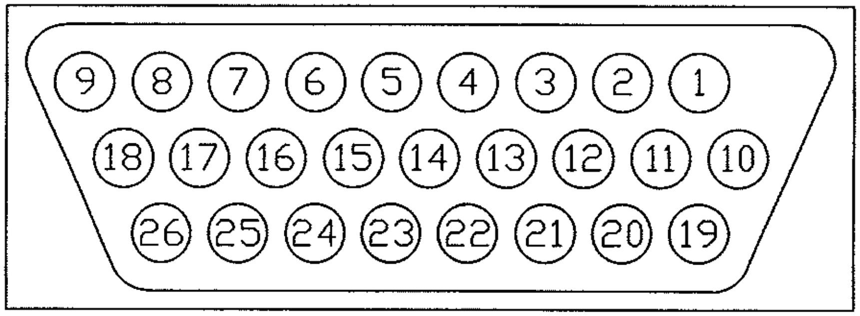
Function	Pin
Channel 1 Sig	1
Channel 1 Ret	2
Channel 2 Sig	3
Channel 2 Ret	4
Channel 3 Sig	5
Channel 3 Ret	6
Channel 4 Sig	7
Channel 4 Ret	8
Single End Gnd	9
Channel 5 Sig	10
Channel 5 Ret	11
Channel 6 Sig	12
Channel 6 Ret	13
Channel 7 Sig	14
Channel 7 Ret	15
Channel 8 Sig	16
Channel 8 Ret	17
Single End Gnd	18
Monitor Signal	19
Monitor Return	20
D/A Output	21
D/A Return	22
N/U	23
N/U	24
N/U	25
N/U	26

Level Meter Connector - 4-Pin Lemo

Function	Pin	Color
Current +	1	Red
Current -	2	Black
Voltage +	3	Green
Voltage -	4	White

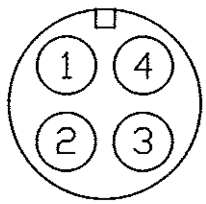
CONNECTOR PIN NUMBERING

ANALOG INTERFACE



(Face of socket or rear of plug)

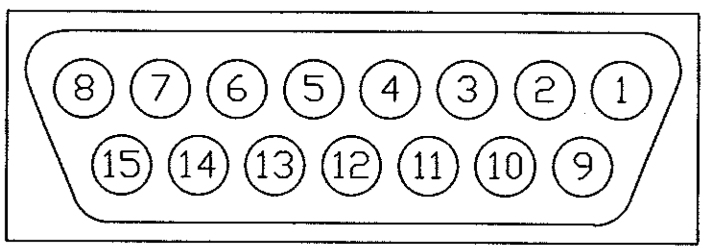
LEVEL SENSOR



Mating Plug:
Lemo FGG1B304

(Face of socket or rear of plug)

multiCARD



(Face of socket or rear of plug)

Figure D.1

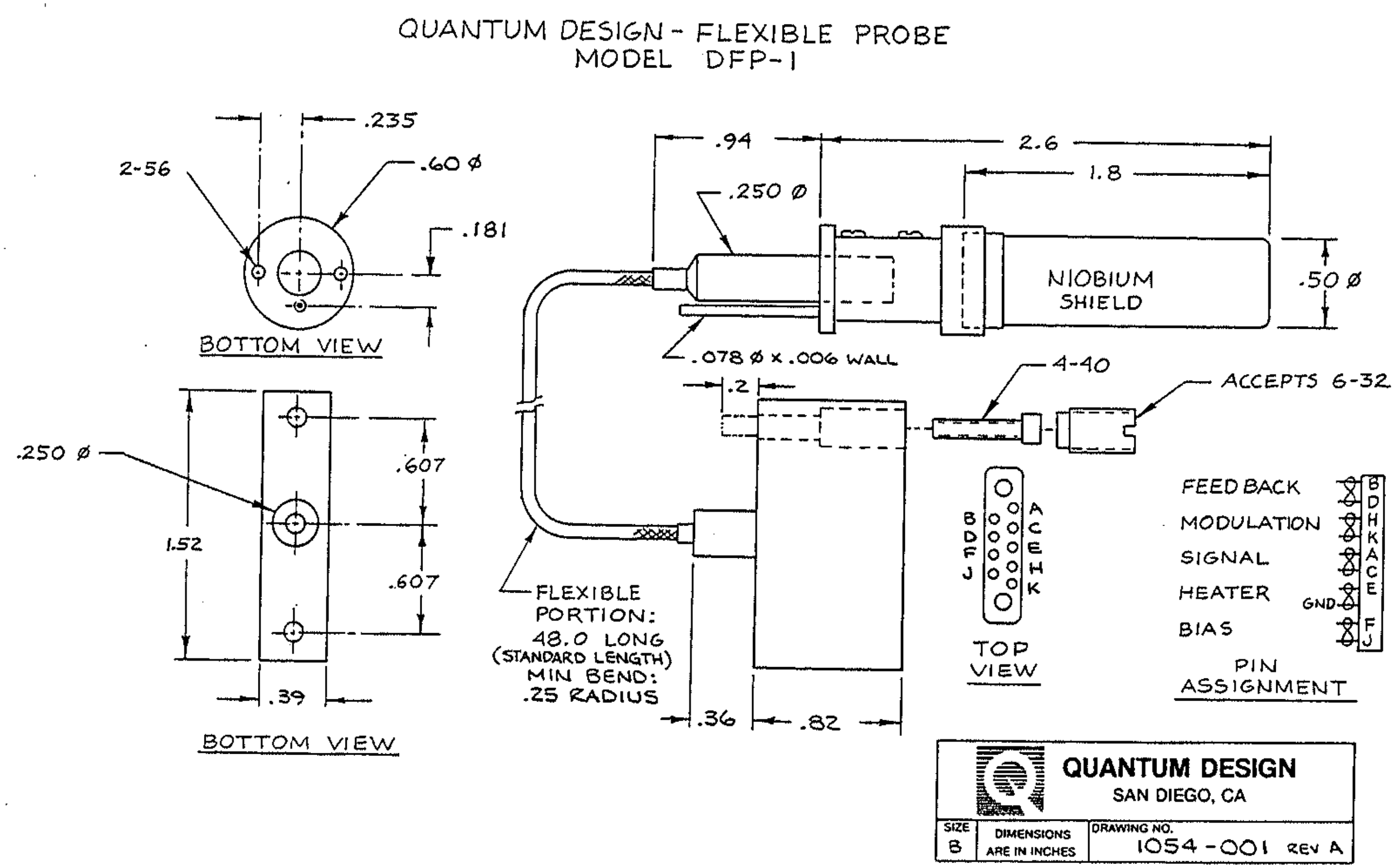

QUANTUM DESIGN - FLEXIBLE PROBE
MODEL DFP-1
.235
2-56
.60 ø
.181
BOTTOM VIEW
.250 ø
.607
1.52
.607
.39
BOTTOM VIEW
.94
2.6
1.8
.250 ø
NIOBIUM
SHIELD
.50 ø
.078 ø x .006 WALL
4-40
ACCEPTS 6-32
.2
FLEXIBLE
PORTION:
48.0 LONG
(STANDARD LENGTH)
MIN BEND:
.25 RADIUS
.36
.82
TOP
VIEW
FEED BACK
MODULATION
SIGNAL
HEATER
GND
BIAS
PIN
ASSIGNMENT
QUANTUM DESIGN
SAN DIEGO, CA
SIZE
B
DIMENSIONS
ARE IN INCHES
DRAWING NO.
1054-001 REV A

Figure D.2

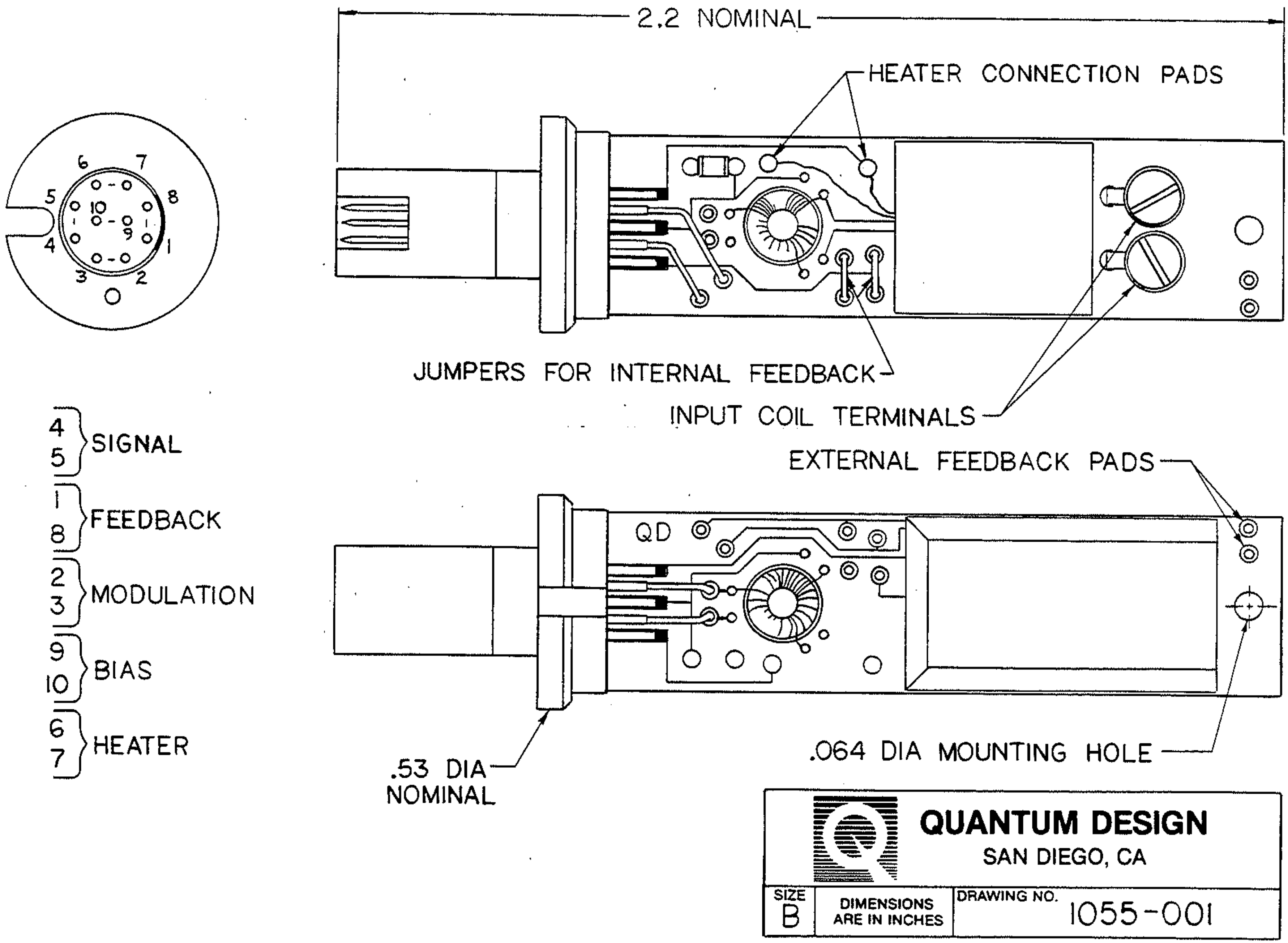

2.2 NOMINAL
HEATER CONNECTION PADS
JUMPERS FOR INTERNAL FEEDBACK
INPUT COIL TERMINALS
EXTERNAL FEEDBACK PADS
QD
.064 DIA MOUNTING HOLE
.53 DIA NOMINAL
4 5 SIGNAL
1 8 FEEDBACK
2 3 MODULATION
9 10 BIAS
6 7 HEATER
QUANTUM DESIGN
SAN DIEGO, CA
SIZE B
DIMENSIONS ARE IN INCHES
DRAWING NO. 1055-001

Figure D.3