Operating Manual

for

Model SMM-601dc microSQUID™ System

By:

Tristan Technologies, Inc.
San Diego, California
USA

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Tristan Technologies, Inc. Part No. 2082-M01

Revision Record		
Date	**Revision**	**Description**
May 07, 2003	version 1.0	Initial Release

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WARRANTY

Tristan Limited Warranty

Tristan Technologies, Inc. warrants this product for a period of twelve (12) months from date of original shipment to the customer. Any part found to be defective in material or workmanship during the warranty period will be repaired or replaced without charge to the owner. Prior to returning the instrument for repair, authorization must be obtained from Tristan Technologies, Inc. or an authorized Tristan service agent. All repairs will be warranted for only the unexpired portion of the original warranty, plus the time between receipt of the instrument at Tristan and its return to the owner.

This warranty is limited to Tristan products that are purchased directly from Tristan, its OEM suppliers, or its authorized sales representatives. It does not apply to damage caused by accident, misuse, fire, flood, acts of nature, failure to properly install, operate or maintain the product in accordance with the printed instructions provided.

This warranty is in lieu of any other warranties, expressed or implied, including merchantability or fitness for purpose, which are expressly excluded. The owner agrees that Tristan's liability with respect to this product shall be as set forth in this warranty, and incidental or consequential damages are expressly excluded.

Table of Contents

1. SYSTEM Overview

The model SMM-601dc microSQUID System (block-diagram is presented in Figure 1.1) has been designed and built by Tristan Technologies, Inc. The system includes the following basic components:

- Liquid Helium Dewar System
- Single Channel LTS SQUID Gradiometer Probe
- SQUID Control System
- Superconducting DC Magnet System
- Sample Motion Control System
- Data Acquisition System

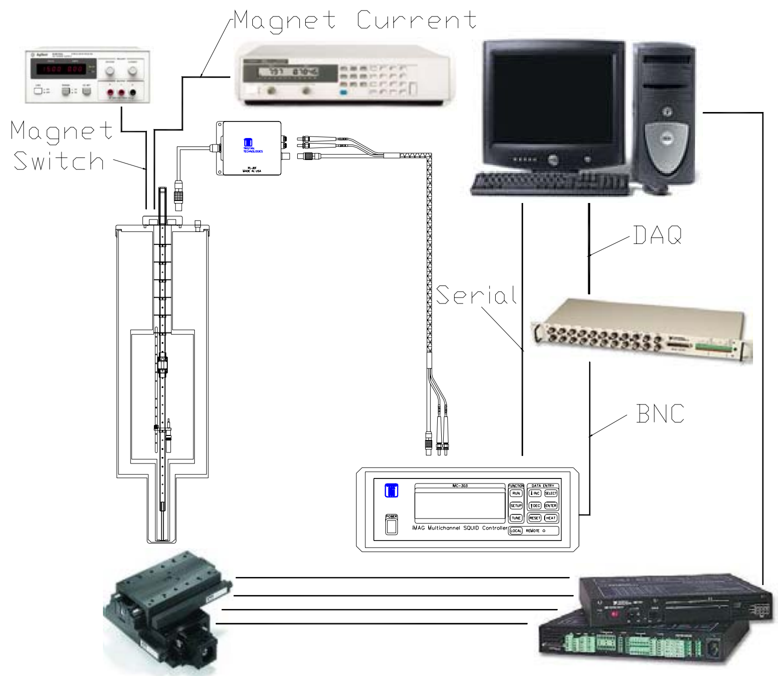

Figure 1.1 System Block Diagram

1.1 INITIAL INSPECTION

All Tristan instruments and equipment are carefully inspected and packaged at Tristan prior to shipment. However, if a unit is received mechanically damaged, notify the carrier and the nearest Tristan representative or the factory in San Diego, California. Keep the shipping container and packing material for the carrier and insurance inspections.

WARNING

THE PROBE IS THE MOST FRAGILE COMPONENT OF THE SYSTEM AND SHOULD BE HANDLED AS SUCH. DAMAGE IS MOST EASILY AVOIDED BY ALWAYS SUPPORTING THE PROBE PROPERLY WHEN IT IS OUT OF THE DEWAR AND BY TAKING CARE NOT TO BUMP THE PROBE INTO OTHER OBJECTS.

If the unit does not appear to be damaged but does not operate to specifications, contact the nearest Tristan representative or the Tristan factory and describe the problem in detail. Please be prepared to discuss all surrounding circumstances, including installation and connection detail. After obtaining authorization from the Tristan representative, return the unit for repair along with a tag to it identifying you as the owner. Please enclose a letter describing the problem in as much detail as possible.

1.2 REPACKING FOR RETURN SHIPMENT

If it is necessary to return the system, repack the unit in its original container with the original packaging materials. If the original packing materials are not available consult a Tristan representative for advice on shipping your system as safely as possible.

WARNING

THE DEWAR MUST BE SHIPPED UPSIDE DOWN. SHIPPING THE DEWAR IN ANY OTHER ORIENTATION WILL RESULT IN DAMAGE NOT COVERED IN THE TRISTAN LIMITED WARRANTY. TAKE CARE TO CLEARLY MARK WHICH SIDE IS UP ON THE DEWAR CRATE WHEN SHIPPING.

WARNING

DAMAGE WHICH OCCURS DURING SHIPPING AND/OR CUSTOMS INSPECTION IS NOT COVERED BY THE TRISTAN LIMITED WARRANTY. WHEN SHIPPING TO TRISTAN, ALWAYS INSURE EQUIPMENT FOR FULL REPLACEMENT VALUE. CONTACT A TRISTAN REPRESENTATIVE IF ASSISTANCE IS REQUIRED IN DETERMINING THE FULL REPLACEMENT VALUE.

1.3 RETURN FROM CUSTOMERS OUTSIDE THE U.S.A.

To avoid delays in customs clearance of equipment being returned, contact the nearest Tristan Technologies representative for complete shipping information and necessary customs requirements. Failure to do so can result in significant delays.

1.4 SYSTEM COMPONENTS

QTY 1 BMD-9AT Liquid Helium Dewar (Serial Number 134)
QTY 1 Storage Baffles Set
QTY 1 ½" Vacuum Valve Actuator
O-Ring and Screw Kit
Dewar Adjustable Tail Wrench
QTY 1 BMP-9 Gradiometer Probe (Serial Number 142)
QTY 1 LSQ/20 LTS dc SQUID (Serial Number A52.38) (Attached)
QTY 1 Custom Length Cryogenic Cable (Serial Number 117-L) (Attached)
QTY 1 AMI Liquid Helium Level Sensor
QTY 1 National Instruments Stepper Motor Drive
QTY 2 Parker Linear Motion Stage
QTY 2 Compumotor Stepper Motor
QTY 1 Non-Magnetic Sample Stage
QTY 1 National Instruments PC to Stepper Driver Cable
QTY 1 Power Cord
SMM-601dc Scanning Magnetic Microscope Manual
QTY 1 Agilent DC Power Supply
QTY 2 Magnet Power Leads
QTY 1 Power Cord
Accessories, Manuals and CD-ROM Manuals
QTY 1 Agilent DC Power Supply
QTY 1 Power Cord
Accessories, Manuals and CD-ROM Manuals
QTY 1 AMI 135 Liquid He Level Monitor
QTY 1 Level Meter Cable
QTY 1 Power Cord
Manuals
QTY 1 Dell Precision Workstation 340
QTY 1 RS-232 Serial Cable
QTY 1 Video Y Cable
QTY 1 Power Cord
QTY 1 Dell Keyboard
QTY 1 Dell Mouse
Dell Manuals and CD-ROMs
Microsoft Win2000 (Installed)
QTY 1 National Instruments PCI DAQ Card (Installed)
QTY 1 National Instruments PCI Motion Card (Installed)
National Instruments Manuals and CD-ROMs
Parker Manuals
Tristan Technologies, Inc. Scan Software (Installed)
Tristan Technologies, Inc. Scan Software Open Code (Installed)
QTY 1 Dell M992 19" Monitor
QTY 1 Monitor cable
QTY 1 Power Cord
Dell Monitor Manuals and CD-ROM
QTY 1 iMC-303 Cryogenic Control Unit
QTY 1 iFL-301-L Flux-Locked Loop
QTY 1 CC-60 Six Meter Fiber Optic Composite Connecting Cable
QTY 1 National Instruments Connection Box
QTY 1 National Instruments SH68 to SH68 DAQ Connection Cable
QTY 1 Power Cord
iMAG® LTS Multi-Channel SQUID System Manual
PC to iMC-303 SQUID Controller Interface Applications Disk

2. CRYOGENIC SYSTEM

The cryogenic system is composed of a liquid helium dewar, single channel probe, custom length cryogenic cable and second order gradiometer detection coil. (These components are shown in figures 2.1 through 2.3)

Figure 2.1 Model BMD-9AT Liquid Helium Dewar

Figure 2.2 Model BMP-601dc Probe

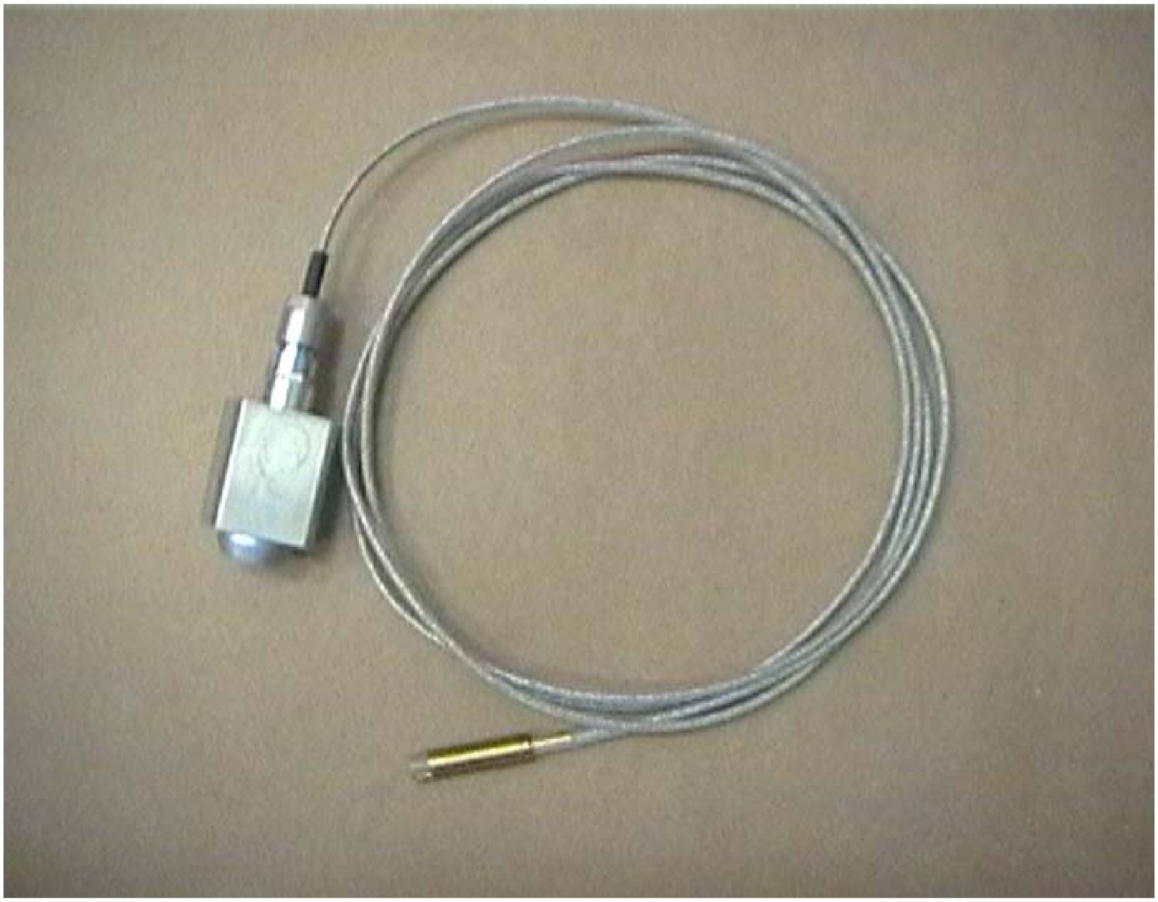

Figure 2.3 Typical Custom Length Cryogenic Cable
Please note that this cable has been installed on the BMP-601dc probe

The dewar performance data are summarized in Table 2.1.

Dewar Volume	9 L
Dewar Gap Cold	Adjustable Set for 5 mm
Dewar Boiloff (1 cm Tail Gap)	2.25 L/day

Table 2.1 Summary of Dewar Performance

2.1 NORMAL INSTALLATION AND OPERATION

2.1.1 PROBE INSTALLATION (WARM DEWAR)

- Inspect dewar and verify internal cavity is free from ice, moisture, or other contaminants.

WARNING

CONTAMINANTS COULD RESULT IN INCORRECT MEASUREMENTS OR PROBE DAMAGE!

- Verify that probe tail is lowered to maximum length.

- Verify dewar top plate o-ring is in place.
- Carefully lower probe assembly into dewar cavity.
- Attach probe top plate to dewar with 8-32 X 1 ¾ screws.

2.1.2 Helium Transfer

- Verify helium level in storage dewar and BMD-9AT dewar.
- Open transfer port at top of probe.
- Transfer observing all standard cryogenic handling and safety procedures.
- Observe transfer levels. Note: Dewar capacity is 9 liters.
- After transferring, plug the transfer port after allowing sufficient vent time.
- Pressurize adjustable dewar tail, remove spacer blocks and depressurize. The dewar tail is now set at 5 mm. (when cooling from dewar from room temperature)
- Verify all connectors at top of probe are free from ice and moisture before making cable connections.

2.1.3 MAGNET CHARGING AND DISCHARGING

Before attempting to charge or discharge the superconducting magnet, the user should read the manuals for the Agilent E3610A and 6541A dc power supplies and be familiar with the modes of their operation.

2.1.3.1 Magnet Cable Connections

- Connect the four-pin connector on the cable shown in Figure 2.4 to the four-pin receptical on the probe top.
- Power on the Agilent E3610A dc power supply, set the power supply to 2A with the "range" button on the front panel and set the voltage output to 15 volts, then power off.
- On the front panel of the Agilent E3610A dc power supply, connect the green wire of the cable shown in Figure 2.4 to the "minus" terminal and the white wire to the "plus" terminal as shown in Figure 2.5. and set the power supply to 2A with the "range" button on the front panel.
- Connect a volt meter capable of measuring millivolts to the black and red leads of the cable shown in Figure 2.4.
- On the rear panel of the Agilent 6541A dc power supply, connect the black magnet lead to the "minus" terminal and the red magnet lead to the "plus" terminal as shown in Figure 2.6 making sure to replace the plastic safety cover on the power supply to prevent shorting of the magnet leads.

- Connect the black magnet lead to the probe top left terminal and the red magnet lead to the probe top right terminal as shown in Figure 2.7.

2.1.3.2 Magnet Charging

- Begin monitoring the volt meter. It should be reading 0 millivolts.
- Select the amount of current to use in charging based upon the plot in Figure 2.8.
- Power on the Agilent 6541A dc power supply, enable the output and set the current and voltage limits. The current limit selected should slightly exceed the desired current input and the voltage limit should never be set to an amount exceeding 5.00 volts.
- Power on the Agilent E3610A dc power supply and begin fluctuating the output of the Agilent 6541A dc power supply between zero and a few milliamps.
- As soon as the volt meter begins reading a non-zero voltage (about 5 seconds after the Agilent E3610 dc power supply is powered), briskly turn up the current on the Agilent 6541A to the desired output.
- Once the Agilent 6541A is set to the desired current, power off the Agilent E3610A and monitor the volt meter until it reads zero millivolts (this amount of time will vary depending upon the amount of current input, but it should not take more than 5 to 15 seconds).
- Record the current from the display of the Agilent 6541A in a laboratory notebook or other secure location, as this value will be vital to the safety of your magnet system in the discharging of the magnet.
- Ramp down the current on the Agilent 6541A to 0A and power off.
- Depending upon the environmental conditions where the system is being operated, the magnet cabling may be left in place during operation, but Tristan Technologies recommends removing the cabling from the probe top to guarantee the lowest SQUID noise.

2.1.3.3 Magnet Discharging

- Begin monitoring the volt meter. It should be reading 0 millivolts.
- Power on the Agilent 6541A dc power supply, enable the output and set the current and voltage limits. The current limit selected should slightly exceed the current recorded in the charging process and the voltage limit should never be set to an amount exceeding 5.00 volts.
- Ramp up the current on the Agilent 6541A to the exact amount recorded in the charging procedure.

- Power on the Agilent E3610A.
- As soon as the volt meter begins reading a non-zero voltage (about 5 seconds after the Agilent E3610 dc power supply is powered), briskly ramp the current on the Agilent 6541A to zero.
- Once the Agilent 6541A current is at zero, power off the Agilent E3610A and monitor the volt meter reading.
- Once the volt meter reads 0 mV, the Agilent 6541A may either be powered down or prepared for charging the magnet to another value.
- As before, the cabling may be left in place during operation of the SQUID system depending upon the environmental conditions where the system is being operated. However, Tristan Technologies recommends removing the cabling from the probe top to guarantee the lowest SQUID noise.

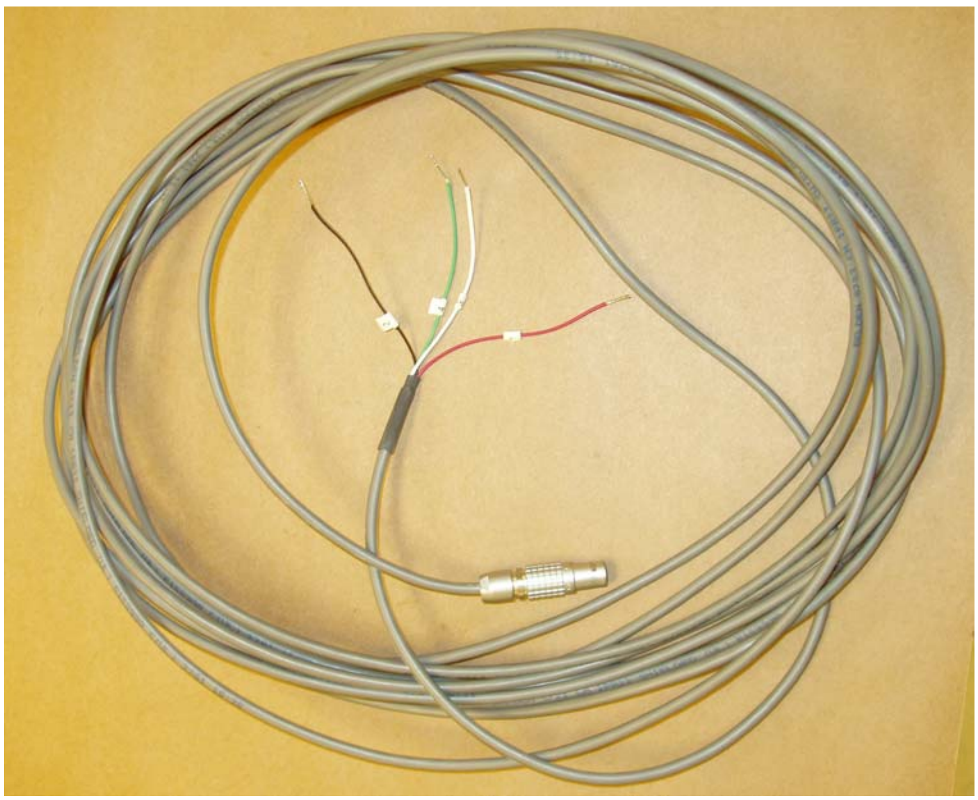

Figure 2.4 Magnet Switch Cable

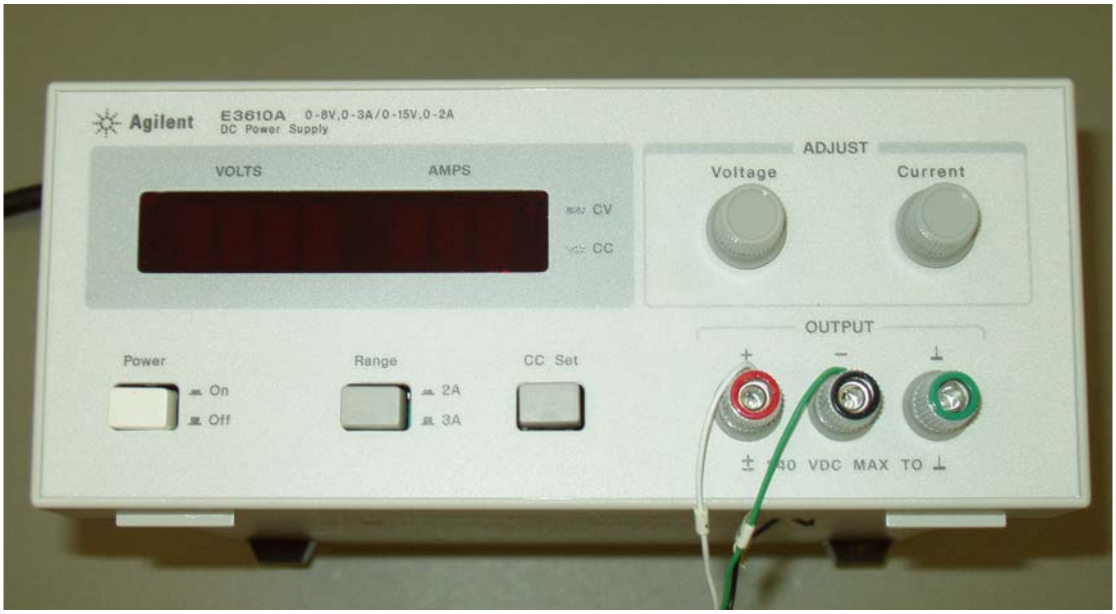

Figure 2.5 Magnet Switch Power Supply

Figure 2.6 Magnet Current Power Supply

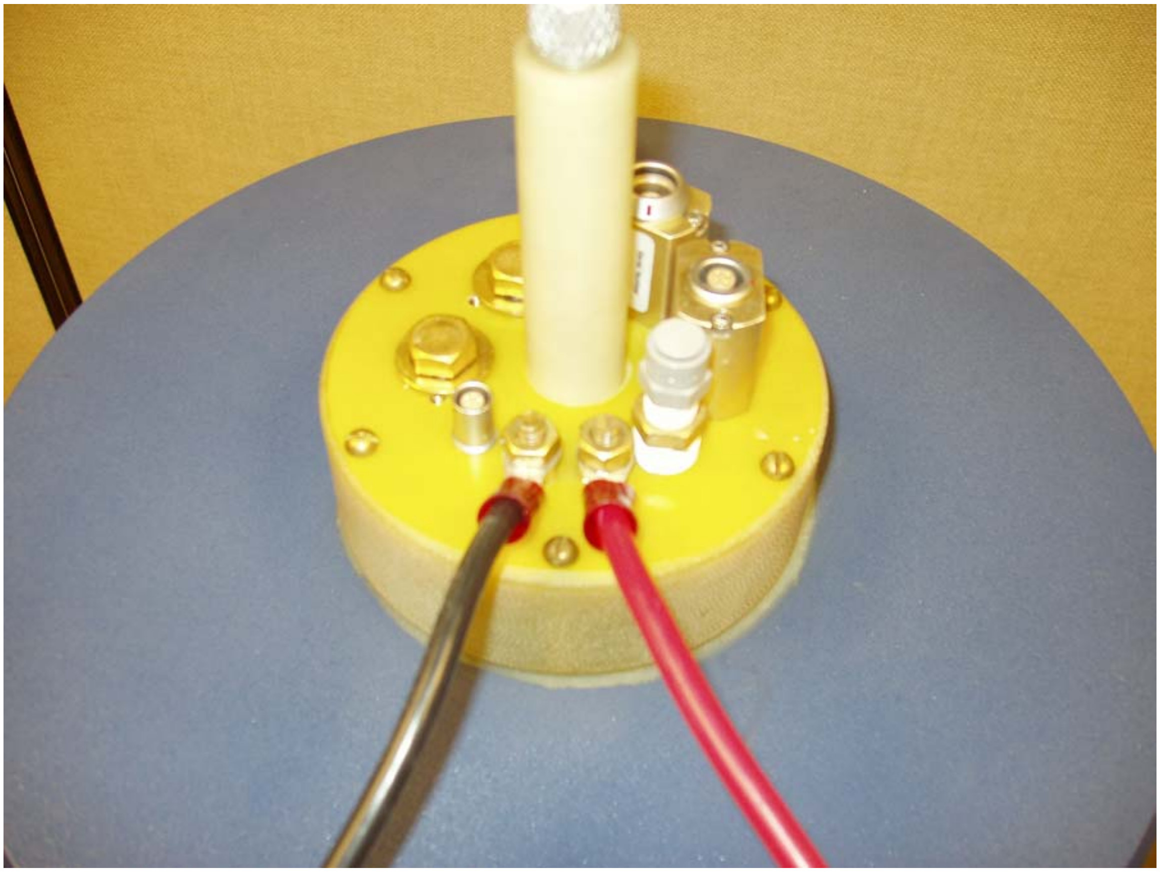

Figure 2.7 Cables on Probe Top Plate

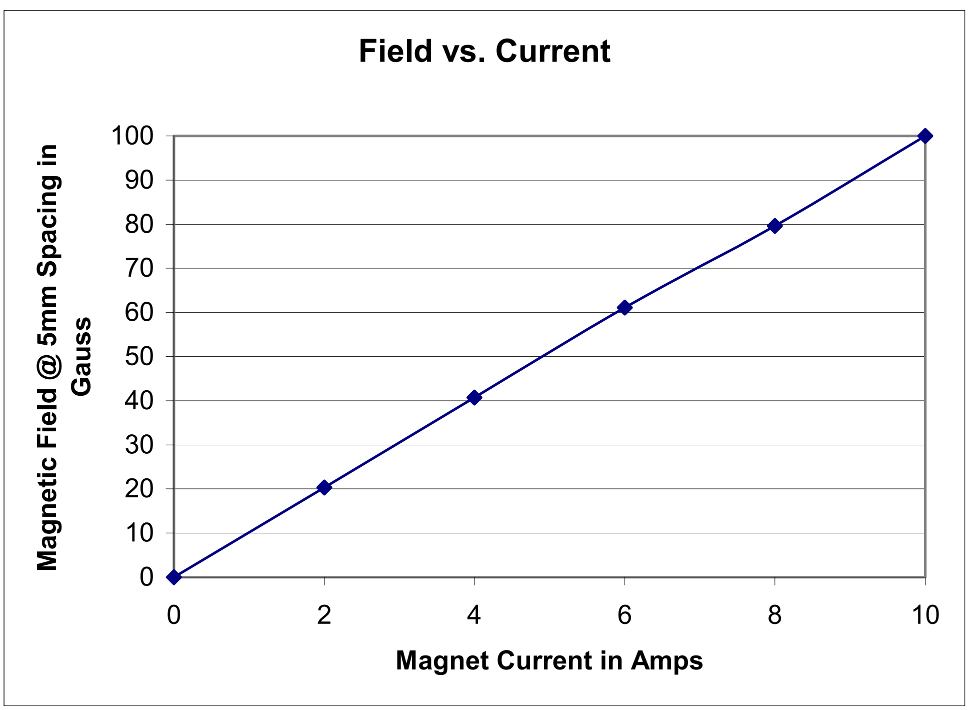

Figure 2.8 Magnet Field vs. Current

2.1.4 PROBE REMOVAL

- Disconnect cables from top of probe.
- Observe all cryogenic handling and safety procedures.
- Remove probe attachment screws.
- Carefully lift probe straight out of the dewar. Rotate probe back and forth to prevent freezing in place.
- Immediately place the bottom of the probe in a plastic bag (garbage bags work well for this) to limit condensation accumulation.
- Insert storage baffles into dewar assembly.

2.1.5 DEWAR WARM – UP

The dewar tail must be lowered prior to warming of the dewar. The minimum safe reference distance for warming the dewar is 90 mm.

WARMING THE DEWAR WITH A REFERENCE DISTANCE OF LESS THAN 90 mm COULD DAMAGE DEWAR AND IS SUCH DAMAGE IS NOT COVERED BY THE Tristan Technologies, Inc. WARRANTY.

Fiberglass dewars such as the one supplied with this system should never be allowed to warm up by simply letting all the helium evaporate. If this is allowed to happen and the inside fiberglass warms to near room temperature, helium gas will diffuse through the dewar walls and soften the vacuum space of the dewar. To prevent this, you should wait for about one to four hours after the helium level has reached 0% and then remove the probe from the dewar. Place the probe inside a tight-fitting plastic bag to prevent excessive condensation of moisture. Turn the dewar upside down to pour out the remaining helium. Then let the dewar warm up to room temperature (leave the neck tube open). If this procedure is used, it will be necessary to make sure that any water which condenses in the dewar is removed prior to using the system again. This can be done by wiping it out using a rag on the end of a rod or by blowing room-temperature air into the tail of the dewar.

WARNING

DO NOT BLOW HOT AIR INTO THE DEWAR AS THIS MAY CAUSE FAILURE OF THE EPOXIED JOINTS.

2.2 SAFETY PRECAUTIONS FOR HANDLING CRYOGENIC LIQUIDS

The potential hazards of handling liquid helium stem mainly from the following properties:

WARNING

1. THE LIQUID IS EXTREMELY COLD (HELIUM IS THE COLDEST OF ALL CRYOGENIC LIQUIDS).
2. THE ULTRA-LOW TEMPERATURE OF LIQUID HELIUM CAN CONDENSE AND SOLIDIFY AIR.
3. VERY SMALL AMOUNTS OF LIQUID HELIUM ARE CONVERTED INTO LARGE VOLUMES OF GAS.
4. HELIUM IS NOT LIFE SUPPORTING.

2.2.1 EXTREME COLD—COVER EYES AND EXPOSED SKIN

Accidental contact of liquid helium or the cold gas that results from its rapid evaporation may cause a freezing injury similar to a burn. Protect your eyes and cover the skin where the possibility of contact exists. Eye protection should always be worn when transferring liquid helium.

2.2.2 KEEP AIR AND OTHER GASES AWAY FROM LIQUID HELIUM

The low temperature of liquid helium or cold gaseous helium can solidify another gas. Solidified gasses and liquid, particularly solidified air, can plug pressure-relief passages and foul relief valves. Plugged passages are hazardous because of the continual need to vent the helium gas which evolves as the liquid continuously evaporates. Therefore, always store and handle liquid helium under positive pressure and in closed systems to prevent the infiltration and solidification of air or other gases. Do not permit condensed air on transfer tubes to run down into the container opening.

2.2.3 KEEP EXTERIOR SURFACES CLEAN TO PREVENT COMBUSTION

Atmospheric air will condense on exposed helium-cooled piping. Nitrogen, having a lower boiling point than oxygen, will evaporate first from condensed air, leaving an oxygen-enriched liquid that may drip or flow to nearby surfaces. Areas and surfaces upon which oxygen-enriched liquid can form, or come in contact with, must be cleaned to oxygen-clean standards to prevent possible ignition of grease, oil, or other combustible substances. Leak-testing solutions should be selected carefully to avoid mixtures which can leave a residue that is combustible. When combustible type foam insulations are used, they should be carefully applied to reduce the possibility of exposure to oxygen-enriched liquid which could, upon impact, cause explosive burning of the foam.

2.2.4 PRESSURE-RELIEF DEVICES MUST BE ADEQUATELY SIZED

While most cryogenic liquids require considerable heat for evaporation, liquid helium has a very low latent heat of vaporization. Consequently, it evaporates very rapidly when heat is introduced or when liquid helium is first transferred into warm or partially-cooled equipment. Even minor deterioration of the vacuum in the helium container can result in significant evaporation. Pressure relief devices for liquid helium equipment must, therefore, be of adequate capacity to release helium vapor resulting from such heat inputs, and thus, prevent hazard due to excessive pressure. This system has been designed to safely vent the evolving helium gas in the event of any reasonable failure mode.

WARNING

DO NOT MAKE ANY MODIFICATIONS TO THIS SYSTEM WHICH MIGHT AFFECT ITS ABILITY TO VENT HELIUM GAS IN THE EVENT OF AN EMERGENCY SUCH AS LOSS OF VACUUM IN THE DEWAR VACUUM SPACE.

If transfer lines can be closed off at both ends so that a cryogenic liquid or the related cold gas can become trapped between the closed ends, a pressure-relief device must be provided in that line to prevent excessive pressure build-up.

2.2.5 KEEP EQUIPMENT AREA WELL VENTILATED

Although helium is nontoxic, it can cause asphyxiation in a confined area without adequate ventilation. Any atmosphere which does not contain enough oxygen for breathing can cause dizziness, unconsciousness, or even death. Helium, being colorless, odorless, and tasteless cannot be detected by the human senses and will be inhaled normally as if it were air. Without adequate ventilation, the expanding helium can displace air and result in an atmosphere that is not life-supporting. The cloudy vapor that appears when liquid helium is exposed to the air is condensed moisture, not the gas itself. The issuing helium gas is invisible. Liquid containers should be stored in large, well ventilated areas.

If a person becomes groggy or loses consciousness when working around helium, get them to a well ventilated area immediately. If breathing has stopped, apply artificial respiration. If a person loses consciousness, summon a physician immediately.

2.3 GENERAL INFORMATION

- Transfer helium with probe inserted.
- Do not touch coils at bottom of probe.
- When probe is removed from dewar, carefully place flat on "V" blocks for support.

3. Sensors and Control Electronics

3.1 SENSOR INITIAL PERFORMANCE TEST

The sensor and control electronics system is composed of a LTS dc SQUID, liquid helium level sensor, flux-locked loop, fiber-optic connecting cable and cryogenic control unit. (These components are shown in figures 3.1 through 3.6)

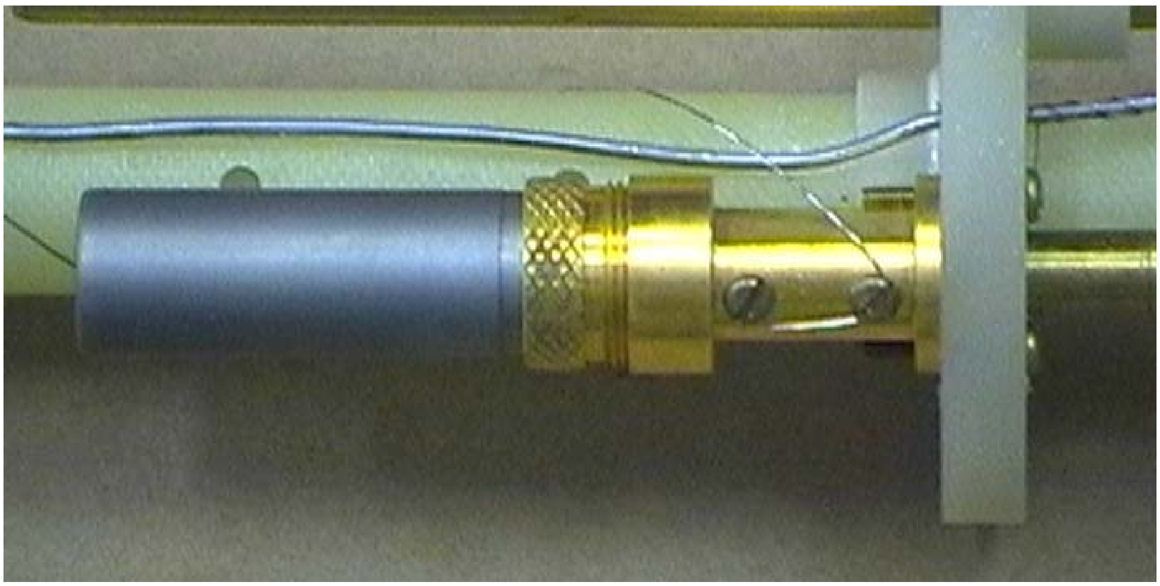

Figure 3.1 Model LSQ/20 LTS dc SQUID

Figure 3.2 Liquid Helium Level Sensor

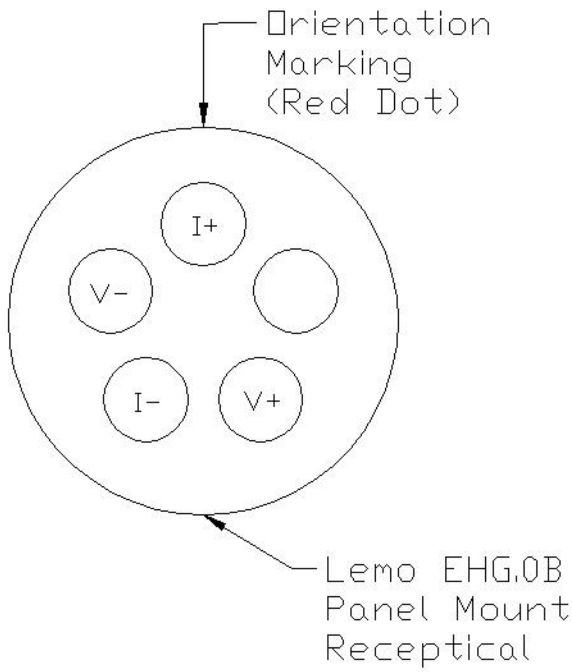

Figure 3.3 Level Detection Diagram

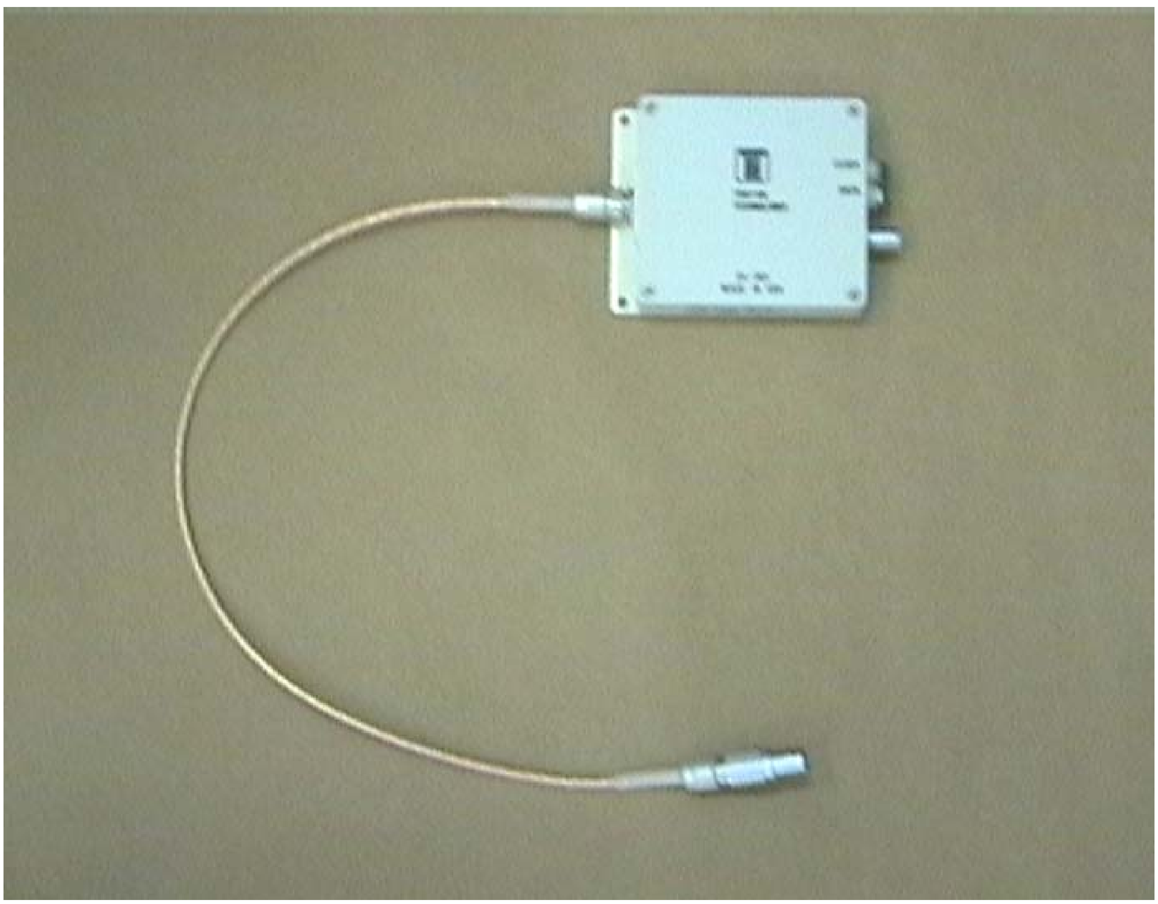

Figure 3.4 Model iFL-301-L Flux-Locked Loop

Figure 3.5 Model CC-60 Fiber Optic Composite Connecting Cable

Figure 3.6 Model iMC-303 Cryogenic Control Unit

The SQUID has been tested with attached pick-up coil at Tristan Technologies. The pick-up coil is configured as a first order gradiometer and was balanced to better than 0.5%. Below are the test results for the SQUID parameters of and noise spectral densities on gain x100 (see Figures 3.7 and 3.8 as well as Table 3.3). To carry out the measurements, the pick-up coils were shielded using lead foil.

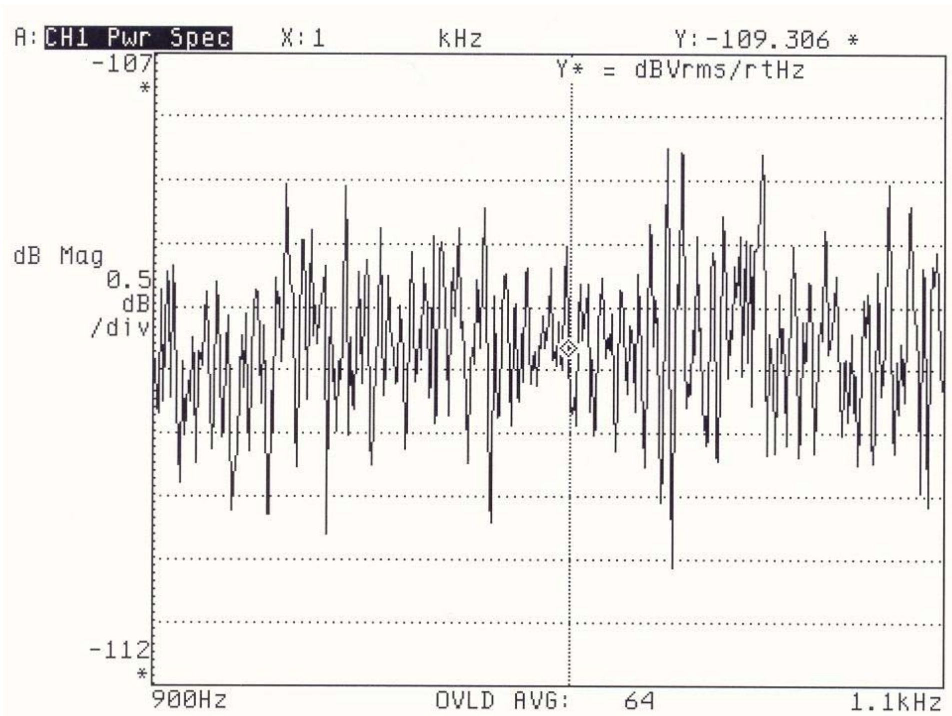

Figure 3.7 dB_Z/dz White Noise Spectrum

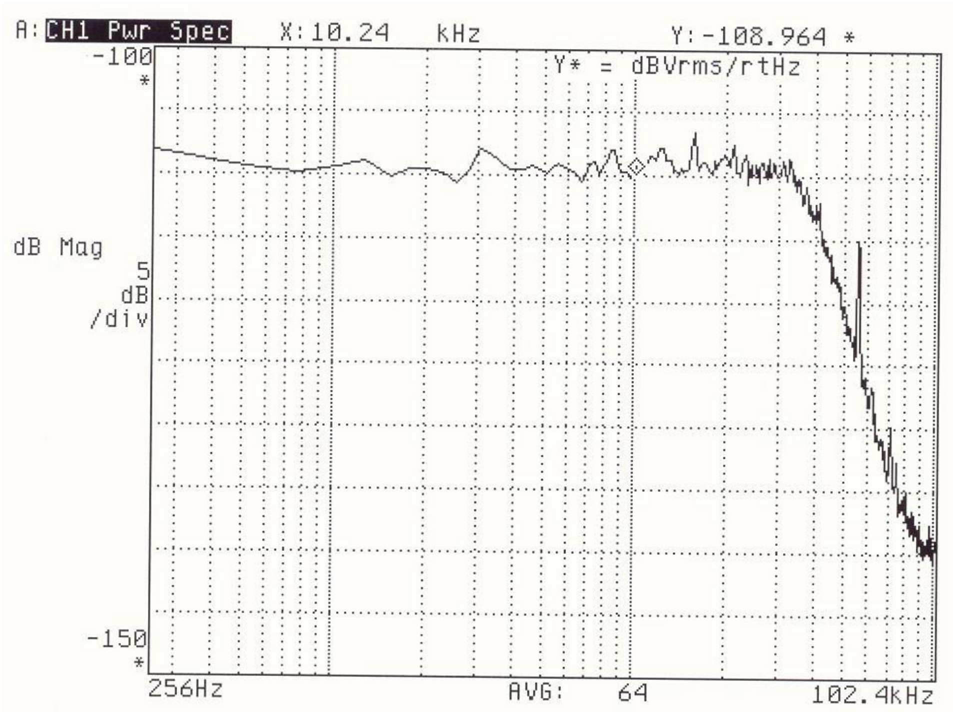

Figure 3.8 dB$_Z$/dz Full Noise Spectrum

Channel	1kHz Noise @ gain x100 dBV$_{rms}$/√Hz	Sensitivity Gain x100 fT/√Hz@ 1 kHz
X	-109.306	33.1

Table 3.3 Summary of Noise and Sensitivity

3.2 FIELD CALIBRATION

The calibration procedure for the system sensors is presented below. The calibration is intended to provide the user with a meaningful conversion from the measured voltage output to appropriate physical properties being measured. The coil configuration is shown in Figure 3.9.

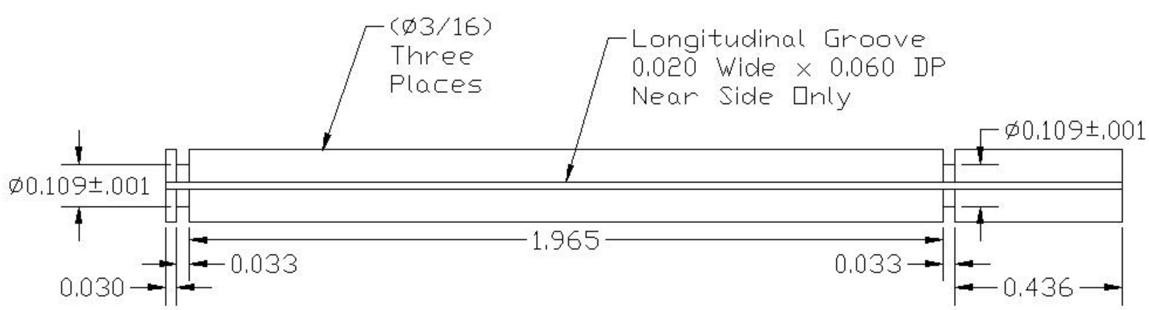

Figure 3.9 Coil Design

3.2.1 CALIBRATION TECHNIQUE

A SQUID channel produces a voltage which is proportional to the change in flux threading the pick-up coil for that channel. The flux induced in the pick-up is due to the combined flux generated by the (generally) complex magnetization, shape and position of the sample. In this calibration procedure, a second coil is used as the sample. The physical dimensions and current of this coil are also known. By also knowing the relative placement of the coil below the pick-up coil, the mutual inductance M can be calculated. The flux induced by the current I in the calibration coil is given by

$$\Phi_{pick-up} = M \times I_{calib}$$

The pick-up coil is configured as a second order gradiometer to cancel the effect of uniform magnetic fields. Thus the signal is due to the net flux threading the pick-up coil set and is due to non-uniformity in the field generated by the sample. The calculation of this net flux is in general difficult because it depends upon the particular details of the source of the magnetic field, and is thus model dependent.

It has become conventional to characterize the net flux induced in a particular gradiometer coil configuration by an average magnetic field applied to the area of one sense of the pick-up coil set; that is, by calculating what uniform magnetic field, applied to just one polarity or sense of the pick-up coil set, would give the observed signal. This technique then yields a means of converting an observed signal to a quantity which characterizes the mean magnitude of the induced field (change) at the pick-up coil site. This technique does not require knowledge of the details of the magnetization of the sample.

If A is the area of one polarity of the pick-up coil set, and V_{calib} is the observed signal due to the calibration current, then the calibration ratio (Volts/Tesla) can be calculated as

$$V/T = \frac{V_{calib} \times A}{\Phi_{pick-up}}$$

With this conversion ratio, the user can convert an observed (change in) voltage signal to an *effective* (change in) magnetic field. It excludes the details of the sample magnetization, and the particular field gradient sensitivity of the channel.

3.2.2 CALIBRATION PROCEDURE

The following steps describe the calibration procedure to be used on each channel. The system has been calibrated at Tristan. However, if some changes are made in the internal circuitry of the sensors, or to check the calibration, the user can utilize this procedure for the system re-calibration.

Coil Mounting. The calibration coil should be mounted on a x-y scanning stage. It should be oriented with its axis vertical and with as small separation between the coil and probe surface as is convenient. Typically, a coil center to probe tail surface distance of 2 mm is suitable. The coil leads should be tightly twisted and exit downward away from the probe. The purpose of the scanning stage is to locate the coil centered directly below the appropriate channel pick-up coil. This is done be scanning the x and y axes and observing the position of the coil center from the data; for present configuration this is the extremum (maximum or minimum, depending upon the polarity) of the observed signal. The calibration and the pick up coils should be on the same axis.

The coil separation Z is defined as the following:

Z = B + D + C,

where B is the distance between the dewar's inside bottom and the closest coil of the pick up coil set, D is the dewar tail separation, C is the distance between the calibration coil and the dewar's outside bottom (see Figure 3.10).

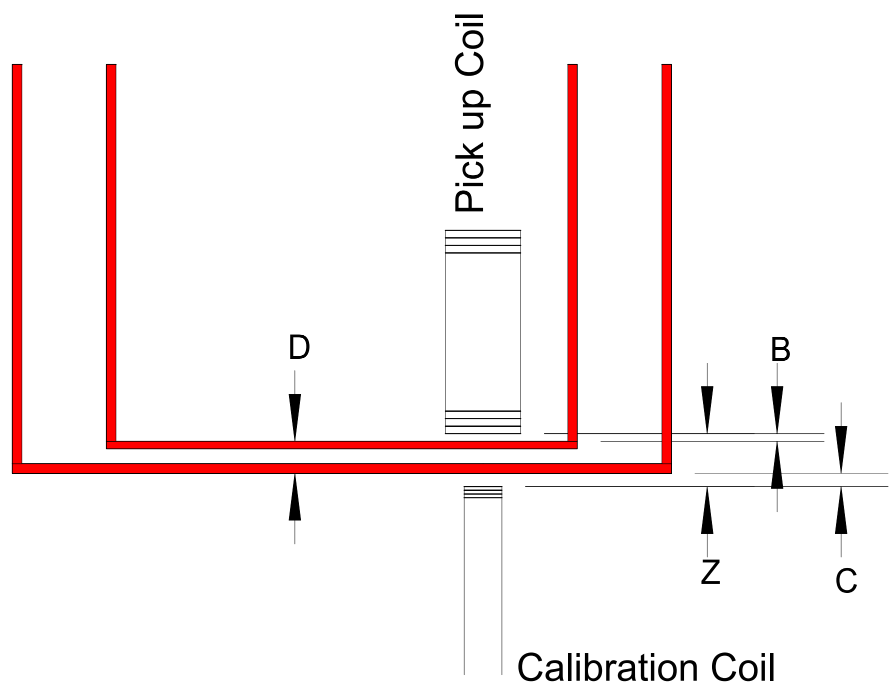

Figure 3.10 Relative position of pick up coil, calibration coil and dewar tail

The calibration coil is placed 1 - 2 mm below the dewar's bottom, and Z is calculated corresponding to this position.

Calibration Current. Because the stage can induce a signal as it is scanned, it is suggested that an AC current be used in the calibration coil. The AC frequency should be chosen away from other potential noises in the local environment (such as the line frequency). A wave form generator or output from a lock-in-detector with appropriate resistor in series can be used to drive the coil. The drive current should be verified by measuring with a laboratory ammeter or by measuring a voltage output from a resistor in series with the calibration coil. Feed the voltage output across this resistor into oscilloscope to check if the signal is sinusoidal. The circuit as shown in Figure 3.11 can be used to drive I_{calib}.

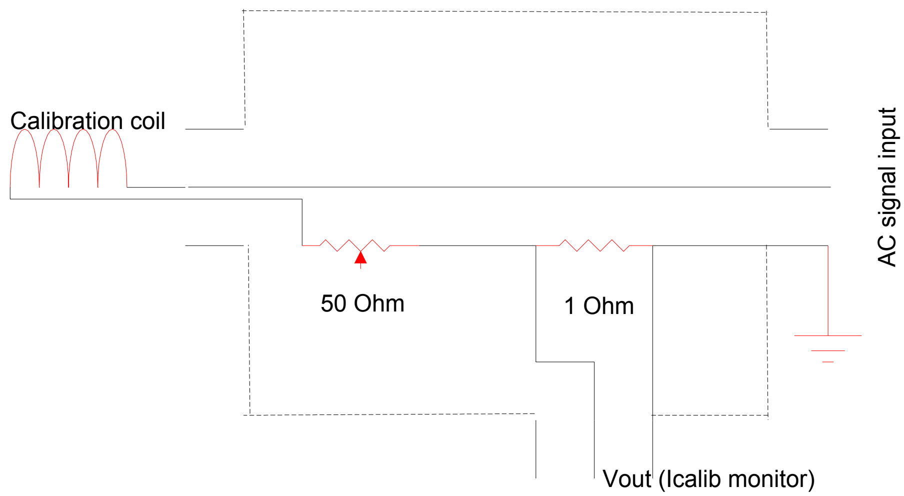

Figure 3.11 Calibration coil circuit

Scan Calibration Coil and V_{calib} Determination. To determine the appropriate calibration coil position for each channel, secure the coil to a x-y table. Apply the required AC signal (I_{calib}) to the calibration coil. Read the SQUID voltage output from the SQUID controller using a lock-in-detector and extracting the peak in-phase lock-in signal. The extremum (polarity depends on particular channel configuration) voltage output is located by moving the table first in the X direction, then in the Y direction. The peak signal, where the calibration coil is centered is defined as V_{calib}. **I_{calib} and V_{calib} are both measured in *peak* values or in *rms* values**.

Mutual Inductance. The diameter, the position, and the number of turns of the calibration coil and the pick-up coil set are needed. For a given separation and orientation (assumed to lie in parallel planes), the mutual inductance can be calculated.

Area. The area of one sense or polarity of the pick-up coil is used. For this SMM-601dc, A is 106 x 10^{-6} m^2.

Calculate V/T. The following formula is used to obtain the V/T (volts per Tesla) ratio.

$$V/T = \frac{V_{calib} \times A}{I_{calib} \times M}$$

Use of Conversion ratio. The conversion of an observed voltage signal to an effective magnetic field should be used with caution. It is important to understand the method for obtaining this ratio, and hence its applicability.

3.2.3 SUMMARY OF THE SYSTEM CALIBRATION

Channel	Calibrated Tesla Per Volt gain x100
dB_Z/dz	9.65 x 10^-9

Table 3.4 Summary of the system calibration

4. DATA ACQUISITION SYSTEM

4.1 Software Definitions

A **data set** is all of the data resulting from a scan together with information that is stored in the file header. The header contains pertinent information inserted automatically, such as the scan geometry and the date, as well as any information entered by the user. The scan data may contain multi-channel, multi-component or multidimensional information.

Displays are windows with contents of one of four types:

1. File headers
2. Time domain plots
3. One spatial dimension plots of scanned (or scanning) data
4. Two spatial dimension intensity plots of scanned (or scanning) data

The contents of a display are referred to as its **elements**. There may be zero to ten elements in each display.

4.2 The Display Control Window

4.2.1 Header

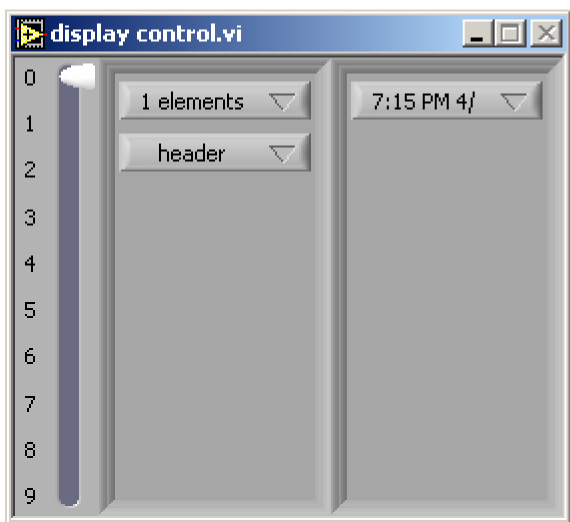

Figure 4.1 Display Control Window for Header

The slide control on the left is the **display number selector**. There are ten display windows available, numbered zero through nine. Any of these may be open simultaneously. The display selector indicates which display window is affected by the control panes to the right.

The first control pane contains the **display controls**. The display controls affect all the elements in the display.

The top control in this pane is the **number of elements** menu. One can select zero through ten elements for the display window. A corresponding number of element control panes will appear to right.

The second control is the **display type** menu. Selecting a type other than *closed*, opens the display window.

The top control in the element control pane(s) is a **data set selector** menu. This menu will contain a list of all data sets scanned during the current session and any loaded in from previous sessions. Newly scanned data sets are added at the top of the list, and those loaded from previous sessions at the bottom.

When the display type *header* is selected, these are the only controls visible. The display window will show the file headers for all data sets selected in element control panes, and in that order.

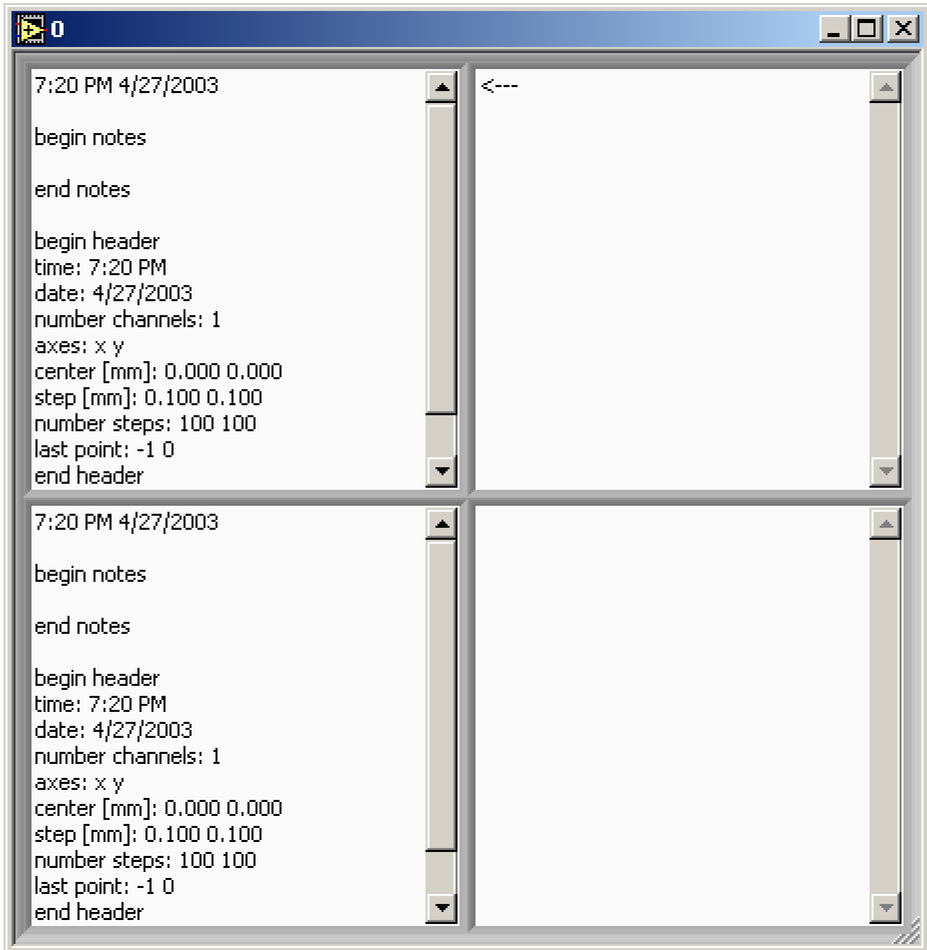

Figure 4.2 Header Display

The title bar shows the number of the display. The first line of the header appears in data set selector menus. This line contains the time and date by default, but may be changed by the user. The next section of the header is for user notes. These notes can be modified at any time and will be saved with the rest of the header when the data set is saved to a file. The next section contains information automatically inserted and should not be edited by the user, in general.

The order of headers is right to left and then down. There may be blank elements in the last row of headers. Elements that contain an arrow indicate that the data set of this element is selected more than once, and need not be shown here. This window may be resized any time. The layout of the headers will be adjusted to better use the new window area.

4.2.2 Time

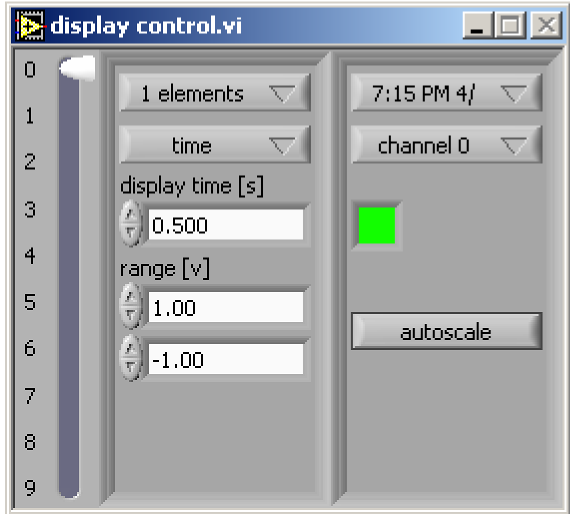

Figure 4.3 Display Control Window for Time

If the display type *time* is selected, more controls are visible.

In the display controls pane the third control is the **display time** control. This sets the time length (horizontal axis) of the time domain plot.

The next two controls set the voltage or magnetic field range (vertical axis) of the time domain plot.

The element control panes also show more controls. The second control in these panes is the **channel selector** menu. This menu will list all channels available in any of the currently available data sets.

The next element control is a **color selector**. Clicking on this control brings up a color selector panel. The plot data points of this element will be shown in the chosen color.

The next element control is the **autoscale** button. Clicking on this button will adjust the range of the plot, so that this particular element will span one half of the vertical range available.

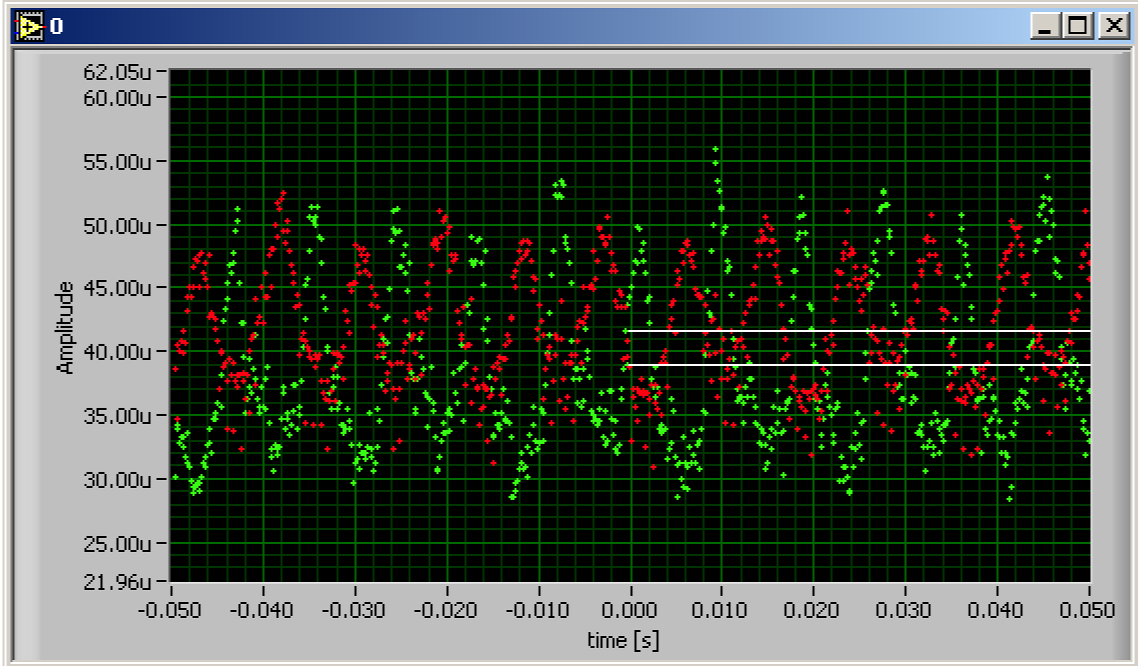

Figure 4.4 Time Display

In addition to the acquired data displayed, there is a constant value fit shown for each element in the plot. This represents the average of the data over the time range from zero to the end of the plot. The range of this average is controlled by the **measure time** control in the main window. This average is the value that is stored in the data set for each point of a scan.

This window will display acquired data anytime, not only during a scan. At high sample rates, each point in this plot may represent many raw data points. The data is averaged and decimated down to a few hundred points for convenient display. This window may be resized any time.

4.2.3 1D

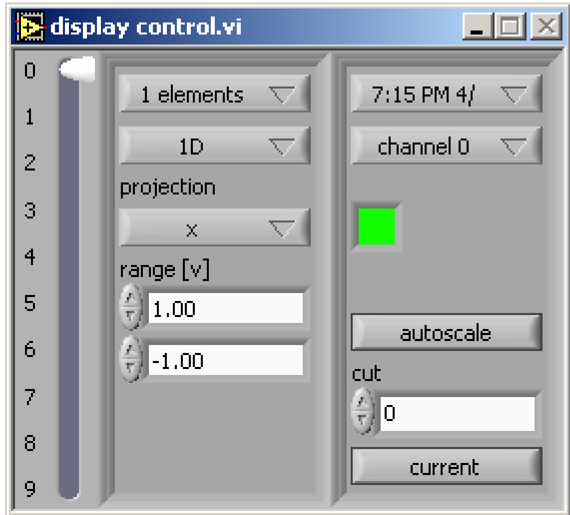

Figure 4.5 Display Control Window for 1D

If the display type *1D* is selected, two more controls are visible. In the display controls pane, the *projection* menu is visible. This menu selects a Cartesian projection for viewing a one dimensional line scan from a two dimensional data set.

In the element control panes, the **cut** control selects which line scan to display. The value is an integer from 0 to N-1. Where N is the number of lines in the scan. Selecting a number higher than N-1 will result in no display.

The **current** button automatically sets the cut to the last line scan available. For a data set that is currently being acquired, this results in a real time plot of the scan. This display may be resized at any time.

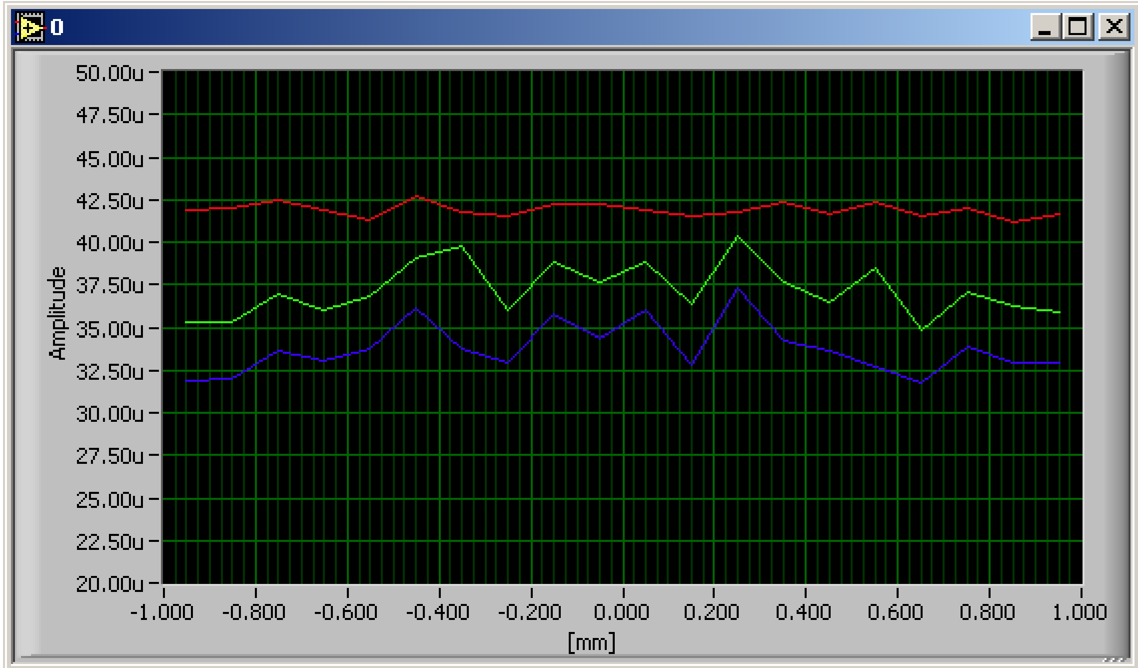

Figure 4.6 1D Display

4.2.4 2D

Figure 4.7 Display Control Window for 2D

The display type *2D* has the most visible controls.

The four buttons below the **pan** label allow one to pan the displayed area along the vertical and horizontal axes. The center of the displayed area is indicated (in mm) in the upper right corner of the display. The **fine** button causes the view to pan with a finer control.

The four buttons below the **zoom** label allow one to zoom in and out along the vertical and horizontal axes independently. The magnification is indicated in the upper right corner of the display. If the **uniform** button is depressed, the zoom is equal in the horizontal and vertical axes regardless of whether the vertical or horizontal buttons are used.

The element control panes now have two color, and two numeric controls under the **range** label. The numeric fields control the values to be associated with these chosen colors. Intermediate values are plotted using a color ramp between the two colors. Values outside the range are not plotted.

A black line indicates the line scan indicated by the projection and cut controls. This is useful to note when switching between *1D* and *2D* display types.

Scan data are bound by a black rectangle. This rectangle appears even when the scan geometry is first being defined in the main window in **new scan** mode, and is useful for defining a scan position relative to a previous scan.

A blue rectangle indicates the outermost boundaries of the scanning stages.

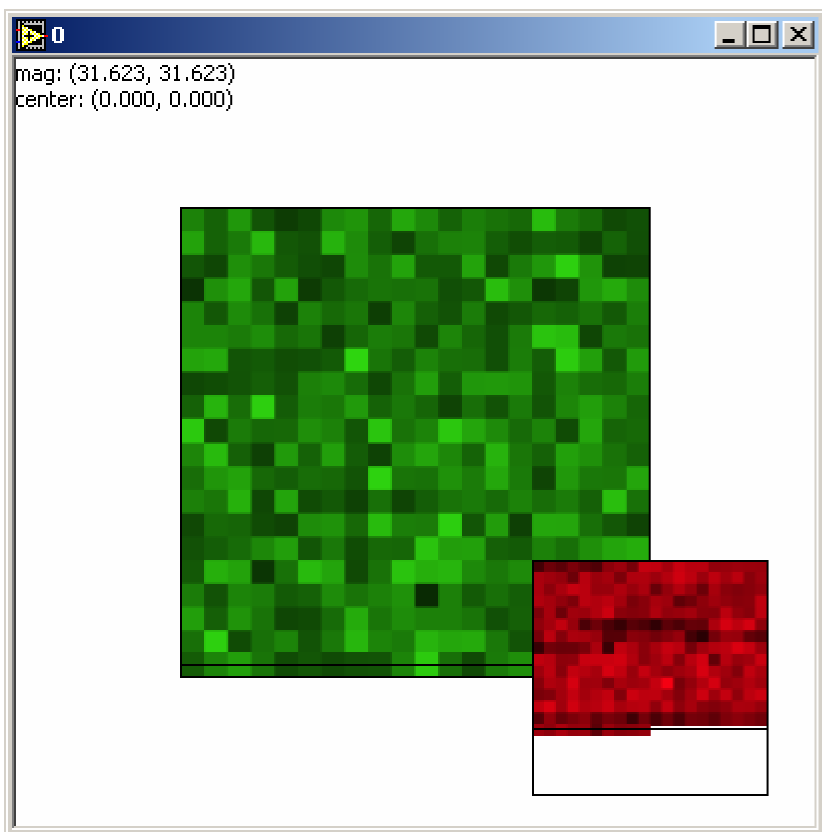

Figure 4.8 2D Display

4.3 The Main Window

The main window has five tabs, which allow navigation to the five control sections, and a **stop** button. To stop the program, click on this button.

4.3.1 SQUID

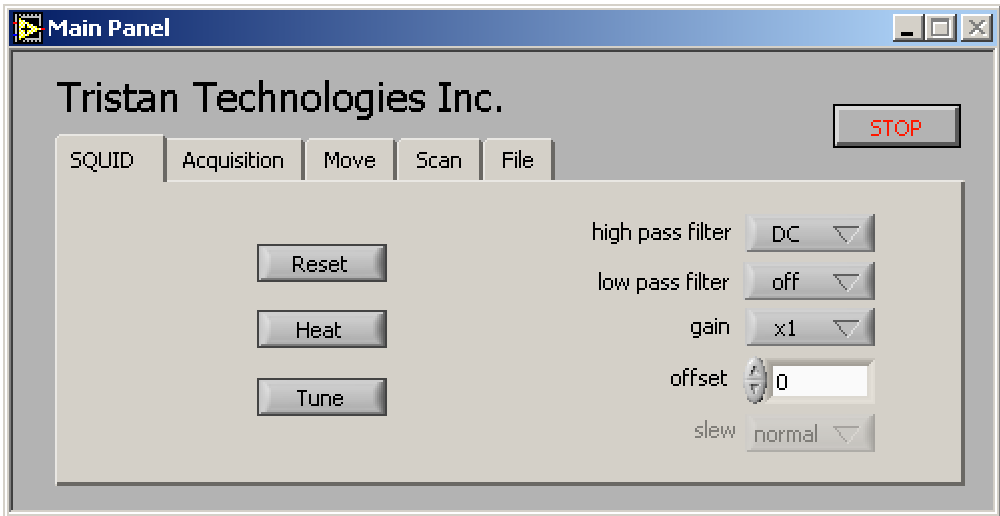

Figure 4.9 SQUID Tab in Main Window

This section has controls that perform functions available from the front panel of iMAG SQUID controller. These functions are described in the iMAG SQUID Controller Manual.

These controls are disabled during a scan, but may be used between scans, or when a scan is paused.

4.3.2 Acquisition

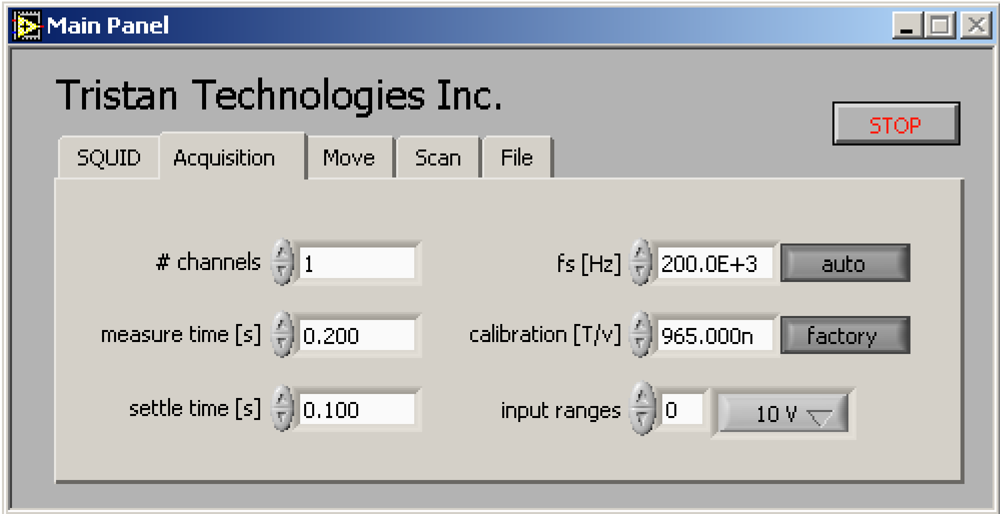

Figure 4.10 Aquisition Tab in Main Window

The **#channels** control sets the number of channels that are acquired and stored during or between scans.

The **measure time** sets the duration of the acquisition used for the measurement of each point in a scan.

Settle time sets the duration of acquisition after a move that is discarded. It may be necessary to set this non-zero to allow for mechanical and SQUID settling.

fs is the sampling frequency in Hertz.

Calibration is a numeric control used to convert from voltage to magnetic field units. If the factory button is depressed, the factory measured value for the system is used. The resulting units are used in the plot displays and range controls. The values are automatically compensated for changes of range and SQUID gain.

Input ranges, controls the maximum range of the acquisition hardware for each channel. The channel is selected by the numeric control and the range by the menu. The range is plus or minus the indicated value. This controls the pre-amplifier gain of the acquisition hardware.

4.3.3 Move

Figure 4.11 Move Tab in Main Window

This section allows the translation stages to be controlled between scans, or when a scan is paused. The **x** and **y** values (in mm) are set to the desired value and the **move** button initiates the move. When resuming a paused scan, the translation stages will return to the appropriate position, regardless of any moves performed.

4.3.4 Scan

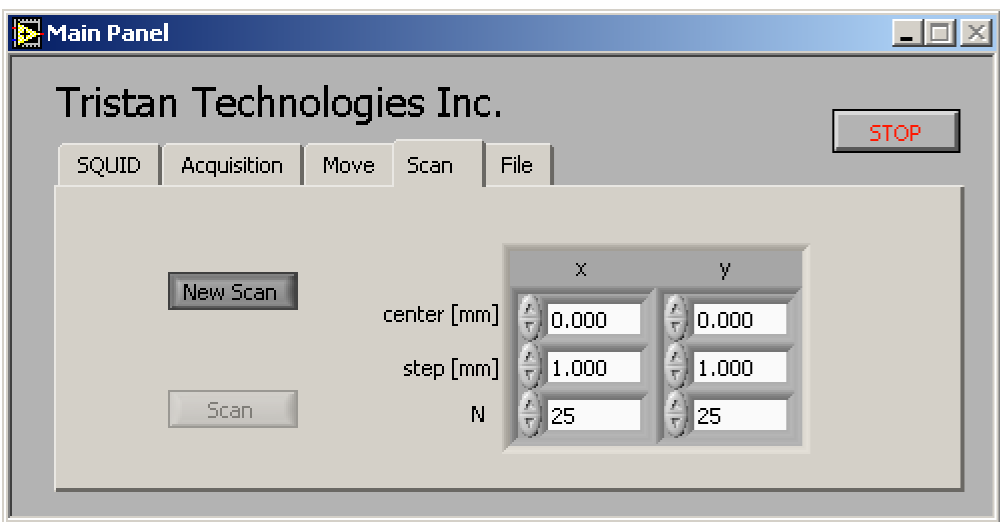

Figure 4.12 Scan Tab in Main Window

The **new scan** button initiates a mode that allows scan parameters to be set for a new scan. The scan geometry controls for each axis as well as the number of channels control in the acquisition section are enabled. Pressing **new scan** again leaves new scan mode and enables the **scan** button.

The scan **button** initiates a scan. A scan can be paused anytime by clicking this button again. A scan can always be resumed unless a new scan is initiated.

The **center** controls for each axis set the position of the center of the scan area.

The **step** controls set the step size between adjacent points in the scan.

The **N** controls set the number of steps along each axis of the scan.

The range of the **center** and **N** controls may be restricted if the resulting scan would be outside the boundaries supported by the translation stages. It is useful to watch a *2D* display when adjusting the scan geometry.

4.3.5 File

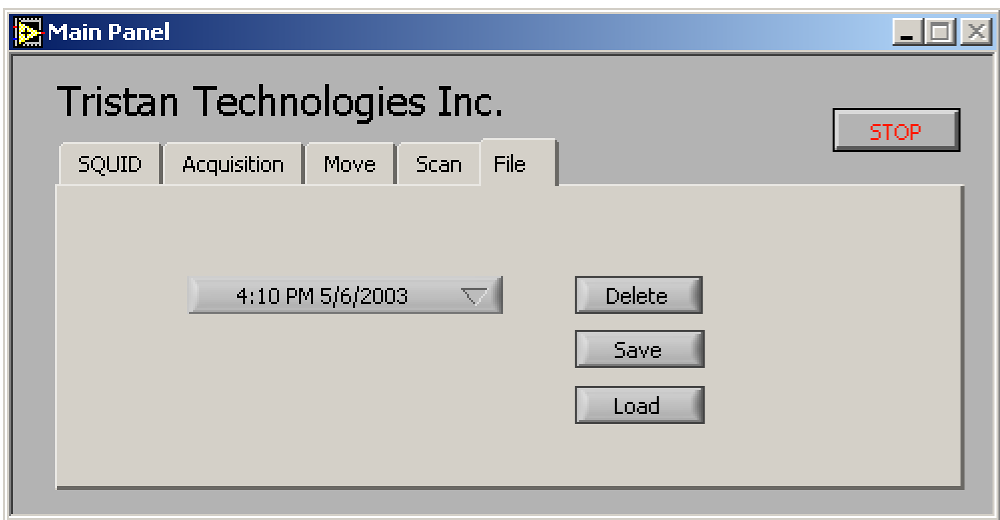

Figure 4.13 File Tab in Main Window

The file section controls the deleting, saving and loading of data sets. The data set used for these operations is selected in the **data set selector** menu. This menu will contain a list of all data sets scanned during the current session and any loaded in from previous sessions. Newly scanned data sets are added at the top of the list, and those loaded from previous sessions at the bottom. There is no protection against deleting unsaved data. .

4.4 Making a Measurement: Step by Step

1. **Start the System Software**
   Double-Click the "scan" icon on the desktop. The software will open and then ask for the motor driver to be powered and enabled for initialization as seen in Figure 4.14.

Figure 4.14 Motor Initialization Sequence Start

   Click OK and wait as the motion stage finds its limit switches and then reset to the origin. This takes about 60 seconds but may vary depending upon the stage position prior to initialization. Notification is given when the initialization is complete, as seen in Figure 4.15.

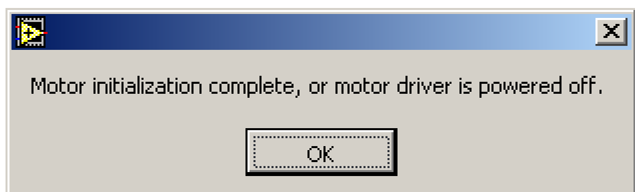

Figure 4.15 Motor Initialization Complete

   Click OK and proceed to the next step.

2. **Tune the Cryogenic Control Unit**
   It may be necessary to press the local button to return control of the instrument to the front panel. Press TUNE. When tuning procedure is finished press RUN.

3. **Place Sample on Scan Stage**
   Place the desired sample on the scan stage.

4. **SQUID Settings**
   Click on the tab labeled SQUID (see Figure 4.9) to adjust the SQUID settings.

5. **Acquisition Settings**
   Click on the tab labeled Acquisition (see Figure 4.10) to adjust the data acquisition parameters.

6. **Move the Stage**
   Click on the tab labeled Move (see Figure 4.11) to adjust, if necessary, the position of the sample relative to the detection coil. This is useful for finding a center to specify on the scan tab.

7. **Starting a Scan**
   Click on the tab labeled scan (see Figure 4.16). Note that the Scan button and Scan Parameters are grayed out.

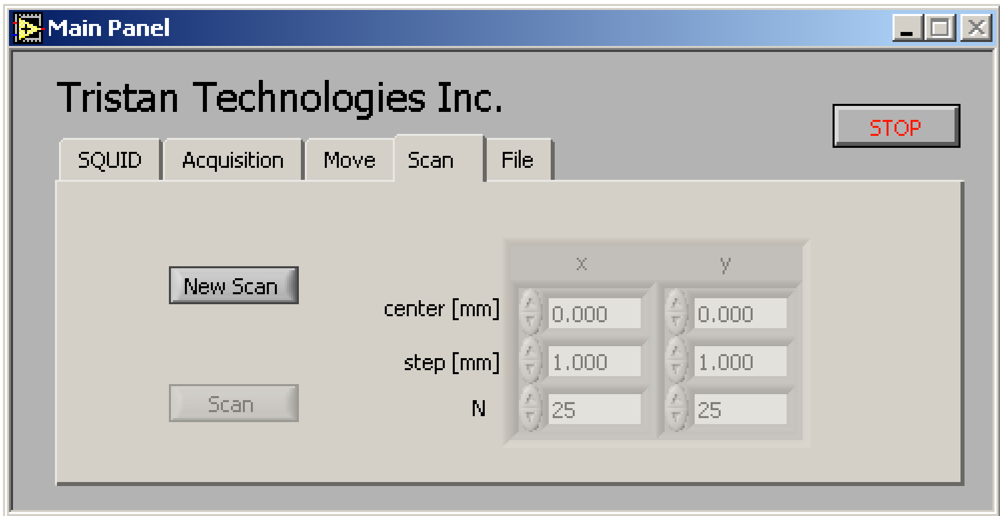

Figure 4.16 Scan Tab on Main Window

Click on the New Scan button. The Scan Parameters are now available (see Figure 4.17).

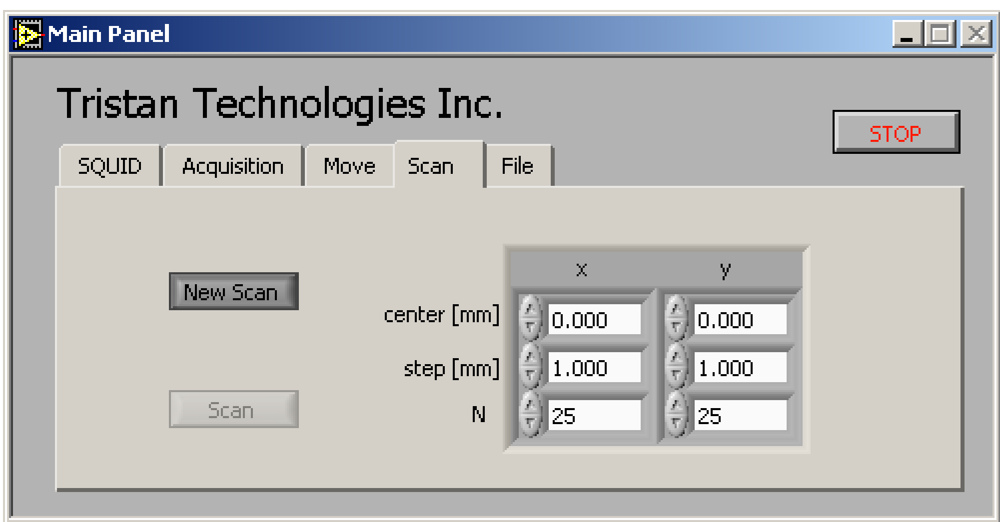

Figure 4.17 Scan Parameters on Scan Tab of Main Window

Once the desired Scan Parameters are selected, click the New Scan button again. The SCAN Parameters are now grayed out and the Scan button is now active (see Figure 4.18).

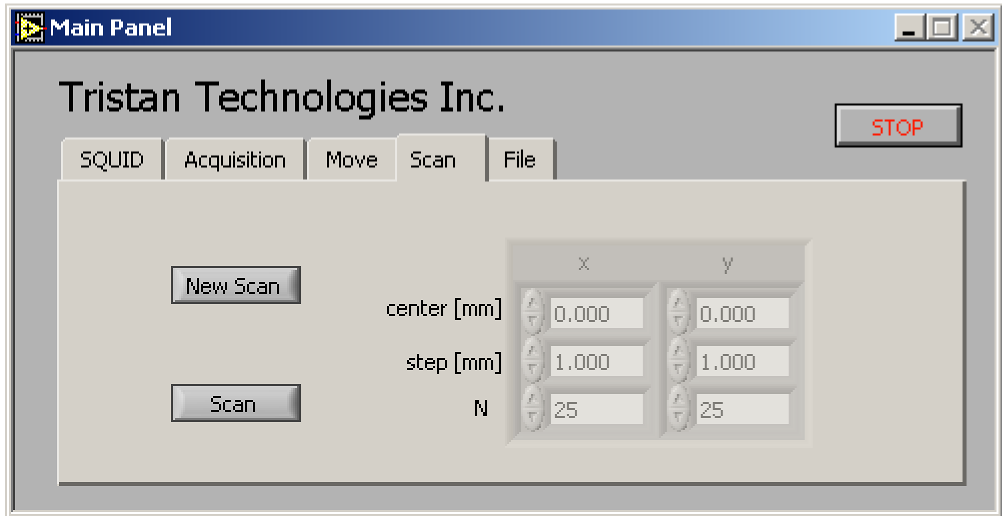

Figure 4.18 Ready to Scan on Scan Tab of Main Window

Clicking the Scan button will initiate the scan and begin the acquisition of data. To go back and change the Scan Parameters, simply click on the New Scan button.

8. **During a Scan**
   In order to watch data in real-time to assess the progress of a scan, select a display from the Display Control window.

9. **After a Scan**
   After a scan is complete remember to click the tab labeled file to save your acquired data. Data not saved will be lost when a new scan is initiated or a previous scan is loaded into the software.