Quantum Design

Physical Property Measurement System®

Torque Magnetometer Option User's Manual

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5,311,125 Magnetic Property Characterization System Employing a Single Sensing Coil Arrangement to Measure AC Susceptibility and DC Moment of a Sample (patent licensed from Lakeshore)
5,647,228 Apparatus and Method for Regulating Temperature in Cryogenic Test Chamber
5,798,641 Torque Magnetometer Utilizing Integrated Piezoresistive Levers.

Foreign Patents
U.K. 9713380.5 Apparatus and Method for Regulating Temperature in Cryogenic Test Chamber

C O N T E N T S

Table of Contents

PREFACE ..... **vii**
Contents and Conventions ..... **vii**
P.1 Introduction vii
P.2 Scope of the Manual vii
P.3 Contents of the Manual viii
P.4 Conventions in the Manual viii

CHAPTER 1 ..... **1-1**
Introduction to the Torque Magnetometer **1-1**
1.1 Introduction 1-1
1.2 Theory of Operation 1-1
1.2.1 Measurement Circuitry 1-3
1.2.2 Calibration Circuitry 1-4
1.2.3 Sample Type and Size 1-4
1.2.4 Rotator Options 1-5
1.2.5 User Bridge Board 1-5
1.3 Overview of System Hardware 1-6

CHAPTER 2 ..... **2-1**
Torque Lever Calibration **2-1**
2.1 Introduction 2-1
2.2 Overview of Torque Lever Calibration 2-1
2.2.1 Calibration Tables 2-1
2.3 Calibrating the Sensitivity of the Torque Lever 2-2
2.3.1 Apply Grease to the Chip 2-2
2.3.2 Mount the Chip on the Platform Board Assembly 2-2
2.3.3 Mount the Platform Board Assembly on the Rotator 2-3
2.3.4 Set the Rotator Motor Position 2-4
2.3.5 Insert the Rotator Probe into the Sample Chamber 2-5
2.3.6 Create the Calibration Table 2-6
2.3.7 Set the Temperature and Field 2-7
2.3.8 Download the Rotator Configuration File 2-8
2.3.9 Set the User Bridge Parameters 2-9
2.3.10 Run the Calibration 2-10
2.4 Description of Calibration Process 2-10

CHAPTER 3 ..... **3-1**
Torque Measurements **3-1**
3.1 Introduction 3-1
3.2 Overview of Torque Measurements 3-1
3.3 Measuring Torque in Immediate Mode 3-2
3.3.1 Mount the Sample on the Chip 3-2
3.3.2 Mount the Chip on the Platform Board Assembly 3-3

3.3.3 Mount the Platform Board Assembly on the Rotator 3-3
3.3.4 Insert the Rotator Probe into the Sample Chamber 3-4
3.3.5 Select the Calibration Table 3-4
3.3.6 Calibrate the Baseline Resistance Ratio 3-5
3.3.7 Download the Configuration File 3-5
3.3.8 Set the User Bridge Parameters 3-6
3.3.9 Measure the Torque 3-6
3.4 Measuring Torque in Sequence Mode 3-7
3.4.1 Torque Measurement Sequence Command 3-8

CHAPTER 4 4-1
Torque Measurements Using CAN-Based (BRT) Module 4-1
4.1 Introduction 4-1
4.2 BRT Module 4-1
4.3 Installing Hardware 4-2
4.3.1 DynaCool 4-3
4.3.2 VersaLab 4-3
4.4 Horizontal Rotator Option 4-4
4.5 Torque Magnetometer Option 4-6

APPENDIX A A-1
Installation Instructions A-1
A.1 Introduction A-1
A.2 Installing the Torque Magnetometer Option A-1
A.2.1 Install the Option Software A-1
A.2.2 Verify the User Bridge Board Installation A-2
A.2.3 Install the Option Interface Cable A-2
A.2.4 Install the Rotator Support Plate A-3
A.2.5 Install the Rotator Motor A-4

APPENDIX B B-1
Torque Magnetometer Interconnections B-1
B.1 Introduction B-1
B.2 Standard Interconnections B-1
B.2.1 Install the Option Software B-1
Figures v
Tables vi

References References-1

Bibliography Bibliography-1

Index Index-1

Figures

Figure 1-1: Components on Torque-Lever Chip 1-2
Figure 1-2: Dimensions of Torque-Lever Chip 1-2
Figure 1-3: Circuit Diagram of Wheatstone Bridge 1-3

Figure 2-1: Platform Board Assembly 2-2
Figure 2-2: Torque-Lever Chip 2-3
Figure 2-3: Horizontal Rotator Support Tool and Horizontal Rotator Transfer Case 2-3
Figure 2-4: Motion Control Dialog Box 2-4
Figure 2-5: Install Tab in Tq-MAG Calibration Dialog Box 2-5
Figure 2-6: Cal Table Tab in Tq-MAG Calibration Dialog Box 2-6
Figure 2-7: Temp/Field Tab in Tq-MAG Calibration Dialog Box 2-7
Figure 2-8: Config Tab in Tq-MAG Calibration Dialog Box 2-8
Figure 2-9: Advanced Tab in Tq-MAG Calibration Dialog Box 2-9

Figure 3-1: Example 1: Sample on Torque-Lever Sample Stage 3-2
Figure 3-2: Example 2: Sample on Torque-Lever Sample Stage 3-2
Figure 3-3: Temperature Tab in Torque Magnetometer Control Center 3-5
Figure 3-4: Tq-MAG Measure Dialog Box 3-7
Figure 3-5: Torque Dialog Box 3-8

Figure 4-1: Horizontal Rotator/Tq-Mag Option Connection Diagram for Dynacool 4-3
Figure 4-2: Horizontal Rotator/Tq-Mag Option Connection Diagram for Versalab 4-4
Figure 4-3: Option Manager Dialog Box 4-5
Figure 4-4: Rotator Setup Dialog Box 4-5
Figure 4-5: Rotator Motion Control Dialog Box 4-6
Figure 4-6: Option Manager Dialog Box 4-7
Figure 4-7: Install Tab in Torque Magnetometer Main Dialog Box 4-7
Figure 4-8: Data File Tab in Torque Magnetometer Main Dialog Box 4-8
Figure 4-9: Sample File Tab in Torque Magnetometer Main Dialog Box 4-8
Figure 4-10: Cal Table Tab in Torque Magnetometer Main Dialog Box 4-9
Figure 4-11: Install Tab in Torque Magnetometer Calibration Dialog Box 4-9
Figure 4-12: Cal Table Tab in Torque Magnetometer Calibration Dialog Box 4-10
Figure 4-13: Temp/Field Tab in Torque Magnetometer Calibration Dialog Box 4-10
Figure 4-14: Utilities Tab in Torque Magnetometer Calibration Dialog Box 4-11
Figure 4-15: Bridge Tab in Torque Magnetometer Main Dialog Box 4-11
Figure 4-16: Torque Magnetometer Measurement Dialog Box 4-12
Figure 4-17: Background Cal Tab in Torque Magnetometer Main Dialog Box 4-13
Figure 4-18: Background Cal Tab in Torque Magnetometer Main Dialog Box (Versalab) 4-13

Figure A-1: Option Manager Dialog Box panel A-1
Figure A-2: Option Interface Cable for User Bridge A-2
Figure A-3: Rotator Motor and Rotator Support Plate A-3

Figure B-1: Wiring Diagram for Platform Board Assembly B-1

Tables

Table 2-1. Temperature Sampling Models and Value of Delta.....2-7
Table 2-2. Default Parameters for User Bridge Channels 2 and 3 2-9

Table B-1: Standard Torque Magnetometer Interconnections.....B-2

P R E F A C E

Contents and Conventions

P.1 Introduction

This preface contains the following information.

- Section P.2 discusses the overall scope of the manual.
- Section P.3 briefly summarizes the contents of the manual.
- Section P.4 illustrates conventions that appear in the manual.

P.2 Scope of the Manual

This manual describes the PPMS Torque Magnetometer (Tq-MAG) option. This manual describes how you install the Torque Magnetometer, the purpose and function of the Torque Magnetometer, and how you use the hardware and software that are unique to the Torque Magnetometer. **Quantum Design** developed the Torque Magnetometer in collaboration with the **IBM Research Division, Zürich Research Laboratory**, and the **Physik-Institut der Universität Zürich, Switzerland**.

The Torque Magnetometer operates in conjunction with the PPMS Horizontal Rotator or Vertical Rotator option and the user bridge board that is a component of the PPMS Resistivity option. For a detailed discussion of these options, refer to the *Physical Property Measurement System: Horizontal Rotator Option User's Manual*, the *Physical Property Measurement System: Vertical Rotator Option User's Manual*, and the *Physical Property Measurement System: Bridge Board User's Manual* (Quantum Design 1996).

P.3 Contents of the Manual

- Chapter 1 introduces the Torque Magnetometer option.
- Chapter 2 explains how to calibrate the torque lever.
- Chapter 3 explains how to measure the torque of a sample.
- Appendix A explains how to install the Torque Magnetometer option.
- Appendix B lists standard interconnections torque lever. for the Torque Magnetometer option.

P.4 Conventions in the Manual

File menu	Bold text distinguishes the names of menus, options, buttons, and panels appearing on the PC monitor or on the Model 6000 PPMS Controller LCD screen.
STATUS	Bold text and all capital letters distinguish the names of keys located on the front panel of the Model 6000 PPMS Controller.
`.cal`	The `Courier` font distinguishes characters you enter from the PC keyboard or from the Model 6000 PPMS Controller front panel. The Courier font also distinguishes code and the names of files and directories.
<Enter>	Angle brackets < > distinguish the names of keys located on the PC keyboard.
<Alt+Enter>	A plus sign + connecting the names of two or more keys distinguishes keys you press simultaneously.
	A pointing hand introduces a supplementary note.
	An exclamation point inside an inverted triangle introduces a cautionary note.
	A lightning bolt inside an inverted triangle introduces a warning.

C H A P T E R 1

Introduction to the Torque Magnetometer

1.1 Introduction

This chapter contains the following information.

- Section 1.2 explains the function of the Torque Magnetometer option.
- Section 1.3 presents an overview of the hardware used with the Torque Magnetometer option.

1.2 Theory of Operation

The Torque Magnetometer option performs fully automated, angular-dependent measurements of the magnetic torque $\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$ experienced by a sample of magnetic moment **m** in an applied magnetic field **B**. When the torque of the sample is known, the moment of the sample can be determined. The Torque Magnetometer can be used as a complementary tool to DC magnetization and AC susceptibility measurements in order to determine the magnetic properties of materials.

The Torque Magnetometer option features microfabricated, silicon, torque-lever chips. Figures 1-1 and 1-2 illustrate a torque-lever chip. The Torque Magnetometer uses a piezoresistive technique to measure the torsion, or twisting, of the torque lever about the lever's symmetry axis. The sample is mounted on a torque-lever chip, and the chip is mounted on a PPMS rotator option. The torque lever twists when a magnetic field is applied to the sample. The system detects the torsion rather than the flexion, or bending, of the torque lever in order to minimize gravitational effects that could introduce spurious signals during angular-dependent measurements. A continuous constantan piezoresistive path incorporating two grids patterned on the legs of the torque lever in the region of high stress senses the torque. A Wheatstone bridge circuit that is integrated on the chip measures, to a high degree of sensitivity, the change in resistance, $\Delta(R1 - R2)$, of the piezoresistor grids. The change in resistance is due to the mechanical stress produced by the magnetic torque in each leg. The user bridge board in the Model 6000 PPMS Controller, or BRT module, measures the voltage across the Wheatstone bridge.

The Torque Magnetometer is fully integrated into the PPMS hardware and software. The Torque Magnetometer uses the full temperature range and field strength that are available to the PPMS, and the Torque Magnetometer software commands are accessed through the PPMS MultiVu application. When the Torque Magnetometer option is active, a command to measure torque may be included in any PPMS sequence.

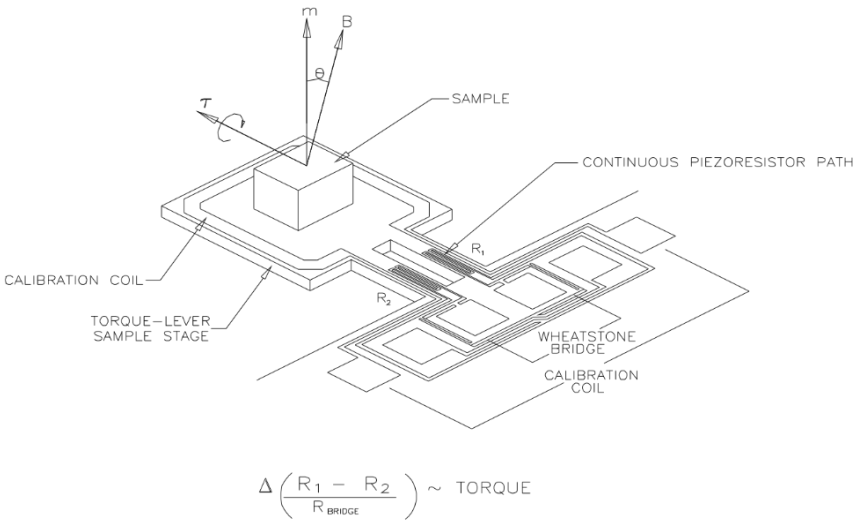


Figure 1-1: Components on Torque-Lever Chip

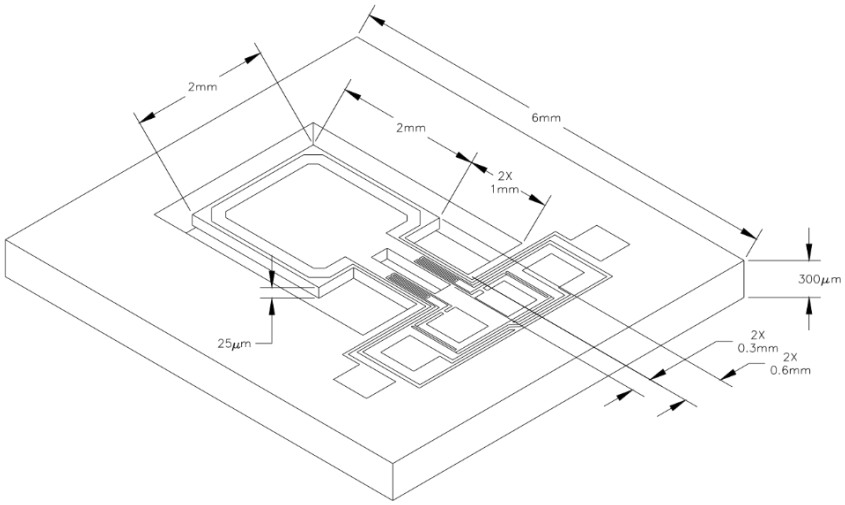


Figure 1-2: Dimensions of Torque-Lever Chip

1.2.1 Measurement Circuitry

The torque-lever chip incorporates a high-sensitivity detection circuit in a Wheatstone bridge configuration. The Wheatstone bridge is directly on the chip; this integrated architecture helps avoid spurious effects that are associated with a split detection circuit.

The Wheatstone bridge is used to measure small changes in the resistance of the piezoresistive path that is on the legs of the torque lever. To measure resistance, the Wheatstone bridge allows the system software to precisely compare the two piezoresistor grids against two other high-precision resistors in the Wheatstone bridge circuit. The two high-precision resistors closely match the resistance of the two piezoresistor grids.

User bridge board channel 2 drives an alternating DC excitation current into the Wheatstone bridge and measures any out-of-balance resistance that can develop across the Wheatstone bridge. By measuring the resistance, the user bridge board can precisely monitor the differential resistance in the piezoresistor grids. The differential resistance is caused by a magnetic torque.

The system software uses a ratiometric measurement of the Wheatstone bridge in order to obtain the highest resolution with a minimum noise level and to reduce temperature hysteresis and magnetoresistive effects. This measurement divides the imbalance of the bridge by the absolute resistance of the bridge. User bridge board channel 3 measures the absolute resistance of the Wheatstone bridge. The system then computes the magnitude of the torque by multiplying the imbalance-to-resistance ratio by the torque coefficient, which is computed during a calibration run. The calibration value is temperature dependent.

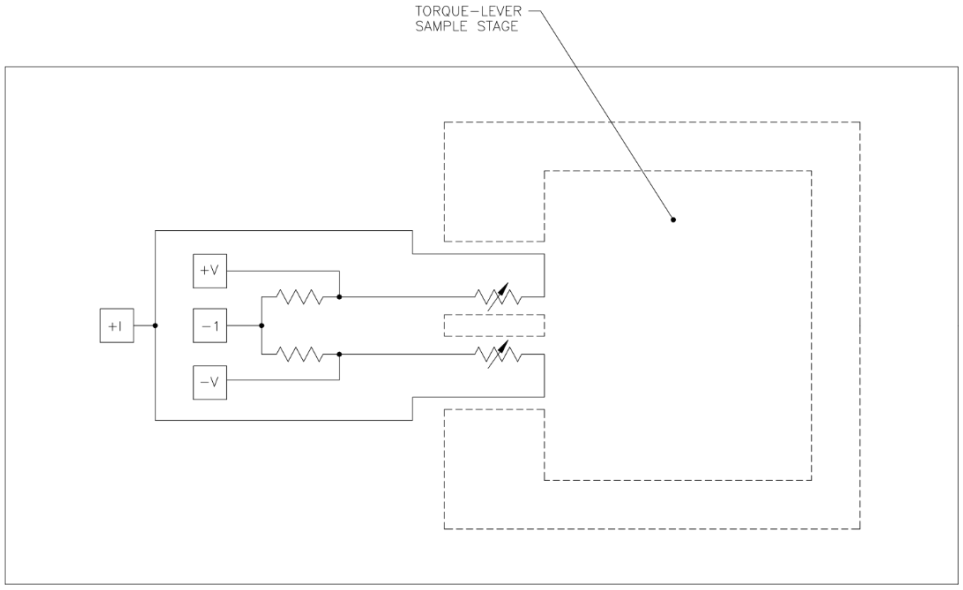


Figure 1-3: Circuit Diagram of Wheatstone Bridge

1.2.2 Calibration Circuitry

The calibration coil, which is a single copper coil loop (A_{coil} = 2.9 mm^2) on top of the torque-lever chip, produces a well-defined magnetic torque τ_{coil} when a small current runs through it. The magnetic torque can be used as a calibration standard for the torsion of the torque lever. Figure 1-1 illustrates the calibration coil.

During a calibration, the torque-lever chip is positioned so that the calibration coil is perpendicular to the external magnetic field. At this orientation, the moment from the coil gives the maximum torque. At a given temperature, a typical current of I_{coil} = ±1.96 mA runs through the coil. The current in the coil produces a well-defined torque that is used as a calibration standard. The system records the change in the resistance ratio. From the change in the resistance ratio, the system calculates a torque coefficient.

The magnetic moment of the calibration coil m_{coil} is defined as

$$m_{coil} = (I_{coil}A_{coil}),$$

and the torque is derived from the equation

$$\tau_{coil} = I_{coil}lA_{coil}B \sin\theta,$$

where I_{coil} and A_{coil} are the current through the calibration coil and the area of the calibration coil, respectively, and B is the applied field.

During calibration, the torque coefficient is calculated as

$$C\tau = \frac{2\tau_{coil}}{\left(\frac{R_1 - R_2}{R_{bridge}}\right)}$$

In general, special care must be taken to limit the excitation current in the calibration coil in order to avoid heating the torque lever at low temperatures. The software thus limits the current to < 2 mA during a typical calibration.

1.2.3 Sample Type and Size

The Torque Magnetometer measures the magnetization component perpendicular to the applied field (torque $\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$) and is therefore best suited to measure small, anisotropic, ordered materials, such as single crystals and thin films. The Torque Magnetometer can measure spin glasses, paramagnetic materials, and isotropic compounds, but these materials usually yield a negligible torque because **m** is generally oriented in the same direction as **B**.

Samples should weigh no more than 10 mg and should have dimensions no greater than 1.5 mm × 1.5 mm × 0.5 mm. You should try to limit sample volume in order to avoid torque signals that are greater than 10^{-5} N·m. Signals greater than 10^{-5} N·m produce a nonlinear response in the torque meter. Torque greater than 5×10^{-5} N·m may break the torque-lever chip.

1.2.4 Rotator Options

The Torque Magnetometer operates in conjunction with the PPMS Horizontal Rotator or Vertical Rotator options. The rotators enable angular-dependent torque data $\tau(\theta)$ to be gathered in the complete range of environmental conditions that are available in the PPMS probe. From this torque data, useful quantities, such as the axes of easy magnetization and the anisotropy energy, can be determined.

If the PPMS has a transverse magnet configuration, the Torque Magnetometer can operate with either the Vertical Rotator or the Horizontal Rotator option. If the PPMS has a longitudinal magnet configuration, the Torque Magnetometer operates with only the Horizontal Rotator. The *Physical Property Measurement System: Horizontal Rotator Option User's Manual* and the *Physical Property Measurement System Vertical Rotator Option User's Manual* discuss the rotators (Quantum Design 1996).

1.2.5 User Bridge Board

The Torque Magnetometer operates in conjunction with the user bridge board found in the PPMS Model 6000 controller or BRT module for the DynaCool and VersaLab platforms. User bridge board channel 1 measures the thermometry on the rotator, channel 2 measures the imbalance across the Wheatstone bridge, and channel 3 measures the absolute resistance of the Wheatstone bridge. The *Physical Property Measurement System: Bridge Board User's Manual* (Quantum Design 1996) discusses the Resistivity option and the user bridge board.

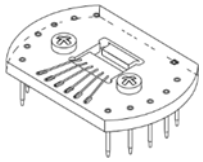
1.3 Overview of System Hardware

Torque-lever chips
The 2-leg torque-lever chip (part number 3084-369) includes a lever that provides the mounting platform for the sample. Two legs containing a piezo-resistor path that incorporates two grids are used to measure the torque applied to the lever. The 2-leg chip can measure up to the maximum torque of 1 x 10^{-5} Nm.

The Torque Magnetometer option includes five chips, one of which is calibrated (part number 4084-369) and the rest uncalibrated (part number 4084-370-01), and a pair of plastic tweezers (HM118) that are used to pick up the chips.

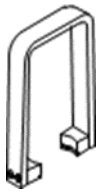
The 3-leg torque-lever chip (part number 3084-368) provides an extra leg to enable users to measure a higher moment sample. The maximum torque which the chip can measure is 1 x 10^{-4} Nm. The 3-leg torque-chips are optional.

Platform board assembly
The platform board assembly (part number 3084-350) connects the torque-lever chip to the rotator platform circuit board.



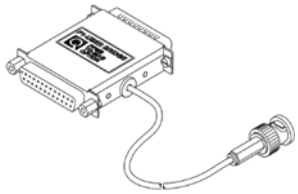
The Torque Magnetometer option includes two platform board assemblies and a small screwdriver that is used to loosen and tighten the screws on the assemblies. Each assembly works with either rotator option.

Sample removal tool
The sample removal tool (part number 4084-366) holds the platform board assembly while the assembly is installed on or removed from the rotator probe.



The Torque Magnetometer option includes one sample removal tool.

Option interface cable
The option interface cable (part number 4084-380) connects the user bridge board to the rotator option and limits the current sent to the Wheatstone bridge and the calibration coil. The option interface cable assembly includes the user bridge box. The BNC connector that is attached to the user bridge box provides the connection for the excitation current to the calibration coil. The BNC is connected to either analog output A2 or A4 on the back of the Model 6000 controller depending on the specific model.



The Torque Magnetometer option includes one option interface cable. Note, this part is not required nor included for DynaCool or VersaLab users.

The Torque Magnetometer option also includes sample boxes of Apiezon N Grease and Apiezon M Grease.

C H A P T E R 2

Torque Lever Calibration

2.1 Introduction

This chapter contains the following information.

- Section 2.2 presents an overview of torque lever calibration.
- Section 2.3 explains how to calibrate the torque lever.
- Section 2.4 describes the calibration process.

2.2 Overview of Torque Lever Calibration

The Torque Magnetometer system uses the calibration coil on the torque lever in order to determine the lever's sensitivity at various temperatures. To calibrate the torque lever, the system takes differential measurements, over a specified temperature range, of the change in the resistance of the torque lever at zero torque and at a known positive and negative torque. The system averages the results of each differential measurement to obtain a torque coefficient at each temperature. The system then saves the torque coefficients to the active calibration table. The system supports sensitivity calibration only in immediate/manual mode.

The sensitivity of a torque lever must be calibrated before the torque-lever chip can be used for sample measurements. Calibrating a torque lever should be necessary only once. One calibration table is thus created for each chip.

2.2.1 Calibration Tables

A calibration table contains the torque coefficients and calibration curve for the calibration of the sensitivity of one torque lever. During calibration, the system constantly updates the active calibration table. Every calibration table has a `.cal` file extension.

In a calibration table, the imbalance and resistance of the Wheatstone bridge are expressed in ohms. The imbalance-to-resistance ratio is dimensionless. Torque is expressed in newton- meters. Note that 1 N·m = 10^{-7} dyne·cm.

2.3 Calibrating the Sensitivity of the Torque Lever

2.3.1 Apply Grease to the Chip

Use a toothpick or the broken edge of a cotton-tipped applicator to apply a small amount of Apiezon N Grease or Apiezon M Grease to the center of the torque-lever sample stage. Apply only enough grease to hold the sample you will measure. Avoid getting grease on the copper contact springs that touch the torque-lever chip.

The grease you apply is not magnetic, but its weight might influence the twisting of the torque lever and should therefore be taken into account during the calibration of the torque lever's sensitivity.

2.3.2 Mount the Chip on the Platform Board Assembly

1. Position the platform board assembly below a microscope and a strong light.
2. Use the screwdriver included with the platform board assembly to loosen, **but not remove**, the two brass screws on top of the assembly. Loosen the screws until the backing support plate, which is between the screws, lowers slightly. Figure 2-1 illustrates the components on the platform board assembly.

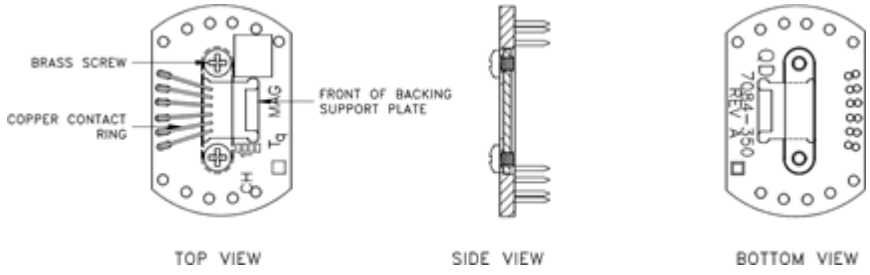


Figure 2-1: Platform Board Assembly

3. Use the plastic tweezers included with the platform board assembly to pick up the torque-lever chip by touching the tweezers to the perimeter of the chip.

CAUTION

The torque-lever chip is delicate and can break easily. Quantum Design recommends that you use only plastic tweezers to handle the chip and that you use the tweezers to pick up only the chip's perimeter. Metal tweezers can more easily bend and break the chip.

4. Use the tweezers to slightly lower the front of the backing support plate, and then position the chip on the backing support plate so that each of the chip's six electrical pads is centered below and touching one of the six copper contact springs on the platform board assembly. Figure 2-2 illustrates the electrical pads on the chip.

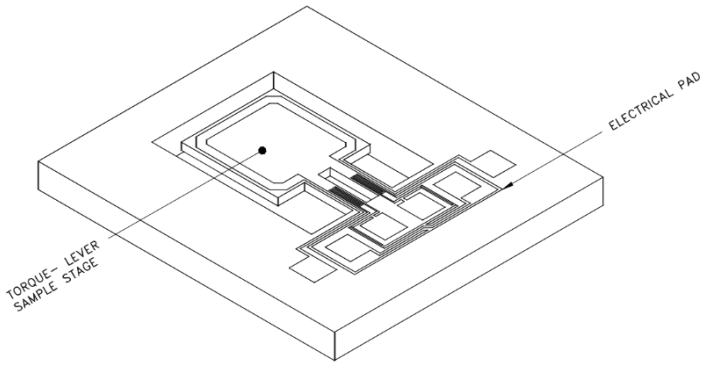


Figure 2-2: Torque-Lever Chip

5. Tilt the platform board assembly sideways to verify that the electrical pads and contact springs are making good electrical contact with each other. If necessary, reposition the chip until all pads and springs are touching.
6. Use the screwdriver to tighten the two brass screws on top of the platform board assembly.

A chip may remain on the platform board assembly permanently. You can use the blank white space on the top of the platform board assembly to identify which chip is mounted on the assembly.

2.3.3 Mount the Platform Board Assembly on the Rotator

The procedures for mounting the platform board assembly on the Horizontal Rotator probe or the Vertical Rotator probe are similar. The following procedure explains how you mount the platform board assembly on the Horizontal Rotator probe.

1. Place the rotator support tool on a flat surface.
2. Lay the rotator probe on top of the center of the rotator support tool. Position the rotator probe so that the chuck key faces upward, and the handle of the rotator probe points toward the arrow on the rotator support tool. Refer to Figure 2-3.

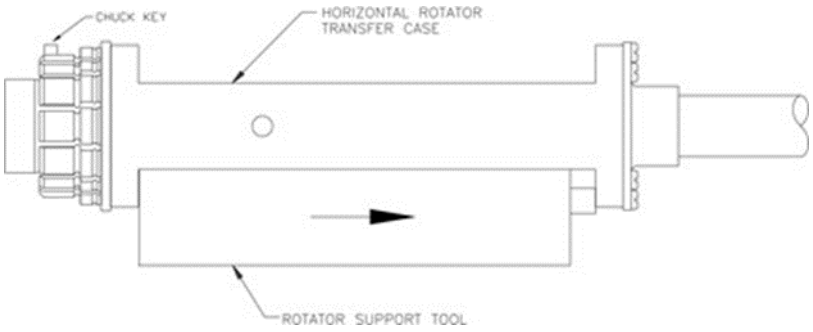


Figure 2-3: Horizontal Rotator Support Tool and Horizontal Rotator Transfer Case

The grooves and ridges on the rotator support tool stabilize the rotator transfer case and prevent the rotator probe from rolling.

3. Use the Torque Magnetometer sample removal tool, like you use tweezers, to pick up the platform board assembly. Hold the platform board assembly so that the torque-lever chip faces upward.

   The special design of the sample removal tool holds the platform board assembly securely but gently and applies even pressure to the assembly.

CAUTION

Use only the Torque Magnetometer sample removal tool to pick up the platform board assembly when you install the assembly on or remove it from the rotator probe. By applying even pressure, the sample removal tool prevents the pins on the platform board assembly from being bent and damaged.

4. Align the pins on the bottom of the platform board assembly with the corresponding sockets on the rotator platform circuit board, and then place the assembly on the circuit board. Use pin #3, which is slightly offset, to help you align the pins and sockets.
5. Verify that the platform board assembly touches the rotator thermometer and verify that all pins and sockets align. If necessary, reposition the assembly. Never force the platform board assembly into place with the wrong orientation.
6. Relax the jaws of the sample removal tool and remove the tool.

2.3.4 Set the Rotator Motor Position

During calibration, the greatest torque is generated when the rotator motor is at 90°. You can use PPMS MultiVu to automatically position the rotator motor. Complete the following steps:

Select **Instrument➤Motion** in the PPMS MultiVu interface. The **Motion Control** dialog box opens.

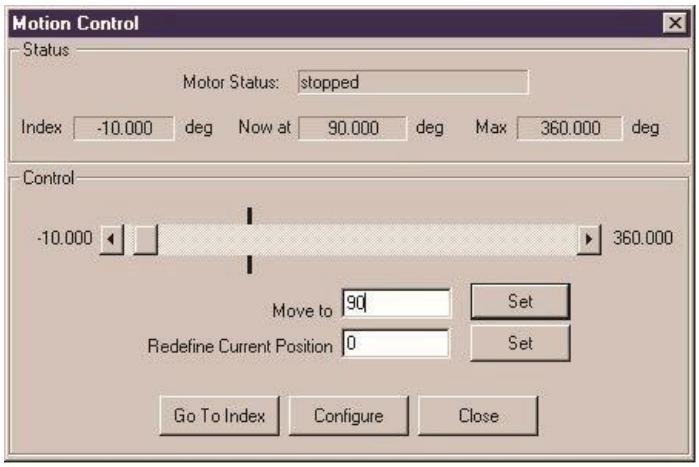


Figure 2-4: **Motion Control** Dialog Box

1. Enter 90 in the **Move** to text box.
2. Select the **Set** button that is to the right of the **Move to** text box.
3. Close the **Motion Control** dialog box.

2.3.5 Insert the Rotator Probe into the Sample Chamber

NOTE

You can use commands in the **Tq-MAG Calibration** dialog box or in the Torque Magnetometer control center to prepare the system for a calibration run. However, the control center does not include the **Calibrate** command. The procedures in sections 2.3.5 through 2.3.10 explain how you use the **Tq-MAG Calibration** dialog box to prepare for and run a calibration.

1. Select **Measure➤Tq-MAG Calibration.** The **Tq-MAG Calibration** dialog box opens, and the system starts to check the hardware configuration. Warning messages pop up if the system detects any problems. As soon as the configuration check is complete, the user bridge board channels power up with their default settings.

   There are four tabs in the **Tq-MAG Calibration** dialog box. The procedures in the tabs step you through the calibration process. Figure 2-5 illustrates the **Install** tab, which is the first tab in the dialog box.

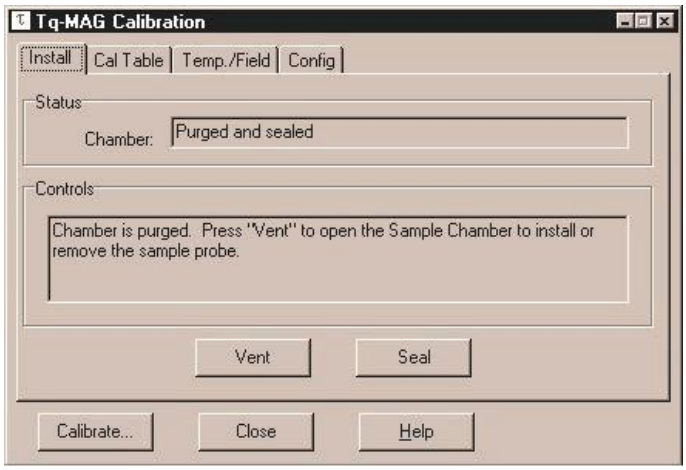


Figure 2-5: **Install** Tab in **Tq-MAG Calibration** Dialog Box

2. Select **Vent**. The sample chamber is flooded with helium unless the system temperature is less than a set minimum temperature.
3. Open the sample chamber when you are prompted to do so.
4. Install the rotator support plate and the rotator motor if these two items are not installed. Refer to sections A.2.4 and A.2.5.
5. Hold the rotator probe so that it is straight, and then slowly and carefully lower it through the opening in the rotator support plate. Do not bend the probe while you lower it. Continue lowering the probe until it just rests on the bottom of the sample chamber.
6. Turn the exposed top of the rotator probe until you feel the keyed connector at the base of the probe drop into position.
7. Push down on the rotator probe to seat it in the connector at the bottom of the sample chamber. Seating the rotator probe allows the O-rings in the rotator probe to tightly close the chamber.
8. Select **Seal**. The sample chamber is purged and sealed.

2.3.6 Create the Calibration Table

1. Select the **Cal Table** tab in the **Tq-MAG Calibration** dialog box.

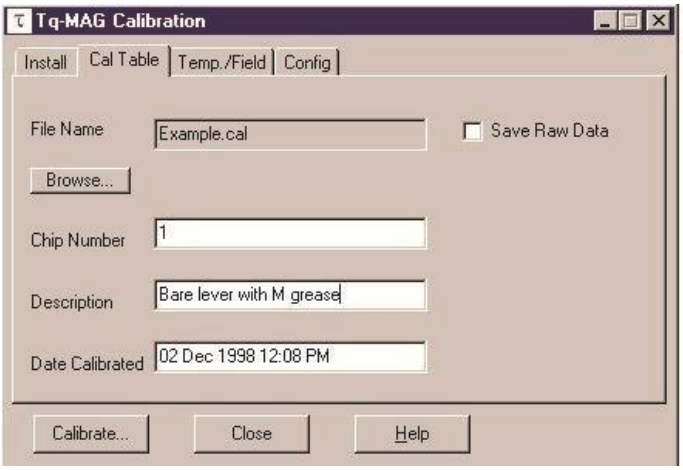


Figure 2-6: **Cal Table** Tab in **Tq-MAG Calibration** Dialog Box

2. Select **Browse**. The **Tq-MAG Create Calibration File** dialog box opens.
3. Use the **File name** text box to enter the name of the new calibration table. In the name, consider including the chip number and a brief description of the sample. The number indicates which chip's calibration data is stored in the calibration table. Both the number and the description help you locate the correct calibration table to use with a sample.
4. Select **Open** and then select Yes if PPMS MultiVu asks you whether you want to create the new calibration table.

   If you have entered or selected the name of an existing calibration table, PPMS MultiVu tells you that you will be appending data to that table. Cancel the pop-up message, and then enter another name for the calibration table.
5. Use the **Chip Number** text box in the **Cal Table** tab to enter the chip number or another suitable identifier if you want to store this information in the header of the calibration table.
6. Use the **Description** text box to enter a brief description or comment if you want to store this information in the header of the calibration table.
7. Enable the **Save Raw Data** check box if you want to save raw measurement data to a raw data file. Raw measurement data consists of all measurement points in each differential measurement. The file containing raw data can be as large as 1 Mbyte. By default, the system discards raw data in order to save disk space. You should be aware, however, that if a malfunction occurs during calibration, the system can use saved raw data to rebuild the active calibration table.

2.3.7 Set the Temperature and Field

1. Select the **Temp/Field** tab in the **Tq-MAG Calibration** dialog box.

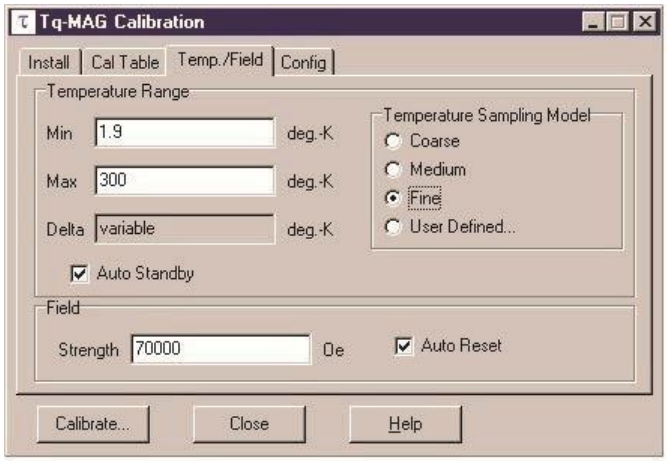


Figure 2-7: **Temp/Field** Tab in **Tq-MAG Calibration** Dialog Box

2. Define the minimum calibration temperature. Use a temperature that equals or is slightly less than the minimum temperature you will use when you measure the torque of the sample. 1.9 K is the default minimum temperature.
3. Define the maximum calibration temperature. Use a temperature that equals or is slightly greater than the maximum temperature you will use when you measure the torque of the sample. 300 K is the default maximum temperature.

   The temperature range ultimately determines the length of the calibration.
4. Select a temperature sampling model. The temperature sampling model roughly defines the number of temperatures at which the system takes measurements, and it defines delta, which is the increment between temperatures.

   The “fine” temperature sampling model is the default sampling model, and spaces temperatures logarithmically. A user-defined temperature sampling model lets you define the increment between temperatures.

Table 2-1. Temperature Sampling Models and Value of Delta

MODEL	VALUE OF DELTA
Coarse	298.1 K
Medium	50 K
Fine	Variable
User Defined	Variable

5. Disable the **Auto Standby** check box if you do not want the system temperature to enter standby mode when the calibration is complete.
6. Define the field strength for the calibration. Quantum Design recommends using your system’s default maximum field strength because it produces the maximum torque.
7. Disable the **Auto Reset** check box if you do not want to set the field to zero when the calibration is complete.

2.3.8 Download the Rotator Configuration File

After the Horizontal Rotator or Vertical Rotator option is installed, the rotator configuration file must be downloaded. The rotator configuration file must be downloaded only once. As long as the same rotator is used, downloading the file again is unnecessary.

Complete the following steps to download the rotator configuration file:

1. Select the Config tab in the **Tq-MAG Calibration** dialog box.

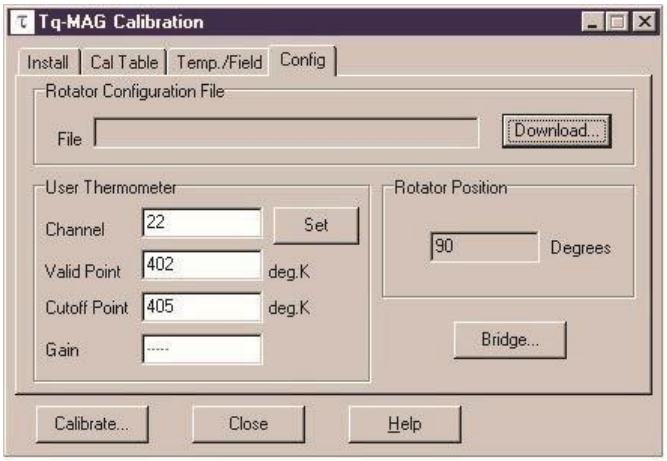


Figure 2-8: **Config Tab** in **Tq-MAG Calibration** Dialog Box

2. Select Download. The **Tq-MAG Download Configuration File** dialog box opens.
3. Locate the configuration file that was shipped with your rotator. The file name includes the characters `###.cfg`, where `###` represents the serial number of the rotator.
4. Select the rotator configuration file. The file is downloaded.

The rotator configuration file and the calibration of the user thermometer define the user thermometer's default parameters, which are listed in the **Config** tab. You may change these parameters, but Quantum Design recommends using the default parameters. If you do change any user thermometer parameter, you must select the **Set** button in the **Config** tab in order to enable the new parameter.

2.3.9 Set the User Bridge Parameters

You may change the parameters that affect channels 2 and 3 on the user bridge board. However, Quantum Design recommends using the factory-defined, default user bridge parameters.

Complete the following steps to review or change the user bridge parameters:

1. Select the **Bridge** button in the **Config** tab. The **Advanced** tab opens and becomes the fifth tab in the **Tq-MAG Calibration** dialog box.

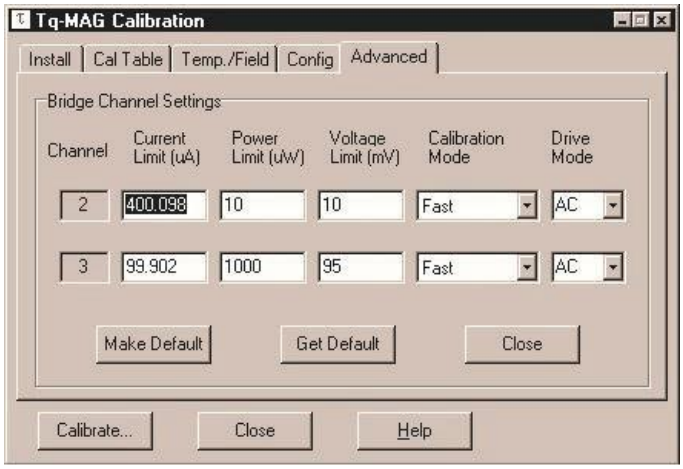


Figure 2-9: **Advanced** Tab in Tq-MAG Calibration Dialog Box

2. Modify the parameters of user bridge board channel 2 only if necessary. Table 2-2 lists the default parameters. Channel 2 measures the imbalance of the Wheatstone bridge.
3. Modify the parameters of user bridge board channel 3 only if necessary. Table 2-2 lists the default parameters. Channel 3 measures the total resistance across the Wheatstone bridge.

Table 2-2. Default Parameters for User Bridge Channels 2 and 3

CHANNEL 2	
PARAMETER	**DEFAULT VALUE**
Current Limit	400 µA
Power Limit	10 µW
Voltage Limit	10 mV
Calibration Mode	Fast
Drive Mode	AC

CHANNEL 3	
PARAMETER	**DEFAULT VALUE**
Current Limit	100 µA
Power Limit	1000 µW
Voltage Limit	95 mV
Calibration Mode	Fast
Drive Mode	AC

4. Select **Make Default** to make the parameters you have just changed the new default parameters.
5. Select **Get Default** to activate the parameters most recently defined with the **Make Default** command.

2.3.10 Run the Calibration

1. Select the **Calibrate** button, which is at the bottom of the **Tq-MAG Calibration** dialog box.
2. Select OK in the pop-up message. If the system is ready for the calibration, the calibration begins immediately. Warning messages pop up if the system detects any problems.

   During calibration, the calibration status window pops up and identifies each operation the system performs. Section 2.4 describes the calibration process.

   You may open the calibration table if you want to follow the progress of the calibration. Select **File➤Open➤DataFile**, and then select **All Files** in the **Files of type** drop-down list. Double-click on the name of the calibration table. The graph view of the table opens. Whenever the system computes another torque coefficient, it plots that coefficient, as a measurement point, in the graph.

   You may pause or abort a calibration at any time. Simply select **Pause** or **Abort** in the calibration status window. To resume a paused calibration, select **Resume** in the calibration status window.

   The system saves calibration status and command information and most calibration error messages to a calibration log file. The log file has the same name as the calibration table, but it has a .log extension instead of a `.cal` extension.

   Wait for the calibration to finish. The specified temperature range determines the length of time the calibration runs. The **Calibration completed** message appears in the calibration status window when the calibration is complete. Another message asks whether you want the system to enter standby mode. If the **Auto Standby** check box is enabled and you do not answer the message within 5 minutes, the system automatically enters standby mode.

When the calibration is complete, you may remove the rotator probe from the sample chamber.

2.4 Description of Calibration Process

The Torque Magnetometer system uses an automated calibration run to calibrate the temperature dependence of the sensitivity of a torque lever. Calibration consists of two phases. First the system measures the resistance and imbalance of the Wheatstone bridge. Then the system takes differential measurements of the torsion of the torque lever.

During the first phase of the calibration, the system sets the field to zero and cools the temperature in the sample chamber to the preselected minimum, or base, temperature. While the temperature cools, the system accurately measures the temperature dependence of the resistance and imbalance of the Wheatstone bridge. User bridge board channel 2 measures the imbalance that develops, as a result of thermal stress on the torque lever during the cool-down, in the Wheatstone bridge. User bridge board channel 3 measures the total resistance across the Wheatstone bridge. The system uses the imbalance-to-resistance ratio to minimize temperature and magnetoresistance effects caused by the wires in the rotator and the PPMS probe. The temperature-dependent resistance ratio constitutes a background “baseline” that is subtracted from the resistance ratio during a sample measurement.

When the system reaches the base temperature, the second phase of the calibration begins. The system sets the maximum field strength. The default maximum field is defined by the PPMS magnet. When the field is stable, the sample chamber begins to warm. At preselected temperature increments, the system takes differential measurements of the torque lever's response to the magnetic torque that is created by the current in the calibration coil. By relating the change in the resistance ratio to the known value of the calibrating torque, the system computes a torque coefficient at a given temperature. The temperature sampling models can vary the spacing between the measurement points.

When the system takes a differential measurement it saves that measurement's averaged result as a torque coefficient in the active calibration table. The torque coefficient converts resistance measurements into a torque in units of newton-meters. At the end of the calibration, the system computes the best fit of the torque coefficients and applies this best fit to the calibration curve. The resultant calibration curve is used during a torque measurement.

C H A P T E R 3

Torque Measurements

3.1 Introduction

This chapter contains the following information.

- Section 3.2 presents an overview of torque measurements.
- Section 3.3 explains how to measure torque in immediate mode.
- Section 3.4 explains how to measure torque in sequence mode.

3.2 Overview of Torque Measurements

To compute the torque of a sample, the Torque Magnetometer option (1) measures the imbalance and resistance of the Wheatstone bridge, (2) subtracts the zero-torque baseline resistance ratio obtained during the first phase of the torque-lever sensitivity calibration, and (3) multiplies the imbalance-to-resistance ratio by the torque coefficient. The system measures the Wheatstone bridge imbalance and resistance by averaging individual readings it has taken at a specified temperature, field, and rotator motor position. The system correctly computes the torque only if the calibration table created for the torque-lever chip is active.

The system supports torque measurements in immediate mode and sequence mode. Immediate mode lets you quickly take a single measurement the torque. Sequence mode lets you take multiple, automated measurements and use both the Torque measurement command and standard PPMS sequence commands. Sequence measurement data can also be saved to a data file. Immediate-mode measurement data cannot be saved to a data file.

3.3 Measuring Torque in Immediate Mode

3.3.1 Mount the Sample on the Chip

1. Estimate the maximum moment and torque of the sample. Limit the sample volume in order to restrict the torque magnitude at high fields. The torque meter's response becomes strongly nonlinear when the torque approaches 10^{-5} N·m, and the torque lever may break when the torque exceeds 10^{-5} N·m.
2. Apply a small amount of glue to the center of the torque-lever sample stage only if you are measuring a sample that is strongly magnetic. Apply only enough glue to attach the sample to the stage. Avoid getting glue on the copper contact springs that touch the torque-lever chip.

   Use tweezers to pick up the sample, then place the sample on top of the sample stage. Position the sample so that it produces the maximum torque and is as close to the center of the stage as possible. Verify that the sample does not touch the calibration coil. If necessary, reposition the sample until it is in the center of the stage and does not touch the coil.

   To achieve maximum torque, Quantum Design recommends that you consider the right-hand rule and orient the sample moment so that is perpendicular to the axis of rotation. Figures 3-1 and 3-2 illustrate how you might position a sample on the stage.

   If you position a sample as shown in Figure 3-1, the sample is positioned well for measurements in which you vary the angle with respect to the applied field. In addition, a sample positioned as shown in Figure 3-1 is less likely to be affected by gravity during rotation than a sample positioned as shown in Figure 3-2.

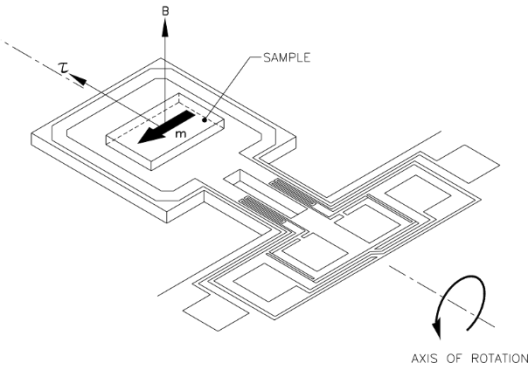


Figure 3-1: Example 1: Sample on Torque-Lever Sample Stage

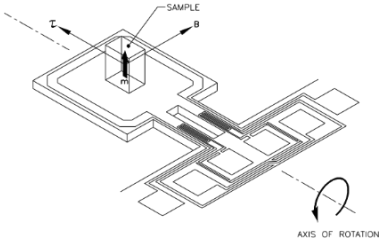


Figure 3-2: Example 2: Sample on Torque-Lever Sample Stage

3.3.2 Mount the Chip on the Platform Board Assembly

1. Position the platform board assembly below a microscope and a strong light.
2. Use the screwdriver included with the platform board assembly to loosen, **but not remove**, the two brass screws on top of the assembly. Loosen the screws until the backing support plate, which is between the screws, lowers slightly. Figure 2-1 illustrates the components on the platform board assembly.
3. Use the plastic tweezers included with the platform board assembly to pick up the torque- lever chip by touching the tweezers to the perimeter of the chip.

CAUTION

The torque-lever chip is delicate and can break easily. Quantum Design recommends that you use only plastic tweezers to handle the chip and that you use the tweezers to pick up only the chip's perimeter. Metal tweezers can more easily bend and break the chip.

4. Use the tweezers to slightly lower the front of the backing support plate, and then position the chip on the backing support plate so that each of the chip's six electrical pads is centered below and touching one of the six copper contact springs on the platform board assembly. Figure 2-2 illustrates the electrical pads on the chip.
5. Tilt the platform board assembly sideways to verify that the electrical pads and contact springs are making good electrical contact with each other. If necessary, reposition the chip until all pads and springs are touching.
6. Use the screwdriver to tighten the two brass screws on top of the platform board assembly.

A sample may remain on a torque-lever chip permanently, and a chip may remain on the platform board assembly permanently. You can use the blank white space on the top of the platform board assembly to identify which sample and chip are mounted on the assembly. Mount the Platform Board Assembly on the Rotator.

3.3.3 Mount the Platform Board Assembly on the Rotator

The procedures for mounting the platform board assembly on the Horizontal Rotator probe or the Vertical Rotator probe are similar. The following procedure explains how you mount the platform board assembly on the Horizontal Rotator probe.

1. Place the rotator support tool on a flat surface.
2. Lay the rotator probe on top of the center of the rotator support tool. Position the rotator probe so that the chuck key faces upwards and the handle of the rotator probe points toward the arrow on the rotator support tool. Refer to Figure 2-3.

   The grooves and ridges on the rotator support tool stabilize the rotator transfer case and prevent the rotator probe from rolling.
3. Use the Torque Magnetometer sample removal tool, like you use tweezers, to pick up the platform board assembly. Hold the platform board assembly so that the torque-lever chip faces upward.

   The special design of the sample removal tool holds the platform board assembly securely but gently and applies even pressure to the assembly.

CAUTION

Use only the Torque Magnetometer sample removal tool to pick up the platform board assembly when you install the assembly on or remove it from the rotator probe. By applying even pressure, the sample removal tool prevents the pins on the platform board assembly from being bent and damaged.

4. Align the pins on the bottom of the platform board assembly with the corresponding sockets on the rotator platform circuit board, and then place the assembly on the circuit board. Use pin #3, which is slightly offset, to help you align the pins and sockets.
5. Verify that the platform board assembly touches the rotator thermometer and verify that all pins and sockets align. If necessary, reposition the assembly. Never force the platform board assembly into place with the wrong orientation.
6. Relax the jaws of the sample removal tool and remove the tool.

3.3.4 Insert the Rotator Probe into the Sample Chamber

NOTE

Commands in the Torque Magnetometer control center initiate all operations that the system should perform before it runs a measurement. The procedures in sections 3.3.4 through 3.3.8 explain how you use the control center to prepare for an immediate-mode measurement.

1. Select the **Install** tab in the Torque Magnetometer control center. The **Install** tab is the first of six tabs in the control center. The procedures in the tabs step you through normal Torque Magnetometer system operation.
2. Select **Vent**. The sample chamber is flooded with helium unless the system temperature is less than a set minimum temperature.
3. Open the sample chamber when you are prompted to do so.
4. Install the rotator support plate and the rotator motor if these two items are not installed. Refer to sections A.2.4 and A.2.5.
5. Hold the rotator probe so that it is straight, and then slowly and carefully lower it through the opening in the rotator support plate. Do not bend the probe while you lower it. Continue lowering the probe until it just rests on the bottom of the sample chamber.
6. Turn the exposed top of the rotator probe until you feel the keyed connector at the base of the probe drop into position.
7. Push down on the rotator probe to seat it in the connector at the bottom of the sample chamber. Seating the rotator probe allows the O-rings in the rotator probe to tightly close the chamber.
8. Select **Seal**. The sample chamber is purged and sealed.

NOTE

You may use the **Data File** tab in the Torque Magnetometer control center to select or create a data file. Immediate-mode torque measurement data is not saved to a data file, but sequence mode data is.

You may use the **Sample** tab in the Torque Magnetometer control center to define the parameters of the sample. All sample parameter information is stored in the selected data file.

3.3.5 Select the Calibration Table

1. Select the **Cal Table** tab in the Torque Magnetometer control center. The tab displays summary data for the active calibration table. The summary data was defined when the calibration table was created.
2. Select Browse. The **Tq-MAG Pick Calibration Table** dialog box opens. The dialog box lists the names of the existing calibration tables.

3. Select the calibration table that was created for the torque-lever chip you are using. As soon as you select the calibration table, the table's name appears in the **Table Name** box, which is at the top of the **Cal Table** tab. All data items defined when the table was created appear in the appropriate boxes in the tab.

3.3.6 Calibrate the Baseline Resistance Ratio

Quantum Design recommends that you calibrate the baseline resistance ratio before you measure the torque of the sample. This calibration is optional, but it ensures a more accurate torque measurement than a measurement computed if the system uses the baseline resistance ratio calibration from the torque-lever sensitivity calibration. When a sample is on the torque- lever chip, the baseline calibration changes slightly.

Complete the following steps to calibrate the baseline resistance ratio:

1. Select the **Temperature** tab in the Torque Magnetometer control center.
2. Change the **Expected Temperature Range** of the baseline calibration only if necessary. Quantum Design recommends using the default expected temperature range, which is the range used during the torque-lever sensitivity calibration.

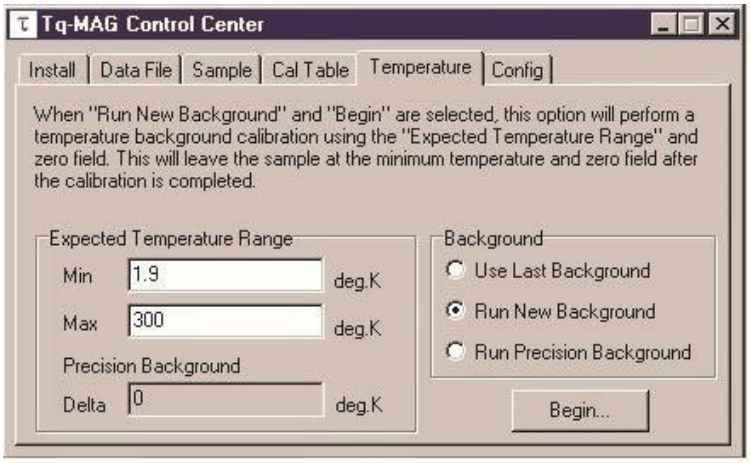


Figure 3-3: **Temperature** Tab in Torque Magnetometer Control Center

3. Verify that the **Run New Background** option is selected.
4. Select **Begin**. The baseline temperature calibration begins. While cooling to the specified minimum temperature, the system measures the imbalance and resistance of the Wheatstone bridge at zero torque and when zero current is in the calibration coil. This latest calibration data is stored in the active calibration table and overwrites the baseline calibration data already in the table. The system then uses the zero-field bridge ratio when it computes the torque of the sample.

3.3.7 Download the Configuration File

After the Horizontal Rotator or Vertical Rotator option is installed, the rotator configuration file must be downloaded. The rotator configuration file must be downloaded only once. As long as the same rotator is used, downloading the file again is unnecessary.

Complete the following steps to download the rotator configuration file:

1. Select the **Config** tab in the Torque Magnetometer control center.
2. Select **Download**. The **Tq-MAG Download Configuration File** dialog box opens.
3. Locate the configuration file that was shipped with your rotator. The file name includes the characters ###.cfg, where ### represents the serial number of the rotator.
4. Select the rotator configuration file. The file is downloaded.

The rotator configuration file and the calibration of the user thermometer define the user thermometer's default parameters, which are listed in the **Config** tab. You may change these parameters, but Quantum Design recommends using the default parameters. If you do change any user thermometer parameter, you must select the Set button in the **Config** tab in order to enable the new parameter.

3.3.8 Set the User Bridge Parameters

You may change the parameters that affect channels 2 and 3 on the user bridge board. However, Quantum Design recommends using the factory-defined, default user bridge parameters.

Complete the following steps to review or change the user bridge parameters:

1. Select the **Bridge** button in the **Config** tab. The **Bridge** tab opens and becomes the seventh tab in the Torque Magnetometer control center.
2. Modify the parameters of user bridge board channel 2 only if necessary. Table 2-2 lists the default parameters. Channel 2 measures the imbalance of the Wheatstone bridge.
3. Modify the parameters of user bridge board channel 3 only if necessary. Table 2-2 lists the default parameters. Channel 3 measures the total resistance across the Wheatstone bridge.
4. Select **Make Default** to make the parameters you have just changed the new default parameters.
5. Select **Get Default** to activate the parameters most recently defined with the Make Default command.

3.3.9 Measure the Torque

1. Modify the system temperature or field or the position of the rotator motor, if necessary. The system takes the torque measurement at the current temperature, field, and motor position. You may set any position that is available to the rotator, and you may use any field that is available to the PPMS. You should use a temperature that is within the calibration temperature range.

2. Select **Measure➤Tq-MAG Measure**. The **Tq-MAG Measure** dialog box opens.

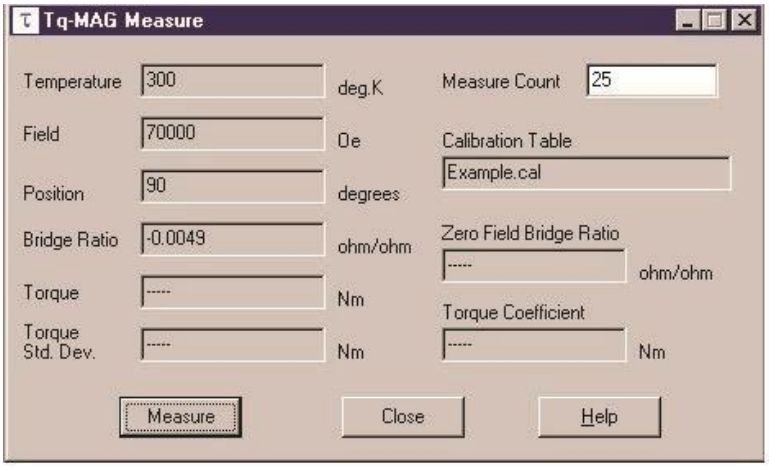


Figure 3-4: **Tq-MAG Measure** Dialog Box

3. Use the **Measure Count** text box to specify the number of readings the system takes and then averages together to compute the imbalance and resistance of the Wheatstone bridge for one sample measurement. Specify a higher number of readings for a sample that is weakly magnetic. Specify a smaller number for a sample that is strongly magnetic or for a relaxation measurement that has short time scales.

   The imbalance and resistance of the Wheatstone bridge is the bridge ratio.

4. Select Measure. The system takes the specified number of readings. During the measurement, you may not use PPMS MultiVu to perform any other function.

   As soon as the measurement is complete, the system averages the individual readings to compute the bridge ratio, and then subtracts the zero-field resistance ratio and multiplies the result by the torque coefficient. The system also averages the temperature, field, and motor position used during the measurement. These values appear in the **Tq-MAG Measure** dialog box. The system does not log the measurement to a data file.

   Once you insert the torque-lever chip into the sample chamber and select the calibration table, you may take any number of torque measurements in immediate mode.

3.4 Measuring Torque in Sequence Mode

The Torque Magnetometer option includes the **Torque** measurement sequence command. You may include the **Torque** command in a sequence file any number of times in order to automate any number of torque measurements. Within the same sequence, you may use any standard PPMS system sequence commands or advanced sequence commands to control PPMS operation as necessary.

Sequence-mode torque measurement data, unlike immediate-mode torque measurement data, can be saved to a data file. The **Data File** tab in the Torque Magnetometer control center displays the name and file location of the data file that is selected to store torque data. You can use the tab to select or create another data file. The **Browse** button in the **Data File** tab opens the **Tq-MAG Select Datafile** dialog box, which can display the names of all existing data files.

Before the system can measure torque in sequence mode, you must install a sample, define parameters as necessary, and select a calibration table–just as you would if you were preparing to run a measurement in immediate mode. Sections 3.3.1 through 3.3.8 explain the procedures you complete before you run a measurement in immediate mode.

The *Physical Property Measurement System: PPMS MultiVu Application User's Manual* (Quantum Design 1998) discusses sequence mode, sequence files, and sequence execution in more detail.

3.4.1 Torque Measurement Sequence Command

To include the **Torque** command in a sequence, you simply double-click on the **Torque** command name in the sequence command bar. You can open the sequence command bar whenever a sequence file is open. The **Torque** command is in the **Measurement** command group.

When you double-click on **Torque**, the **Torque** dialog box opens. To add the command to a sequence, you simply select the **OK** button that is near the bottom of the **Torque** dialog box. Notice, however, that you may use the dialog box to select parameters that are measured when the torque is measured. You may also specify the number of readings that are taken and then averaged together to compute one sample measurement. Several default parameters are automatically selected in the **Torque** dialog box; refer to Figure 3-5.

The **Torque** command also includes a filter-data option, which prompts the system to filter out extremely unusual data readings. By default, the **Filter Data** check box is selected.

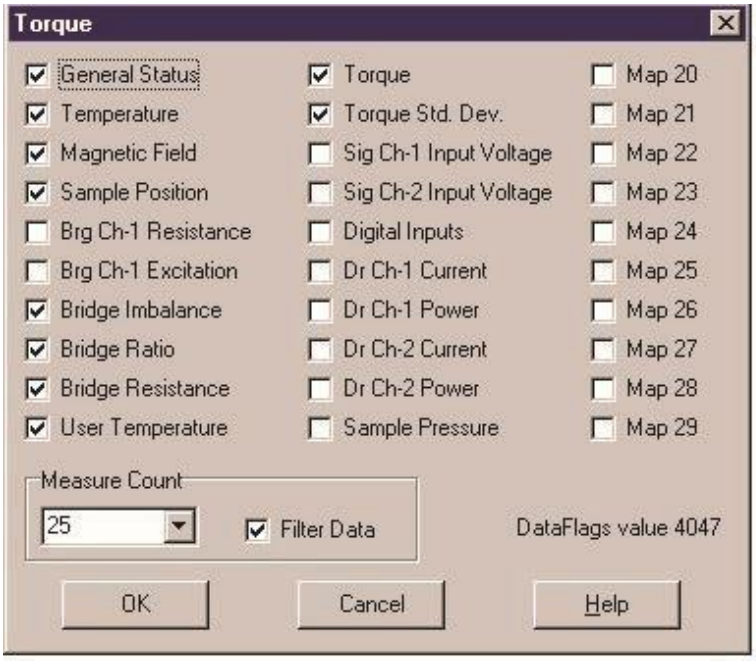


Figure 3-5: **Torque** Dialog Box

C H A P T E R 4

Torque Measurements Using CAN-Based (BRT) Module

4.1 Introduction

This chapter contains the following information.

- Section 4.2 discusses the BRT module.
- Section 4.3 provides instructions on installing the hardware in either DynaCool or VersaLab measurement platforms.
- Section 4.4 discusses activating and use of the Horizontal Rotator Option.
- Section 4.5 discusses activating and use of the Torque Magnetometer Option.

4.2 BRT Module

The BRT (**B**ridge, **R**otator and **T**q-Mag) CAN-based module and cable (3084-006-02) are utilized on the DynaCool and VersaLab platforms for the Torque Magnetometer option. This module includes an SROM chip, which contains all the important parameters for the Rotator and Tq-Mag options.

4.3 Installing Hardware

If not yet installed, insert the BRT module into the module bay. **To avoid damaging the module, install or remove CAN modules only if the power on the power drawer has been turned off.** Once in place, secure with the thumb screws located on the top and bottom of the module. Then turn back on the power drawer to activate CAN modules.

Refer to section 3.3.1 for instructions on mounting a sample onto a Tq-Mag chip carrier. Once mounted, install a chip carrier onto the horizontal rotator platform.

4.3.1 DynaCool

Refer to sections A.2.4 and A.2.5 for instructions on installing the rotator support plate and motor. Note that the support clip is slightly different from the one used by the PPMS.

To connect the BRT module to the probe, the Tq-Mag cable (3084-006-02) should be connected as shown below in Diagram 1. Connect the Rotator/MFP experiment cable (3084-010-02) to the probe (Grey LEMO connector) and the 4-pin LEMO cable to the BRT module (TEMP: JL-3). Connect the Tq-Mag cable (3084-006-02) to the Rotator/MFP experiment cable box and to the BRT module (BRIDGE: JL-1).

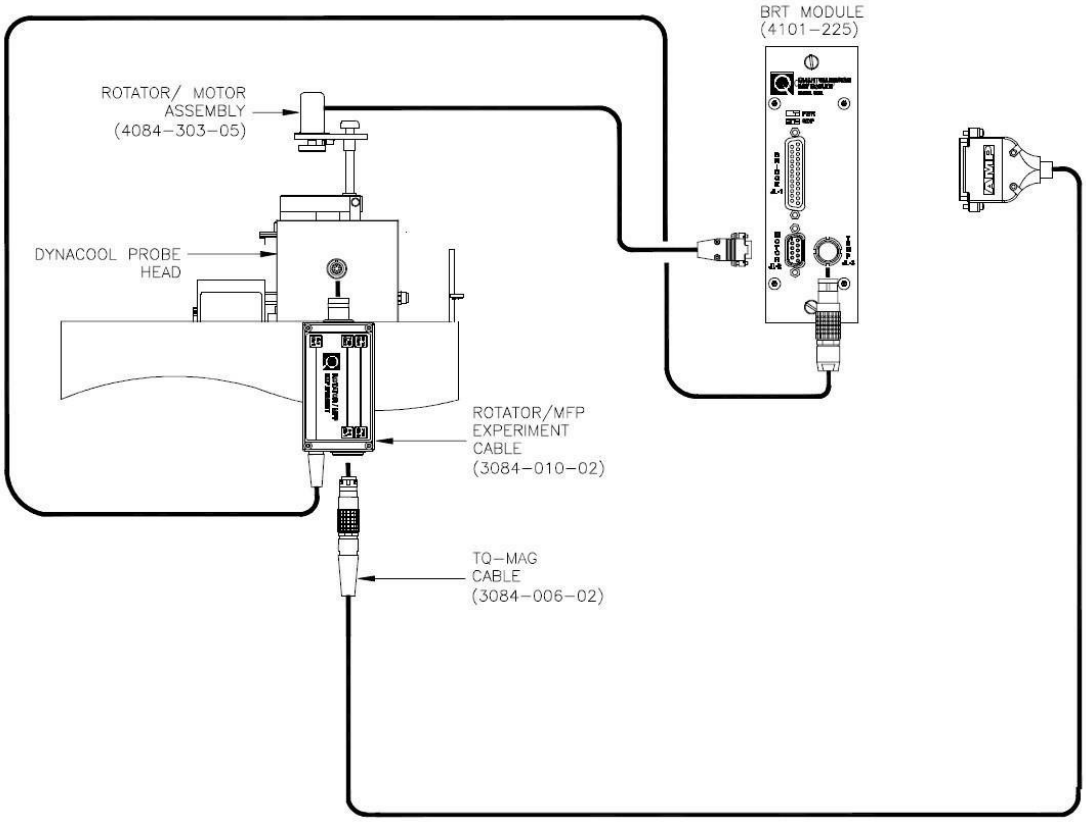


Figure 4-1: Horizontal Rotator/Tq-Mag Option Connection Diagram for Dynacool

4.3.2 VersaLab

In order to connect the Rotator/ Motor Assembly to the VersaLab Probe Head, refer to sections A.2.4 and A.2.5 for instructions on installing the rotator support plate and motor. Note that the support plate mounts differently from either the PPMS or DynaCool systems. For the VersaLab, locate the two pins and attach the support plate onto the flange, which has corresponding cut-outs for a proper alignment.

To connect the BRT module to the probe, the option cables should be connected as shown below in Diagram 2. Connect the Rotator/MFP experiment cable (3084-010-02) to the probe (Grey LEMO connector) and the 4-pin LEMO cable to the BRT module (TEMP: JL-3). Connect the Tq-Mag cable (3084-006-02) to the Rotator/MFP experiment cable box and to the BRT module (BRIDGE: JL-1).

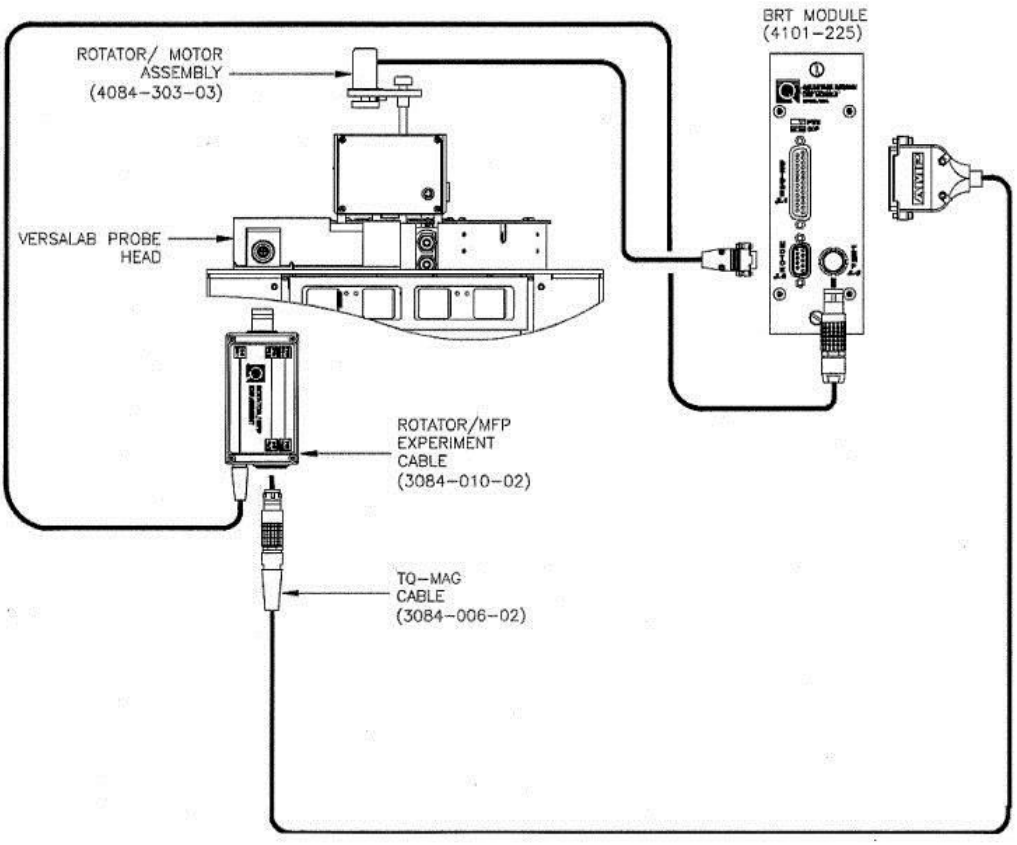


Figure 4-2: Horizontal Rotator/Tq-Mag Option Connection Diagram for Versalab

4.4 Horizontal Rotator Option

Enable an option by selecting **Utilities -> Activate Option**. The **Option Manager** dialog box opens. The dialog box lists all options that are available on your DynaCool (or VersaLab) and indicates whether each option is active. Deactivate any active measurement option. To do so, click on the option name in the **Active Options** panel and select **Deactivate**. The option name moves to the Available options panel.

To activate the Rotator option, click on **Rotator** in the **Available Options** panel and select **Activate**. The option name moves to the **Active Options** panel. After activating the Rotator the probe specific parameters are downloaded from the SROM. Motion control is enabled only after activation. Always activate the Rotator option first before activating the Torque Magnetometer option.

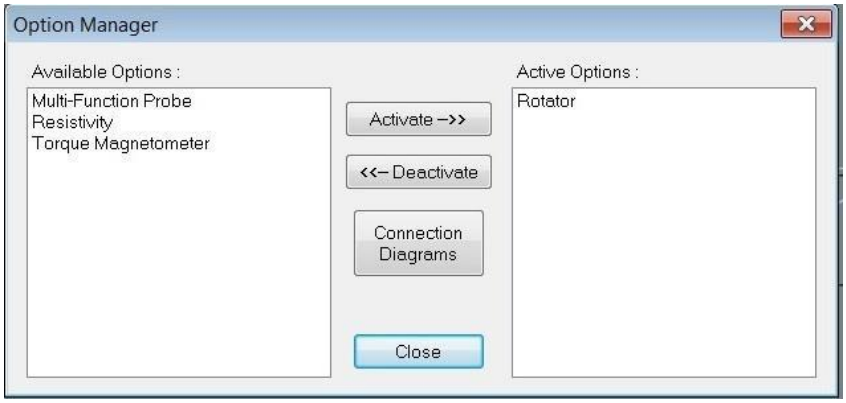


Figure 4-3: Option Manager Dialog Box

Select right Motor Resolution for the motor, which is installed in the system. Otherwise, there could be damage to the motor and/or the Rotator.

When activating the Rotator option, the **Rotator Setup** window will appear. Begin by selecting the rotator serial number. Next, the motor resolution can either be set to **Lo-Res** or **Hi-Res**. Lastly, **Enable User Temp** (on as a default, ch. 4 bridge). After pressing OK, the temperature control is automatically switched to the User Temp from the Block Temp. In case the Rotator is disconnected unintentionally from the sample tube or a circuit becomes open, the User Temp will switch back to the Block Temp to maintain the temperature set point for safety reasons. When the rotator is reconnected, the User Temp will recover from the Block Temp, as long as the rotator option remains activated. Note that it takes up to several seconds for the control temperature to switch between the Block and User Temp.

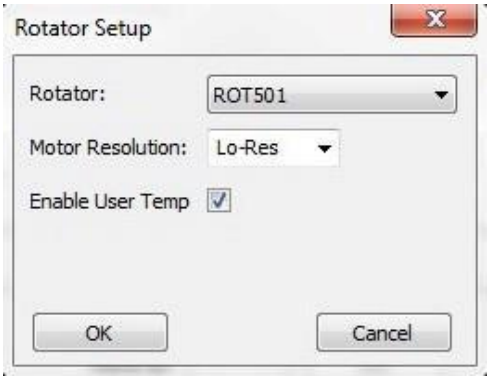


Figure 4-4: Rotator Setup Dialog Box

Set up the Rotator by first disconnecting it from the motor. The following sequence will assist in this process. Pressing **Go to Index** moves the motor until a pin hits the Index switch. This motion corresponds to a -10 degree rotation. In the window, **Redefine Current Position**: as -10 degrees and press **Set**. Then set the position to 0 by setting the parameter to 00.00 in the **Move to:** box. At this point, attach the motor to the rotator. Make sure that the vertical line on the motor and rotator disk should line up. Note that an angle dial may show a few degrees off from 0 in some instances. As long as it is within +/- 5 degrees, it is OK to proceed. If the dial is not at 0, set **Redefine Current Position:** as the angle indicated by the dial. Using the **Move to:** dialog, set the position to either 0 or 90 degrees. The angle on the dial should now correspond the angle entered. The rotator angle is now calibrated and the Rotator is ready for use.

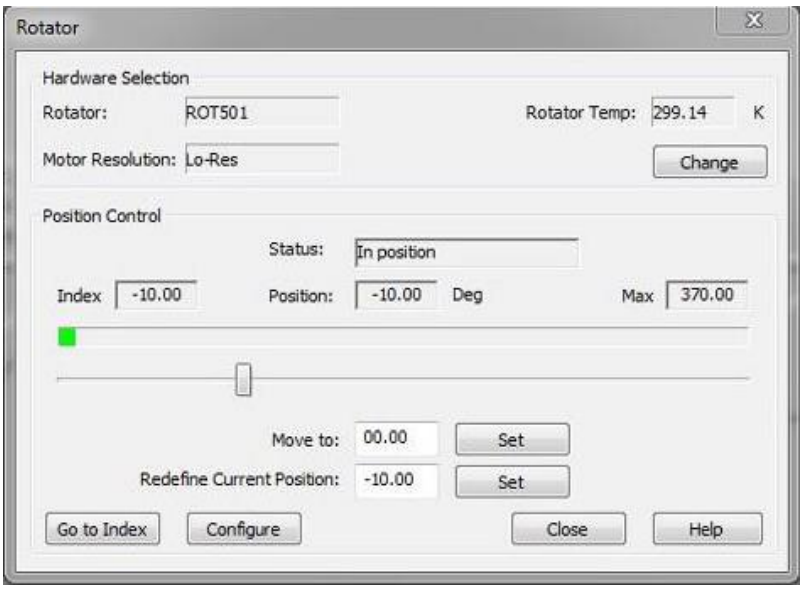


Figure 4-5: Rotator Motion Control Dialog Box

Additionally, one can select the operating speed of the motor. By clicking **Configure**, a **Position Configuration** window appears, where one can select the speed of the motor. Please note a maximum speed of 10 Deg/Sec for the low-resolution motor and 1 Deg/Sec for the high-resolution motor.

4.5 Torque Magnetometer Option

In order to activate the Torque Magnetometer option, make sure the Rotator option has been activated first. Then click on **Torque Magnetometer** in the **Available Options** panel and select **Activate**. The option name moves to the **Active Options** panel. The Torque Magnetometer control center opens as soon as the Torque Magnetometer software is integrated into PPMS MultiVu. The **Option Manager** dialog box automatically closes.

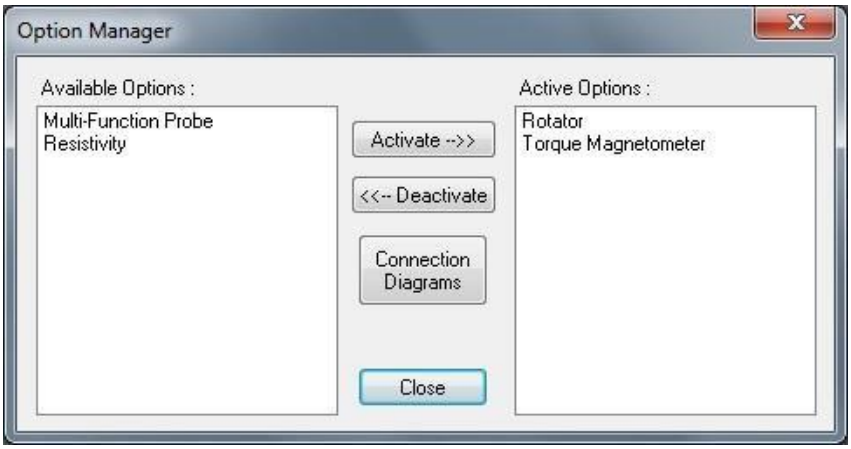


Figure 4-6: Option Manager Dialog Box

The **Torque Magnetometer Main** window appears. In the **Install** tab, install a sample if it is not done yet.

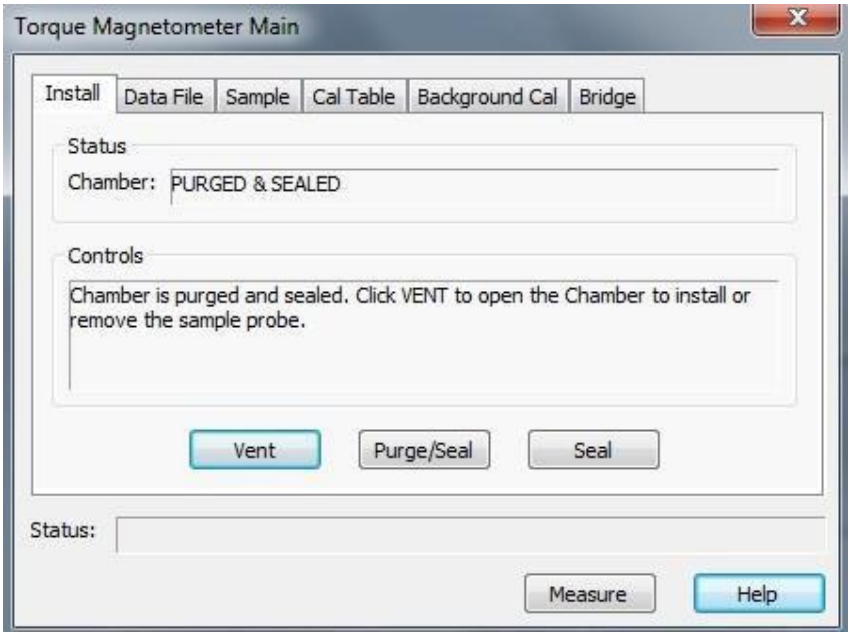


Figure 4-7: Install Tab in Torque Magnetometer Main Dialog Box

Select the **Data File** tab to create a new data file. Then **Browse** to select a folder and create a new data file.

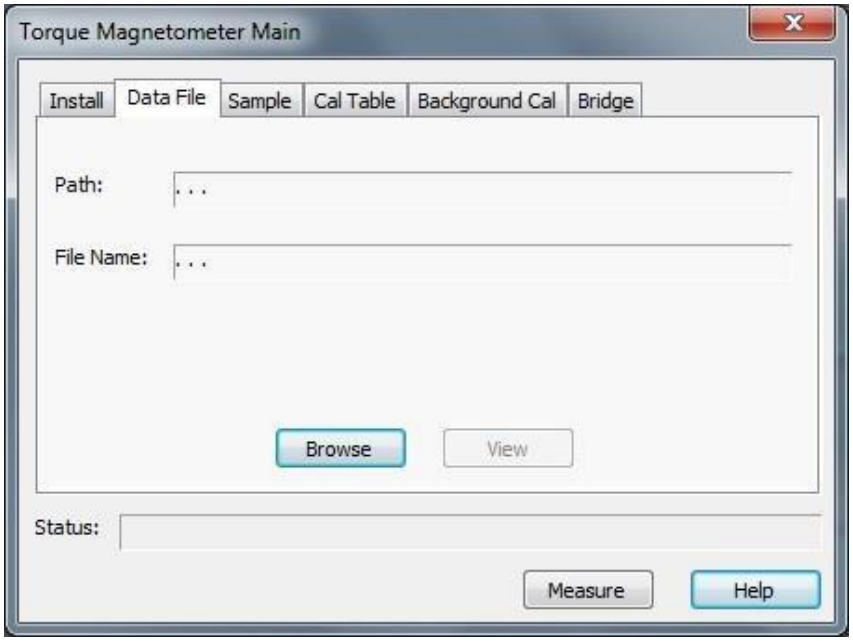


Figure 4-8: Data File Tab in Torque Magnetometer Main Dialog Box

In the **Sample** tab, enter information relevant to the sample prior to measuring.

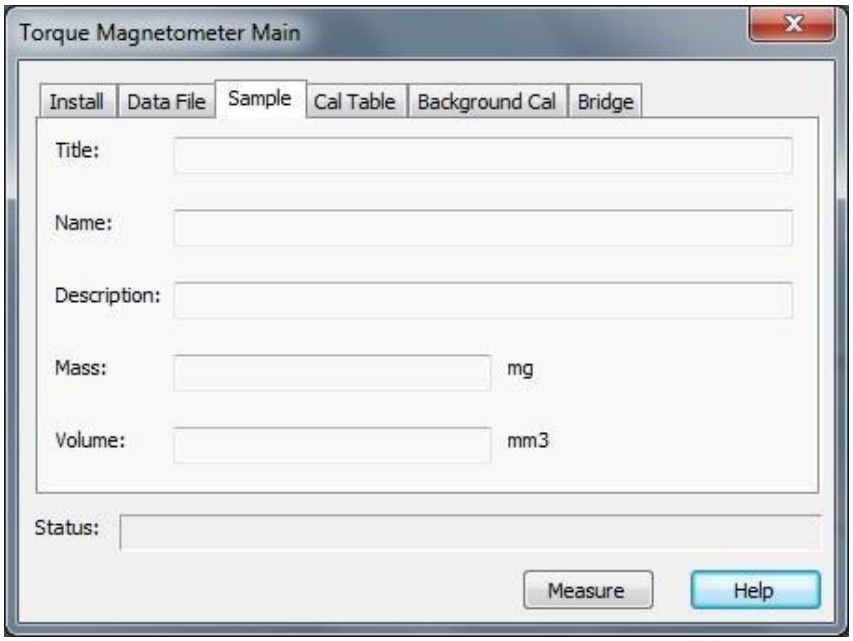


Figure 4-9: Sample File Tab in Torque Magnetometer Main Dialog Box

The Torque Magnetometer system uses a calibration coil on the torque lever to determine the lever's sensitivity at various temperatures. To calibrate the torque lever, the system takes differential measurements, over a specified temperature range, of the change in the resistance of the torque lever at zero torque and at a known positive and negative torque. The system averages the results of each differential measurement to obtain a torque coefficient at each temperature. The system saves the torque coefficients to the active calibration table. In the Cal Table, one can

select an existing calibration table or create a new calibration table. Every calibration table has a `.cal` file extension. **Browse** a data folder to locate an existing calibration table.

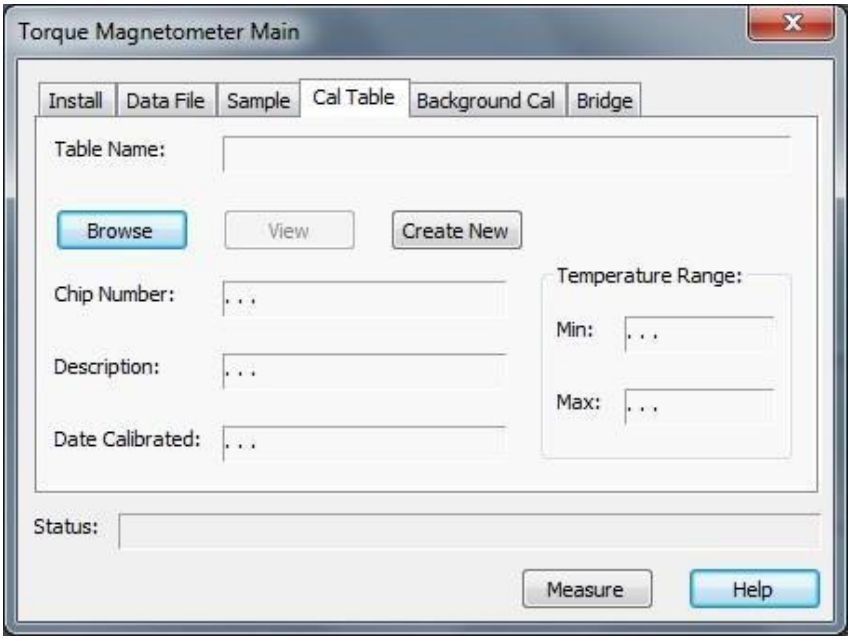


Figure 4-10: Cal Table Tab in Torque Magnetometer Main Dialog Box

To create a new calibration table, hit Create New. Then, an **Install** tab appears, to let users to install a sample if it has not been done.

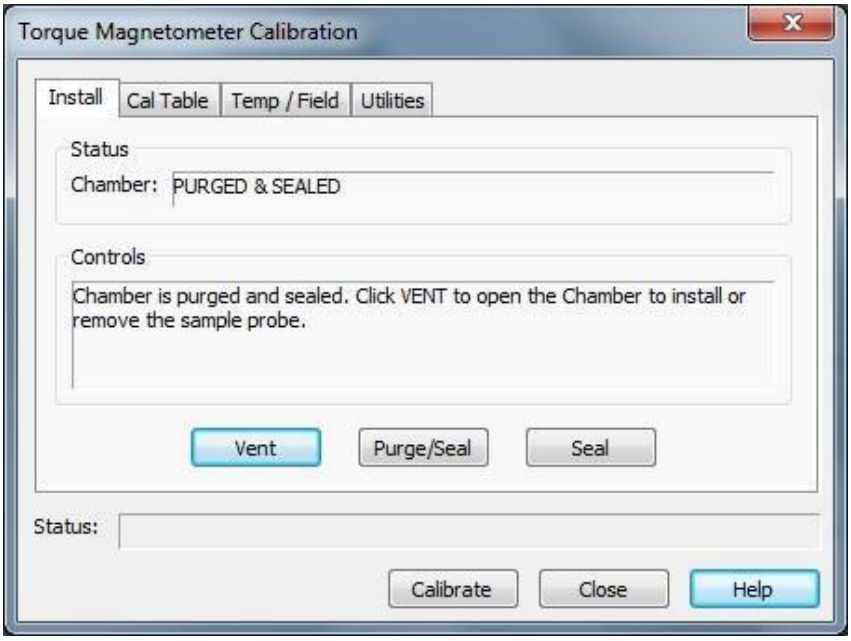


Figure 4-11: Install Tab in Torque Magnetometer Calibration Dialog Box

In the **Cal Table** tab, **Browse** a data folder to create a new calibration file. You may add information regarding the calibration into the **Chip Number**, **Description**, and **Date Calibrated** fields. Always check **Save Raw Data**.

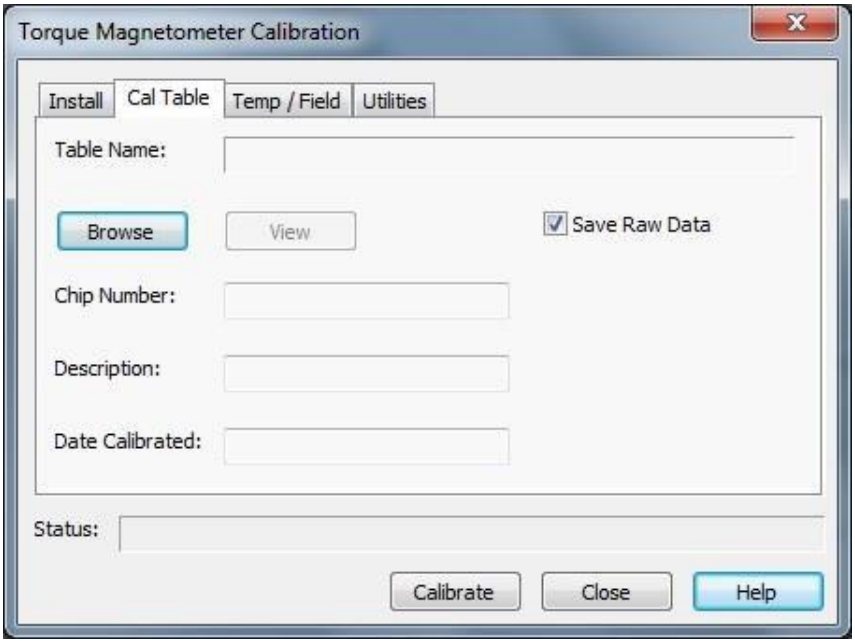


Figure 4-12: Cal Table Tab in Torque Magnetometer Calibration Dialog Box

In **Temp/Field** tab, specify **Min**, **Max** temperature and a maximum **Field Strength**. Set **Temperature Sampling Model** to be **Fine**. Turn on **Auto Reset** to turn down the magnetic fields after the calibration is finished. Click **Calibrate** to start the calibration. It takes an overnight run to complete the calibration. The calibration progress will be shown during the process.

Ensure that the rotation angle is set to 90° before starting the calibration procedure.

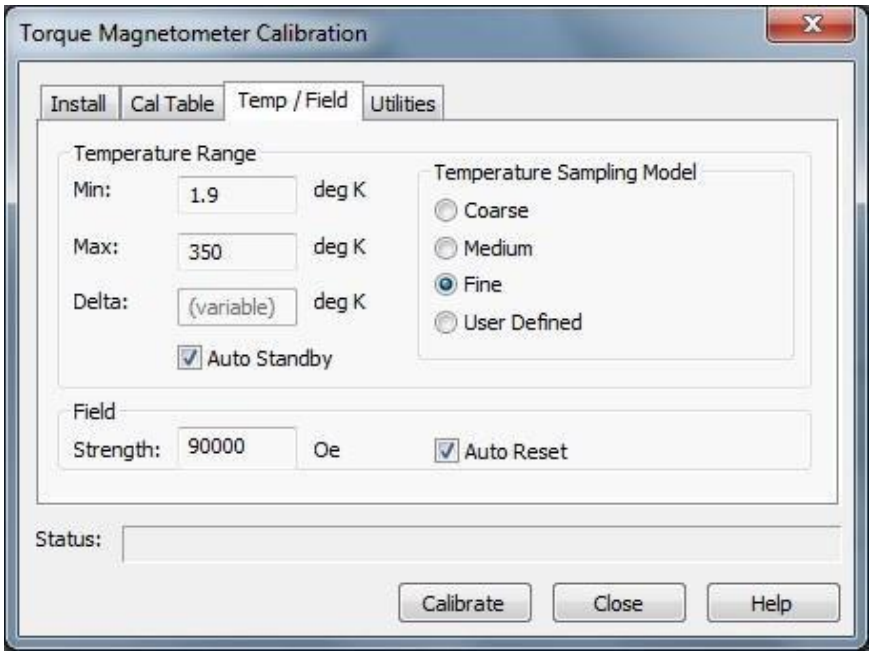


Figure 4-13: Temp/Field Tab in Torque Magnetometer Calibration Dialog Box

When a calibration file needs to be rebuilt, **Browse** a raw data file and a corresponding calibration file and select **Rebuild**.

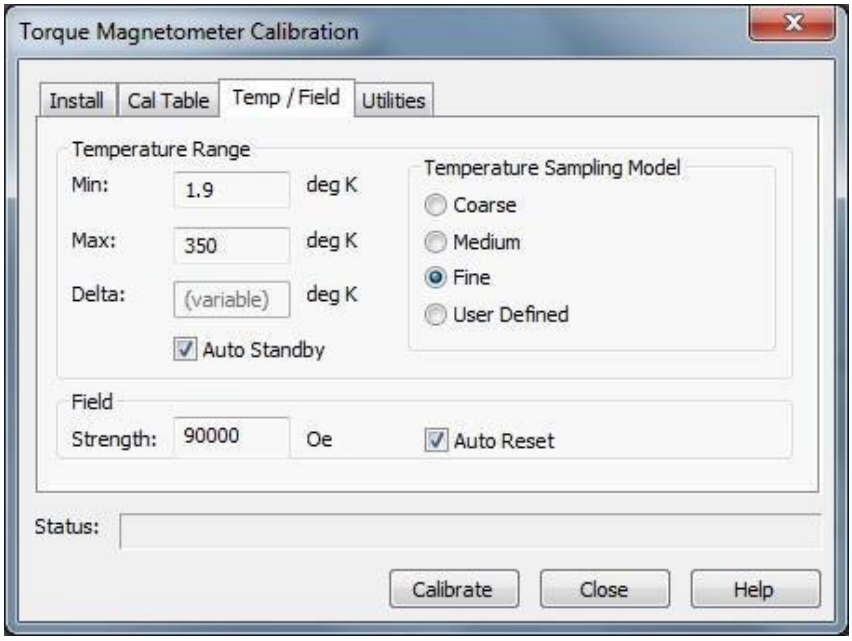


Figure 4-14: Utilities Tab in Torque Magnetometer Calibration Dialog Box

To activate two bridge channels 2 and 3, return to the **Torque Magnetometer Main** window and select the **Bridge** tab. Click the two **ON** boxes and select **Set Hardware**. Current, Power, and Voltage limits are preset as default values.

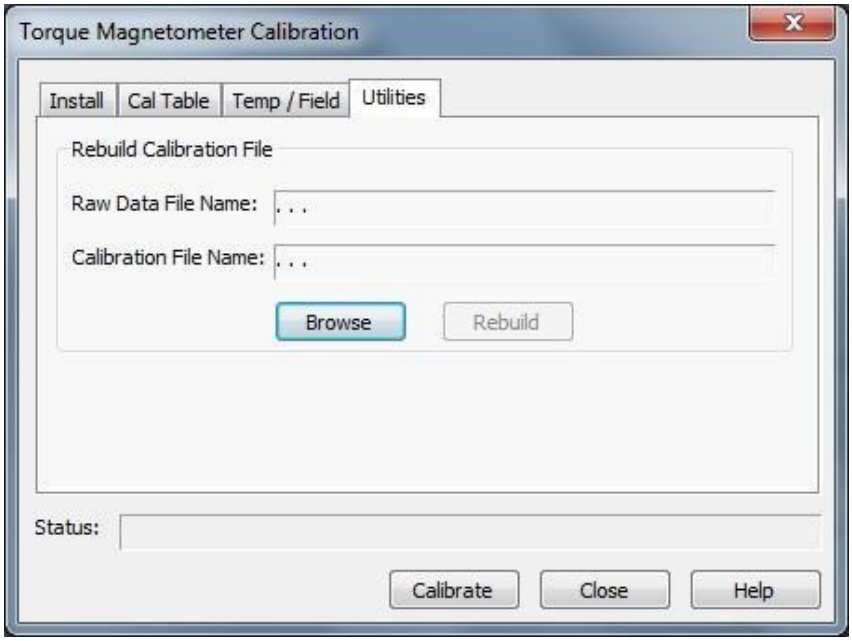


Figure 4-15: Bridge Tab in Torque Magnetometer Main Dialog Box

Then hit **Measure** and a **Torque Magnetometer Measurement** window will appear. Prior to seeing this window, one can select a Calibration Table, if available. Without selecting the Calibration Table,

parameters on the right side of the window, such as Torque and etc., will not be displayed. Selecting either **Measure (once)** or **Monitor (continuously)** will show values being measured or monitored. **Aborting** will stop the measurement or monitoring. Note that the specifications for the Tq-Mag chips are as follows. The bridge imbalance (bridge 2) resistance is less than 3.5 ohms, where the sign (plus or minus) of the value does not matter. The bridge resistance (bridge 3) is 400-800 ohms. Make sure that these values are measured prior to carrying out a calibration or an experiment.

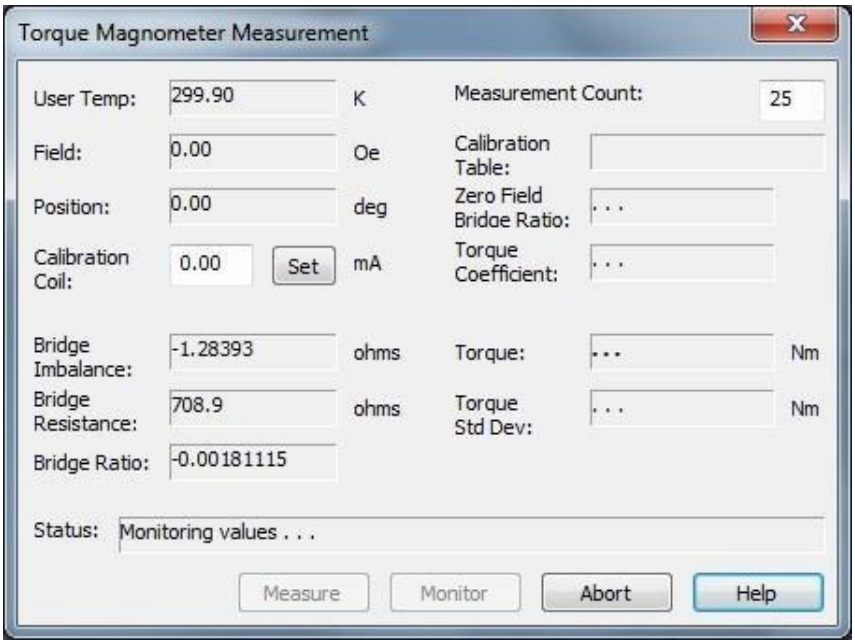


Figure 4-16: Torque Magnetometer Measurement Dialog Box

Prior to measuring the torque of the sample, Quantum Design recommends calibrating the baseline resistance ratio This calibration is optional, but it ensures a more accurate torque measurement than a measurement computed if the system uses the baseline resistance ratio calibration from the torque-lever sensitivity calibration. When the sample is on the torque-lever chip, the baseline calibration changes slightly.

Complete the following steps to calibrate the baseline resistance ratio:

1. Change the **Expected Temperature Range** in the Background Cal. Use the default expected temperature range, which is the range used during the torque-lever sensitivity calibration.
2. Verify that the **Run New Background** option is selected.
3. Select **Begin**. The baseline temperature calibration begins. While cooling to the specified minimum temperature, the system measures the imbalance and resistance of the Wheatstone bridge at zero torque and when zero current is in the calibration coil. This latest calibration data is stored in the active calibration table and overwrites the baseline calibration data already in the table. The system uses the zero-field bridge ratio when it computes the torque of the sample.

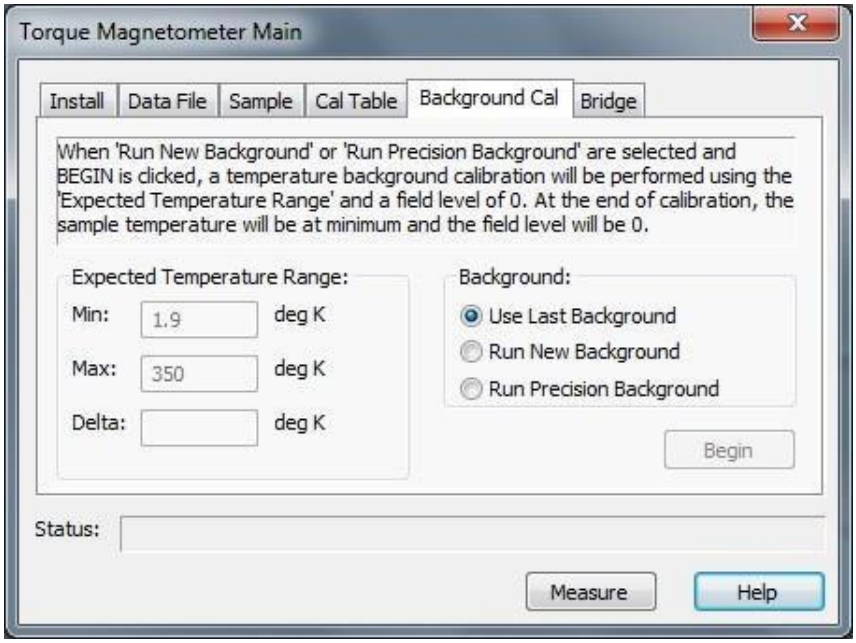


Figure 4-17: Background Cal Tab in Torque Magnetometer Main Dialog Box

For the VersaLab,

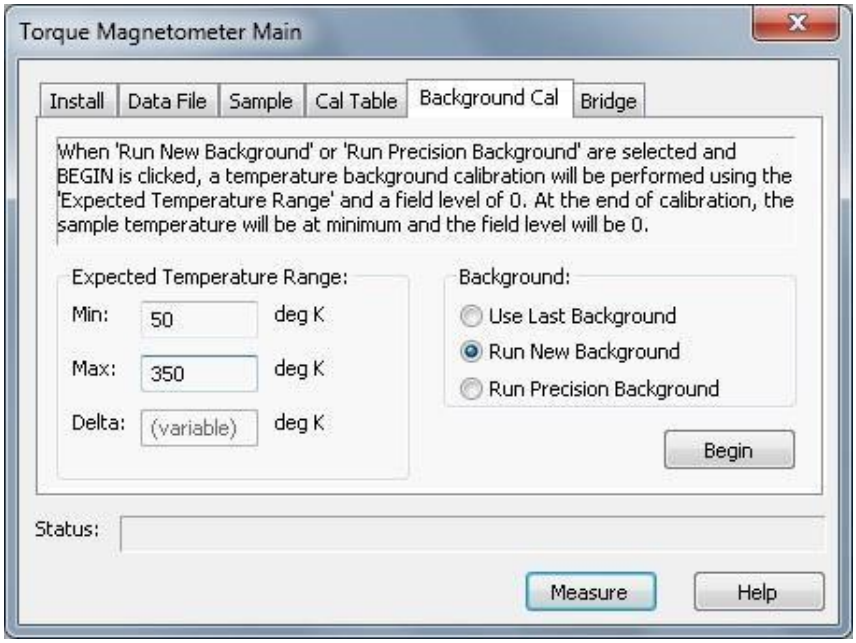


Figure 4-18: Background Cal Tab in Torque Magnetometer Main Dialog Box (Versalab)

A P P E N D I X A

Installation Instructions

A.1 Introduction

This appendix contains the following information.

- Section A.2 contains procedures for installing the Torque Magnetometer option.

A.2 Installing the Torque Magnetometer Option

A.2.1 Install the Option Software

1. Insert Torque Magnetometer Disk 1 into the PC.
2. Select the A: drive.
3. Select Setup.exe.
4. Complete all on-screen instructions the InstallShield wizard prompts you to perform.
5. Select **Utilities➤Activate Option**. The **Option Manager** dialog box opens. The dialog box lists all options that are available on your PPMS and indicates whether each option is active.
6. Deactivate any active measurement option. Click on the option name in the **Active Options** panel, and then select **Deactivate**. The option name moves to the **Available** options panel.

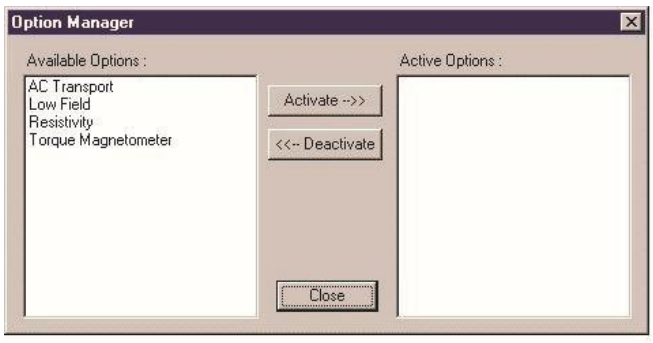


Figure A-1: **Option Manager** Dialog Box panel

Only one measurement option may be active at a time. An error message pops up if you try to activate a second measurement option. More than one non-measurement option may be active at a time. A measurement option and any number of non-measurement options may also be active simultaneously.

7. Activate the Torque Magnetometer option. Click on Torque Magnetometer in the **Available Options** panel, and then select **Activate**. The option name moves to the Active Options panel. The Torque Magnetometer control center opens as soon as the Torque Magnetometer software is integrated into PPMS MultiVu. The **Option Manager** dialog box automatically closes.

A.2.2 Verify the User Bridge Board Installation

Verify that the user bridge board is installed in the Model 6000 PPMS Controller and properly connected to the PPMS probe head and the ports on the Model 6000. The *Physical Property Measurement System: Hardware Manual* (Quantum Design 1998) discusses the proper usage of all PPMS ports and connections.

A.2.3 Install the Option Interface Cable

1. Disconnect the user bridge cable from the "P1−User Bridge" port that is on the rear of the Model 6000. The Physical Property Measurement System: Hardware Manual (Quantum Design 1998) illustrates all ports on the Model 6000.
2. Attach the female connector of the user bridge cable to the male connector on the option interface cable. Use the provided screws to hold the connectors in place.
3. Attach the female connector of the option interface cable to the "P1−User Bridge" port. Use the provided screws to hold the connectors in place.
4. Attach the BNC connector, which extends from the side of the option interface cable's user bridge box, to the "A4−Analog Outputs" for Model 6000 versions which have four analog outputs or "A2−Analog Outputs" for Model 6000 versions which only have two analog outputs. The analog output ports are found on the rear of the Model 6000 controller.

   The latest version of the Torque Magnetometer option software (version 2.1.1 Build 2 or later) prompts the installer to select which analog output they would like to use.

   Note, the option interface cable is not used for CAN-based (DynaCool or VersaLab) systems.

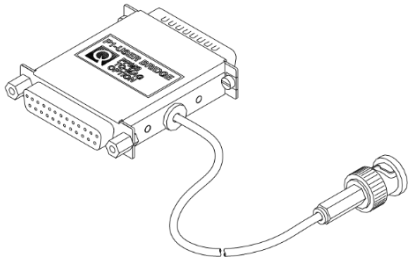


Figure A-2: Option Interface Cable for User Bridge

CAUTION

Remove the option interface cable when the Torque Magnetometer option is not in use. If the option interface cable is used with other PPMS options, the excitation current generated by the BNC connector destroys the accuracy of any measurements that are taken.

A.2.4 Install the Rotator Support Plate

The procedures for installing the Horizontal Rotator hardware or Vertical Rotator hardware are similar.

1. Open the sample chamber. Refer to the *Physical Property Measurement System: Hardware Manual* (Quantum Design 1998).
2. Remove any puck or option components that are in the sample chamber. Refer to the *Physical Property Measurement System: Hardware Manual* or to the appropriate PPMS option manual.
3. Hold the rotator support plate so that its centering clip faces the rear of the probe head, and then place the rotator support plate over the top of the probe head. Verify that the centering clip faces upward.

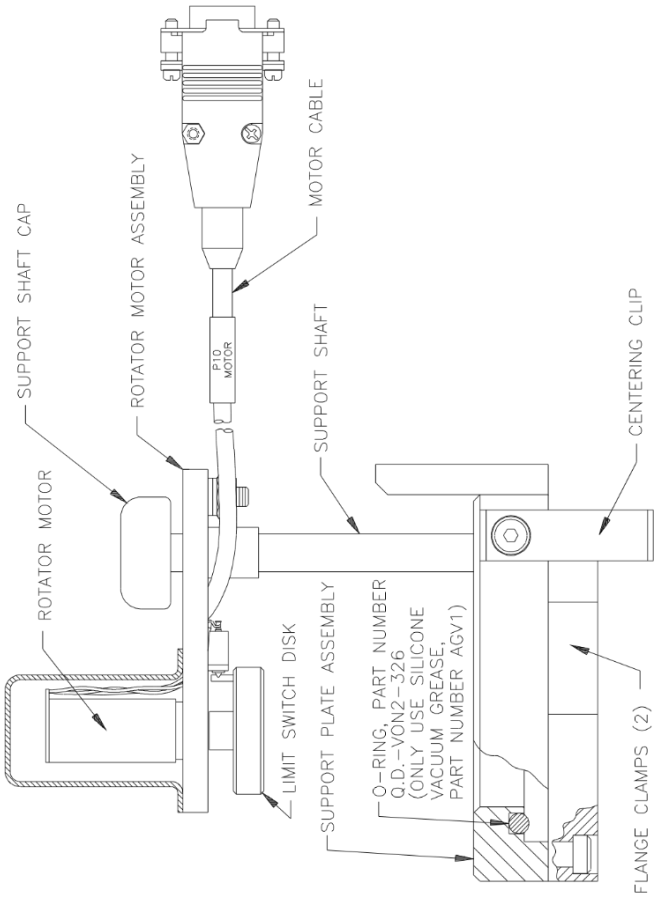


Figure A-3: Rotator Motor and Rotator Support Plate

4. Squeeze the two flange clamps on the rotator support plate together until they click into place and thus lock the support plate onto the top of the probe head. You may temporarily remove one or both of the relief valves from the PPMS helium fill ports in order to access the flange clamps.
5. Flip the centering clip downward to capture the two flange clamps and to lock the rotator support plate against the probe head.

A.2.5 Install the Rotator Motor

1. Attach the DB-9 connector of the rotator motor cable to the “P10−Motor” port on the rear of the Model 6000. Tighten the connector screws.
2. If you are installing the Horizontal Rotator, lift up the rotator motor and swing it to one side of the sample chamber in order to allow entry into the chamber.

A P P E N D I X B

Torque Magnetometer Interconnections

B.1 Introduction

This appendix contains the following information.

- Section B.2 lists standard interconnections for the . Torque Magnetometer option.

B.2 Standard Interconnections

B.2.1 Install the Option Software

Figure B-1 illustrates the standard interconnections between the rotator platform and the platform board assembly.

Table B-1 lists standard interconnections between the PPMS probe head, the Model 6000 PPMS Controller, and the Torque Magnetometer when the standard user bridge cable (part number 3084-003) and the Torque Magnetometer option interface cable (part number 3084-380) are in use.

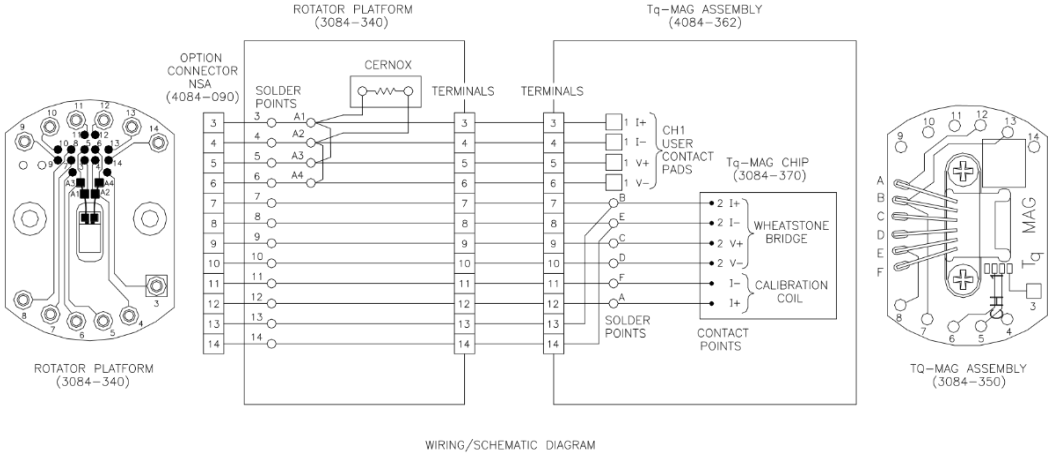


Figure B-1: Wiring Diagram for Platform Board Assembly

Table B-1: Standard Torque Magnetometer Interconnections

OPTION INTERFACE CABLE	GRAY LEMO CONNECTOR ON PROBE HEAD	PLATFORM BOARD ASSEMBLY	TQ-MAG FUNCTION
5	3	3	Channel 1, I+ Rotator thermometer
18	4	4	Channel 1, I- Rotator thermometer
6	5	5	Channel 1, V+ Rotator thermometer
19	6	6	Channel 1, V- Rotator thermometer
7	7	7	Channel 2, I+ Wheatstone bridge resistance imbalance
20	8	8	Channel 2, I- Wheatstone bridge resistance imbalance
8	9	9	Channel 2, V+ Wheatstone bridge resistance imbalance
21	10	10	Channel 2, V- Wheatstone bridge resistance imbalance
9	7	7	Channel 3, I+ Absolute Wheatstone bridge resistance
22	8	8	Channel 3, I- Absolute Wheatstone bridge resistance
10	13	13	Channel 3, V+ Absolute Wheatstone bridge resistance
23	14	14	Channel 3, V- Absolute Wheatstone bridge resistance
BNC connector	11	12	Calibration coil, I+
BNC connector	12	11	Calibration coil, I-

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Index

Baseline resistance ratio
  calculating, 2-11
  calibrating before torque measurement, 3-5
  using to compute torque, 3-1, 3-5
BNC connector
  Analog Outputs port, A-2
  providing current to calibration coil, 1-6
  negative effect on other measurement types, A-2
Bridge ratio, definition of, 3-7

Calibration. *See* Torque lever calibration
Calibration coil
  in illustration of torque-lever chip, 1-2
  magnetic moment of, 1-4
  producing calibration standard, 1-4. *See also* Torque lever calibration: Description of
Calibration curve, 2-1, 2-11
Calibration log file, 2-10
Calibration table
  associated with single torque-lever chip, 2-1
  contents of, 2-1, 2-11
  creating, 2-6
  opening, 2-10
  selecting for torque measurement, 3-5
Calibration temperature range
  determining length of torque lever calibration 2-7, 2-10
  setting, 2-7
Coarse temperature sampling model, 2-7
Constantan piezoresistive path, description of, 1-1. *See also* Piezoresistive path

Data file, saving sequence-mode data, 3-1, 3-4, 3-7
Delta, value of, 2-7

Filter Data check box, 3-8
Fine temperature sampling model, 2-7

Horizontal Rotator option. *See also* Platform board assembly: Mounting on Horizontal Rotator probe
  compatibility with longitudinal and transverse magnet configurations, 1-5
  configuration file, downloading, 2-8, 3-6
hardware, installing. *See* Rotator motor: Installing; Rotator support plate
  probe, inserting in sample chamber. See Rotator probe

Immediate mode
  and torque lever calibration, 2-1. *See also* Torque lever calibration: Procedures for
  and torque measurement, 3-1. *See also* Torque measurement: Immediate mode
Installation. *See* Torque Magnetometer: Installing

Manual mode. *See* Immediate mode
Medium temperature sampling model, 2-7
Model 6000 PPMS Controller, housing user bridge board, 1-1, A-2

Option interface cable
  electronic interconnections, B-2
  function of, 1-6
  installing, A-2
  negative effect on other measurement types, A-2

Piezoresistive path
  description of, 1-1
  in illustration of torque-lever chip, 1-2
  resistance change in, measuring. *See* Wheatstone bridge: Measuring resistance change
Piezoresistive technique, 1-1
Piezoresistor grids. *See* Piezoresistive path
Platform board assembly
  components on, illustration of, 2-2
  function of, 1-6
  mounting on Horizontal Rotator probe, 2-3−2-4, 3-3−3-4
  mounting torque-lever chip on, 2-2−2-3, 3-3
  wiring diagram, B-1
PPMS MultiVu application
  including Torque Magnetometer commands, 1-1
  integrating Torque Magnetometer software into, A-1−A-2
  using to set rotator motor position, 2-4

Raw measurement data, saving, 2-6
Resistivity option, 1-5
Rotator motor
  illustration of, A-3
  installing, A-4
  setting position of, 2-4
Rotator options. *See also* Horizontal Rotator option; Vertical Rotator option
  increasing range of torque measurements, 1-5
Rotator platform, wiring diagram for, B-1
Rotator probe, inserting in sample chamber, 2-5, 3-4
Rotator support plate, installing, A-3

Sample
mounting on torque-lever chip, 3-2
parameters, defining, 3-4
recommended types of, 1-4
specifying measurement count for, 3-7
Sample removal tool
illustration of, 1-6
picking up platform board assembly, 2-4, 3-3−3-4
Sensitivity calibration. *See* Torque lever calibration
Sequence mode
and torque measurement, 3-1. *See also* Torque measurement: Sequence mode

Temperature sampling models, function of, 2-7, 2-11
Torque coefficient
calculating, 1-4, 2-1, 2-11
stored in calibration table, 2-1, 2-11
using to compute torque, 3-1, 3-7
Torque lever calibration. *See also* Calibration coil
aborting, 2-10
description of, 2-1, 2-11
generating maximum torque during, 2-4
pausing, 2-10
performing prior to taking torque measurements, 2-1
procedures for, 2-2−2-10
recommended magnetic field strength for, 2-7
temperature range determining length of, 2-7, 2-10
Torque-lever chip. *See also* Calibration coil; Wheatstone bridge
calibrating. *See* Torque lever calibration
components, illustration of, 1-2
description of, 1-1, 1-6
dimensions, illustration of, 1-2
electrical pads on, illustration of, 2-3
generating torsion, 1-1, 2-11
mounting on platform board assembly, 2-2−2-3, 3-3
mounting sample on, 3-2
proper handling of, 2-2, 3-3
Torque-lever sample stage
applying grease to, 2-2
in illustration of torque-lever chip, 1-2, 2-3
mounting sample on. *See* Torque-lever chip: Mounting sample on
sample on, illustration of, 1-2, 3-2
Torque Magnetometer
automating operation of. *See* Sequence mode
as complement to other measurement types, 1-1
electronic interconnections, B-1−B-2
hardware, overview of, 1-6 installing, A-1−A-4
overview of operation, 1-1. *See also* Torque lever calibration; Torque measurement
sample types to use with, 1-4
using piezoresistive technique, 1-1
Torque Magnetometer control center
activated when Torque Magnetometer software is installed, A-2
using to prepare for calibration run, 2-5
using to prepare for torque measurement, 3-4−3-6
Torque measurement
as angular-dependent measurement, 1-1
automating, 3-1, 3-7
data, saving to data file, 3-1, 3-4, 3-7
description of, 1-1, 3-1, 3-7
generating maximum torque during, 3-2
in immediate mode, procedures for, 3-2−3-7
measure count, specifying, 3-7
measurement circuitry for, 1-3
in sequence mode, 3-7−3-8
using calibration temperature range for, 3-6
Torque measurement sequence command, including in sequence, 3-8
Tq-MAG Calibration dialog box, using for torque lever calibration, 2-5−2-10
Tq-MAG Measure dialog box, using for torque measurement, 3-7

User bridge board
connecting to rotator option. *See* Option interface cable
as part of Resistivity option, 1-5
User bridge board channel 2
measuring imbalance of Wheatstone bridge, 1-3, 1-5, 2-9, 3-6. *See also* Torque lever calibration: Description of
parameters, 2-9
User bridge board channel 3
measuring resistance of Wheatstone bridge, 1-3, 1-5, 2-9, 3-6. *See also* Torque lever calibration: Description of parameters, 2-9
User thermometer, defining parameters for, 2-8, 3-6

Vertical Rotator option
compatibility with transverse magnet configuration, 1-5
configuration file, downloading, 2-8, 3-6
hardware, installing. *See* Rotator motor: Installing; Rotator support plate
probe, inserting in sample chamber. *See* Rotator probe

Wheatstone bridge
circuit diagram, illustration of, 1-3. *See also* Platform board assembly: Wiring diagram
and generating imbalance-to-resistance ratio, 2-11, 3-1, 3-7
in illustration of torque-lever chip, 1-2
measuring resistance change, 1-1, 1-3