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# **SQM-160**

**Rate/Thickness Monitor**

## **User's Guide**

**Version 4.06**

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## **Safety Information**

Read this manual before installing, operating, or servicing this equipment. Do not install substitute parts, or perform any unauthorized modification of the product. Return the product to Sigma Instruments for service and repair to ensure that safety features are maintained.

### **Safety Symbols**

**WARNING:** Calls attention to a procedure, practice, or condition that could possibly cause bodily injury or death.

**CAUTION:** Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.



Refer to all manual Warning or Caution information before using this product to avoid personal injury or equipment damage.



Hazardous voltages may be present.



Earth ground symbol.



Chassis ground symbol.



Equipotential ground symbol.

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## **Warranty Information**

This Sigma Instruments product is warranted against defects in material and workmanship for a period of 2 years from the date of shipment, when used in accordance with the instructions in this manual. During the warranty period, Sigma Instruments will, at its option, either repair or replace products that prove to be defective.

## **Limitation of Warranty**

Defects from, or repairs necessitated by misuse or alteration of the product, or any cause other than defective materials or workmanship are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. UNDER NO CIRCUMSTANCES SHALL SIGMA INSTRUMENTS BE LIABLE FOR CONSEQUENTIAL OR OTHER DAMAGES RESULTING FROM A BREACH OF THIS LIMITED WARRANTY, OR OTHERWISE.

## **Return Policy**

The purchaser may return this product in like-new condition within 30 days after shipment for any reason. In case of return, purchaser is liable and responsible for all freight charges in both directions.

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## 1.0 Introduction

Congratulations on your purchase of the SQM-160 Deposition Rate/Thickness Monitor. The SQM-160 is an easy-to-use instrument for measuring many types of thin-film coatings. This chapter will help to get you up and running quickly. Please review the entire manual for detailed operational, programming, and safety information.

## 1.1 Installation

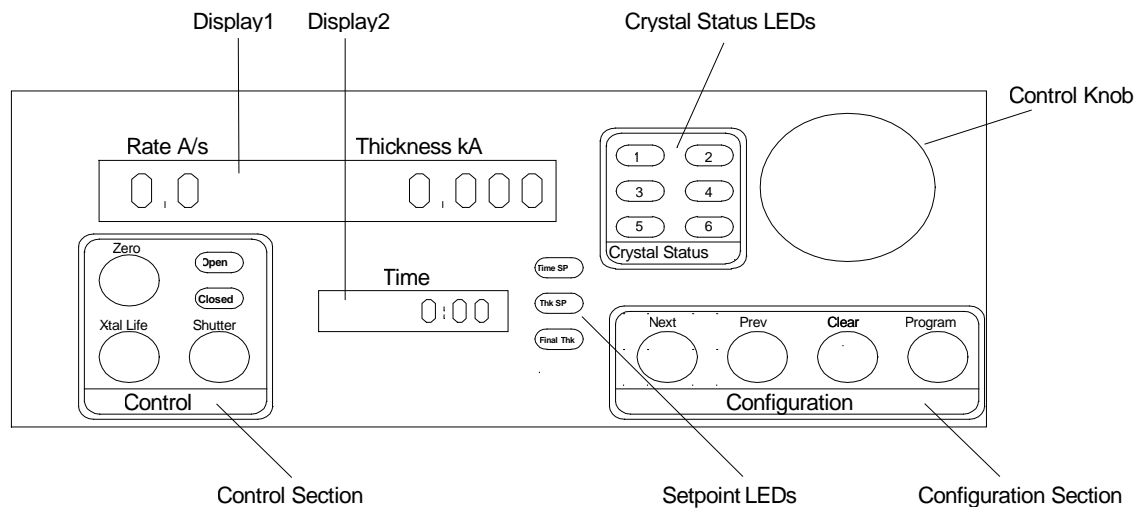
This section assumes you are familiar with thin-film monitors. Refer to Sections 1.3 and 1.4 for detailed system hookup information.

**WARNING:** Maintain adequate insulation and physical separation of sensor, I/O, and option card wiring from hazardous voltages.

Rack Installation	The SQM-160 occupies a 3.5" high, half-rack space. Rack installation requires either a half-rack adapter kit (900-014) or a full rack extender kit (900-008). Install the unit in a 19" rack with the appropriate hardware. See Chapter 3 for extender assembly instructions.
Power Connection	<b><u>WARNING:</u></b> Verify that the power cable provided is connected to a properly grounded mains receptacle.
Sensor Connections	Connect the BNC cables and oscillator from your vacuum chamber feedthrough to the SQM-160 Sensor Input(s).
Digital I/O Connections	Refer to Appendix C for details on wiring digital I/O to the SQM-160 Relay I/O connector.
Computer Connection	If you would like to use the supplied Windows™ software to collect data or program the SQM-160, attach a 9-pin straight-thru cable from the SQM-160 RS-232 connector to your computer's serial port.
Option Connections	If you have purchased the optional Four Sensor Card, connect the BNC cables and oscillator from your vacuum chamber feedthrough to these additional four inputs.

Move the rear panel power switch to the On (I) position. The SQM-160 will briefly display its software version, then go to normal operating mode.

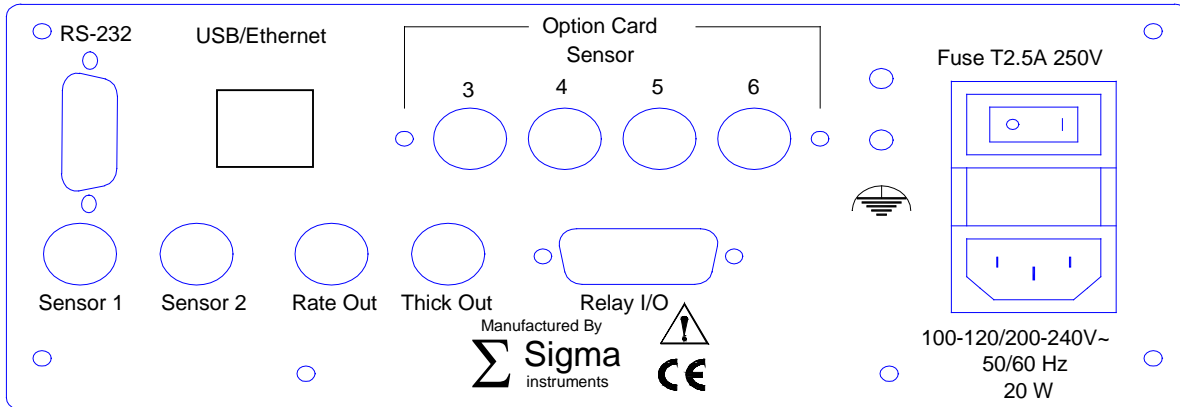
## 1.2 Front Panel




### Front Panel Controls

Display 1	Displays rate/thickness or frequency in normal operation. Displays setup parameter name in program mode.
Display 2	Displays deposition time, or sensor # displayed when scrolling through sensor readings. Displays setup parameter values in program mode.
Control Section	Zero thickness reading. Toggle display between Crystal Life and Rate/Thickness. Open/close shutter relay.
Configuration Section	Program enters setup mode. Next/Prev moves thru menus. Clear cancels change and returns value to its original setting.
Setpoint LEDs	Illuminate when the indicated setpoint is reached.
Crystal Status LEDs	Illuminate when a crystal is active and operating. Flashes when an active crystal fails.
Control Knob	Used to adjust values or scroll though menu selections. Pushing the control knob stores the current setting.

1.3 Rear Panel



Rear Panel Connections

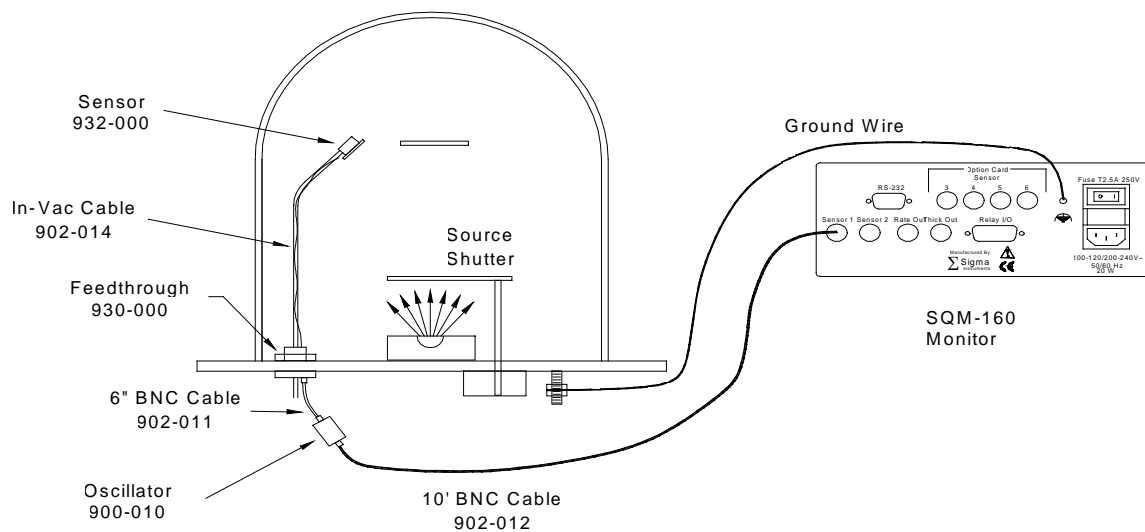
- Sensor 1 & 2                      Connection to quartz crystal sensors. See Section 1.4 for detailed hookup..
- Rate and Thickness Outputs      Provides 0-5V analog outputs for rate and thickness readings. For connection to strip chart recorders or similar instruments.
- Relay I/O                              Connects 4 relays and 4 digital inputs to external equipment for process control. See Appendix C for connections.
- RS-232                                  Connection to computer serial port for programming and data acquisition.
- USB/Ethernet                          Optional connection to computer USB or Ethernet port for programming and data acquisition
- Option Card                              Provides an additional four sensor measurement channels.
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Measurement ground terminal useful for common system and cable grounding.
- Power Connector                      **WARNING:** Use removable power cords only of the specified type and rating, attached to a properly grounded receptacle.

### 1.4 System Connections

The diagram shows typical vacuum system wiring. The table identifies each component's function.

**WARNING:** Maintain adequate insulation and physical separation of sensor wiring from hazardous voltages.



#### System Components

Sensor	Holds the quartz crystal used to measure rate and thickness. Crystals must be replaced occasionally.
In-Vac Cable	A coaxial cable that connects the sensor to the feedthrough.
Feedthrough	Provides isolation between vacuum and atmosphere for electrical and cooling lines.
6" BNC Cable	Provides a flexible connection from the feedthrough to the oscillator. Keep this cable as short as possible.
Oscillator	Contains the electronics to operate the quartz crystal. Total cable length to the crystal should be under 40" (1 meter).
10' BNC Cable	Connects the oscillator to the SQM-160. Lengths up to 100' (30 meters) are acceptable.
Ground Wire	A wire, typically braided, that connects the vacuum system to the SQM-160 ground terminal.

## 1.5 Film Setup

This section will help you set up the SQM-160 to measure a film. Refer to Chapter 2 for detailed programming instructions.

*Note: User actions with front panel controls are indicated by a Box. Results shown on displays are indicated by a Dashed Box.*

Enter Program Mode	If the Crystal Life display is shown, press <span style="border: 1px solid black; padding: 0 2px;">Xtal Life</span> to return to Rate/Thickness mode. Press <span style="border: 1px solid black; padding: 0 2px;">Program</span> to enter the film setup menu.
Select a Film	Turn the <span style="border: 1px solid black; padding: 0 2px;">Control Knob</span> to select one of the nine possible films, then press the <span style="border: 1px solid black; padding: 0 2px;">Control Knob</span> to enter the film parameters menu.
Set Film Parameters	Turn the <span style="border: 1px solid black; padding: 0 2px;">Control Knob</span> to set the first film parameter (Density). The parameter value is shown in <span style="border: 1px dashed black; padding: 0 2px;">Display 2</span> . Press the Control Knob to save the value and move to the next film parameter. If you press <span style="border: 1px solid black; padding: 0 2px;">Clear</span> , the film parameter returns to its original value. Continue to set each parameter. When the last film parameter is entered, the SQM-160 returns to normal mode.
Set System Parameters	To Enter the system menu, press <span style="border: 1px solid black; padding: 0 2px;">Program</span> , then <span style="border: 1px solid black; padding: 0 2px;">Prev</span> . Set system parameters by turning, then pushing, the <span style="border: 1px solid black; padding: 0 2px;">Control Knob</span> as described above. Press <span style="border: 1px solid black; padding: 0 2px;">Program</span> to return to Normal mode.

If the sensor(s) you selected during film setup are connected to the SQM-160, the Crystal Status LEDs should be lit. If not, return to the Film Parameters menu and set the Sensor Average parameter to the desired sensor(s).

If the Crystal Status LED is flashing, it is most likely that sensor is not properly connected. A small test crystal, supplied with each oscillator module, can be used to test sensor connections external to the vacuum chamber. Referring to Section 1.4, disconnect the oscillator from its 6" BNC cable. Attach the test crystal to the oscillator's feedthrough connector. The Crystal Status LED will remain lit if the external sensor connections are correct.

Refer to the Troubleshooting section of Chapter 2 for assistance in troubleshooting sensor problems.

## 1.6 Depositing a Film

If you have followed this Quick Start chapter, you are ready to deposit a film. Follow the procedure below to begin deposition.

Verify Sensor Operation	Verify that the Crystal Status LED for the measuring sensor is lit, and not blinking.
Display Rate/Thickness	<u>Display 1</u> should be displaying Rate on the left and Thickness on the right. If the Crystal Life display mode is active, press the <u>Xtal Life</u> switch to return to Rate/Thickness mode. If the Program Mode is active, press <u>Program</u> to return to normal mode.
Zero Thickness	If needed, press the Zero switch to zero the thickness reading.
Start Deposition	Apply power to your source evaporation supply. If the SQM-160 shutter relay is connected, press the Shutter switch to open the source shutter and begin deposition.

The Rate and Thickness displays should begin to move from zero.

If the displays remain at zero, check your system setup to assure that you are actually evaporating. Also check that the deposited material is reaching the sensor.

If the display is erratic or noisy, first check your sensor connections. Refer to the Troubleshooting section of Chapter 2 for information that can help in identifying the cause of noisy readings.

If the rate and thickness readings do not match your expectations, refer to the Film Parameter (Density, Z-Factor, Tooling) and Sensor Tooling sections of Chapter 2.

Please take time to review the remainder of this manual for detailed operational, programming, and safety information.



## 2.0 Introduction

This section details the operation of the SQM-160 menus and front panel controls. It is arranged by common user tasks.

**Note:** User actions with front panel controls are indicated by a **Box**. Results shown on displays are indicated by a **Dashed Box**.

## 2.1 Menu Selection

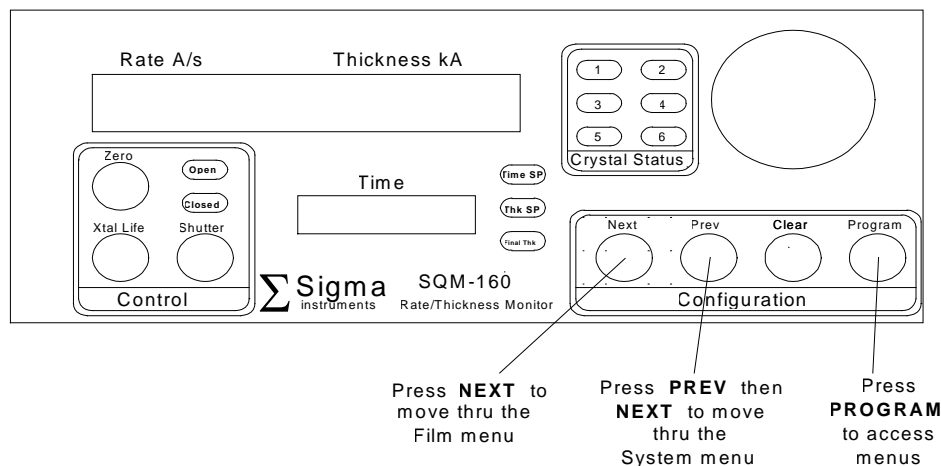
Two menus provide control of the SQM-160 programming. The Film Parameters Menu allows you to customize each of the nine stored films. The System Parameters Menu sets values that remain constant for **all** films.

The Configuration Section of the SQM-160 front panel contains four switches used to access the program menus. Within the program menus, the **Control Knob** is also used to adjust values and select menu choices. In program mode, **Display 1** shows the parameter to be changed. **Display 2** shows the selected parameter's value.

**Note:** If Crystal Life is shown on the SQM-160 displays, press the Xtal Life switch to return the displays to rate/thickness or frequency display.

To enter the Film Parameters Menu, press the **Program** switch. The SQM-160 displays the currently active film. Turn the control knob to select a different film, then press **Next** to display the first parameter for the selected film.

To enter the System Parameters Menu, press the **Program** switch. Then press **Prev** to display the first system parameter.

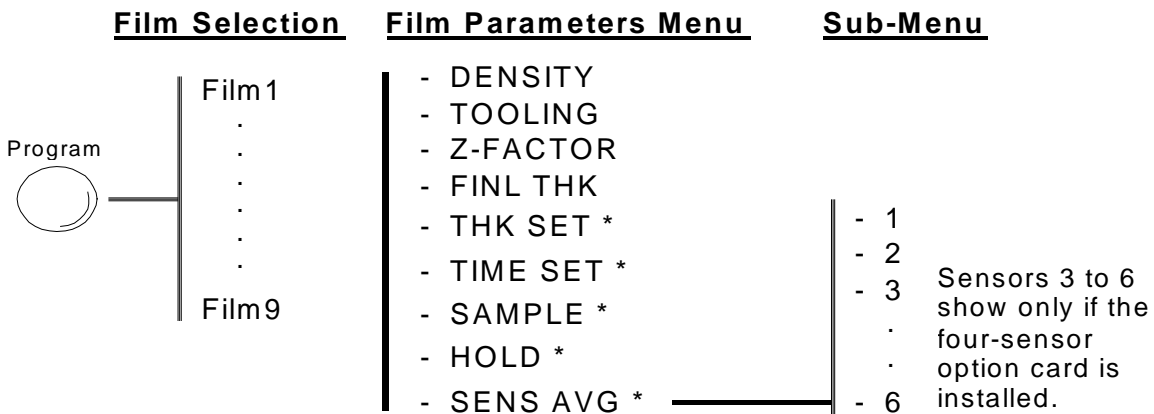


## 2.2 Film Parameters

The Film Parameters Menu programs the SQM-160 for the materials that will be deposited as thin films. Nine films can be stored, but only one film is active at any time.

1. Press **Program** to enter program mode.
2. Use the **Control Knob** to scroll to the desired Film # (1-9).
3. Depress the **Control Knob** or **Next** to enter the film parameters menu for the selected film.
4. Use **Next** and **Prev** to move through the film parameters, shown in **Display 1**.
5. Use the **Control Knob** to adjust the parameter value, shown in **Display 2**, to the desired setting.
6. Depress the **Control Knob** or **Next** to save the displayed value and move to the next material parameter. Press **Clear** to abandon the change and return to the original setting.
7. Press **Program** to exit the Film Parameters Menu and return to normal mode.

The diagram and table that follow detail the parameters available in the Film Parameters Menu. Refer to later sections of this chapter for instructions on setting specific film parameters.



**Note:** Depending on System Menu setup, selections marked with a \* may not be available. Consult the table that follows for details.

### Film Parameters

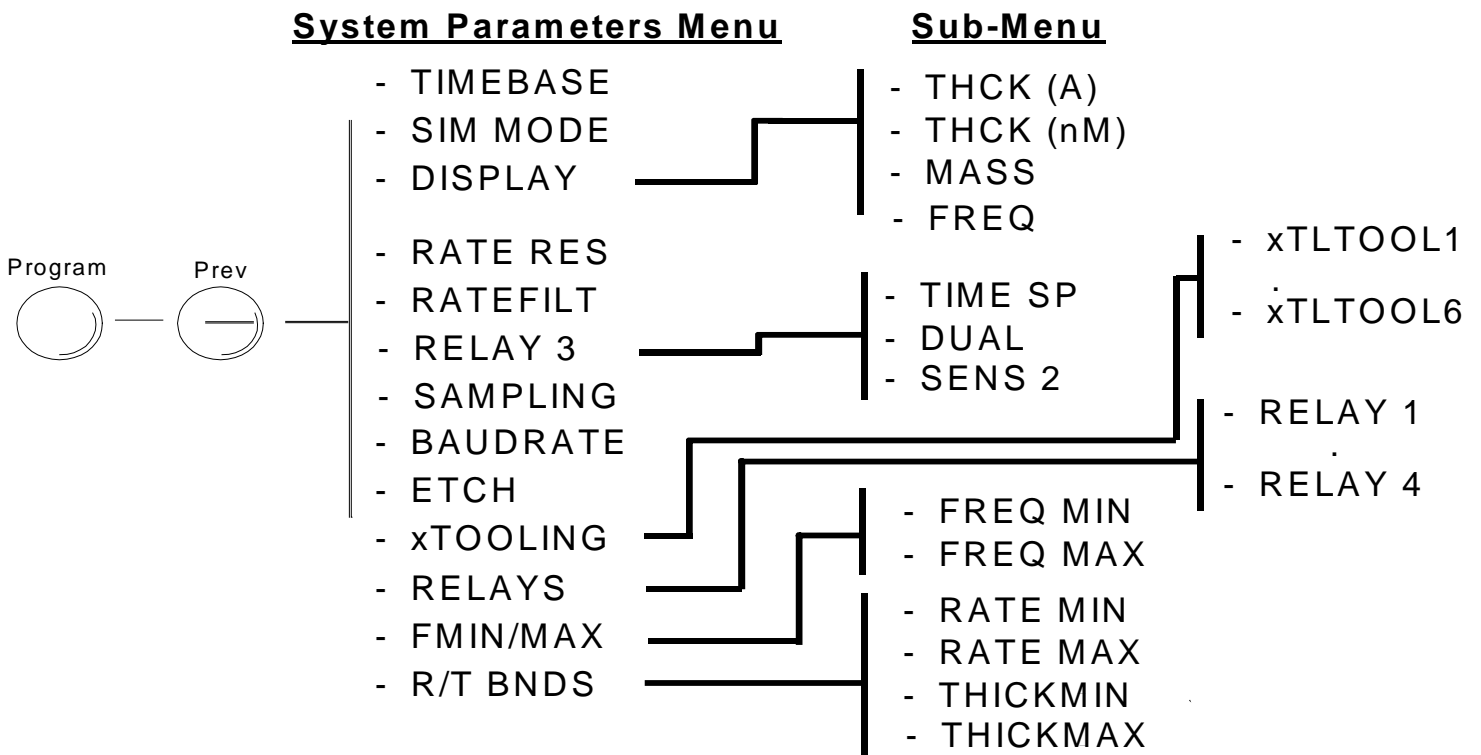
<u>Display</u>	<u>Description</u>	<u>Range</u>	<u>Default</u>	<u>Units</u>
<b>DENSITY</b>	Density of the material being deposited. Consult the Appendix for common material densities.	0.5 – 99.99	1.00	gm/cc
<b>TOOLING</b>	Overall Tooling Factor for this film. See the Sensor Tooling section of this chapter.	10 – 399	100	%
<b>Z-FACTOR</b>	Z-Factor of the material being deposited. Consult the Appendix for common material Z-Factors.	0.10 – 10.00	1.0	
<b>FINL THK</b>	Desired Final Thickness of deposited material. Lights Final Thk LED when reached.	0.000 – 99.99	0.500	kÅ
<b>THK SET</b>	Thickness value that closes the Thickness Setpoint relay and lights Thk SP LED. *Not available when Sampling is ON in System Menu.	0.000 – 99.99	0	kÅ
<b>TIME SET</b>	Elapsed time that closes the Timer Setpoint relay and lights Time SP LED. *Not available when Relay 3 is set to Dual or Sensor 2 in the System Menu.	0:00 – 99:59	0	Min: Sec
<b>SAMPLE</b>	The time for the sensor shutter to remain open when Rate Sampling is enabled in the System Menu. *Not available when Sampling is OFF in System Menu.	0 - 9999	0	Sec
<b>HOLD</b>	The time for the sensor shutter to remain closed when Rate Sampling is enabled in the System Menu. *Not available when Sampling is OFF in System Menu.	0 - 9999	0	Sec

<b>SENS AVG</b>	Enable/disable crystals for this film. See the Sensor Selection section of this chapter. *Not available Relay 3 is set to Dual in the System Menu.	Enabled/ Disabled	Ch1 Enabled
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### 2.3 System Parameters

The System Parameters Menu sets values that pertain to the overall functions of the SQM-160 and to your vacuum system’s setup. System parameters apply to **all** films.

1. Press **Program** to enter program mode.
2. Press **Prev** to enter the System Parameters Menu.
3. Use **Next** and **Prev** to move through the system parameters.
4. Use the **Control Knob** to adjust the parameter value shown in **Display2** to the desired setting.
5. Press **Clear** to abandon the change and return to the original setting.
6. Depress the **Control Knob** or **Next** to save the displayed value and move to the next material parameter. Press **Clear** to abandon the change and return to the original setting.
7. Press **Program** to exit the System Parameters Menu and return to normal mode.



### System Parameters

<u>Display</u>	<u>Description</u>	<u>Range</u>	<u>Default</u>	<u>Units</u>
<b>TIMEBASE</b>	Time required for a measurement.	0.15 – 2.00	0.25	Sec.
<b>SIM MODE</b>	Simulates sensor inputs.	On/Off	Off	
<b>DISPLAY</b>	Toggles between Rate/Thickness in Angstroms, Rate/Thickness in Nanometers, Frequency, and Mass (ugm/cc) displays.	THCK/nAnM/ FREQ/MASS	Rate	
<b>RATE RES</b>	Sets rate resolution to .01 or .1 Å/s.	Hi/Low	Low	
<b>RATEFILT</b>	Number of rate readings averaged.	1 – 20	8	
<b>RELAY 3</b>	Timer causes relay to close when time setpoint is reached. Dual causes relay to close (to activate dual sensor) when sensor 1 fails. Sensor 2 causes relay to activate a sensor shutter when Sensor 2 is assigned to a film.	On/Off	Off	
<b>SAMPLING</b>	When Sampling is ON the sensor shutter periodically “samples” the rate. After a period, the shutter closes and the SQM-160 “holds” the same rate reading until the next sample period. Sample and Hold times are set in the Film Menu.	On/Off	Off	
<b>BAUDRATE</b>	Serial baud rate to PC.	2.4 – 19.2	19.2	kbps
<b>ETCH</b>	Sets rate negative for etching.	On/Off	Off	
<b>xTOOLING</b>	Tooling value assigned to each sensor. See the Sensor Tooling section of this chapter.	10 – 399	100	%
<b>RELAYS</b>	Assigns normally open or normally closed operation for each relay. <i>Note: All relays are open with power off.</i>	NO/NC	NO	

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<b>FMIN/MAX</b>	Sub-menu sets minimum and maximum crystal frequencies.	4.00 – 6.00	5.00	MHz
<b>R/T BNDS</b>	Rate and Thickness Bounds sub-menu.	4.10-6.10	6.10	
<b>RATE MIN</b>	Deposition Rate for zero output (zero Volts).	0 – 999	0	Å/s
<b>RATE MAX</b>	Deposition Rate for full scale output (+5 Volts).	9.9 – 999	100	Å/s
<b>THICKMIN</b>	Thickness for zero output (zero Volts).	0 – 99.99	0.00	kÅ
<b>THICKMAX</b>	Thickness for full scale output (+5 Volts).	0 – 99.99	1.00	kÅ

## 2.4 Sensor Selection

The SQM-160 comes standard with two sensor inputs. Four additional sensors are available by adding a Sensor Option Card. A specific sensor can each be assigned to each film, or multiple sensors can be averaged for a film. The averaging option provides more uniform coverage of the deposition area, and provides a backup sensor capability. If one of multiple sensors assigned to a film fails, the sensor is automatically removed from rate/thickness calculations.

**Note:** *If Relay 3 Dual is selected in the System Menu, Sensors 1 and 2 are set up as a primary/secondary sensor pair. In that case, sensor averaging is disabled. See Section 2.11 for information on dual sensors.*

To assign a sensor, or sensors, to a film:

1. Press **Program** to enter Program mode.
2. Use the **Control Knob** to scroll to the desired Film # (1-9).
3. Depress the **Control Knob** or **Next** to enter the film parameters menu for the selected film.
4. Press **Next** until **SENS AVG** is shown.
5. Use the **Control Knob** to scroll through the sensors in **Display2**.
6. Depress the **Control Knob** to toggle the sensor on/off.

*Sensor status can be seen by observing the Crystal Status LEDs:*

*If the LED is not illuminated, the crystal is disabled.*

*If the LED is illuminated, the crystal is enabled and receiving valid readings.*

*If the LED is blinking, the crystal is enabled, but is not receiving valid readings.*

7. Continue selecting sensors until the Crystal Status LEDs indicate the desired setup.
8. Press **Program** to exit the Film Parameters Menu and return to normal mode.
9. Turn the **Control Knob** to sequence through each sensor's reading on **Display1**.  
When a single number is shown in **Display2**, it is the sensor number whose readings are shown in **Display1**. When time is shown in **Display2**, **Display1** shows the average of all assigned sensors.

## 2.5 Sensor Frequency

The Sensor Min/Max frequencies establish the operating range for the sensing quartz crystals. Both values are used to determine the % life that is displayed in Xtal Life mode.

When the sensor frequency drops below the minimum, the SQM-160 indicates a sensor failure by blinking the Crystal Status display.

To set sensor minimum and maximum frequencies:

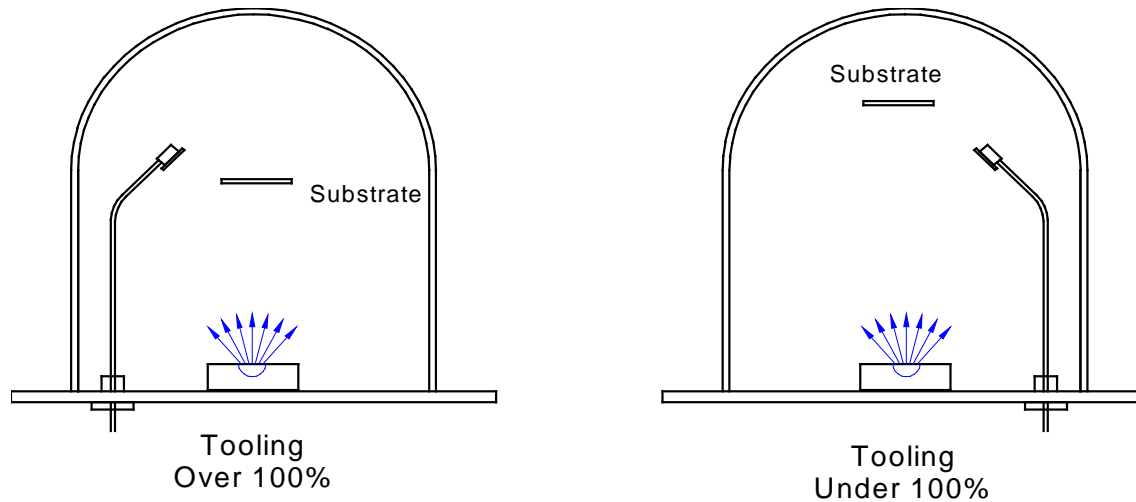
1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **FMIN/FMAX** is shown.
4. Depress the **Control Knob** to display **FREQ MIN**.
5. Adjust the **Control Knob** to the desired minimum operating frequency on **Display2**.
6. Depress the **Control Knob** to accept the minimum value and display **FREQ MAX**.
7. Adjust the **Control Knob** to the desired maximum operating frequency on **Display2**.
8. Depress the **Control Knob** to accept the maximum value.
9. Press **Program** to exit the System Parameters Menu and return to normal mode.

Crystals sometimes fail unexpectedly, or exhibit erratic frequency shifts (mode hopping) before total failure. Depending on the material, crystals may fail well before the typical 5 MHz value. If you find that crystals fail early consistently, set FREQ MIN to a value higher than 5 MHz to provide a Crystal Life warning before actual failure.

A sensor whose initial value exceeds the maximum will also cause a blinking Crystal status. You can set the maximum frequency slightly above the nominal values with no effect on accuracy.

## 2.6 Sensor Tooling

Sensor Tooling adjusts for the difference in deposition rate between the sensor and the substrate being coated. It is an empirically determined value that matches the sensor readings to your vacuum system.



**xTooling** is set in the System Parameters menu. It adjusts the tooling for each individual sensor before it is averaged. xTooling for a sensor applies to all films. If the individual sensor xToolings are set properly, a sensor failure will not cause a jump in the average Rate and Thickness reading.

To adjust xTooling:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **xTOOLING** is shown, then press the **Control Knob**.
4. Adjust the **Control Knob** to set the **xTLTOOL 1** value. Depress the **Control Knob** to save the value and move to **xTLTOOL 2**.
5. Repeat Step 4 for each of the installed sensors.
6. Press **Program** to exit the System Parameters menu and return to normal mode.

**Film Tooling** is set in the Film Parameters Menu, and is applied to the averaged Rate and Thickness for all sensors assigned to that film. Film Tooling is a film-specific value, and is seldom required.

## 2.7 Display Units

The SQM-160 can display crystal measurements in several different units. To select the display units:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **DSP.....** is shown.
4. Turn the **Control Knob** left or right to select the desired display mode:
  - THCK - Rate in A/s, Thickness in kA
  - nAnM - Rate in nM/s, Thickness in uM
  - MASS - Rate in ng/cc/s, Thickness in ng (nanograms)
  - FREQ – Frequency in Hz

**Note:** When Nanometers is selected a small “n” appears between the rate and thickness displays. When Mass is selected a small “m” appears between the rate and thickness displays.

5. Depress the **Control Knob** to accept your choice.
6. Press **Program** to exit the System Parameters menu and return to normal mode.

## 2.8 Crystal Life

The SQM-160 calculates the remaining crystal life based on the FMin/Max values set in the System Parameters Menu (see Section 2.5).

To display the remaining crystal life for the sensors used by the currently active film:

1. Press the **Xtal Life** switch in the front panel Control section.
2. The sensor is shown in **Display 1** and the % remaining life is shown in **Display2**.
3. Turn the **Control Knob** to display the % life of other sensors active for this film.
4. Press **Xtal Life** again to return to normal rate/thickness, or frequency display.

**Note:** You cannot enter program mode while the crystal life display is active.

## 2.9 Zero Thickness

Before starting each film deposition, you will probably want to reset the SQM-160 Thickness value to zero. To zero Thickness:

1. Press the **Zero** switch in the front panel Control section.

*In addition to zeroing Thickness, pressing the Zero switch has these effects:*

1. *The Time display is reset to its programmed value, and starts counting down.*
2. *The Thickness Setpoint and Timer relays open.*
3. *The Time SP, Thk SP, and Final Thk LEDs turn off.*

## 2.10 Shutter Operation

The SQM-160 Shutter switch controls a relay that is normally connected to the source shutter.

To open or close the Shutter relay:

1. Press the **Shutter** switch in the front panel Control section.

*The Open and Closed LEDs illuminate to indicate the shutter status.*

**Note:** *If Relay 3 is set to Sensor 2 in System Menu, the operation of the Shutter switch/relay changes slightly. In this case, the shutter relay will activate only if Sensor 1 is assigned to the active film. If sensor 2 is assigned to the active film, Relay 3 will close instead.*

## 2.11 Dual Sensors

Dual shuttered sensors provide a backup (secondary) sensor in case of primary sensor failure. When Relay 3 is programmed for Dual sensors in the System menu, the SQM-160 will automatically switch to Sensor 2 when Sensor 1 readings stop or become erratic.

To program the SQM-160 for dual sensors:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **RELAY 3** is shown.
4. Turn the **Control Knob** right to select DUAL sensor function.
5. Depress the **Control Knob** to accept the value.
6. Press **Program** to exit the System Parameters menu and return to normal mode.
7. In the film menu, assign only Sensor 1 to the film. The backup sensor 2 is automatically assigned internally.

**Note:** Relay 3 is a multi-function relay. It can be programmed as a dual sensor shutter, or to close when a programmed time has elapsed, or as a sensor 2 shutter relay. Section 2.10 and 2.13 discuss the other Relay 3 functions.

## 2.12 Rate Sampling

In Rate Sampling mode, the SQM-160 opens a sensor shutter for a fixed time to “sample” the process rate, then closes the shutter and “holds” the last rate reading for a fixed time. While the shutter is closed (hold mode), the SQM-160 calculates thickness based on the last sampled rate.

**Note:** *Rate sampling can significantly extend crystal life in a high deposition rate process. However, unless the process is very stable, the thickness calculation during hold mode may be incorrect. Do not use rate sampling if your rate varies during deposition.*

To program the SQM-160 for Rate Sampling:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **SAMPLING** is shown.
4. Turn the **Control Knob** right to turn ON rate sampling. Depress the **Control Knob** to accept the value.
5. Press **Program** to exit the System Parameters menu and return to normal mode.
6. Press **Program** to re-enter Program mode.
7. Use the **Control Knob** to scroll to the desired Film # (1-9), then depress the **Control Knob** or **Next** to enter the film parameter menu for the selected film.
8. Press **Next** until **SAMPLE** is shown.
9. Use the **Control Knob** to set the sample time period. Depress the **Control Knob** to accept the sample value and display **HOLD**.
10. Use the **Control Knob** to set the hold time period. Depress the **Control Knob** to accept the Hold value.
11. Press **Program** to exit the Film Parameters menu and return to normal mode.

**Note:** *The rate sampling relay is a dual function relay. It can be programmed either to sample rate or to close when a programmed thickness is reached. Section 2.14 discusses the Thickness Setpoint function. Consult Appendix C for relay wiring.*

### 2.13 Time Setpoint

The Time Setpoint provides a convenient way to signal a timed event. The Time Setpoint closes a relay a programmed time period after the Zero switch is pushed.

To program the Time Setpoint:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **RELAY 3:** is shown.
4. Turn the **Control Knob** right to select TIME. Depress the **Control Knob** to accept the value.
5. Press **Program** to exit the System Parameters menu and return to normal mode.
6. Press **Program** to re-enter Program mode.
7. Use the **Control Knob** to scroll to the desired Film # (1-9), then depress the **Control Knob** or **Next** to enter the Film Parameter menu for the selected film.
8. Press **Next** until **TIME SET:** is shown.
9. Use the **Control Knob** to set the timer setpoint. Depress the **Control Knob** to accept the value.
10. Press **Program** to exit the Film Parameters menu and return to normal mode.

Press **Zero** to open the relay and begin counting down the Time Setpoint. When the time reaches zero, the Time SP LED illuminates and the relay closes.

**Note:** Relay 3 is a multi-function relay. It can be programmed as a dual sensor shutter, or to close when a programmed time has elapsed, or as a sensor 2 shutter relay. Section 2.10 and 2.11 discuss the other Relay 3 functions.

## 2.14 Thickness Setpoint

The Thickness Setpoint closes a relay when a programmed thickness is reached. This setpoint is independent from Final Thickness, which always closes the source shutter.

To program the Thickness Setpoint:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **SAMPLING** is shown.
4. Turn the **Control Knob** right to turn OFF the Sampling function. Depress the **Control Knob** to accept the value.
5. Press **Program** to exit the System Parameters menu and return to normal mode.
6. Press **Program** to re-enter Program mode.
7. Use the **Control Knob** to scroll to the desired Film # (1-9), then depress the **Control Knob** or **Next** to enter the Film Parameter menu for the selected film.
8. Press **Next** until **THK SET** is shown, not FINL THK.
9. Use the **Control Knob** to set the thickness setpoint. Depress the **Control Knob** to accept the value.
10. Press **Program** to exit the Film Parameters menu and return to normal mode.

When the Thickness Setpoint is reached, the Thk SP LED lights and the relay closes. You can use the **Zero** switch to open the relay and zero thickness at any time.

**Note:** *The Thickness Setpoint relay is a dual function relay. It can be programmed either to indicate a thickness, or to control a sensor shutter for rate sampling. Section 2.12 discusses the Rate Sampling function. Consult Appendix C for relay wiring.*

## 2.15 Simulate Mode

In Simulate mode, the SQM-160 simulates attached sensors. It is an easy way to become familiar with the SQM-160 front panel controls and programming. You can open/close the shutter to simulate deposition, zero readings, and display crystal life. You can also test the Time and Thickness setpoint relays and LEDs.

To enter Simulate mode:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **SIM MODE** is shown.
4. Turn the **Control Knob** left or right to enable and disable Simulate mode.
5. Depress the **Control Knob** to accept the value.
6. Press **Program** to exit the System Parameters menu and return to normal mode.

## 2.16 Relay Operation

The four relays of the SQM-160 are physically single-pole, normally-open (1FormA) relays. However, each can be programmed to act as either normally-open or normally-closed during SQM-160 operation. It is important to keep in mind that all relays will open if the SQM-160 is turned off or loses power. Consult Appendix C for relay wiring.

To set the relay operating mode:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Press **Next** until **RELAYS** is shown.
4. Turn the **Control Knob** left or right to select NO (normally open) or NC (normally closed). Depress the **Control Knob** to accept the value.
5. Repeat Step 4 for each of the installed sensors.
6. Press **Program** to exit the System Parameters menu and return to normal mode.

## 2.17 Analog Output Configuration

The SQM-160 System Parameters must be set to match the device that will be attached to the Rate or Thickness output.

To set up the analog outputs in the System Parameters menu:

1. Press **Program** to enter Program mode.
2. Press **Prev** to enter the System Parameters menu.
3. Use **Next** to move through the system parameters until **R/T BNDS** is displayed.
4. Depress the **Control Knob** to display **RATE MIN**.
5. Adjust the **Control Knob** to the Rate desired for a 0V output.
6. Depress the **Control Knob** to save the value and display the **RATE MAX** setting.
7. Adjust the **Control Knob** to the Rate desired for a 5V output.
8. Depress the **Control Knob** to save the value and display the **THICK MIN** setting.
9. Repeat steps 5-8 to adjust the Thickness output values.
10. Press **Program** to exit the System Parameters menu and return to normal mode.

Refer to System Parameters Setup in Chapter 2 for more information on setting SQM-160 System Parameters.

## 2.18 Troubleshooting

Most SQM-160 problems are caused by defective crystals or improper film setup. Follow the procedures below to identify and correct common problems.

### **No Reading, or Erratic Readings from Sensors:**

First, replace the quartz crystal. Crystals sometimes fail unexpectedly, or exhibit erratic frequency shifts (mode hopping) before total failure. Depending on the material, crystals may fail well before the typical 5 MHz value. If you find that crystals consistently fail early, you may want to set Freq Min to a value higher than 5 MHz.

Verify that the sensors, oscillator and cabling are connected as shown in Section 1.4.

Next, in the System Menu, assure that Sim Mode is OFF, Dsp Freq is ON, and F Min/Max are set properly (typically Freq Min=5.0 MHz, Freq Max=6.0 MHz).

FMIN: \_\_\_\_\_ FMAX: \_\_\_\_\_

In the Film menu, assure that Sens Avg is set for the proper inputs. When an input is selected, its LED will be on (crystal OK) or blinking (crystal defective). Record the LED state (on/off/blinking) below:

INPUT 1: \_\_\_\_\_ INPUT 2: \_\_\_\_\_

While not depositing, observe the frequency display for each active sensor. The value should be stable, between Freq Min and Freq Max.

FREQ 1: \_\_\_\_\_ FREQ 2: \_\_\_\_\_

If the sensor reading is outside the frequency limits: Replace the crystal, or reprogram the Freq Min/Max values.

If the sensor reading is zero or unstable: Recheck the wiring from the sensor to the SQM-160, and verify that the SQM-160 is properly grounded. Especially check that the quartz crystal is properly seated in the sensor head. Try a different SQM-160 input. If both SQM-160 inputs show zero or unstable readings, the problem is almost certainly a wiring or sensor problem.

If the problem is not corrected: Referring to Section 1.4, disconnect the 6" BNC cable from the external oscillator module. A 5.5 MHz test crystal and BNC barrel adapter is supplied with each SQM-160. Attach the test crystal to the oscillator Sensor connector. The display should read about 5.5 MHz, very stable. If not, contact Sigma Instruments technical support. Test all SQM-160 inputs.

FREQ 1: \_\_\_\_\_ FREQ 2: \_\_\_\_\_

When the frequency reading is stable, start the deposition process. As material is deposited on the crystal, the frequency reading should drop steadily. If not, check your source supply for erratic output. Also assure that the sensor is not too close to the source (particularly in sputtering).

### **Incorrect Rate or Thickness Measurement:**

First complete the procedures in Section 2.14 to assure accurate frequency readings.

Set the System Menu xTooling as described in Section 2.6. Incorrect xTooling values will cause consistently low or high rate/thickness values for every material.

Once the System menu xTooling is set, set Tooling in the Film menu to 100 unless you are certain that another value is needed for a specific film.

Verify that the Density and Z-Factor values match those in the Materials Parameters Appendix. If the material is not listed, check a materials handbook. Density has a significant effect on rate/thickness calculations.

Z-Factor corrects for stresses as a crystal is coated. If accuracy deteriorates as crystals are used, verify the Z-Factor. The relationship between Z-Factor and Acoustic Impedance is discussed in the Materials Appendix.



### 3.0 Introduction

There are three options available for the SQM-160: the Four-Sensor Card (P/N 502-062), the Half-Rack Adapter (P/N 900-014), and the Full Rack Extender (P/N 900-008).

### 3.1 Option Card Installation

The SQM-160 motherboard has a 36-pin header to accommodate the optional Four-Sensor Card. The Four-Sensor Card expands the SQM-160 inputs to a total of six quartz crystal sensors.

**WARNING:** Hazardous voltages are present inside the SQM-160 when it is connected to a power source. Remove the power cable before opening the case to install the option card.

Remove Top Cover	Use a #1 Phillips screwdriver to remove the eight screws that attach the top cover to the chassis. Remove the top cover.
Remove Option Cover Plate	Use a #1 Phillips screwdriver to remove the two 4-40 back panel screws that secure the option cover plate. Remove the option cover plate.
Insert Option Card	Insert the option card's BNC connectors, <u>from the inside</u> , through the rear panel openings. Align the 36-pin option card connector with the mating pins on the main board, then press the option card connector onto the main board pins.
Secure Option Card	Secure the option card by installing the supplied four nuts on the BNC connectors.
Replace Top Cover	Replace the top cover and attach it to the chassis with the eight screws from Step 1.

### 3.2 Four-Sensor Card Configuration

The SQM-160 automatically detects the presence of the Four-Sensor Card.

Refer to System Connections in Chapter 1 for sensor hookup information.

Refer to Sensor Selection in Chapter 2 to assign the sensors to a film.

### 3.3 Rack Installation

The Half Rack Adapter kit (PN 900-014) mounts one SQM-160 on one side of a standard 19" equipment rack. It consists of one rack-mount ear and two 10-32 flat head screws for attaching the ear to the unit. (The other half of the 3½" high rack space is empty, allowing the mounting of another half-rack piece of equipment next to the SQM-160, if desired.)

The Full Rack Extender option (PN 900-008) mounts a single SQM-160 into a full-width 19" rack space. Follow the steps below to assemble the extender and mount the SQM-160:

Remove SQM-160 Mounting Ear	Determine on which side of the SQM-160 you want to attach the rack extender. If a rack-mount ear is already attached to the SQM-160 on that side, remove the two 10-32 flat head screws that mount the ear and remove the rack-mount ear.
Assemble the Extender	Assemble the extender "box" using the eight 6-32 flat head screws, two end panels, and two main panels. Thread two socket head captive panel screws from the inside of one side of the extender. Continue to thread the captive screws until their threads are completely exposed on one side.
Attach the Extender	Place the extender next to the SQM-160, and thread the captive screws into the SQM-160 threaded holes that were previously used to mount the rack ear. Tighten the captive screws to secure the extender to the SQM-160.
Attach the Mounting Ears	Attach the mounting ear previously removed from the SQM-160 to the extender using the same 10-32 flat head screws. If a rack-mount ear is not already attached to the SQM-160, attach it also.
Mount the SQM-160	Slide the entire assembly into an empty 3½" high 19" rack-mount space. Secure the assembly with four rack screws (not supplied).



### 4.0 Introduction

**WARNING:** There are no adjustments or user-serviceable parts inside the SQM-160.  
For maintenance or repair, contact

Sigma Instruments  
120 Commerce Drive, Unit 1  
Fort Collins, CO 80524 USA  
970-416-9660

### 4.1 Cleaning

Use a damp cloth, wetted with water or a mild detergent, to clean the outer surfaces.



## A. Material Parameters

In the table below, an \* is used to indicate that the material's Z Factor is not known. A method of determining Z Factor empirically follows the materials table.

Formula	Density	Z-Ratio	Material Name
Ag	10.500	0.529	Silver
AgBr	6.470	1.180	Silver Bromide
AgCl	5.560	1.320	Silver Chloride
Al	2.700	1.080	Aluminum
Al <sub>2</sub> O <sub>3</sub>	3.970	0.336	Aluminum Oxide
Al <sub>4</sub> C <sub>3</sub>	2.360	*1.000	Aluminum Carbide
AlF <sub>3</sub>	3.070	*1.000	Aluminum Fluoride
AlN	3.260	*1.000	Aluminum Nitride
AlSb	4.360	0.743	Aluminum Antimonide
As	5.730	0.966	Arsenic
As <sub>2</sub> Se <sub>3</sub>	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B <sub>2</sub> O <sub>3</sub>	1.820	*1.000	Boron Oxide
B <sub>4</sub> C	2.370	*1.000	Boron Carbide
BN	1.860	*1.000	Boron Nitride
Ba	3.500	2.100	Barium
BaF <sub>2</sub>	4.886	0.793	Barium Fluoride
BaN <sub>2</sub> O <sub>6</sub>	3.244	1.261	Barium Nitrate
BaO	5.720	*1.000	Barium Oxide
BaTiO <sub>3</sub>	5.999	0.464	Barium Titanate (Tetr)
BaTiO <sub>3</sub>	6.035	0.412	Barium Titanate (Cubic)
Be	1.850	0.543	Beryllium
BeF <sub>2</sub>	1.990	*1.000	Beryllium Fluoride
BeO	3.010	*1.000	Beryllium Oxide
Bi	9.800	0.790	Bismuth
Bi <sub>2</sub> O <sub>3</sub>	8.900	*1.000	Bismuth Oxide
Bi <sub>2</sub> S <sub>3</sub>	7.390	*1.000	Bismuth Trisulfide
Bi <sub>2</sub> Se <sub>3</sub>	6.820	*1.000	Bismuth Selenide
Bi <sub>2</sub> Te <sub>3</sub>	7.700	*1.000	Bismuth Telluride
BiF <sub>3</sub>	5.320	*1.000	Bismuth Fluoride
C	2.250	3.260	Carbon (Graphite)
C	3.520	0.220	Carbon (Diamond)
C <sub>8</sub> H <sub>8</sub>	1.100	*1.000	Parlyene (Union Carbide)

## Appendix

Formula	Density	Z-Ratio	Material Name
Ca	1.550	2.620	Calcium
CaF <sub>2</sub>	3.180	0.775	Calcium Fluoride
CaO	3.350	*1.000	Calcium Oxide
CaO-SiO <sub>2</sub>	2.900	*1.000	Calcium Silicate (3)
CaSO <sub>4</sub>	2.962	0.955	Calcium Sulfate
CaTiO <sub>3</sub>	4.100	*10~	Calcium Titanate
CaWO <sub>4</sub>	6.060	*1.000	Calcium Tungstate
Cd	8.640	0.682	Cadmium
CdF <sub>2</sub>	6.640	*1.000	Cadmium Fluoride
CdO	8.150	*1.000	Cadmium Oxide
CdS	4.830	1.020	Cadmium Sulfide
CdSe	5.810	*1.000	Cadmium Selenide,
CdTe	6.200	0.980	Cadmium Telluride
Ce	6.780	*1.000	Cerium
CeF <sub>3</sub>	6.160	*1.000	Cerium (III) Fluoride
CeO <sub>2</sub>	7.130	*1.000	Cerium (IV) Dioxide
Co	8.900	0.343	Cobalt
CoO	6.440	0.412	Cobalt Oxide
Cr	7.200	0.305	Chromium
Cr <sub>2</sub> O <sub>3</sub>	5.210	*1.000	Chromium (III) Oxide
Cr <sub>3</sub> C <sub>2</sub>	6.680	*1.000	Chromium Carbide
CrB	6.170	*1.000	Chromium Boride
Cs	1.870	*1.000	Cesium
Cs <sub>2</sub> SO <sub>4</sub>	4.243	1.212	Cesium Sulfate
CsBr	4.456	1.410	Cesium Bromide
CsCl	3.988	1.399	Cesium Chloride
CsI	4.516	1.542	Cesium Iodide
Cu	8.930	0.437	Copper
Cu <sub>2</sub> O	6.000	*1.000	Copper Oxide
Cu <sub>2</sub> S	5.600	0.690	Copper (I) Sulfide (Alpha)
Cu <sub>2</sub> S	5.800	0.670	Copper (I) Sulfide (Beta)
CuS	4.600	0.820	Copper (II) Sulfide
Dy	8.550	0.600	Dysprosium
Dy <sub>2</sub> O <sub>3</sub>	7.810	*1.000	Dysprosium Oxide
Er	9.050	0.740	Erbium
Er <sub>2</sub> O <sub>3</sub>	8.640	*1.000	Erbium Oxide
Eu	5.260	*1.000	Europium
EuF <sub>2</sub>	6.500	*1.000	Europium Fluoride

## Appendix

Formula	Density	Z-Ratio	Material Name
Fe	7.860	0.349	Iron
Fe <sub>2</sub> O <sub>3</sub>	5.240	*1.000	Iron Oxide
FeO	5.700	*1.000	Iron Oxide
FeS	4.840	*1.000	Iron Sulphide
Ga	5.930	0.593	Gallium
Ga <sub>2</sub> O <sub>3</sub>	5.880	*1.000	Gallium Oxide (B)
GaAs	5.310	1.590	Gallium Arsenide
GaN	6.100	*1.000	Gallium Nitride
GaP	4.100	*1.000	Gallium Phosphide
GaSb	5.600	*1.000	Gallium Antimonide
Gd	7.890	0.670	Gadolinium
Gd <sub>2</sub> O <sub>3</sub>	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium
Ge <sub>3</sub> N <sub>2</sub>	5.200	*1.000	Germanium Nitride
GeO <sub>2</sub>	6.240	*1.000	Germanium Oxide
GeTe	6.200	*1.000	Germanium Telluride
Hf	13.090	0.360	Hafnium
HfB <sub>2</sub>	10.500	*1.000	Hafnium Boride,
HfC	12.200	*1.000	Hafnium Carbide
HfN	13.800	*1.000	Hafnium Nitride
HfO <sub>2</sub>	9.680	*1.000	Hafnium Oxide
HfSi <sub>2</sub>	7.200	*1.000	Hafnium Silicide
Hg	13.460	0.740	Mercury
Ho	8.800	0.580	Holmium
Ho <sub>2</sub> O <sub>3</sub>	8.410	*1.000	Holmium Oxide
In	7.300	0.841	Indium
In <sub>2</sub> O <sub>3</sub>	7.180	*1.000	Indium Sesquioxide
In <sub>2</sub> Se <sub>3</sub>	5.700	*1.000	Indium Selenide
In <sub>2</sub> Te <sub>3</sub>	5.800	*1.000	Indium Telluride
InAs	5.700	*1.000	Indium Arsenide
InP	4.800	*1.000	Indium Phosphide
InSb	5.760	0.769	Indium Antimonide
Ir	22.400	0.129	Iridium
K	0.860	10.189	Potassium
KBr	2.750	1.893	Potassium Bromide
KCl	1.980	2.050	Potassium Chloride
KF	2.480	*1.000	Potassium Fluoride
KI	3.128	2.077	Potassium Iodide

## Appendix

Formula	Density	Z-Ratio	Material Name
La	6.170	0.920	Lanthanum
La <sub>2</sub> O <sub>3</sub>	6.510	*1.000	Lanthanum Oxide
LaB <sub>6</sub>	2.610	*1.000	Lanthanum Boride
LaF <sub>3</sub>	5.940	*1.000	Lanthanum Fluoride
Li	0.530	5.900	Lithium
LiBr	3.470	1.230	Lithium Bromide
LiF	2.638	0.778	Lithium Fluoride
LiNbO <sub>3</sub>	4.700	0.463	Lithium Niobate
Lu	9.840	*1.000	Lutetium
Mg	1.740	1.610	Magnesium
MgAl <sub>2</sub> O <sub>4</sub>	3.600	*1.000	Magnesium Aluminate
MgAl <sub>2</sub> O <sub>6</sub>	8.000	*1.000	Spinel
MgF <sub>2</sub>	3.180	0.637	Magnesium Fluoride
MgO	3.580	0.411	Magnesium Oxide
Mn	7.200	0.377	Manganese
MnO	5.390	0.467	Manganese Oxide
MnS	3.990	0.940	Manganese (II) Sulfide
Mo	10.200	0.257	Molybdenum
Mo <sub>2</sub> C	9.180	*1.000	Molybdenum Carbide
MoB <sub>2</sub>	7.120	*1.000	Molybdenum Boride
MoO <sub>3</sub>	4.700	*1.000	Molybdenum Trioxide
MoS <sub>2</sub>	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na <sub>3</sub> AlF <sub>6</sub>	2.900	*1.000	Cryolite
Na <sub>5</sub> Al <sub>3</sub> F <sub>14</sub>	2.900	*1.000	Chiolite
NaBr	3.200	*1.000	Sodium Bromide
NaCl	2.170	1.570	Sodium Chloride
NaClO <sub>3</sub>	2.164	1.565	Sodium Chlorate
NaF	2.558	0.949	Sodium Fluoride
NaNO <sub>3</sub>	2.270	1.194	Sodium Nitrate
Nb	8.578	0.492	Niobium (Columbium)
Nb <sub>2</sub> O <sub>3</sub>	7.500	*1.000	Niobium Trioxide
Nb <sub>2</sub> O <sub>5</sub>	4.470	*1.000	Niobium (V) Oxide
NbB <sub>2</sub>	6.970	*1.000	Niobium Boride
NbC	7.820	*1.000	Niobium Carbide
NbN	8.400	*1.000	Niobium Nitride
Nd	7.000	*1.000	Neodymium
Nd <sub>2</sub> O <sub>3</sub>	7.240	*1.000	Neodymium Oxide
NdF <sub>3</sub>	6.506	*1.000	Neodymium Fluoride

## Appendix

Formula	Density	Z-Ratio	Material Name
Ni	8910	0.331	Nickel
NiCr	8.500	*1.000	Nichrome
NiCrFe	8.500	*10~	Inconel
NiFe	8.700	*1.000	Permalloy
NiFeMo	8.900	*10~	Supermalloy
NiO	7.450	*1.000	Nickel Oxide
P <sub>3</sub> N <sub>5</sub>	2.510	*1.000	Phosphorus Nitride
Pb	11.300	1.130	Lead
PbCl <sub>2</sub>	5.850	*1.000	Lead Chloride
PbF <sub>2</sub>	8.240	0.661	Lead Fluoride
PbO	9.530	*1.000	Lead Oxide
PbS	7.500	0.566	Lead Sulfide
PbSe	8.100	*1.000	Lead Selenide
PbSnO <sub>3</sub>	8.100	*1.000	Lead Stannate
PbTe	8.160	0.651	Lead Telluride
Pd	12.038	0.357	Palladium
PdO	8.310	*1.000	Palladium Oxide
Po	9.400	*1.000	Polonium
Pr	6.780	*1.000	Praseodymium
Pr <sub>2</sub> O <sub>3</sub>	6.880	*1.000	Praseodymium Oxide
Pt	21.400	0.245	Platinum
PtO <sub>2</sub>	10.200	*1.000	Platinum Oxide
Ra	5.000	*1.000	Radium
Rb	1.530	2.540	Rubidium
RbI	3.550	*1.000	Rubidium Iodide
Re	21.040	0.150	Rhenium
Rh	12.410	0.210	Rhodium
Ru	12.362	0.182	Ruthenium
S <sub>8</sub>	2.070	2.290	Sulphur
Sb	6.620	0.768	Antimony
Sb <sub>2</sub> O <sub>3</sub>	5.200	*1.000	Antimony Trioxide
Sb <sub>2</sub> S <sub>3</sub>	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandium
Sc <sub>2</sub> O <sub>3</sub>	3.860	*1.000	Scandium Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si <sub>3</sub> N <sub>4</sub>	3.440	*1000	Silicon Nitride
SiC	3.220	*1.000	Silicon Carbide
SiO	2.130	0.870	Silicon (II) Oxide
SiO <sub>2</sub>	2.648	1.000	Silicon Dioxide

## Appendix

Formula	Density	Z-Ratio	Material Name
Sm	7.540	0.890	Samarium
Sm <sub>2</sub> O <sub>3</sub>	7.430	*1.000	Samarium Oxide
Sn	7.300	0.724	Tin
SnO <sub>2</sub>	6.950	*1.000	Tin Oxide
SnS	5.080	*1.000	Tin Sulfide
SnSe	6.180	*1.000	Tin Selenide
SnTe	6.440	*1.000	Tin Telluride
Sr	2.600	*1.000	Strontium
SrF <sub>2</sub>	4.277	0.727	Strontium Fluoride
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta <sub>2</sub> O <sub>5</sub>	8.200	0.300	Tantalum (V) Oxide
TaB <sub>2</sub>	11.150	*1.000	Tantalum Boride
TaC	13.900	*1.000	Tantalum Carbide
TaN	16.300	*1.000	Tantalum Nitride
Tb	8.270	0.660	Terbium
Tc	11.500	*1.000	Technetium
Te	6.250	0.900	Tellurium
TeO <sub>2</sub>	5.990	0.862	Tellurium Oxide
Th	11.694	0.484	Thorium
ThF <sub>4</sub>	6.320	*1.000	Thorium.(IV) Fluoride
ThO <sub>2</sub>	9.860	0.284	Thorium Dioxide
ThOF <sub>2</sub>	9.100	*1.000	Thorium Oxyfluoride
Ti	4.500	0.628	Titanium
Ti <sub>2</sub> O <sub>3</sub>	4.600	*1.000	Titanium Sesquioxide
TiB <sub>2</sub>	4.500	*1.000	Titanium Boride
TiC	4.930	*1.000	Titanium Carbide
TiN	5.430	*1.000	Titanium Nitride
TiO	4.900	*1.000	Titanium Oxide
TiO <sub>2</sub>	4.260	0.400	Titanium (IV) Oxide
Tl	11.850	1.550	Thallium
TlBr	7.560	*1.000	Thallium Bromide
TlCl	7.000	*1.000	Thallium Chloride
TlI	7.090	*1.000	Thallium Iodide (B)
U	19.050	0.238	Uranium
U <sub>3</sub> O <sub>8</sub>	8.300	*1.000	Tri Uranium Octoxide
U <sub>4</sub> O <sub>9</sub>	10.969	0.348	Uranium Oxide
UO <sub>2</sub>	10.970	0.286	Uranium Dioxide
V	5.960	0.530	Vanadium
V <sub>2</sub> O <sub>5</sub>	3.360	*1.000	Vanadium Pentoxide
VB <sub>2</sub>	5.100	*1.000	Vanadium Boride
VC	5.770	*1.000	Vanadium Carbide
VN	6.130	*1.000	Vanadium Nitride

## Appendix

Formula	Density	Z-Ratio	Material Name
VO <sub>2</sub>	4.340	*1.000	Vanadium Dioxide
W	19.300	0.163	Tungsten
WB <sub>2</sub>	10.770	*1.000	Tungsten Boride
WC	15.600	0.151	Tungsten Carbide
WO <sub>3</sub>	7.160	*1.000	Tungsten Trioxide
WS <sub>2</sub>	7.500	*1.000	Tungsten Disulphide
WSi <sub>2</sub>	9.400	*1.000	Tungsten Suicide
Y	4.340	0.835	Yttrium
Y <sub>2</sub> O <sub>3</sub>	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb <sub>2</sub> O <sub>3</sub>	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn <sub>3</sub> Sb <sub>2</sub>	6.300	*1.000	Zinc Antimonide
ZnF <sub>2</sub>	4.950	*1.000	Zinc Fluoride
ZnO	5.610	0.556	Zinc Oxide
ZnS	4.090	0.775	Zinc Sulfide
ZnSe	5.260	0.722	Zinc Selenide
ZnTe	6.340	0.770	Zinc Telluride
Zr	6.490	0.600	Zirconium
ZrB <sub>2</sub>	6.080	*1.000	Zirconium Boride
ZrC	6.730	0.264	Zirconium Carbide
ZrN	7.090	*1.000	Zirconium Nitride
ZrO <sub>2</sub>	5.600	*1.000	Zirconium Oxide

Z-Factor is used to match the acoustic properties of the material being deposited to the acoustic properties of the base quartz material of the sensor crystal.

$$\text{Z-Factor} = Z_q / Z_m$$

For example, the acoustic impedance of gold is  $Z=23.18$ , so:

$$\text{Gold Z-Factor} = 8.83 / 23.18 = .381$$

Unfortunately, Z Factor is not readily available for many materials. Z Factor can be calculated empirically using this method:

1. Deposit the material until Crystal Life is near 50%, or near the end of life, whichever is sooner.
2. Place a new substrate adjacent to the used quartz sensor.
3. Set QCM Density to the calibrated value; Tooling to 100%. Zero thickness.
4. Deposit approximately 1000 to 5000 Å of material on the substrate.
5. Use a profilometer or interferometer to measure the actual substrate film thickness.
6. Adjust the Z Factor of the instrument until the correct thickness reading is shown.

Another alternative is to change crystals frequently. For a crystal with 90% life, the error is negligible for even large errors in the programmed versus actual Z Factor.

## B. Specifications

### Measurement

Number of Sensors	2 standard, plus 4 optional
Sensor Frequency Range	4.0 MHz to 6.0 MHz
Reference Frequency Accuracy	.002%
Reference Frequency Stability	+/- 2ppm (total, 0 to 50°C)
Frequency Resolution*	.06 Hz @ 6 MHz
Rate Resolution*	.055 Å/s
Rate Display	.01 or .1 Å/s
Thickness Resolution*	.027 Å
Thickness Display	1 Å
*@ 2 readings/sec, Density=2.70 gm/cc	

### Film Parameters

Stored Films	9
Density	0.5 – 99.99 gm./cc
Tooling	10 – 399 %
Z-Factor	0.10 – 10.00
Final Thickness	0.000 – 99.99 kÅ
Thickness Setpoint	0.000 – 99.99 kÅ
Time Setpoint	0:00 – 99:59 mm:ss
Sample/Hold	0-9999 sec.
Sensor Average	Any combination of installed sensors

### System Parameters

Measurement Period	.15 to 2 sec.
Simulate Mode	On/Off
Frequency Mode	On/Off
Rate Resolution	.01/.1 Å/s
Measurement Filter	1 to 20 readings
Dual Crystal 1/2	On/Off
Rate Sampling	On/Off
RS-232 Baud Rate	2.4/4.8/9.6/19.2 kb/s
Etch Mode	On/Off
Crystal Tooling 1-6	10-399 %
Crystal Fail Min/Max	4.0 to 6.0 MHz / 4.1 to 6.1 MHz

**Digital I/O**Digital Inputs  
Functions4  
Open Shutter  
Close Shutter  
Zero Thickness  
Zero Time  
5VDC, non-isolated

Input Rating

Relay Outputs  
Functions4  
Shutter  
Sample/Hold or Thickness Setpoint  
Dual Sensor Shutter or Time Setpoint  
Crystal Fail

Relay Rating

30Vrms or 30VDC, 2A maximum

**General Specifications**

Mains Power Supply

100-120/200-240~, ±10% nominal  
50/60 Hz

Power Consumption

20W

Operating Environment

0°C to 50°C  
0 to 80% RH non-condensing  
0 to 2,000 meters  
Indoor Use Only  
Class 1 Equipment (Grounded Type)  
Suitable for Continuous Operation  
Ordinary Protection (not protected  
against harmful ingress of moisture)  
Pollution Degree 2  
Installation (Overvoltage) Category II  
for transient overvoltages

Storage Environment

-40°C to 70°C

Rack Dimensions (HxWxD)

88.5mm x 212.7mm x 196.9mm

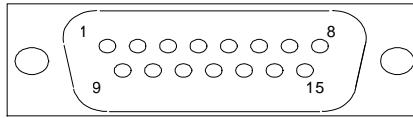
Weight

2.7 kg (6 pounds)

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## C. I/O Connections

A 15-pin female D-sub connector is included with the instrument to connect digital I/O to the SQM-160 Relay I/O connector. The figure below shows the solder-side pin assignments for the supplied connector.



**Relay I/O Connector Rear View**

<b>Pins</b>	<b>Function</b>	<b>Description</b>
1,2 Relay 4	Crystal Fail Relay	Contacts close when all enabled sensors have failed.
3,4 Relay 3	Time Setpoint, Dual Sensor or Sensor 2 Relay	If Relay 3 is set to TIME in the System menu, contacts close when timer counts down to zero from its programmed Timer Setpoint value. If DUAL is selected, contacts close when Sensor 1 fails. If SENS2 is selected, contacts close when shutter is pushed if Sensor 2 is programmed for the active film.
5,6 Relay 2	Shutter Relay	Controlled by front panel shutter switch. Contacts close when Shutter Open is selected. If SENS2 is selected for Relay 3 in the System menu, the shutter relay contacts close only if Sensor 1 is programmed for the active film.
7,8 Relay 1	Sampling or Thickness Setpoint	If Sampling is ON in System Menu, contacts close during Sample, open during Hold. If Sampling is OFF contacts close when Thickness Setpoint is reached.
9	Zero Timer Input	Grounding this pin zeroes the setpoint timer.
10	Zero Thick Input	Grounding this pin zeroes the thickness display.
11	Close Shutter Input	Grounding this pin opens the shutter relay.
12	Open Shutter Input	Grounding this pin closes the shutter relay.
13,14,15	Ground	

**WARNING:** The inputs are not isolated! The voltage level applied must be limited to between 0 and +5 volts with respect to Ground.

**WARNING:** Output relays are rated for 30Vrms or 30VDC, at 2A maximum. Proper fusing and adequate wiring insulation and separation should be provided to assure these limits are not exceeded.

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## **D. EC Declaration of Conformity**

**Manufacturer's Name:** Sigma Instruments

**Manufacturer's Address:** 120 Commerce Drive, Unit 1  
Fort Collins, CO 80524 USA

**declares that the product:**

**Product Name:** Rate/Thickness Monitor

**Product Model:** SQM-160

**Product Options:** All Options

**conforms to the following Directives:**

73/23/EEC (93/68/EEC)  
89/336/EEC

Low Voltage Directive  
Electromagnetic Compatibility Directive

**uses the following standards:**

EN 61010-1

EN 50081-2

EN 55011

EN 50082-2

EN 61000-4-2

EN 61000-4-3

EN 61000-4-4

EN 61000-4-6

ENV 50204

Safety of Electrical Equipment for

Measurement, Control, and Laboratory Use

Generic Standard for Emissions

Radiated and Conducted Emissions (Class A)

Generic Standard for Immunity

Electrostatic Discharge

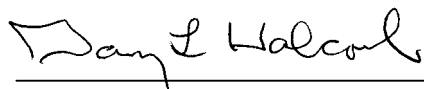
Radiated RF Electro-Magnetic Field

Electrical Fast Transient/Burst

Conducted RF

Radiated RF

And complies with the Essential Health and Safety Requirements.



Gary L. Halcomb    President

Fort Collins, Colorado, USA

January 2003

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