SQM-160

Rate/Thickness Monitor

User's Guide

Version 4.09

INFICON

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…Now part of INFICON 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.

Warranty Information

This INFICON product is warranted against defects in material and workmanship for a period of two (2) years from the date of shipment, when used in accordance with the instructions in this manual. During the warranty period, INFICON 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 INFICON BE LIABLE FOR CONSEQUENTIAL OR OTHER DAMAGES RESULTING FROM A BREACH OF THIS LIMITED WARRANTY, OR OTHERWISE.

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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

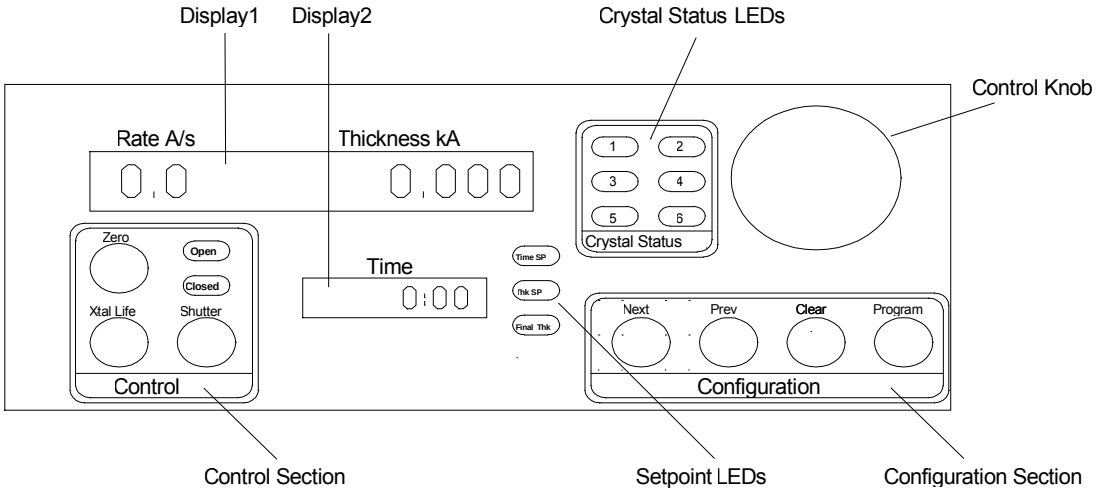
This section assumes you are familiar with thin-film monitors. Refer to Sections 1.3 and 1.4 for detailed system hookup information.

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

Rack Installation	The SQM-160 occupies a 3.5" high, half-rack space. Rack installation requires an optional 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	***WARNING***: 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). See section 1.4.
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™ Comm software with the SQM-160,see Appendix D.
Option Connections	If you have purchased the optional Four Sensor Card, connect the four additional sensors to these four inputs.

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

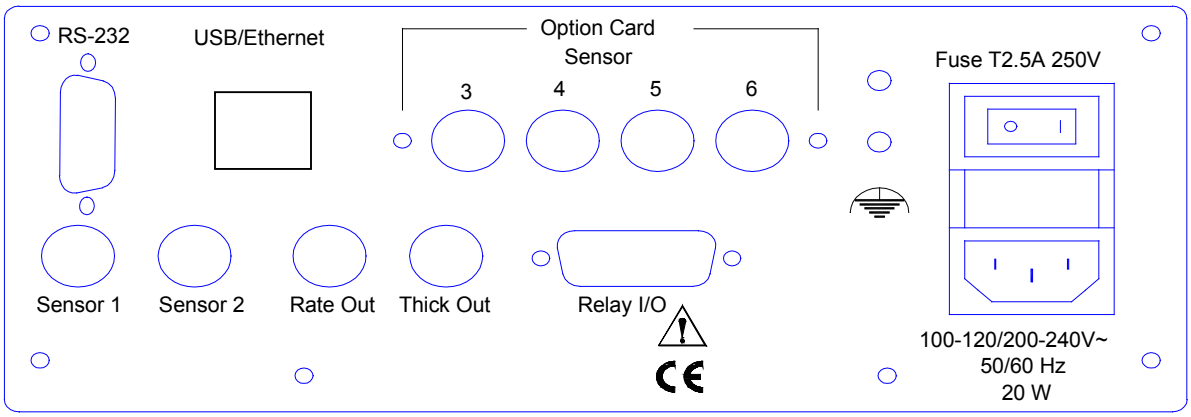
1.2 Front Panel



Front Panel Controls

Display 1	Displays rate/thickness or frequency in normal operation. If multiple sensors are being used, and Display shows Time, then this is the average of those sensors. Turn the Control Knob right to display each individual sensor's readings. Displays the setup parameter name in program mode.
Display 2	Displays deposition time, or the sensor # displayed on Display 1 when scrolling through sensor readings. Displays setup parameter values in program mode.
Control Section	Pushbutton to zero the thickness reading. Pushbutton to toggle display between Crystal Life and Rate/Thickness readings. Pushbutton to Open/Close shutter relay. Two LED shutter relay status display.
Configuration Section	Pushbutton to enter/exit program mode. Pushbutton to cancel a change and return to original value. Pushbuttons to move to Next/Previous parameter.
Setpoint LEDs	Illuminates when the indicated setpoint is reached.
Crystal Status LEDs	Illuminates when the crystal is active and operating properly. Flashes when an active crystal fails. Off when that crystal is not being used.
Control Knob	Used to adjust values or scroll though menu selections. Pushing the control knob stores the current setting.

1.3 Rear Panel



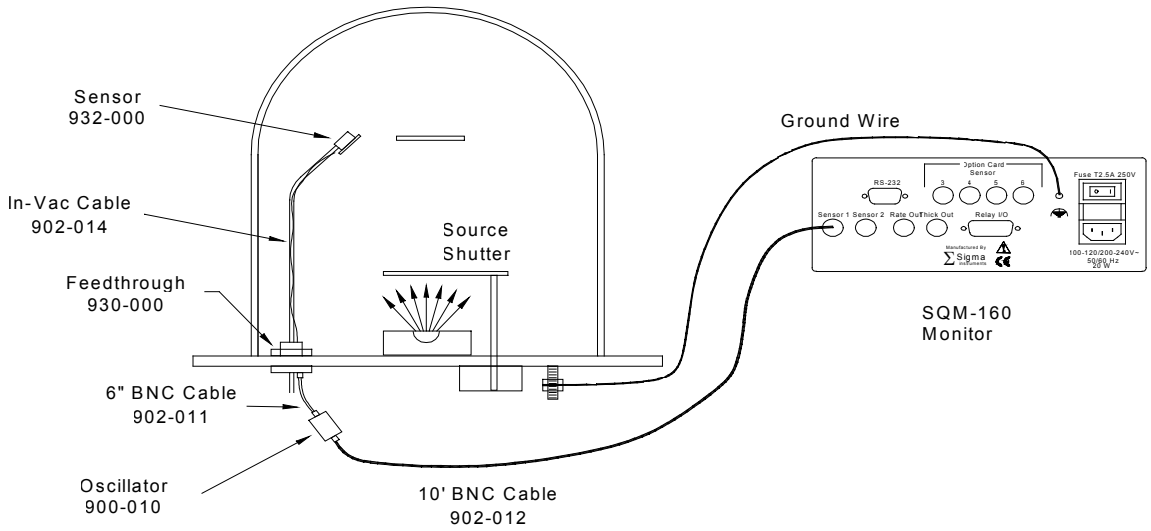
Rear Panel Connections

Sensor 1 & 2	Connection to quartz crystal sensors. See Section 1.4 for detailed hookup information.
Rate and Thick Outputs	Provides 0-5V analog outputs for Sensor 1 & 2 rate and thickness readings. For connection to strip chart recorders,etc.
Relay I/O	Connects 4 relays and 4 digital inputs to external devices. See Appendix C for connections.
RS-232	Connection to computer for programming and data acquisition. See Appendix D.
USB/Ethernet	Optional connection to computer USB or Ethernet port for programming and data acquisition. See Appendix D.
Option Card	Provides four additional sensor measurement channels.
	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	Microdot 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, preferably 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	Press Program to enter the film setup menu. If the Crystal Life display is shown, first press Xtal Life to return to Rate/Thickness mode then press Program.
Select a Film	Turn the Control Knob to select one of the 99 possible films, then press the Control Knob to enter that Film Menu.
Set Film Parameters	Turn the Control Knob to set the first film parameter (Density). The parameter value is shown in Display 2. Press the Control Knob to save the value and move to the next parameter. If you press Clear, the film parameter returns to its original value. Continue to set each parameter. Be sure to press the Control Knob to store each parameter. Press Program to exit Program mode and return to normal mode.
Set System Parameters	To Enter the System Menu, press Program, then Prev. Set system parameters by turning, then pushing, the Control Knob as described above. Press Program to return to Normal mode.

If the sensor(s) you selected during Film setup are connected properly to the SQM-160, the Crystal Status LEDs should be lit. If not, return to the Film Menu and set the Sensor Average parameter to the desired sensor(s). See Section 2.4 for detailed information on assigning sensors to a film.

If the Crystal Status LED is flashing, it is most likely that the 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. To use the test crystal, 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(s) is lit, and not blinking.
Display Rate/Thickness	Display 1 should be displaying Rate on the left and Thickness on the right. If the Crystal Life display mode is active, press the Xtal Life switch to return to Rate/Thickness mode. If the Program Mode is active, press Program 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

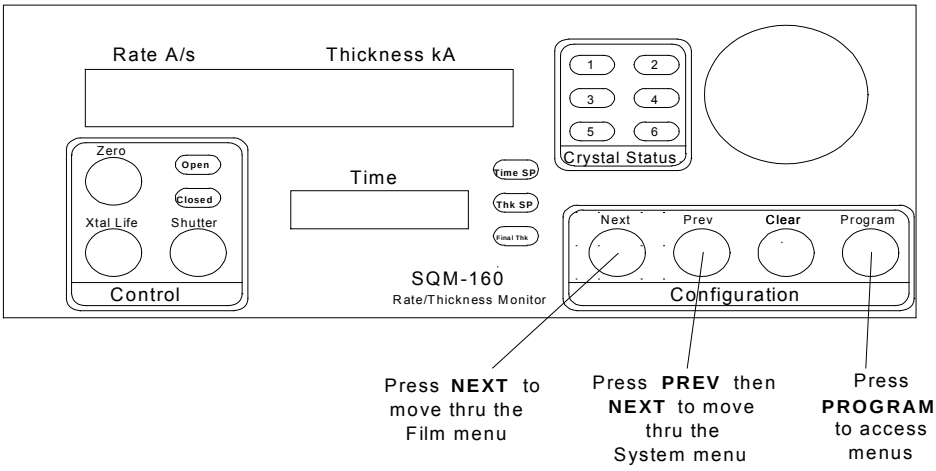
Two menus provide control of the SQM-160 programming. The Film Menu allows you to customize each of the stored films. The System Menu sets values that remain constant for all films.

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 normal rate/thickness or frequency display.*

To enter the Film Menu, press the Program switch. The SQM-160 displays the currently selected film. If desired, turn the control knob to select a different film. Press Next to display the first parameter for the selected film.

To enter the System Menu, press the Program switch. Then press Prev before any other switches.

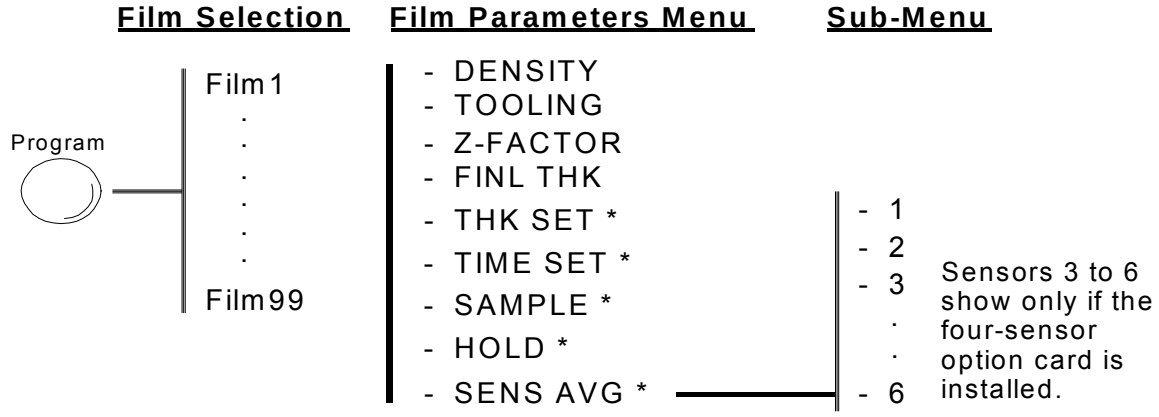


2.2 Film Menu

The Film Menu programs the SQM-160 for the materials that will be deposited as thin films. Ninety 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 # (1-99).
3. Depress the Control Knob or Next to enter the film parameters 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 Display2, 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 Menu and return to normal mode.

The diagram and table that follow detail the parameters available in the Film 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.*

***Note**: You can clear film memory by pressing Zero-XtalLife-Shutter while powering up the SQM-160.*

Film Menu

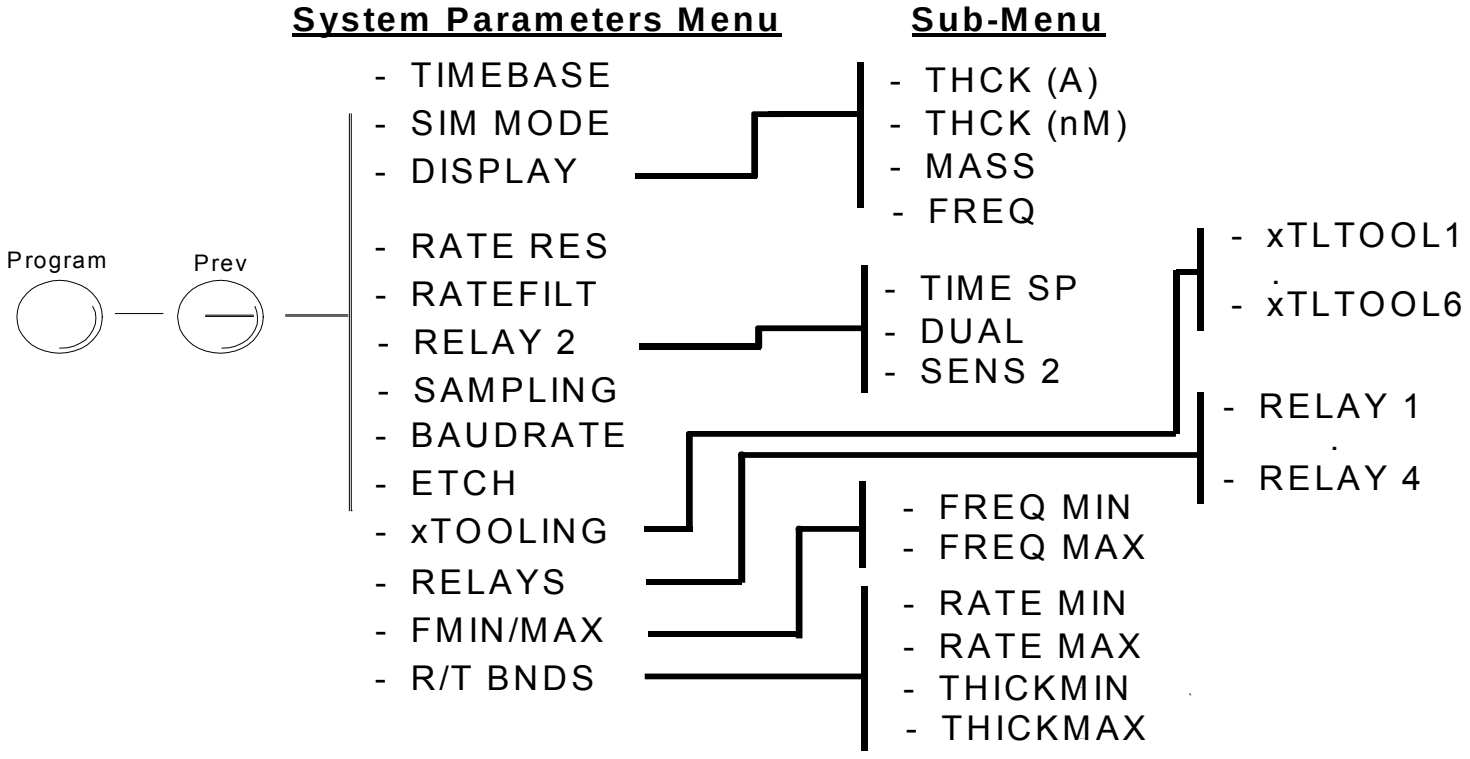
Display	Description	Range	Default	Units
DENSITY	Density of the material being deposited. Consult the Appendix for common material densities.	0.5 – 99.99	1.00	gm/cc
TOOLING	Overall Tooling Factor for this film. See the Sensor Tooling section of this chapter.	10 – 399	100	%
Z-FACTOR	Z-Factor of the material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

SENS AVG	Enable/disable crystals for this film. See the Sensor Selection section of this chapter. *Not available when Relay 2 is set to Dual in the System Menu.	Enabled/ Disabled	Ch1 Enabled

2.3 System Menu

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

1. Press Program to enter program mode.
2. Press Prev to enter the System 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 Menu and return to normal mode.



System Menu

Display	Description	Range	Default	Units
TIMEBASE	Time required for a measurement. Longer times yield higher accuracy.	0.15 – 2.00	0.25	Sec.
SIM MODE	Simulates sensor inputs.	On/Off	Off	
DISPLAY	Selects Rate/Thickness in Angstroms, Rate/Thickness in Nanometers, Frequency, or Mass (ugm/cc) display.	THCK/nAnM/ FREQ/MASS	Rate	
RATE RES	Sets rate resolution to .01 or .1 Å/s.	Hi/Low	Low	
RATEFILT	Number of rate readings averaged.	1 – 20	8	
RELAY 2	Select Timer to cause 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	Timer	
SAMPLING	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	
BAUDRATE	Serial baud rate to PC.	2.4 – 19.2	19.2	kbps
ETCH	Sets rate negative for etching.	On/Off	Off	
xTOOLING	Tooling value assigned to each sensor. See the Sensor Tooling section of this chapter.	10 – 399	100	%
RELAYS	Assigns normally open or normally closed operation for each relay. ***Note:*** *All relays are open with power off.*	NO/NC	NO	

FMIN/MAX	Sub-menu sets minimum and maximum crystal frequencies.	4.00 – 6.00 4.10-6.10	5.00 6.10	MHz
R/T BNDS	Rate and Thickness Bounds sub-menu for analog outputs.			
RATE MIN	Deposition Rate for zero output (zero Volts).	0 – 999	0	Å/s
RATE MAX	Deposition Rate for full scale output (+5 Volts).	9.9 – 999	100	Å/s
THICKMIN	Thickness for zero output (zero Volts).	0 – 99.99	0.00	kÅ
THICKMAX	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 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 2 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 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 Menu and return to normal mode.

9. Turn the Control Knob to sequence though 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 (or reads above the maximum), the SQM-160 indicates a sensor failure by blinking the Crystal Status display.

To set sensor minimum and maximum frequencies:

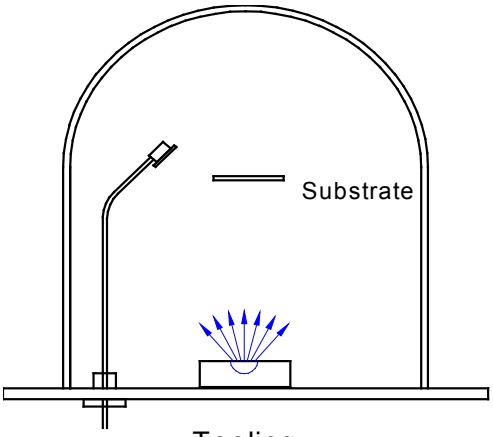
1. Press Program to enter Program mode.
2. Press Prev to enter the System Menu.
3. Press Next until FMIN/FMAX is shown.
4. Depress the Control Knob to display FREQ MIN.
5. Adjust the Control Knob to the desired minimum operating frequency on Display2.
6. Depress the Control Knob to accept the minimum 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 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 minimum. If you find that crystals fail early consistently, set FREQ MIN to a value higher than 5 MHz to provide a Crystal Life warning consistent with actual failure.

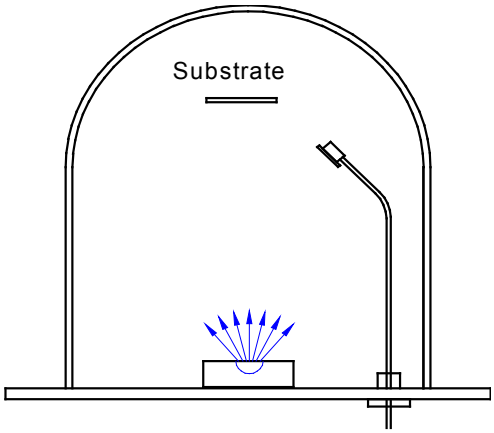
A sensor whose initial value exceeds the maximum will also cause a blinking Crystal status. You can set the maximum frequency slightly above the nominal values with no effect on accuracy.

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.



Tooling
Over 100%



Tooling
Under 100%

xTooling is set in the System 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 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 Menu and return to normal mode.

Film Tooling is set in the Film 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 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 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 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 2 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 2 will close instead.*

2.11 Dual Sensors

Dual shuttered sensors provide a backup (secondary) sensor in case of primary sensor failure. When Relay 2 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 Menu.

3. Press Next until RELAY 2: 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 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 2 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 2 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 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 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 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. After a pre-programmed time period, the Time Setpoint closes a relay when the Zero switch is pushed.

To program the Time Setpoint:

1. Press Program to enter Program mode.
2. Press Prev to enter the System Menu.
3. Press Next until RELAY 2 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 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 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 2 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 2 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 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 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 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 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 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 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 Menu and return to normal mode.

2.17 Analog Output Configuration

The SQM-160 analog outputs 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 Menu:

1. Press Program to enter Program mode.
2. Press Prev to enter the System 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 Menu and return to normal mode.

Refer to System Menu 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 5 MHz lower limit. 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 as described in Section 2.4. 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 within, say 1Hz..

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 sensor 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 oscillator. 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 Rack Mounting

The Full Rack Extender option (PN 900-008) mounts a single SQM-160 into a full-width 19” rack space. Follow these steps 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 same10-32 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).

The Half Rack Adapter kit (PN 900-014) mounts one SQM-160 to another 3½” high instrument. It consists of two rack-mount ears and a small adapter bracket. Mount one rack mount ear to the SQM-160, and the other to the second instrument. Attach the two instruments using the adapter bracket.

If you want to connect two SQM-160s side-by-side, contact INFICON for the best method in your installation.

4.0 Maintenance

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

INFICON
Two Technology Place
East Syracuse, New York
13057 USA
Tel +1.315.434.1100
Fax +1.315.437.3803

4.1 Cleaning

Use a soft cloth, moistened with water or a mild cleaner, 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_2O_3	3.970	0.336	Aluminum Oxide
Al_4C_3	2.360	*1.000	Aluminum Carbide
AlF_3	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_2Se_3	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B_2O_3	1.820	*1.000	Boron Oxide
B_4C	2.370	*1.000	Boron Carbide
BN	1.860	*1.000	Boron Nitride
Ba	3.500	2.100	Barium
BaF_2	4.886	0.793	Barium Fluoride
BaN_2O_6	3.244	1.261	Barium Nitrate
BaO	5.720	*1.000	Barium Oxide
$BaTiO_3$	5.999	0.464	Barium Titanate (Tetr)
$BaTiO_3$	6.035	0.412	Barium Titanate (Cubic)
Be	1.850	0.543	Beryllium
BeF_2	1.990	*1.000	Beryllium Fluoride
BeO	3.010	*1.000	Beryllium Oxide
Bi	9.800	0.790	Bismuth
Bi_2O_3	8.900	*1.000	Bismuth Oxide
Bi_2S_3	7.390	*1.000	Bismuth Trisuiphide
Bi_2Se_3	6.820	*1.000	Bismuth Selenide
Bi_2Te_3	7.700	*1.000	Bismuth Telluride
BiF_3	5.320	*1.000	Bismuth Fluoride
C	2.250	3.260	Carbon (Graphite)
C	3.520	0.220	Carbon (Diamond)
C_8H_8	1.100	*1.000	Parlyene (Union Carbide)

Formula	Density	Z-Ratio	Material Name
Ca	1.550	2.620	Calcium
CaF_2	3.180	0.775	Calcium Fluoride
CaO	3.350	*1.000	Calcium Oxide
$CaO\text{-}SiO_2$	2.900	*1.000	Calcium Silicate (3)
$CaSO_4$	2.962	0.955	Calcium Sulfate
$CaTiO_3$	4.100	*10~	Calcium Titanate
$CaWO_4$	6.060	*1.000	Calcium Tungstate
Cd	8.640	0.682	Cadmium
CdF_2	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_3	6.160	*1.000	Cerium (III) Fluoride
CeO_2	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_2O_3	5.210	*1.000	Chromium (III) Oxide
Cr_3C_2	6.680	*1.000	Chromium Carbide
CrB	6.170	*1.000	Chromium Boride
Cs	1.870	*1.000	Cesium
Cs_2SO_4	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_2O	6.000	*1.000	Copper Oxide
Cu_2S	5.600	0.690	Copper (I) Sulfide (Alpha)
Cu_2S	5.800	0.670	Copper (I) Sulfide (Beta)
CuS	4.600	0.820	Copper (II) Sulfide
Dy	8.550	0.600	Dysprosium
Dy_2O_3	7.810	*1.000	Dysprosium Oxide
Er	9.050	0.740	Erbium
Er_2O_3	8.640	*1.000	Erbium Oxide
Eu	5.260	*1.000	Europium
EuF_2	6.500	*1 .000	Europium Fluoride

Formula	Density	Z-Ratio	Material Name
Fe	7.860	0.349	Iron
Fe_2O_3	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_2O_3	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_2O_3	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium
Ge_3N_2	5.200	*1.000	Germanium Nitride
GeO_2	6.240	*1.000	Germanium Oxide
GeTe	6.200	*1.000	Germanium Telluride
Hf	13.090	0.360	Hafnium
HfB_2	10.500	*1.000	Hafnium Boride,
HfC	12.200	*1.000	Hafnium Carbide
HfN	13.800	*1.000	Hafnium Nitride
HfO_2	9.680	*1.000	Hafnium Oxide
$HfSi_2$	7.200	*1.000	Hafnium Silicide
Hg	13.460	0.740	Mercury
Ho	8.800	0.580	Holminum
Ho_2O_3	8.410	*1.000	Holminum Oxide
In	7.300	0.841	Indium
In_2O_3	7.180	*1.000	Indium Sesquioxide
In_2Se_3	5.700	*1.000	Indium Selenide
In_2Te_3	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

Formula	Density	Z-Ratio	Material Name
La	6.170	0.920	Lanthanum
La_2O_3	6.510	*1.000	Lanthanum Oxide
LaB_6	2.610	*1.000	Lanthanum Boride
LaF_3	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
$LiNbO_3$	4.700	0.463	Lithium Niobate
Lu	9.840	*1.000	Lutetium
Mg	1.740	1.610	Magnesium
$MgAl_2O_4$	3.600	*1.000	Magnesium Aluminate
$MgAl_2O_6$	8.000	*1.000	Spinel
MgF_2	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_2C	9.180	*1.000	Molybdenum Carbide
MoB_2	7.120	*1.000	Molybdenum Boride
MoO_3	4.700	*1.000	Molybdenum Trioxdide
MoS_2	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na_3AlF_6	2.900	*1.000	Cryolite
$Na_5AL_3F1_4$	2.900	*1.000	Chiolite
NaBr	3.200	*1.000	Sodium Bromide
NaCl	2.170	1.570	Sodium Chloride
$NaClO_3$	2.164	1.565	Sodium Chlorate
NaF	2.558	0.949	Sodium Fluoride
$NaNO_3$	2.270	1.194	Sodium Nitrate
Nb	8.578	0.492	Niobium (Columbium)
Nb_2O_3	7.500	*1.000	Niobium Trioxide
Nb_2O_5	4.470	*1.000	Niobium (V) Oxide
NbB_2	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	Neodynium
Nd_2O_3	7.240	*1.000	Neodynium Oxide
NdF_3	6.506	*1.000	Neodynium Fluoride

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_3N_5	2.510	*1.000	Phosphorus Nitride
Pb	11.300	1.130	Lead
$PbCl_2$	5.850	*1.000	Lead Chloride
PbF_2	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
$PbSnO_3$	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_2O_3	6.880	*1.000	Praseodymium Oxide
Pt	21.400	0.245	Platinum
PtO_2	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
S8	2.070	2.290	Sulphur
Sb	6.620	0.768	Antimony
Sb_2O_3	5.200	*1.000	Antimony Trioxide
Sb_2S_3	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandium
Sc_2O_3	3.860	*1.000	Scandium Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si_3N_4	3.440	*1000	Silicon Nitride
SiC	3.220	*1.000	Silicon Carbide
SiO	2.130	0.870	Silicon (II) Oxide
SiO_2	2.648	1.000	Silicon Dioxide

Formula	Density	Z-Ratio	Material Name
Sm	7.540	0.890	Samarium
Sm_2O_3	7.430	*1.000	Samarium Oxide
Sn	7.300	0.724	Tin
SnO_2	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_2	4.277	0.727	Strontium Fluroide
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta_2O_5	8.200	0.300	Tantalum (V) Oxide
TaB_2	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_2	5.990	0.862	Tellurium Oxide
Th	11.694	0.484	Thorium
ThF_4	6.320	*1.000	Thorium.(IV) Fluoride
ThO_2	9.860	0.284	Thorium Dioxide
$ThOF_2$	9.100	*1.000	Thorium Oxyfluoride
Ti	4.500	0.628	Titanium
Ti_2O_3	4.600	*1.000	Titanium Sesquioxide
TiB_2	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_2	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_3O_8	8.300	*1 .000	Tri Uranium Octoxide
U_4O_9	10.969	0.348	Uranium Oxide
UO_2	10.970	0.286	Uranium Dioxide
V	5.960	0.530	Vanadium
V_2O_5	3.360	*1.000	Vanadium Pentoxide
VB_2	5.100	*1.000	Vanadium Boride
VC	5.770	*1.000	Vanadium Carbide
VN	6.130	*1.000	Vanadium Nitride

Formula	Density	Z-Ratio	Material Name
VO_2	4.340	*1.000	Vanadium Dioxide
W	19.300	0.163	Tungsten
WB_2	10.770	*1.000	Tungsten Boride
WC	15.600	0.151	Tungsten Carbide
WO_3	7.160	*1.000	Tungsten Trioxide
WS_2	7.500	*1.000	Tungsten Disulphide
WSi_2	9.400	*1.000	Tungsten Suicide
Y	4.340	0.835	Yttrium
Y_2O_3	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb_2O_3	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn_3Sb_2	6.300	*1.000	Zinc Antimonide
ZnF_2	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_2	6.080	*1.000	Zirconium Boride
ZrC	6.730	0.264	Zirconium Carbide
ZrN	7.090	*1.000	Zirconium Nitride
ZrO_2	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 iterferometer 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, 4 additional optional
Sensor Frequency Range	4.0 MHz to 6.0 MHz
Reference Frequency Accuracy	.002%
Reference Frequency Stability	+/- 2ppm (total, 0 to 50°C)
Thickness Display Resolution	1 Å
Frequency Resolution*	+/- 0.12 Hz (Std.), +/- 0.03 Hz (HiRes)
Rate Resolution*	0.60 Å/s (Std.), 0.037 Å/s (HiRes)
Thickness Resolution*	0.15 Å (Std.), 0.037 Å (HiRes)

*Density = 1, Period = 4 rdgs/sec (Std.)
10 rdgs/sec. (HiRes)

Film Parameters

Stored Films	99
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

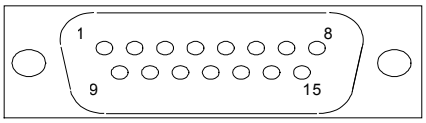
Digital Inputs	4
Functions	Open Shutter Close Shutter Zero Thickness Zero Time
Input Rating	5VDC, non-isolated
Relay Outputs	4
Functions	Shutter Sample/Hold or Thickness Setpoint Dual Sensor Shutter or Time Setpoint Crystal Fail
Relay Rating	30Vrms or 30VDC, 2A maximum

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)

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

Pins	Function	Description
1,2 Relay 1	Crystal Fail Relay	Contacts close when all enabled sensors have failed.
3,4 Relay 2	Time Setpoint, Dual Sensor, or Sensor 2 Relay	If Relay 2 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 3	Shutter Relay	Controlled by front panel shutter switch. Contacts close when Shutter Open is selected. If SENS2 is selected for Relay 2 in the System menu, the shutter relay contacts close only if Sensor 1 is programmed for the active film.
7,8 Relay 4	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.

C. Communications

Communications with a computer is by RS-232, or optional USB or Ethernet. RS-232 requires a standard 9-pin straight through cable.

For USB communications, first install the SQM-160 Comm program supplied on the CD-ROM. When the SQM-160 is connected to a USB port, it will be found and installed automatically by Windows.

For Ethernet communications, the SQM-160 is supplied with a fixed TC/IP address of 192.168.1.200. That address can be changed using the Dgdiscvr program on the CDROM. To change the IP address:

Run dgdiscvr.exe and find the unit (it may take a minute, click Refresh)
Double click on unit (should be highlighted)
Enter User Name: **root** and Password: **dbps**
Click Login
Click Configuration, Network and set
1 – Change IP=192.168.1.200 to your new IP address.
Click Apply, then Log Out

SQM-160 Comm

This Windows program allows you to set film parameters and names, download them to the SQM-160, and collect data from the instrument. The data can be graphed, and also saved in a spreadsheet format.

SQM-160 Communications Protocol

The SQM-160 communicates with a host computer via an ASCII based protocol. The instrument defaults to 19200 baud, 8 data bits, and no parity. The baud rate can be changed in the System Menu of the SQM-160, but is always 8 data bits with no parity.

The basic protocol is:

<sync character> <length character> <1 to n data characters> <CRC1><CRC2>

Once a valid command has been transmitted to the SQM-160, a response is returned. The structure of the packet is identical in both the command and response. In the response, the first character is a Response Status. These are summarized in the following table.

Response Letter	Meaning
A	Command understood, normal response
B	Command understood, but instrument reset
C	Invalid command
D	Problem with data in command
E	Instrument in wrong mode for this command

The sync character is an exclamation point '!'. Anytime this character is received, the communications for that packet is reset. Following the sync character is the length character. This is the number of characters in the packet starting with the length and counting the 2 CRC characters. This character has a decimal 34 added to it so there cannot accidentally be a sync character embedded in the packet. The two character CRC is computed using the following algorithm:

1. The CRC is initialized to 3FFF hex.
2. Each character in the message is examined, bit by bit, and added to the CRC in the following manner:
   a) The character is exclusive or'd with the CRC.
   b) The CRC is shifted right one bit position.
   c) If the character's least significant bit is a 0 then the CRC is exclusive or'd with 2001 hex.
   d) Steps b and c are repeated for each of the 8 bits in the character.

The CRC contains 14 significant bits. This is split into two characters of 7 bits each, and then a decimal 34 is added to offset the character outside the range of the Sync Character. See the code example in the SQM-TERM.C file for an example of managing the CRC.

Command: @

Parameters: None

Description: Returns the model number and software version number.

Example: @ AMON Ver 2.01

Command: A

Parameters: [1..99], Values | ?

Description: Film parameters. The parameters available for change or inspection are

Label, Density, Tooling, Z-Factor, Final Thickness, Thickness Setpoint, Time Setpoint, Sensor Average

The parameters are sent/retrieved in that order. The label is a maximum of 8 characters, and is terminated by a space character. If you want to send a space embedded in a Label, use an underscore character '_'. Each parameter is separated by a space.

Each film's parameters are accessed by using the ASCII character associated with film number directly after the Command. For example Film 1-9 are ASCII characters "1" (ASC 49) to "9" (ASC 57). Film 10 is a ":" character (ASC 58), etc. The parameters are edited by adding a value after the command film number.

The parameters are inspected by issuing a command, film number, then a question mark. An example of the Set/Get command for Film 4 is:

Example: A4LENS_1 6.23 125 1.05 1.525 0.450 30 1
A4? ALENS 1 6.23 125 1.05 1.525 0.450 30 1

Command: B

Description: System 1 parameters. The parameters available for change or inspection are Time Base, Simulation Mode, Frequency Mode, Rate Resolution, Rate Filter, Crystal Tooling and the parameters are sent/retrieved in that order.

Example: B? A0.25 0 0 0 8 100 100 100 100 100 100

Command: C

Description: System 2 parameters. The parameters available for change or inspection are Minimum Frequency, Maximum Frequency, Minimum Rate, Maximum Rate, Minimum Thickness, Maximum Thickness, Etch Mode and the parameters are sent/retrieved in that order.

Example: C? 5.000 6.000 0.000 100.00 0.000 1.000 0

Command: D

Parameters: 1 to 9

Description: Sets the active film.

Example: D1 Set the active film to Film #1

Command: J

Parameters: None.

Description: Read the number of channels installed. The number of channels will be either an ASCII two or six.

Example: J A2 The unit has two channels available.

Command: L

Parameters: [1..6]

Description: Read the current Rate for a channel.

Example: L1 A9.32 Channel one’s rate is 9.32 Angstroms/S

Command: M

Parameters: None.

Description: Read the current Average Rate.

Example: M A10.42 Average Rate is 10.42 Angstroms/S

Command: N

Parameters: [1..6]

Description: Read the curent thickness for a channel.

Example: N4 A1.187 Channel four's Thickness is 1.187 Kilo Angstroms.

Command: O

Parameters: None.

Description: Read the current Average Thickness

Example: O A2.376 The current Average Thickness is 2.376 kilo Angstroms.

Command: P

Parameters: [1..6]

Description: Read the current Frequency for a channel.

Example: P2 A5701563.2 Channel two's current Frequency 5701563.2Hz

---

Command: R

Parameters: [1..6]

Description: Read the Crystal Life for a channel.

Example: R3 A57.82 Channel three's remaining life is 57.82%.

Command: S

Parameters: None.

Description: Zero Average Thickness and Rate.

Example: S A

Command: T

Parameters: None.

Description: Zero Time

Example: T A Zeroes time display on unit.

Command: U

Parameters: 0,1, or ?

Description: Toggles shutter open/closed or reads shutter state.

Example:			
	U1	A	Shutter is opened
	U?	A1	Shutter Status is open
	U0	A	Shutter is closed.

Command: Y

Parameters: None.

Description: Read the Power-Up Reset flag. The Power-Up Reset flag is set during boot-up of the unit and stays set until read through the RS-232 interface. After the flag is read, it is reset and will not be set again until the unit is power cycled.

Example:			
	Y	A1	Power-Up Reset flag is set.
	Y	A0	Power-Up Reset flag is reset.

Command: Z

Parameters: None.

Description: Set all Film and System menu parameters to defaults.
Note that this command can take over 1 second to complete

Example:	Z	A	All Film and System parameters are set to defaults.

SIGMACOM.DLL Function Descriptions

This dll acts as an interpreter between an application and the SQM160. The dll transforms function calls to specific command sequences that the unit understands.

Transfer of data to the unit, in general, requires two function calls. The first function call is to transfer the data to the unit. The data to be sent is usually contained in the function's parameter(s). The second function call is to *ChkCommDone*. This function call ensures that the data was sent properly to the unit.

Data retrieval requires three function calls. The first function call is used to tell the unit what data is being requested. The second function call is to *ChkCommDone*. This function call is used to determine when all of the data has been transferred from the unit to the dll or if an error occurred in the communications. The third function call is used to retrieve the data from the dll.

InitComm

Parameters: 16 Bit Integer, 32 Bit Integer
Return : 16 Bit Integer.

InitComm is used to initialize the dll com port. The function's first parameter is the com port number to initialize (1 - 99 are valid). The second parameter is the baud rate for the port. The function returns zero if initialization was successful or a bit flag to indicate the failure of the initialization :

bit 0 : Communications Port handle is invalid.
bit 1 : Communications Port Set parameters invalid (Baud Rate)
bit 2 : Communications Port Set timeouts invalid.
bit 3 : Communications Port Set mask invalid.
bit 4 : Communications Port Error – Already exists.
bit 5 : Communications Port Set Read Thread fail.
bit 6 : Communications Port Set Read Thread priority fail.

Example:

```
ReturnVal =InitComm(1,19200)    initialize Com1 to 19200 baud
if (ReturnVal != 0)             if port did not initialize correctly
     CloseComm()                close the port
```

ClearComm

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

ClearComm is used to clear the communications buffers in the dll.

Example: ReturnVal =ClearComm() Clear the comm buffers in the dll

CloseComm

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

CloseComm is used to close the currently opened communications port. *CloseComm* should always be used before attempting to open another port or before exiting the dll's calling application. The dll can have only one port open at a time.

Example:

ReturnVal =CloseComm() Close the currently open comm port

ChkCommDone

Parameters: None.
Return : 16 Bit Integer.

ChkCommDone is used to check the status of a single communications iteration. The function returns one of five different types of values:

-1:	communications not complete
Positive integer :	communications complete, value is byte count of returned message.
-99 :	communications complete, but return message incomplete due to timeout with unit.
-98 :	communications complete, but return message not valid due to a CRC error.
-97 :	communications complete, but message not understood by unit.

Example:

ReturnVal =ChkCommDone() check communications status

SendGetVers

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetVers is used to retrieve the software version of the unit from the unit. This function must precede the use of the *GetVers* function

GetVers

Parameters: Pointer to Null-Terminated string.
Return : 16 Bit Integer, always returns a 1.

GetVers is used to retrieve the software version of the unit from the dll. This function must be preceded by the *SendGetVers.* The Null-terminated string is used to return the version from the dll.

Example:

```
ReturnVal = SendGetVers()                  tell unit to transfer version
                                           to dll
do while(ChkCommDone == -1)                wait for comm to finish
ReturnVal = GetVers(&VersionString[0]) VersionString contains
                                           version info
```

Set160Film

Parameters: Pointer to a Film Structure.
Return : 16 Bit Integer, always returns a 1.

SetFilm is used to set a Film's parameters in the unit. All of the parameters are passed to the function through the Film Structure.

Example:

```
ReturnVal = SetFilm(&FilmStruct)     set film parameters to
                                     FilmStruct values
do while(ChkCommDone == -1)          wait for comm to finish
```

SendGetFilm

Parameters: 16 Bit Integer.
Return : 16 Bit Integer, always returns a 1.

SendGetFilm is used to get a Film's parameters from the unit. The Film's number (1 - 9) is passed to the function. This function must precede the use of *GetFilm*.

Get160Film

Parameters: Pointer to a Film Structure.
Return : 16 Bit Integer, always returns a 1.

GetFilm is used to retrieve a Film's parameters, the film requested by *SendGetFilm,* from the dll. The parameters are passed through the Film Structure.

Example:

```
ReturnVal = SendGetFilm(FilmNum)tell unit to transfer Film #
                                FilmNum to dll
```

```
do while(ChkCommDone == -1)      wait for comm to finish
ReturnVal = GetFilm(&FilmStruct) FilmStruct contains Film info
```

SetSys1

Parameters: Pointer to a System1 Structure.
Return : 16 Bit Integer, always returns a 1.

SetSys1 is used to set the System1 Parameters. The parameters are passed to the function through the System1 Structure.

Example:

```
ReturnVal = SetSys1(&Sys1Struct)     set System1 parameters to
                                     Sys1Struct values
do while(ChkCommDone == -1)          wait for comm to finish
```

SendGetSys1

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetSys1 is used to get the System1 Parameters from the unit. This function must precede the use of the *GetSys1* function.

GetSys1

Parameters: Pointer to a System1 Structure.
Return : 16 Bit Integer, always returns a 1.

GetSys1 is used to retrieve the System1 Parameters from the dll. The parameters are passed through the System1 Structure.

Example:

```
ReturnVal = SendGetSys1()        tell unit to transfer System1
                                 parameters
do while(ChkCommDone == -1)      wait for comm sequence to finish
ReturnVal = GetSys1(&Sys1Struct) Sys1Struct contains
System1 info
```

SetSys2

Parameters: Pointer to a System2 Structure.
Return : 16 Bit Integer, always returns a 1.

SetSys2 is used to set the System2 Parameters. The parameters are passed to the function through the System2 Structure.

Example:

```
ReturnVal = SetSys2(&Sys2Struct)     set System2 parameters to
                                     Sys2Struct values
```

```
do while(ChkCommDone == -1)          wait for comm to finish
```

SendGetSys2

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetSys2 is used to get the System2 Parameters from the unit. This function must precede the use of the *GetSys2* function.

GetSys2

Parameters: Pointer to a System2 Structure.
Return : 16 Bit Integer, always returns a 1.

GetSys2 is used to retrieve the System2 Parameters from the dll. The parameters are passed through the System2 Structure.

Example:

ReturnVal = SendGetSys2()	tell unit to transfer System2 parameters
do while(ChkCommDone == -1)	wait for comm sequence to finish
ReturnVal = GetSys2(&Sys2Struct)	Sys2Struct contains System2 info

SendGetNumCh

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetNumCh is used to get the number of channels installed from the unit. This function must precede the use of the *GetNumCh* function.

GetNumCh

Parameters: None.
Return : 16 Bit Integer, Number of channels installed.

GetNumCh is used to retrieve the number of channels installed from the dll. The number of channels is returned by the function.

Example:

ReturnVal = SendGetNumCh()	tell unit to transfer Number of channels
do while(ChkCommDone == -1)	wait for comm sequence to finish
ReturnVal = GetNumCh()	ReturnVal contains Number of channels

ZeroStartTime

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

ZeroStartTime is used to zero the beginning time before acquiring data with *GetAllData*.

SendGetAllData

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetAllData is used to get the data from the unit. This function must precede the use of the *GetAllData* function.

GetAllData

Parameters: Pointer to an AllData Structure.
Return : 16 Bit Integer, always returns a 1.

GetAllData is used to retrieve the data from the dll. The parameters are passed through the AllData Structure. If the TimeStamp parameter of the AllData structure returned is equal to -1 then the unit does not have new data available.

Example:

```
ReturnVal = ZeroStartTime()                          zero the run time
do
    ReturnVal = SendGetAllData()                     tell unit to transfer AllData
    do while(ChkCommDone == -1)                      wait for comm to finish
    ReturnVal = GetAllData(&AllDataStruct)           AllDataStruct contains run info
    if (AllData.TimeStamp != -1) then                if new data available
        ProcessData()                                 then graph or save data
while(Running)
```

SendCrystalLife

Parameters:16 Bit Integer
Return : 16 Bit Integer, always returns a 1.

SendCrystalLife is used to get the crystal life for a channel from the unit. The parameter is the channel number to retrieve.This function must precede the use of the *CrystalLife* function.

CrystalLife

Parameters: None.
Return : Double.

CrystalLife is used to retrieve the Crystal life remaining for the channel requested by *SendCrystalLife* from the dll. The Crystal life is returned by the function.

Example:

```
ReturnVal = SendCrystalLife(XtalNum)   tell unit to transfer Life for
                                       XtalNum
do while(ChkCommDone == -1)            wait for comm to finish
ReturnVal = CrystalLife()              ReturnVal contains Life for
                                       XtalNum
```

ZeroReadings

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

ZeroReadings is used to command the unit to zero the rate and thickness values for all channels and the average rate and thickness.

Example:

```
ReturnVal =ZeroReadings()              tell unit to reset Rate and
Thickness
do while(ChkCommDone == -1)    wait for comm sequence to finish
```

ZeroTime

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

ZeroTime is used to command the unit to zero the system time.

Example:

```
ReturnVal =ZeroTime()                  tell unit to reset time
display
do while(ChkCommDone == -1)            wait for comm to finish
```

ShutterState

Parameters: 16 Bit Integer
Return : 16 Bit Integer, always returns a 1.

ShutterState is used to command the unit to set the shutter open or closed.

Example:

```
ReturnVal =Shutter(0)          tell unit to toggle open the shutter
do while(ChkCommDone == -1)    wait for comm sequence to finish
```

SendGetShutter

Parameters: None.
Return : 16 Bit Integer.

SendGetShutter is used to retrieve the condition of the shutter, open or closed, from the unit.

GetShutter

Parameters: None.
Return : 16 Bit Integer, Shutter value (0 = Closed, 1 = Open).

GetShutter is used to retrieve the value of the shutter from the dll. The returned value from the function is the value of the shutter :

Example:

```
ReturnVal = SendGetShutter()     tell unit to transfer Shutter value
do while(ChkCommDone == -1)      wait for comm sequence to finish
ReturnVal = GetShutter()         ReturnVal contains Shutter value
```

SendGetReset

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

SendGetReset is used to get the value of the power up reset flag from the unit.

GetReset

Parameters: None.
Return : 16 Bit Integer, Flag value (0 = flag not set, 1 = flag set).

GetReset is used to get the value of the power up reset flag from the dll. The value of the flag is the return value of the function :

Example:

```
ReturnVal = SendCrystalLife(XtalNum)   tell unit to transfer Life left
                                       for XtalNum
do while(ChkCommDone == -1)            wait for comm to finish
ReturnVal = CrystalLife()              ReturnVal contains Life left
                                       for XtalNum
```

LoadDefaults

Parameters: None.
Return : 16 Bit Integer, always returns a 1.

LoadDefaults is used to cause the unit to load the default values into every film and system parameter.

Example:

```
ReturnVal =LoadDefaults()        tell unit to load default values
do while(ChkCommDone == -1)      wait for comm sequence to finish
```

Data Structures:

The size of each data type in the structures is :

double : 8 bytes, the LSB is thrown out before transmission to the unit.

int : 2 bytes.

char : 1 byte.

Film Data

double	Density	film density
double	Tooling	film tooling
double	ZFactor	film zfactor
double	FinThk	film End Thickness
double	ThkSet	film Thickness Setpoint
double	TimeSet	film Time Setpoint
double	SnsAvg	Sensors to average
char	Name[8]	film Name
int	FilmNum	film Number

System1 Data

double	TimeBase	
double	SimMode	simulation mode (1 = on, 0 = off)
double	FreqDisp	frequency display (1 = on, 0 = off)
double	RateRes	rate resolution (1 = hi, 0 = low)
double	RateFilt	rate filter depth (1 - 20)
double	XTool[6]	six individual crystal tooling

System2 Data

double	FMin	minimum frequency
double	FMax	maximum frequency
double	RMin	minimum rate
double	RMax	maximum rate
double	TMin	minimum thickness
double	TMax	maximum thickness
double	EtchMode	Etch mode on/off

AllData

double	TimeStamp	time relative to start time data was acquired
double	AvgRate	average rate
double	AvgThick	average thickness
double	ChRate[6]	up to six individual channels of rate
double	ChThick[6]	up to six individual channels of thickness
double	ChFreq[6]	up to six individual channels of frequency

E. EC Declaration of Conformity

This is to certify that this equipment, designed and manufactured by:

INFICON Inc.
Two Technology Place
East Syracuse, NY 13057
USA

meets the essential safety requirements of the European Union and is placed on the market accordingly. It has been constructed in accordance with good engineering practice in safety matters in force in the Community and does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made.

In addition, this is to certify that this equipment has also been designed and manufactured, having regard to the state of the art, to ensure complies with the Protection Requirements of EMC directive 2004/108/EC.

A Technical Documentation File is also available for review by competent authorities and will be maintained for a period of ten years after the date on which the equipment was last manufactured. In additional to this file, technical, installation, maintenance and application information concerning this equipment can also be found in the Operating Manual(s) for this product or product family.

Equipment Description: SQM-160 Rate / Thickness Monitor (including all options).

Applicable Directives: 2006/95/EC (LVD)
2004/108/EC (General EMC)
2002/95/EC (RoHS)

Applicable Standards:

Safety: EN 61010-1:2001

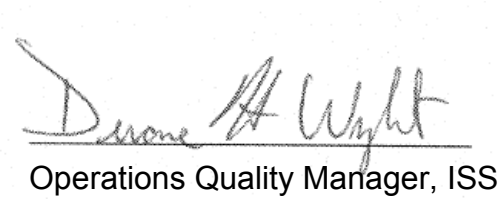
Emissions: EN 61326-1:1997/A1: 1998/A2: 2001 (Radiated & Conducted Emissions)
Class A: Emissions per Table 3
(EMC – Measurement, Control & Laboratory Equipment)

Immunity: EN 61326-1:1997/A1: 1998/A2: 2001 (General EMC)
Class A: Immunity per Table A1
(EMC – Measurement, Control & Laboratory Equipment)

RoHS: Fully compliant

CE Implementation Date: January 2003 (Updated December 2008)

Authorized Representative: Duane H. Wright



Operations Quality Manager, ISS
INFICON Inc.

ANY QUESTIONS RELATIVE TO THIS DECLARATION OR TO THE SAFETY OF INFICON'S PRODUCTS SHOULD BE DIRECTED, IN WRITING, TO THE VICE-PRESIDENT OF OPERATIONS AT THE ABOVE ADDRESS.

Revised 12/24/08 (Rev B)