
SQC-300 Series Thin Film Deposition Controllers

User's Guide

Version 4.10

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Safety Information

Read this manual before installing, operating, or servicing 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.

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

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Return Policy

The purchaser may return this product in 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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Chapter 1 - Quick Start

1.0 Introduction

Sigma's SQC-300 series instruments are multi-channel QCM-based deposition controllers. They provide a unique combination of accuracy and powerful features in a compact, low cost instrument.



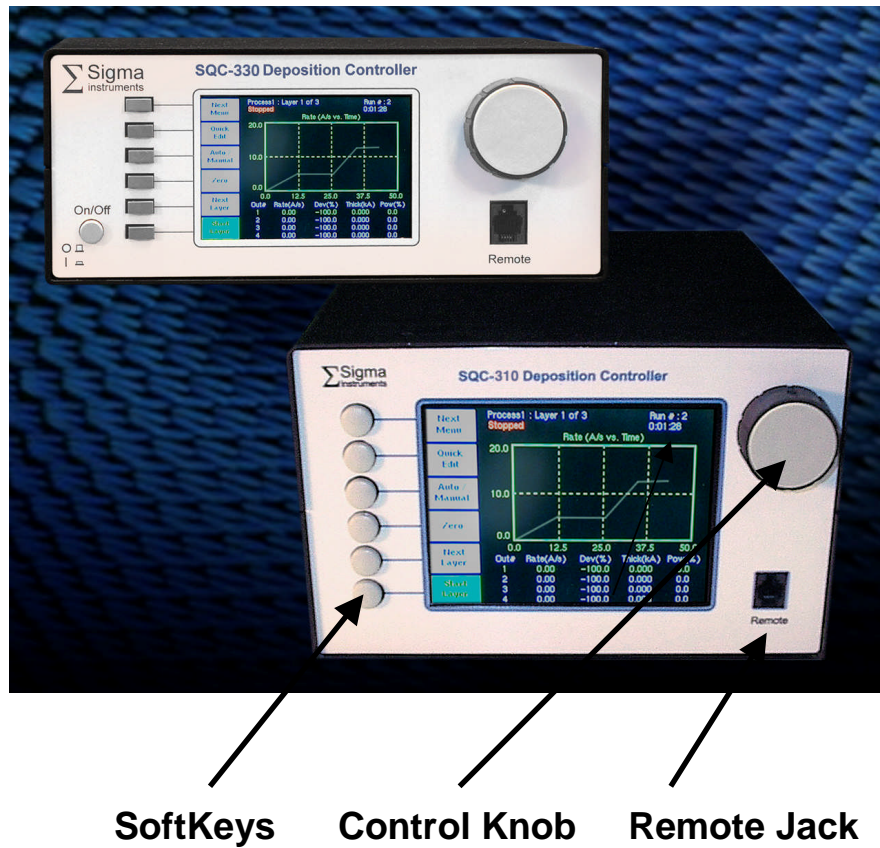
The standard SQC-300 measures up to two quartz crystal sensors, and controls up to two evaporation sources. Eight process control relays, and eight digital inputs are included to support a broad range of external devices. The number of sensors, outputs, and digital I/O can be doubled with an optional expansion card. A co-deposition software option allows simultaneous deposition of up to four materials. RS-232 and USB communications are standard, with Ethernet optional.

The SQC-300 series is available in two models, the 5 1/4" high SQC-310 and the 3 1/2" high SQC-330. Other than a different display and case size, the two instruments are identical.

Note: *The SQC-310 and SQC-330 are referred to in this manual as the SQC-300 series. If there is a reason to distinguish between the two models, the SQC-310 or SQC-330 model number will be called out.*

This chapter will aid you in the initial setup and operation of your system. Please review the entire manual for detailed operational, programming, and safety information.

1.1 Front Panel



Front Panel Controls

SoftKeys

Provide access to instrument operations and setup menus. The functions of the SoftKeys change to adapt to different operations and are displayed on the left of the screen.

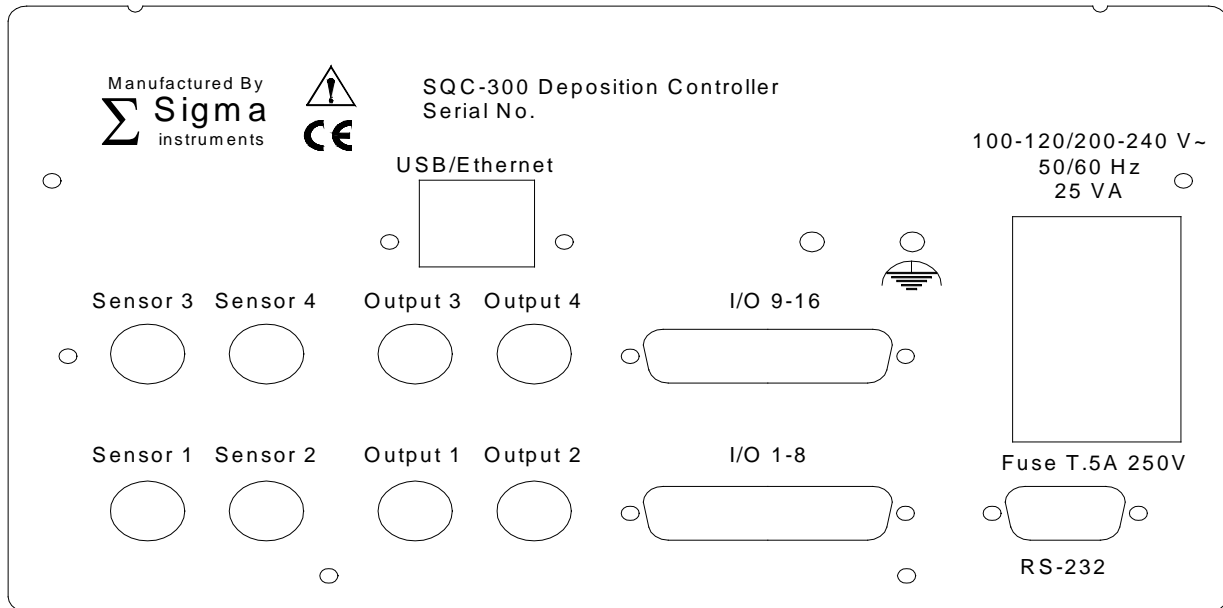
Control Knob

Used to adjust values and select menu items. Pushing the control knob stores the current setting and moves to the next, similar to a keyboard's Enter key.


Remote Jack

Connection jack for the optional handheld remote controller. See Appendix D.

1.2 Rear Panel

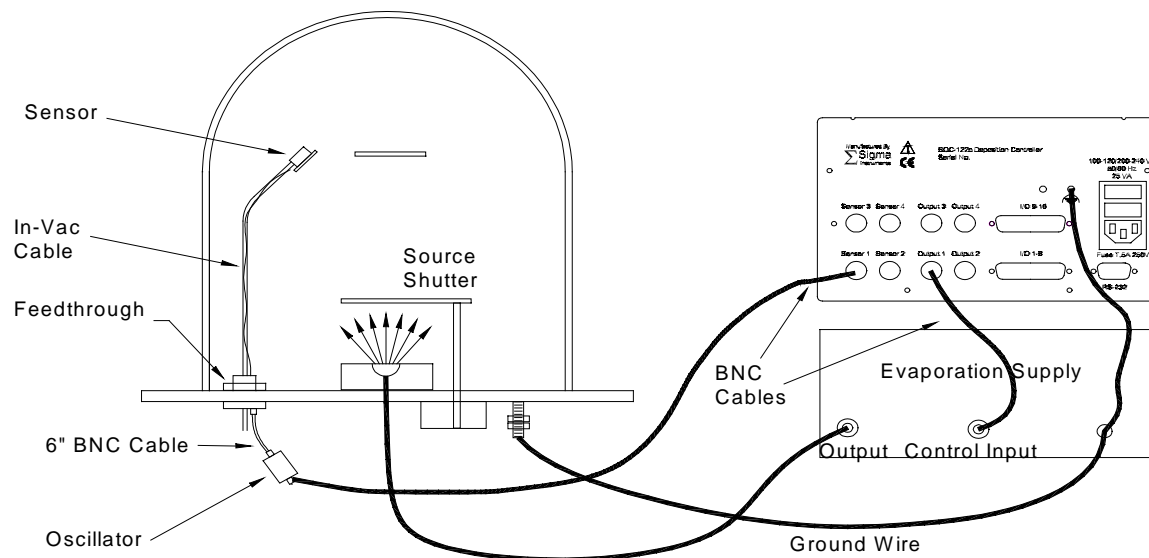


Rear Panel Connections

- Sensor 1 & 2** Connects to quartz crystal sensor (see next section).
- Output 1 & 2** Connects the SQC-300 output to your evaporation supply control input (see next section).
- I/O (1-8)** Connects 8 relays and 8 digital inputs to external equipment for process control. See Appendix C for wiring.
- RS-232** Connects to a computer for programming and data acquisition.
- USB or Ethernet** RS-232 and USB are standard. Ethernet option replaces USB.
- Sensor 3 & 4,**
Output 3 & 4,
I/O 9-16 Increases the number of input, output, and digital I/O connections when the optional expansion card is installed.
-  Measurement ground terminal useful for common system and cable grounding.
- Power Input and Fuse** Connects to mains power. The SQC-300 automatically detects mains voltages of 100-120 and 200-240VAC, 50/60 Hz

WARNING: For continued protection, replace fuses with the proper type and rating. Use power cords only of the specified type and rating, attached to a properly grounded receptacle.

1.3 System Connections



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".
- Sensor Input BNC Cable** Connects the oscillator to the SQC-300 input. Lengths up to 100' are acceptable.
- Control Output BNC Cable** Connects the SQC-300 output to the evaporation source's control voltage input. Keep the length below 10'.
- Ground Wire** A wire, typically braided, that connects the vacuum system to the SQC-300 ground terminal. Important for noise rejection.

1.4 Installation

WARNING: Care should be exercised to route SQC-300 cables as far as practical from other cables that carry high voltages or generate noise. This includes other line voltage cables, wires to heaters that are SCR-controlled, and cables to source power supplies that may conduct high transient currents during arc down conditions.

Rack Installation

The SQC-310 occupies a 5.25" high, half-rack space. The SQC-330 is identical, but has a smaller display and occupies a 3.5" high, half-rack space. An optional installation kit is available to adapt to a full rack (see Chapter 4). Install the unit in a 19" rack with the supplied hardware.

Power Connection

The SQC-300 automatically detects mains voltages of 100-120 and 200-240VAC, 50/60Hz.

WARNING: Verify that the power cable provided is connected to a properly grounded mains receptacle.

Sensor Input Connections

Connect the BNC cables and oscillators from your vacuum chamber feedthrough to the desired SQC-300 sensor inputs. See the previous section for cabling details.

Source Output Connections

Connect the BNC cables from the SQC-300 output connectors to your evaporation supply control input. Consult your Power Supply operator's manual for control input wiring instructions.

Digital I/O Connections

Refer to Appendix C for details on wiring digital I/O to the SQC-300 Relay I/O connectors.

Computer Connection

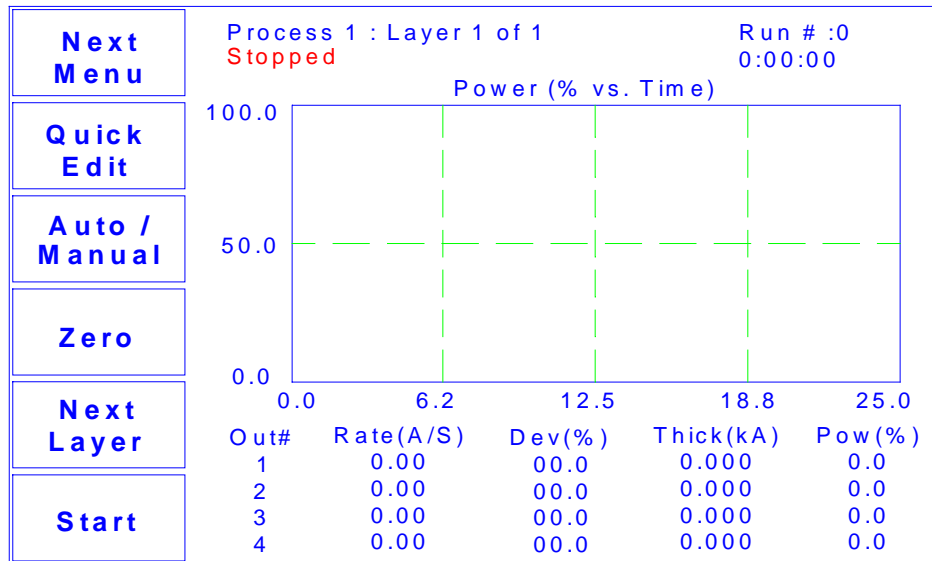
If you want to collect data or program the SQC-300, attach a straight-thru RS-232 cable from the RS-232 connector to your computer's serial port.

You can also communicate via USB using a standard USB cable. If you ordered the Ethernet option, the USB connection is replaced with an RJ-45 Ethernet connector.

1.5 Menus

At power up the SQC-300 briefly displays initialization and version information, then the Main screen.

Note: If you are prompted for a password, use the switches along the left of the screen to enter the password. The top switch is “1”, the bottom switch is “6.” See the System Parameters section of this manual for password setup information.



Main Screen

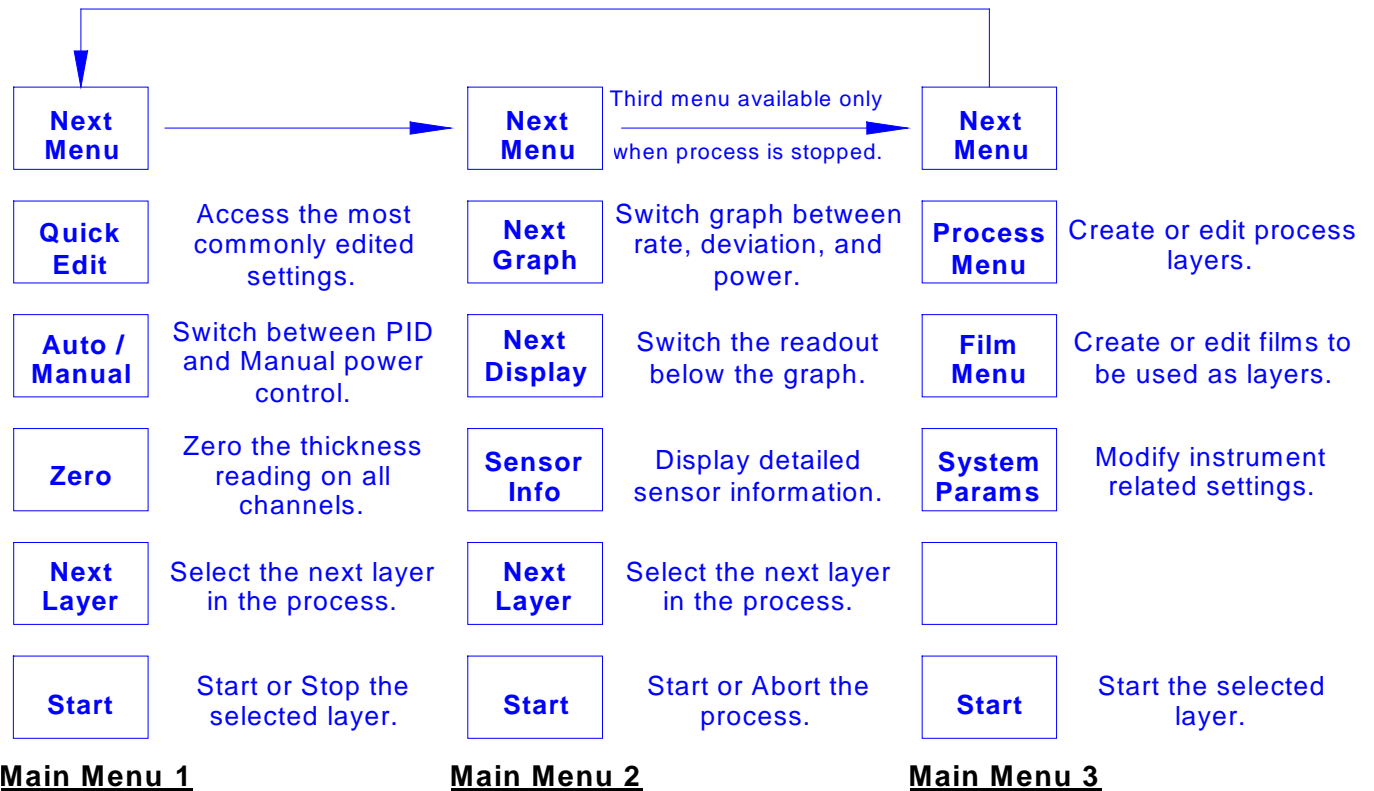
The first line of the Main screen shows the name of the currently selected process. After the process name are the layer that will run when the Start SoftKey is pushed, and the total number of layers in the process. Further to the right is the number of times this process has been run.

The second line of the Main screen is a status line. It displays the current phase of the deposition cycle, and other status or error messages. When the process is running, the right side of this line shows the process elapsed time.

Three graphs are possible: rate, rate deviation, and output power. The graphs scale the vertical axis and scroll the horizontal axis based on the data displayed.

Below the graph are two lines that show deposition readings (four lines if the option card is installed). This section shows current rate, rate deviation, thickness, and output power as shown above. Alternatively it can show measured rate and thickness versus rate and thickness setpoints.

The six SoftKey legends along the left side of the screen will change, depending on the status of the process and the functions you select. Press Next Menu to display alternate main screen menus:

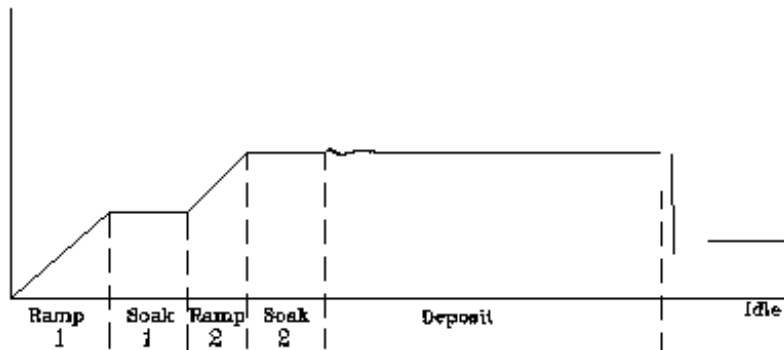


Because Main Menu 3 provides access to functions that can completely redefine a process, it is available only when the process is stopped.

Spend some time now moving between the three menus. Pay particular attention to the effects that the Main Menu 2 selections have on the display. We will cover the setup parameters of Main Menu 3 in the Building a Process section.

1.6 Thin Film Deposition Overview

The SQC-300 stores the recipes, and provides the operating functions, required to control thin film deposition processes. A typical thin film deposition cycle is shown below.



The cycle can be broken into three distinct phases:

- Pre-conditioning (ramp/soak)
- Deposition
- Post-conditioning (feed/idle)

During pre-conditioning, power is supplied in steps to prepare the evaporation source for deposition. Once the material is near the desired deposition rate, material deposition begins.

During deposition, the PID loop adjusts the evaporation source power as required to maintain the desired rate. In Co-deposition multiple films can be deposited simultaneously.

When the desired thickness is reached, the evaporation source is set to idle power. At this point the process may be complete, or deposition of another layer may begin.

1.7 Building a Process

This section presents a brief guide to building and running a simple one layer process. Chapter 2 covers instrument operation in much greater detail.

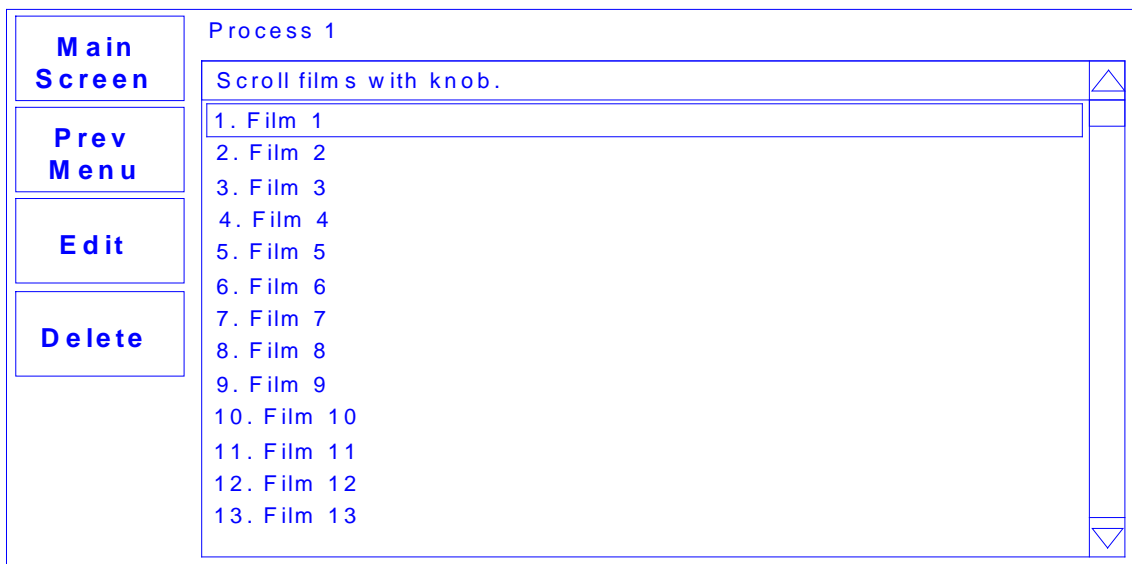
Create a Film

A film is a material to be deposited, and its associated deposition settings. Initially the list of films may be empty.

Press **Next Menu** until the Film Menu SoftKey is displayed. Press **Film Menu** to view a list of stored films. Turn the setting knob to scroll to an entry in the list that is currently labeled <Empty>.

Press the **Create** SoftKey to create a default film at that location. Note the film number that you just created. For now, accept the default film parameters.

Press **Main Screen** to return to the main screen.



Film Select Menu

Note: Films are numbered from 1 to 50. Film names, process names, and materials can be changed using the SQC-300 Comm program and a computer. See Chapter 5.

Now that we are sure that at least one film exists, we will build a simple single layer process using that film.

Select Process

Press the **Process Menu** SoftKey to view a list of processes.

Turn the setting knob to scroll to an entry in the list that is labeled <Empty>.

Press the **Create** SoftKey to create a default process at that location.

Press the **Select** SoftKey to make the selection the active process.

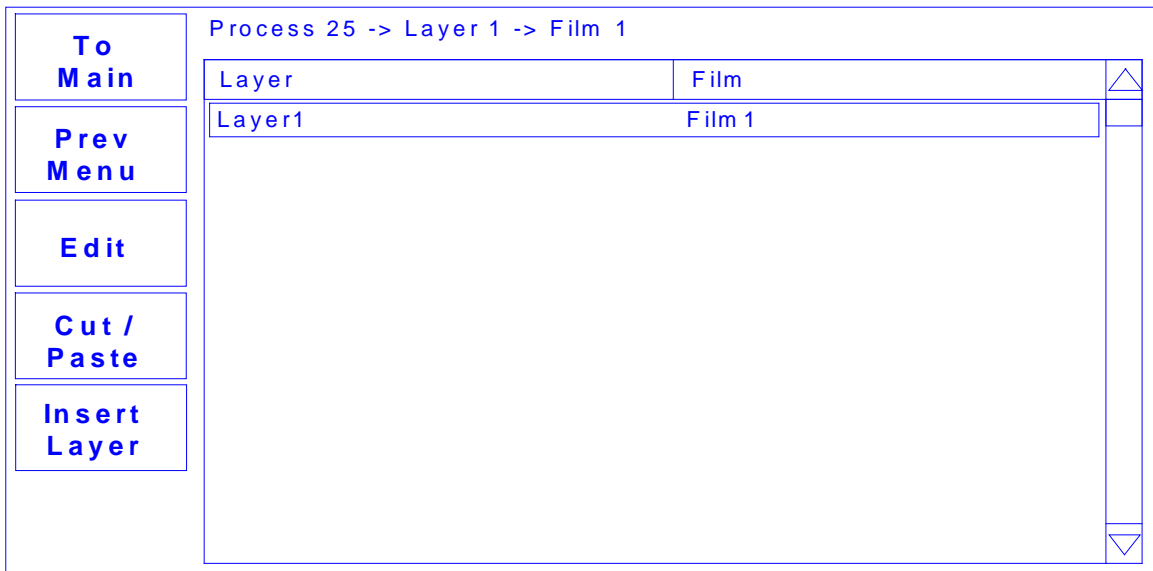
Edit Process

Press the **Edit** SoftKey to view a list of layers in the selected process. The layers list should be blank.

Insert Layer

Press **Insert Layer**, then scroll down the list of films to the film you just created.

Press **Insert Layer** to insert the selected film as Layer 1. The display returns to the Layer Select menu.



Layer Select Menu

A process consists of one or more layers. Each layer can have a different film, or even multiple films (Co-deposition). For this example, we will stop with only a single layer.

Edit Layer

With Layer 1 selected, press **Edit** to display the Layer Edit menu for Layer 1.

Process 1 -> Layer 1 -> Film 1			
Parameter	Value	Units	
Init Rate	10.0	A/s	
Fnl Thk	0.100	k/A	
Time Setpoint	0:00:00	h:m:ss	
Thickness Limit	0.000	kA	
Start Mode	Manual	Auto/Man.	
Output	Out1	Out1/Out2	
Max. Power	90.0	%	
Slew Rate	90.0	%	
Sensor 1	On	On/Off	
Sensor 2	Off	On/Off	
Sensor 3	Off	On/Off	
Sensor 4	Off	On/Off	
Ramp1	Disabled	En/Dis	

Layer Edit Menu**Edit Menu Operation**

To edit a setting in any menu, turn the control knob to scroll to the desired setting, then press the **Edit** SoftKey. The cursor moves to the setting value, and the SoftKey functions change to show:

Next: Store the parameter and move to next parameter for editing.

Cancel: Stop editing and return the selected parameter to its previous value.

Enter: Stop editing and save values for selected parameter.

In Edit mode, adjust the control knob to set the desired parameter value.

Edit Layer 1

Spend some time navigating through the Layer 1 parameters and editing values. When you are comfortable, be sure your values for Layer 1 match those shown above.

Press **Main Menu** to return to the Main Screen.

We have completed the design of a single layer process.

1.8 Depositing a Film

Note: You can simulate the steps below, without actually depositing a film, by going to the System Params Menu and selecting Simulate Mode ON. Simulate mode is useful for testing processes before applying power to the evaporation supply. See Section 3.6 for detailed System Parameters Menu information.

Verify Sensor Operation

Press **Next Menu** until the Sensor Info option is shown.

Press **Sensor Info** to display the quartz sensor readings. Sensor 1 should be ON and display a % life of over 50%. If not, check your sensor connections (Section 1.3), and refer to Min/Max Frequency (Section 3.6).

Press **Exit** to return to the main screen.

Show Power Graph

Press the **Next Graph** SoftKey until the graph shows Power (% vs. Time).

Verify Output Operation

Press the **Next Menu** SoftKey until the Auto/Manual SoftKey is displayed. Now press **Auto/Manual** until Manual/Auto is displayed. Press **Start** to begin deposition in manual mode.

Slowly turn the control knob to increase the control voltage to your evaporation supply. Verify that the Power(%) reading for Output 1 (lower right, below graph) approximates the actual output of your evaporation supply. If not, check your hookup (Section 1.3), and refer to Scale Voltage (Section 3.6).

Caution: Observe the output power versus your evaporation supply's actual output. If there is a problem, press the **Stop** SoftKey immediately.

Enter Auto Mode

Press the **Next Menu** key until the Manual/Auto SoftKey is shown. Press **Manual/Auto** to change the SoftKey display to Auto/Manual. This places the output under PID deposition control.

Press **Stop** at any time to halt deposition and set output power to zero.

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

Chapter 2 - Operation

2.0 Introduction

This chapter describes common tasks associated with operating the SQC-300. It assumes that you understand basic operation of the menus and parameter setup as described in Chapter 1. Detailed definitions of each parameter can be found under the appropriate menu description in Chapter 3.

2.1 Definitions

Several terms will be used repeatedly throughout this manual. It is important that you understand each of these terms.

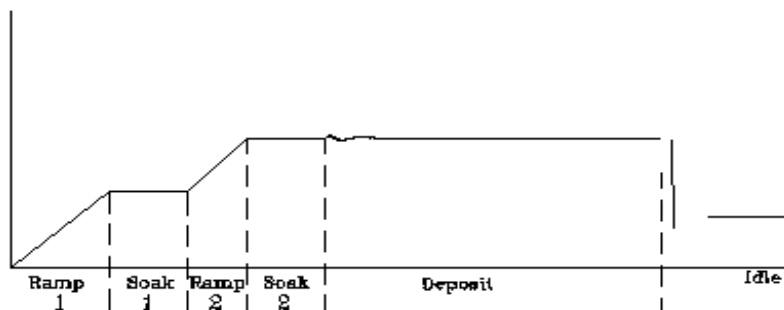
Material: A physical material to be deposited. A database of approximately 100 materials is stored in the SQC-300, and additional materials may be added using the setup software. Three parameters completely define a material: Name, Density, and Z-Factor. A table of common materials, their density, and Z-Factor is listed in Appendix A.

Film: A film describes in detail how a material will be deposited. It includes the material definition and all of the preconditioning, deposition, and post conditioning variables necessary to accurately deposit the material. Because the film definition does not include rate and thickness information, a single film can be used in several different layers and processes. The SQC-300 stores up to 25 films.

Layer: Layers are the basic building blocks of processes. A layer consists of a film and the thickness and rate setpoints for that stage of the process. Layers also define which outputs and sensors will be used at that point in the process. Co-deposition of multiple films occurs when more than one output is active during a layer.

Process: A process is a sequence of layers to be deposited. The SQC-300 can store up to 25 processes, consisting of a total of 1000 layers.

Phase: A step in the deposition cycle. Preconditioning phases include Ramp 1, Soak 1, Ramp 2, Soak 2. Deposit phases include indexer rotate, shutter delay, deposition, and deposition rate ramps. Post conditioning phases include Feed Ramp, Feed, and Idle Power.



2.2 Defining a Film

A film is a material to be deposited, plus all of its associated setup parameters. Keep in mind that a film can be used in multiple layers, or even multiple processes. Editing a film's parameters will cause changes to every location where the film is used.

To define a film, press **Next Menu** until Film Menu is shown (Menu 3). Press **Film Menu**. A list of 25 films (or <Empty>) will be displayed. To define a new film, scroll to <Empty> and press **Create**. A new Film# is added to the list of existing films (you can use the SQC-300 setup software later to assign descriptive film names). Press **Edit** to display the parameters for this film.

Process 1 Editing: Film 1			
Parameter	Value	Units	
P Term	50	None	
I Term	0.7	Sec.	
D Term	0.0	Sec.	
Film Tooling	100	%	
Pocket	None		
Crystal Quality	Disabled		
Crystal Stability	Disabled		
Xtal Fail Mode	Halt		
Material	Aluminum		
Density	2.73	gm/cc	
Z Factor	1.08		

Film Edit Menu

P Term is the proportional gain, that is the % process rate change divided by the % input power change. The I Term (integral) sums the rate deviations over time to more accurately achieve the rate setpoint. The D Term (derivative) speeds response to sudden changes in rate. Volumes have been written on determining the proper PID settings. See the section on Loop Tuning later in this chapter for a common PID loop tuning procedure. Start with P=25, I=.5, D=0.

Film Tooling adjusts for differences in actual versus measured thickness for this film (material). This parameter is seldom used, but can adjust for material specific dispersion patterns. See Xtal Tooling in the System Parameters menu for the more commonly used tooling correction.

Pocket selects the source pocket used for this film. This parameter requires that the I/O Setup section of the System Parameters menu be programmed for pocket relays.

The next chapter covers Crystal Quality, Stability, and Fail Mode. For initial operation leave Quality and Stability disabled, and Fail Mode set to Halt.

With Material highlighted, press **Edit** to scroll through the list of available materials. Select the desired material and press **Enter**. You could also change the Density and Z-Factor for the selected material, but it is unlikely those values are wrong. To add a new material or edit the name of an existing material, you must use the SQC-300 setup software.

Film conditioning adjusts the output power level to achieve a desired material state before and after deposition. Press **Film Conds** to enter the film conditioning menu.

Process 1 Editing: Film 1	
Parameter	Value Units
Ramp1 Power	25.0 %
Ramp1 Time	0:00:10 h:mm:ss
Soak1 Time	0:00:05 h:mm:ss
Ramp2 Power	50.0 %
Ramp2 Time	0:00:05 h:mm:ss
Soak2 Time	0:00:05 h:mm:ss
Feed Power	0.0 %
Ramp Time	0:00:00 h:mm:ss
Feed Time	0:00:00 h:mm:ss
Idle Power	0.0 %
Ramp Time	0:00:00 h:mm:ss

Film Conditioning Menu

Ramp1 starts at 0% power and increases the power during Ramp1 Time to the Ramp 1 power level. Set the Ramp 1 Power and Time to gradually bring the material to a near molten state. Set the Soak 1 Time to a value that will allow the material to homogeneously achieve that state. Ramp 2 is used to slowly bring the material to a power level that nearly matches the desired deposition power. Use Soak 2 to hold the material at that level until deposition (i.e. rate control) begins.

If you use wire feed to replenish material after deposition, set the Feed Power and times as required. The idle conditioning phase typically ramps output power back toward zero at the end of a process.

From the Film Conds menu, press **Prev Menu** to return to the main Film Params menu.

Now press **Deposit Controls**. The Deposit Controls menu contains parameters that modify operation during the deposition phase.

Process 1 Editing: Film 1		
Parameter	Value	Units
Shutter Delay	0:00:00	h:mm:ss
Capture	0.0	%
Control Error	(Ignore, Stop, Hold)	
Setting	Stop	
Error	0.0	%
Rate Sampling	(Cont, Time, Acc based)	
Setting	Continuous	%

Deposition Controls Menu

Shutter delay causes the SQC-300 to delay opening the shutter until the process has stabilized at the desired deposition rate. Capture is the % rate deviation that must be achieved to open the shutter and go to the Deposit phase. Shutter delay is the maximum amount of time to wait for capture to be achieved. Set Shutter Delay and Capture to zero to disable this feature.

During co-deposition, the SQC-300 waits for all films to achieve capture before moving to the deposit phase. If any film fails to achieve rate capture within its programmed shutter delay time, an error occurs.

If the SQC-300 is unable to maintain the desired deposition rate (for example, out of material or a bad sensor), one of three actions is possible. Keep trying (Ignore), set power to zero to halt deposition (Stop), or maintain constant power (Hold) and extrapolate thickness from the last good rate reading. Until your process is known and stable, it is best to leave the Control Error setting on Ignore.

Rate sampling can extend sensor life in high rate processes. Select Cont (continuous) to disable rate sampling. A Time selection closes the shutter for a fixed time, then opens the shutter for a fixed time to sample the rate. Acc Based (accuracy based) sampling closes the shutter for a fixed time, then opens the shutter until the desired rate is achieved. Rate Sampling assumes a very stable process!

2.3 Defining a Process

To define a process, press **Next Menu** until the Process Menu SoftKey is shown. Press **Process Menu**. A list of 100 processes (or <Empty>) will be displayed. To define a new process, scroll to <Empty> and press **Create**. A new Process# is added to the list of existing processes (use the SQC-300 setup software to assign descriptive process names).

Press **Select**, then **Edit** to display the sequence of layers and films that comprise the selected process. To add the first layer, press **Insert Layer**. Select a film from the films screen and press **Insert Layer**. To add more layers, scroll to below the last layer and press **Insert Layer**. Layers are always added above the selected layer.

To insert a layer in a sequence of layers, scroll to below the desired location in the layer sequence, and press **Insert Layer**. Select a film from the list and press **Insert Normal** to insert the new layer above the selected layer. The selected layer and subsequent layers will be shifted down.

Hint: When building a process it may be easiest to add a “dummy” last layer and keep inserting above that layer. When the process is complete, delete the “dummy” layer.

To add a Codeposited film to an existing layer, scroll to below the desired Co-deposition layer. Press **Insert Layer**, select the desired film, then press **Insert Codep**. The Codeposited film will be inserted in the layer above the selected layer, and indented to show that it is a Co-deposition film.

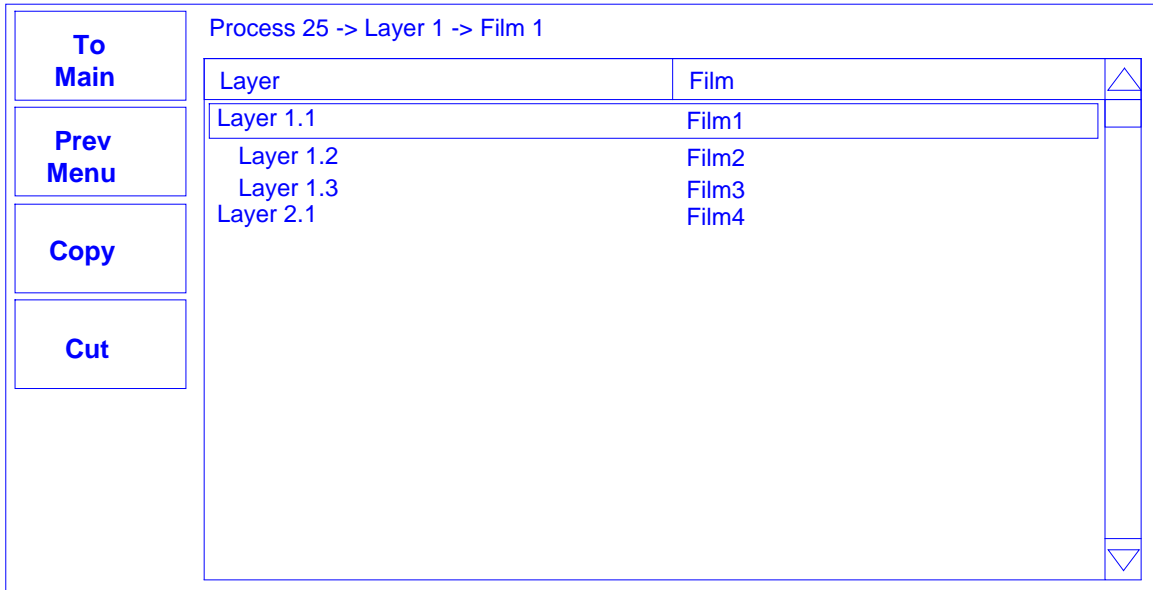
The display below shows two films being Codeposited with Film1, then a fourth film being deposited as an additional layer. While layers are always numbered sequentially, the films are sequential only for this example. Any film can be used in any layer.

Process 25 -> Layer 1 -> Film 1	
Layer	Film
Layer 1.1	Film1
Layer 1.2	Film2
Layer 1.3	Film3
Layer 2.1	Film4

Layer Select Menu

To delete a layer, highlight it in the Layer Select menu and press **Cut/Paste**.

On the Cut/Paste menu, press **Cut** to remove the layer. Press Prev Menu to return to the Layer Select menu.



Cut/Paste Menu

To move or duplicate a layer, highlight it in the Layer Select menu and press **Cut/Paste**. On the Cut/Paste menu, press **Cut** to remove the layer to memory (or press **Copy** to save a copy to memory without removing the layer). A copy of the layer is saved to the cut/paste clipboard memory. Without leaving the Cut/Past menu, highlight the layer that you want to insert the cut layer above and press **Paste Normal** or **Paste Codep**.

Operations on the Cut/Past menu can be repeated several times. Each cut operation overwrites the cut/paste memory. Pressing Prev Menu on the Cut/Past menu returns to the Layer Select menu. The contents of copy/paste memory are lost!

Note: Once a film is assigned to a process layer, you cannot change the film. Instead, cut the layer, then insert a new layer and select the desired film.

2.4 Defining a Layer

To edit a Process Layer, press **Process Menu**. Select the desired process, then press **Edit**. Finally, select the desired layer and press **Edit**.

Process 1 -> Layer 1 -> Film 1			
Parameter	Value	Units	
Init Rate	10.0	A/s	
FnI Thk	0.100	k/A	
Time Setpoint	0:00:00	h:m:ss	
Thickness Limit	0.000	kA	
Start Mode	Manual	Auto/Man.	
Output	Out1	Out1/Out2	
Max. Power	90.0	%	
Slew Rate	90.0	%	
Sensor 1	On	On/Off	
Sensor 2	Off	On/Off	
Sensor 3	Off	On/Off	
Sensor 4	Off	On/Off	
Ramp1	Disabled	En/Dis	

Layer Edit Menu

Initial Rate and Final Thickness are the main process setpoints for the film used in this layer. Time Setpoint and Thickness Limit are secondary values that will activate a relay when they are reached.

Start Mode controls operation in multi layer processes. In Auto Start the layer starts immediately on completion of the previous layer. Manual Start waits for a user signal via the front panel, digital input, or communications port to start the layer. Don't confuse this Manual Start mode with the Manual Power SoftKey function.

The Output entry assigns the layer/film parameters to a specific SQC-300 rear panel output. The layer and film parameters for power, preconditioning, PID settings, etc. will be applied to the selected output. Assign the Max Power and Slew Rate appropriate for this material and your power supply. For now, set both to 100%. Set them to lower values if you find that small power changes cause excessively large changes in deposition rate.

The SQC-300 can use multiple sensors to measure a film's deposition rate and thickness. If multiple sensors are selected, an average of the sensors is used. Set each sensor that will be used to measure this film to ON.

Rate Ramps allow the PID controlled deposition rate to change over time, under PID control. Each rate ramp has a starting thickness, an elapsed time to ramp to the new rate, and a new rate setpoint. Each process layer can have up to two rate ramps.

2.5 Sensor Setup

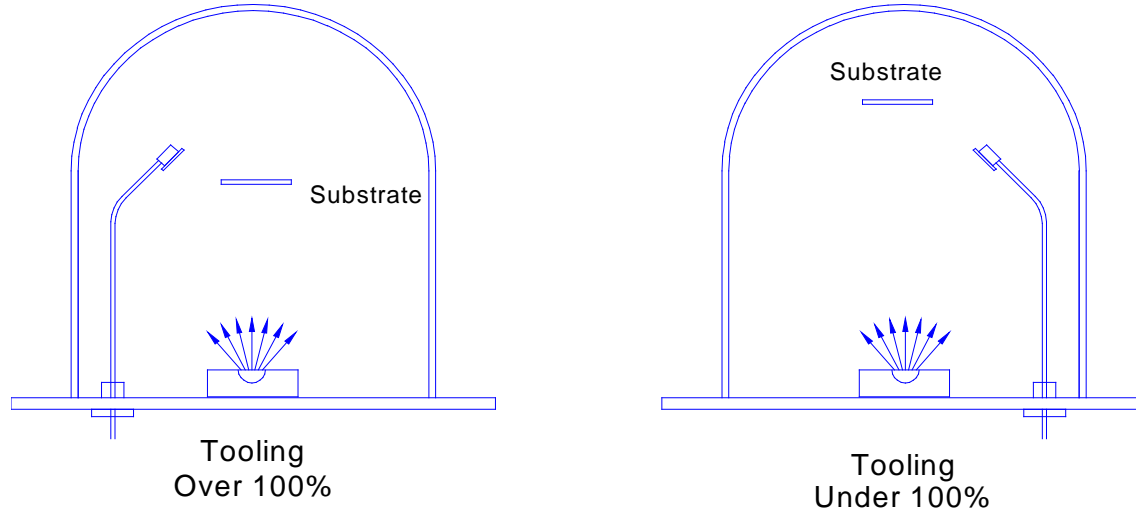
Sensor setup involves selecting the sensor(s) to be used, setting the Min/Max crystal frequencies, and adjusting the Tooling Factor.

In the **System Params** menu, Max Frequency is the initial frequency of a new crystal, typically 6.0×10^6 Hz (6 MHz). Due to manufacturing tolerances, some crystals may oscillate above 6 MHz initially, which would be detected as a sensor error. Set the Max Frequency slightly above the nominal value, to say 6.1 MHz, to avoid this problem.

Min Frequency is the frequency where the SQC-300 will flag a sensor as bad. For a 6 MHz crystal, the Min Frequency is typically 5 MHz. Crystal failure is often predicted by periods of “mode hopping,” where the crystal briefly makes an abrupt change in frequency, or stops oscillating altogether. Some materials will cause crystals to fail or mode hop well before 5 MHz. It is good practice to set the Min Frequency to a value that indicates crystal failure in your process well before crystals actually fail.

To better determine impending crystal failure, Crystal Quality and Stability parameters are also available for each Film. See Chapter 3, Film Menus, for more information on setting Crystal Quality and Stability.

Xtal Tooling and System Tooling (**System Params** menu) adjusts for the difference in measured deposition rate between the sensor and the substrate being coated.



In the left illustration above, the sensor will measure less rate or thickness than is actually deposited on the substrate because of its positioning. In the right illustration, the sensor will measure high. Tooling is the ratio of the actual substrate deposition rate or thickness, to that measured by the sensor.

Let's assume that at the end of deposition the sensor measures a thickness of 1.000 kÅ. But, suppose the actual substrate is deposited to 1.100 kÅ thickness (as

determined by some other means, such as a stylus profilometer). Then the tooling for this sensor would be:

$$(1.100 / 1.000) \times 100 = 110$$

A simple rule to remember is: If the rate/thickness reading is low, then increase the tooling value. If the rate/thickness reading is high, then lower the tooling value.

Xtal Tool 1 and 2 adjust the tooling for each individual sensor. It is particularly important when using sensor averaging to balance multiple sensors so that their measurements match. System Tooling applies to the overall Rate and Thickness measurements of all sensors. It is sometimes used to adjust for some systematic difference in the actual vs. measured readings. In general, Crystal Tooling (Xtal Tool 1 and 2) should be used instead.

Multi Xtal Count sets the number of crystals in a multi-crystal sensor head. For a standard single or dual sensor head, leave the value at 0.

Once the sensor parameters are set, test your sensor setup to assure reliable readings at the SQC-300. Press **Next Menu** until the Sensor Info option is shown, then press **Sensor Info**.

Any connected sensor (whether programmed On or Off) should display its frequency and % remaining life, as defined by Min and Max Frequency setup. For a new sensor, the value should be near 100%. If the % Life is 0.00% or jumps around, check your cabling and the installation of the sensor in its holder.

Sigma supplies a small 5.5 MHz “test crystal adapter” with each oscillator. If the % Life reading is not correct, remove the 6” BNC that is connected to your feedthrough at the oscillator. Connect the test crystal and adapter to the oscillator connector labeled Feedthrough. For a typical setup of 6 MHz Max Frequency and 5 MHz Min Frequency, the % Life display should be near 50%.

Sensors are assigned to each Layer, as described in the Chapter 3, Layer Edit.

More information on locating system and sensor problems is described in the Troubleshooting section, later in this chapter.

2.6 Source Setup

The SQC-300 controls deposition rate by varying the control voltage to an external evaporation (source) supply.

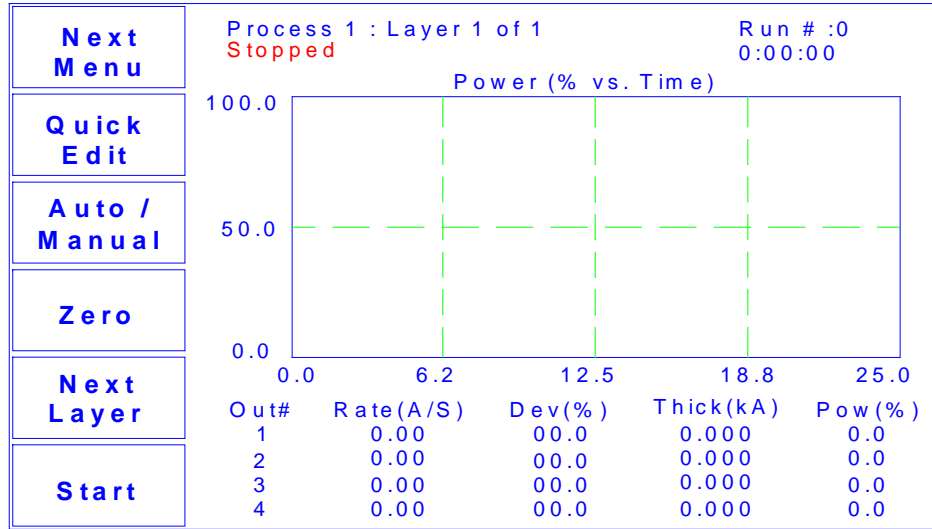
The SQC-300 output voltage range is set in the **Systems Params** menu. For the supply connected to each output, set the Scale to the control voltage that corresponds to 100% output on the source supply. The SQC-300 uses 0 volts as 0% output, and the programmed value as 100% output. Scale values from -10 volts to 10 volts are possible.

If you find that very small changes in control voltage yield large changes in deposition rate, you can lower the Scale value to decrease the dynamic range. Also, each Film has a Max Power and Slew Rate parameter that may be used to customize response to that film.

2.7 Running a Process

Once a Process is defined with the desired Layers, and the sensors and source supply are properly connected, the deposition process is ready to run. This section describes the steps to select, start, and stop a process.

There are three Main Menu screens while the process is stopped (two when it is running). Pressing the Next Menu SoftKey accesses the three screens. Next Menu is the first SoftKey in each of the three menus. Likewise, Start/Stop is the last SoftKey on each Main Menu. Main Menu 1 displays the SoftKeys used to control the process.



Main Screen

The **Quick Edit** SoftKey (available while the process is running) provides easy access to the most commonly set process parameters.

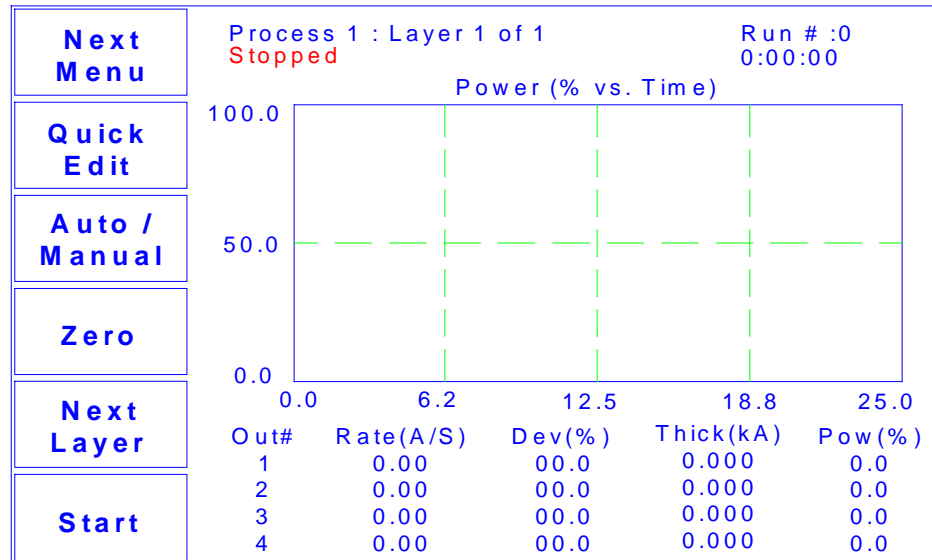
The screenshot shows the 'Quick Edit Menu' with the following structure:

- Left Panel (SoftKeys):** To Main, Edit, Next Layer.
- Header:** Process 1 --> Layer 1 --> Film 1
- Table:**

Parameter	Value	Units
Init Rate	0.2	A/s
Fnl Thk	3.0	kA
P Term	70	None
I Term	0.1	Sec.
D Term	0.0	Sec.
Max. Power	99.0	%
Slew Rate	99.0	%
Material	Aluminum	
Density	2.73	gm/cm ³
Zfactor	1.00	

Quick Edit Menu

Press **Next Layer** and **Prev Layer** on the Quick Edit screen to review each layer. Press **To Main** to return to the Main screen.

Main Screen

The **Auto/Manual** key alternates between Automatic (PID) output control and Manual (user) output control. In Manual mode, the SQC-300 immediately starts the deposition phase for the current layer, whether the process was stopped or running. However, the PID loop is disabled and the front panel control knob controls output power.

In Manual Mode, you will usually display the Rate Graph, and manually adjust the output power to achieve the desired deposition rate. It is easy to exceed a layer's Final Thickness in Manual mode, so watch the Thickness reading carefully. Manual mode is particularly useful for determining preconditioning power levels, and loop tuning.

Moving from Manual mode to Auto mode places the SQC-300 into automatic (PID) control. The PID control loop will try to achieve rate setpoint, so there may be a rapid change in output power.

Note: Don't confuse the Auto/Manual SoftKey with a layer's Manual/Auto Start parameter. Manual/Auto Start is an Edit Layer parameter that tells the SQC-300 to wait for operator intervention before starting a Layer.

The **Zero** SoftKey can be used to zero the thickness reading at any time. It is not normally needed, since the SQC-300 automatically zeroes the thickness at the beginning of each layer. However, it is useful when simulating a process, and when operating in Manual mode.

Next Layer moves the starting point for the **Start** SoftKey to the next layer, wrapping back layer 1 at the end of the process.

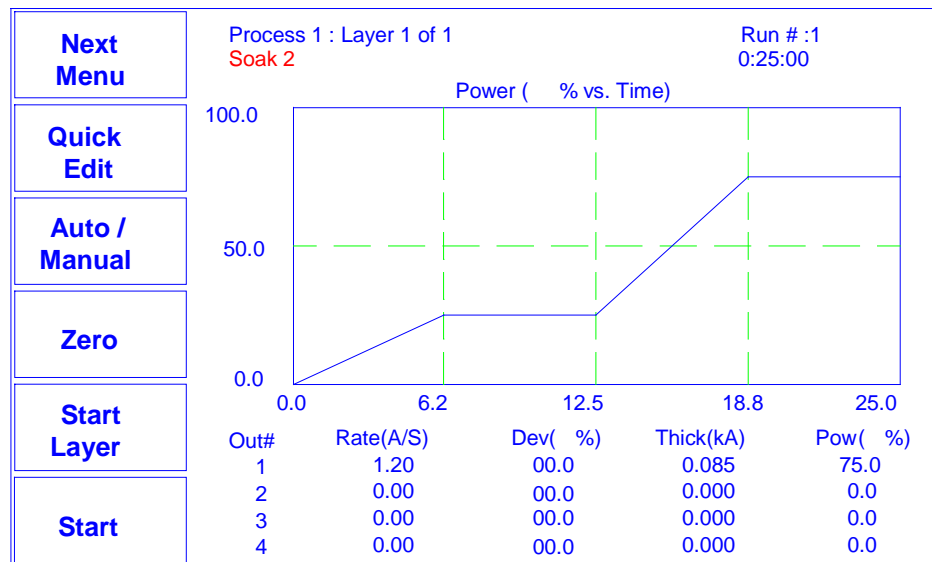
The last SoftKey on this menu is used to Start and Stop the deposition cycle. Press **Start** to start the layer shown on the first line of the screen at the preconditioning phase.

Press **Stop** to halt the current layer. You can restart the current layer pressing Start. Press Next Layer, then Start, to start any other process layer.

Note: It is best (and safest!) to place the SQC-300 in Simulate mode when a process is first run. If the bottom SoftKey does not show Start Simulate, press **System Params** and turn Simulate Mode ON.

Enough preliminaries, let's start the process!

Press **Start** to start deposition. If the first layer Start mode was programmed as Manual, you will need to press the Start Layer SoftKey now to start the layer.

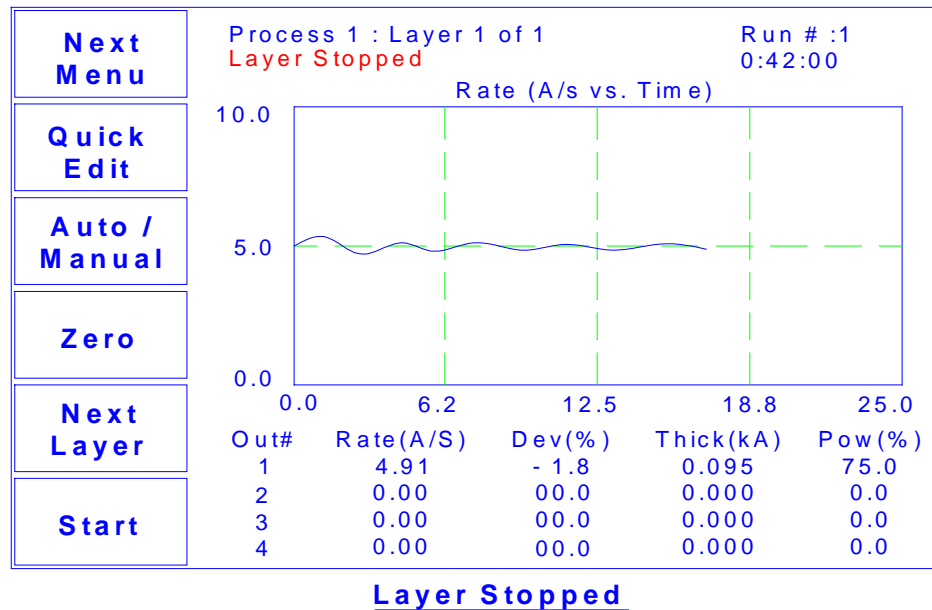


Preconditioning

The process starts with the first layer preconditioning phase. When preconditioning is complete, the deposition phase begins. The deposition phase ends when Final Thickness is reached for the layer, then Feed and Idle phases run (if programmed).

If the second layer is Auto Start, its cycle begins immediately when the first layer is complete. If the second Layer is Manual Start, or it's the last layer in the process, the process halts and waits for operator intervention.

While the process is running, a Stop Layer SoftKey is shown. Pressing **Stop Layer** temporarily halts the current Layer.



Start repeats the stopped layer, beginning with preconditioning. **Next Layer** allows you to select another layer to start.

Note: Pressing the Abort SoftKey on Main Menu 2 at any time completely aborts the process.

Spend some time in Simulate mode verifying that the process sequences through each phase of each layer as expected. If not, use the Quick Setup, Process, and Film menus to make corrections.

Because the process is being “simulated,” some parameters will not be correct for your process (particularly PID). However, you can become familiar with the effect of each parameter in this simulated process. Also practice using the Next Menu options, especially Auto/Manual modes.

Once you have verified the process in Simulate Mode, you may return to the System Params menu and turn Simulate OFF to start testing your process. Use the next section to finalize the loop PID settings.

2.8 Loop Tuning

This section will help you adjust your control loop PID parameters to achieve a stable deposition process. Keep in mind that there is no “best” way to determine PID parameters, and no one set of settings that are best.

Set System Parameters: Be sure that the output Scale and crystal Min/Max Frequency parameters are accurate for your system. All Tooling parameters are best set to 100% for now. A Period of .25 seconds is also a good starting point. Simulate should be OFF.

Create a One-Layer Test Process: Create a new film with all default values. Create a new process that has the new film as its only layer, and select it as the current process. In the Quick Setup menu set Init Rate to your desired rate and Final Thickness to a large value, say 10X your desired Final Thickness. Select the proper Sensor(s), Output, and Material. Set Max Power to 100% and Slew Rate to 100%.

Test the Setup: Press Auto/Manual to start the layer in Manual mode. Slowly turn the control knob to a power of 10%, and verify that your power supply output is about 10% of full scale. Continue to turn the control knob until a Rate(A/s) above 0 is shown. Again, verify that the power supply output agrees with the SQC-300 Power(%) reading. If the readings don't agree, check your wiring and process setup. In particular, verify that the System Parameters output scale agrees with your power supply input specifications.

Determine Open Loop Gain: Slowly adjust the control knob until the Rate(A/s) reading approximately matches your desired rate (Init Rate in the Quick Setup menu). Record the desired rate Power(%) reading as PWR_{DR} . Slowly lower the power until the Rate(A/s) reading is just at (or near) zero. Record the zero rate Power(%) reading as PWR_{OR} .

Determine Open Loop Response Time: Calculate 1/3 of your desired rate ($RATE_{1/3}$), and 2/3 of the desired rate ($RATE_{2/3}$) for this layer. Slowly increase the power until Rate(A/s) matches $RATE_{1/3}$. Get ready to record the loop's response to an input change. Quickly adjust Power(%) to PWR_{DR} . Measure the time for the Rate (A/s) reading to reach $RATE_{2/3}$. You may want to do this several times to get an average response time reading. Displaying the Rate graph will also help. Twice the measured time is the step response time, $TIME_{SR}$. $TIME_{SR}$ is typically .7 to 1.5 seconds for E-Beam evaporation, 5 to 20 seconds for thermal evaporation.

Return the output power to 0%, then press Manual/Auto to return to Auto mode. Follow these steps to set the loop PID parameters:

Set PID Values: In the Quick Setup menu set $P=25$, $I=TIME_{SR}$, $D=0$. Exit the Quick Setup menu. Press Start and observe the Power graph. The power should rise from 0%, and stabilize near PWR_{DR} with little ringing or overshoot. If there is more than about 10% overshoot, lower the P Term. If the time to reach PWR_{DR} is very slow,

increase the P Term. A lower I Term will increase response time, a higher value will eliminate ringing and setpoint deviations. It is unlikely you will need any D Term.

Continue to Start the process and adjust PID until steady-state response is smooth and the step response is reasonably controlled. You don't need to totally eliminate ringing during the step if the steady-state response is smooth, preconditioning will minimize step changes.

Set Preconditioning: The power level you recorded as PWR_{OR} is the power where deposition just begins. That's a good value for Ramp 1 power in the Film Conds menu. PWR_{DR} , or slightly less, is a good value for Ramp 2 Power. This will eliminate a large step change when entering the deposition phase.

Once PID terms are established for a material, they will typically be similar for other materials. Only the P Term and preconditioning power levels may need adjustment.

2.9 Troubleshooting

Most SQC-300 problems are caused by defective crystals or improper film setup, particularly incorrect PID settings for the control loop. Follow the procedures below to identify and correct common problems.

No Readings, or Erratic Readings from Sensors:

Disconnect the deposition source supply. This eliminates the possibility that a noisy source, or poor loop tuning, are causing an unstable PID loop.

Verify that the sensors, oscillator and cabling are connected as shown in Section 1.5. Assure that a good ground connection has been made to the SQC-300 chassis.

Replace the quartz crystal. Crystals sometimes fail unexpectedly, or exhibit erratic frequency shifts 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 Min Frequency in the System Menu to a value higher than 5 MHz.

In the System Menu, assure that Simulate Mode is OFF, and Frequency Min/Max are set properly for your crystals (typically Freq Min=5.0 MHz, Freq Max=6.0 MHz). Some manufacturer's crystals exceed 6 MHz when new. Setting Frequency Max to 6.1 MHz will correct that problem, with no bearing on instrument accuracy.

Press Film Menu, Edit, and assure that the proper sensors are enabled. Press Exit to Main, then Next Menu until the Sensor Info SoftKey shows. Press Sensor Info to show sensor Frequency and % Life.

While not depositing, observe the % Life display for each active sensor. The value should be stable, between 20% and 100%.

If the % Life reading is zero or unstable: Recheck the wiring from the sensor to the SQC-300, and verify that the SQC-300 is properly grounded. Also check that the crystal is seated properly in the sensor head.

Swap the sensor to the other SQC-300 input. If both SQC-300 inputs show zero or unstable readings, the problem is almost certainly a wiring or sensor problem.

If the % Life is less than 50%: Replace the crystal and assure that % Life is near 100%, very stable. If % Life is not near 100%, check the Frequency Min/Max limits.

If the problem is not corrected: Referring to Section 1.5, disconnect the 6" M/F 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.

When the frequency reading is stable, reconnect the source supply. Start the deposition process in Manual mode with 0% power. The % Life readings should remain stable.

Slowly raise the % Power until a rate reading is displayed above the graph. As material is deposited on the crystal, the % Life reading should remain stable, or drop slowly and consistently. 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 2.9.1 to assure reliable sensor operation.

Set the Xtal Tooling as described in the System Menu section of Chapter 3. Incorrect Xtal Tooling values will cause consistently low or high rate/thickness values for every material.

Once the Xtal Tooling is set, set Film 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 readings are initially accurate, but deteriorate as crystal life drops below 60-70%, you need to adjust the Z-Factor or replace crystals more frequently. The relationship between Z-Factor and Acoustic Impedance is discussed in the Materials Appendix.

Poor Rate Stability:

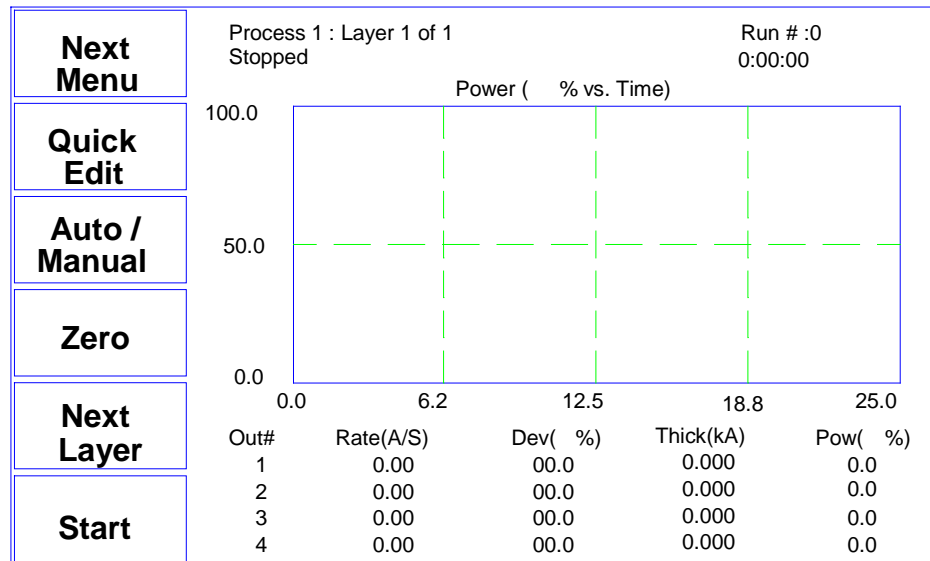
First, be sure that a stable rate can be achieved in Manual mode, as explained in Section 2.9.1. Once a stable rate is achieved in Manual mode, follow the Loop Tuning procedures of Section 2.8.

Chapter 3 - Menus

3.0 Introduction

Three menus on the Main Screen control SQC-300 operation. The SoftKeys associated with each of these menus leads to sub menus. This chapter describes the function of each setting in each menu. It is arranged by Main Screen menus, then by major sub menus.

The Main Screen for the SQC-300 is shown below.



Main Screen

At the top of the screen you will find information about the current process, layer, and run status. Immediately below is the current deposition phase and error conditions.

The central graph displays either Rate, Rate Deviation, or Output Power. If multiple materials are being deposited, the graph shows each material in a different color.

Below the graph is a display of deposition readings. This display always shows the current rate and thickness readings. The remaining columns can be set to display either Power and Deviation readings or Rate and Thickness setpoints. For a standard SQC-300 there will be two lines, corresponding to the two control outputs. With an expansion card installed there will be four lines, as shown.

The Main Screen SoftKey legends will change based on the Menu selection and the current process status. The three different menus for the main screen are accessed by press Next Menu SoftKey.

3.1 Main Screen, Menu 1

The table below describes the function of each SoftKey on Main Screen, Menu 1.

Next Menu	Sequences through each of the three Main Screen menus.
Quick Edit	Displays the Quick Setup Menu of commonly changed process values. If this key is not visible, the active process has no layers defined.
Auto / Manual	Toggles between Auto and Manual power control. When Auto/Manual is shown, output power is set by the SQC-300 to achieve the programmed deposition rate. When Manual/Auto is shown, the control knob sets the output power.
Zero	Zeros the thickness reading. Useful for resetting or extending the current deposition layer.
Next Layer	Sequences through each process layer. Use this key to start or restart the process at any layer. Only visible when the process is stopped.
Start Layer	Each layer in a process can be defined as Auto Start or Manual Start. Auto Start layers begin immediately on completion of the previous layer. Manual start layers wait for the operator to press Start Layer. Only visible when waiting to start a Manual Start layer.
Start/Stop	Starts or halts the current process. Sets all outputs to zero.

3.2 Main Screen, Menu 2

The table below describes the function of each SoftKey on Main Screen, Menu 2.

Next Menu Sequences through each of the three Main Screen menus.

Next Graph Sequences through the graph options for the Main Screen. Choose between Rate, Rate Deviation, and Power graphs. The Y axis of the Rate Deviation graph can be scaled in the System Params menu. A fourth “graph” screen displays rate, thickness, and power in large text format for easy viewing.

Next Displays Toggles between data display options at the bottom of the Main Screen. The first display option shows Rate, Rate Deviation, Thickness, and Power readings. The second option shows Rate measurements in the first column and Rate setpoints in the second column. Thickness measurements are shown in the third column, then Thickness setpoints in the fourth.

Sensor Info Replaces the Main Screen with the Sensor screen.

Exit	Sensor #	1	2	3	4
	Enable	ON	OFF	OFF	OFF
	Freq	5.543210	5.543210	5.543210	5.543210
	Life	55.36%	0.00%	0.00%	0.00%

[Sensor Info](#)

Next Layer Sequences through each process layer. Use this key to start or restart the process at any layer.

Start Layer Each layer in a process can be defined as Auto Start or Manual Start. Auto Start layers begin immediately on completion of the previous layer. Manual start layers wait for the operator to press Start Layer. Only visible when waiting to Manual Start.

Start/Stop Starts or halts the current process. Sets all outputs to zero.

3.3 Main Screen, Menu 3

Menu 3 can be accessed only while the process is stopped. This menu gives access to process, film, and system setup parameters that cannot be altered while a process is running.

To change these parameters when a process is running: Stop the process; modify the parameters; then restart the process at the desired layer.

The table below describes the function of each SoftKey on Main Screen Menu 3.

Next Menu	Sequences through each of the three Main Screen menus.
Process Menu	A process is a sequence of layers of deposited film(s). The Process Menu selection allows you to build and edit the sequence of process layers.
Film Menu	A film is basically a material plus the setup information necessary to deposit that material. Settings on the Film Menu include pre/post conditioning, deposition error controls, and the physical chamber setup for that material.
System Params	System parameters control the overall operation of the SQC-300. Tooling, crystal frequency, and operating modes are examples of settings found on the System Parameters Menu.

The remainder of this chapter provides a detailed explanation of each sub menu and its settings.

3.4 Quick Setup Menu

The Quick Setup Menu provides access to the most commonly adjusted parameters for the current process and layer.

Process 1 --> Layer 1 --> Film 1			
Parameter	Value	Units	
Init Rate	0.2	A/s	
Fnl Thk	3.0	kÅ	
P Term	70	None	
I Term	0.1	Sec.	
D Term	0.0	Sec.	
Max. Power	99.0	%	
Slew Rate	99.0	%	
Material	Aluminum		
Density	2.73	gm/cm ²	
Zfactor	1.00		

Quick Edit Menu

- To Main** Returns to the Main Screen Menu 1.
- Edit** Selects the highlighted parameter for edit. SoftKey functions change to:
Next: Store parameter and move to next for editing.
Cancel: Stop editing and undo changes to selected parameter.
Enter: Stop editing and save values for selected parameter.
Control Knob: Turn to adjust value. Push to store value and move to next parameter.
- Prev Layer** Displays the parameters for the previous layer in the process.
- Next Layer** Displays the parameters for the next layer in the process.

Quick Setup parameters are described below:

Initial Rate: The beginning rate of deposition for this layer.

Final Thickness: The desired final thickness of this layer. The deposition phase of this layer will end when this thickness is reached.

P Term: Sets the gain of the control loop. High gains yield more responsive (but

potentially unstable) loops. Try a value of 50, then gradually increase/decrease the value to respond to step changes in rate setpoint.

I Term: The integral term controls the time constant of the loop response. A small I term, say .5 to 1 seconds, will smooth the response of most loops.

D Term: The differential term causes the loop to respond quickly to changes. Use 0 or a very small value to avoid oscillations.

Max Power: The maximum output power allowed for the selected output. The Scale output voltage is a function of the deposition power supply input specifications, and is set in the System Parameters menu. Max Power controls the maximum power that can be used by this process layer.

Slew Rate: The maximum power change allowed on an output, per second. If power or rate ramps exceed this value, an error will occur.

Material: Selects a material assigned to this film. As materials change, their density and Z-Factor are updated.

Density: Sets the density for this material. Material density has a significant impact on deposition calculations.

Z-Factor: Sets the Z-factor, an empirically determined measure of a material's effect on quartz crystal frequency change. Z-Factor is the ratio of the acoustic impedance of the sensor to that of the deposited material. It is used to match the acoustic (oscillation) properties of the material to the quartz sensor. If you know the "acoustic impedance" of your material, divide it by 8.83 (the acoustic impedance of SiO₂) to obtain the material's Z-Factor.

Ramp 1: During the deposition of a layer, it may be desirable to change the deposition rate. For example, you may want to deposit slowly at first, then increase the rate once an initial thickness is reached. Enabling rate ramps provides that capability. Once enabled, these parameters are added to the list.

Start Thickness: The deposited thickness at which the new rate will begin.

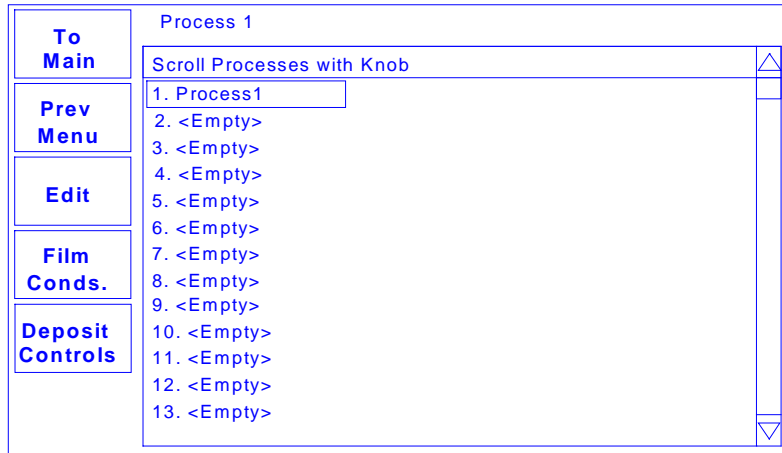
Ramp Time: Time allowed for the rate to change from initial rate to new rate.

New Rate: The rate of deposition, which is reached at the end of Ramp 1.

Ramp 2: Two rate ramps are available for each layer. The start thickness for Ramp 2 should be greater than the start thickness for Ramp 1.

3.5 Process Menu

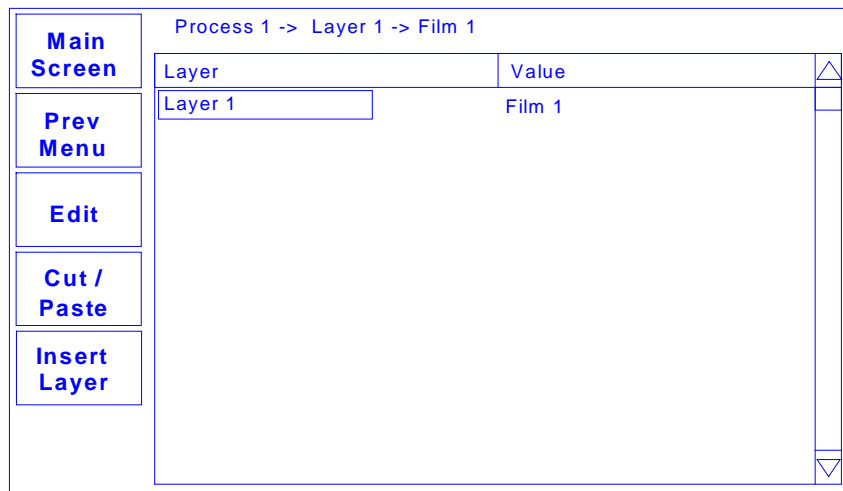
There are several tiers of Process Menu. The first menu (shown below) selects the current process. The current process is the process that is ready to run, and also the process that is selected for editing.



Process Select Menu

Main Screen	Returns to the Main Screen, Menu 3.
Prev Menu	Steps back through the sequence of process menus: Process Select <--> Layer Select <--> Layer Edit. On this topmost Process Menu, returns to the Main Menu.
Select / Edit	Select sets the highlighted process as the current process. Edit displays the Layer Select Menu for the current process.
Delete	Deletes the highlighted process and all of its layers.

Selecting Edit on the Process Select Menu shows the sequence of layers that will be deposited in the selected process.



Layer Select Menu

- Main Screen** Returns to the Main Screen Menu 3.
- Prev Menu** Returns to the Process Select Menu.
- Edit** Displays the Layer Edit Menu for the highlighted layer (see the next section).
- Cut / Paste** Used to develop the sequence of layers in a process. Pressing Cut/Paste displays a sub menu.
- The highlighted layer may be Cut (removed from the process) or Copied to the clipboard. The layer on the clipboard can then be Pasted anywhere in the list of layers (see next page).
- Insert Layer** Shows the list of 50 films. Select a film, then press Insert Normal or Insert Codep to insert the film as a new layer.

3.6 Layer Edit Menu

Each layer consists of a film (i.e. a material), plus the deposition rate and thickness that are desired for the layer. The Layer Edit Menu provides access to these layer parameters:

Process 1 -> Layer 1 -> Film 1			
Parameter	Value	Units	
Init Rate	0.0	A/s	
Finl Thk	0.000	k/A	
Time Setpoint	0:00:00	h:mm:ss	
Thickness Limit	50.0	%	
Start Mode	Manual	Auto/Man.	
Ramp1	Disabled	En/Dis	
Ramp2	Disabled	En/Dis	

Layer Edit Menu

To Main

Returns to the Main Menu.

Prev Menu Edit

Returns to the Layer Select Menu.

Selects the highlighted parameter for edit. SoftKey functions change to:

Next: Store parameter and move to next for editing.

Cancel: Stop editing and undo changes to selected parameter.

Enter: Stop editing and save values for selected parameter.

Control Knob: Turn to adjust value. Push to store value and move to next parameter.

Control Knob

Scrolls through the list of layer parameters.

A description of each parameter on the Layer Edit Menu follows:

Initial Rate: The beginning rate of deposition for this layer.

Final Thickness: The desired final thickness of this layer. The deposition phase of this layer will end when this thickness is reached.

Time Setpoint: Sets an arbitrary time, after deposition begins, when the time setpoint relay is activated.

Thickness Limit: Sets an arbitrary thickness when the thickness limit relay is activated.

Start Mode: Determines whether a layer begins automatically upon completion of the previous layer. If Manual start is selected, the previous layer ends at its idle power and waits for the user to push the Start button.

Output: Selects the control voltage output that is active for the selected layer.

Max Power: The maximum output power allowed for the selected output. The Scale output voltage is a function of the deposition power supply input specifications, and is set in the System Parameters menu. Max Power controls the maximum power that can be used by this process layer.

Slew Rate: The maximum power change allowed on an output, per second. If power or rate ramps exceed this value, an error will occur.

Sensor 1-4: Allows each quartz crystal Sensor to be selected for the selected film. If multiple sensors are assigned to a film, their readings are averaged. If multiple sensors are assigned to a film, and one fails, it is excluded from measurements.

Other selections, besides Sensor On/Off, may appear if certain relays or inputs are assigned in the System Parameters, I/O Setup menu:

If a Dual Crystal Shutter relay is assigned to Sensor 1 or 3 in the I/O Setup Menu, Sensor 1 or 3 becomes the primary sensor and Sensor 2 or 4 the secondary sensor. If the primary sensor fails, measurement automatically switches to the secondary sensor. The secondary sensor will be used until the process completes or is aborted. The next process run will return to the primary sensor.

If a Multi Crystal Move relay is assigned to a sensor in the I/O Setup Menu, a Xtal Switch selection is also shown in this menu. If a sensor fails, a relay is pulsed to move to the next sensor in the head. Selection continues until a good sensor is found, or all crystals in the multi-crystal head have failed.

If Multi Xtal Ready inputs are assigned in I/O Setup, you can select a specific crystal of the multi-crystal head for each layer. This is useful for depositing only one type of material on each crystal. If a specific sensor of a multi-crystal head is selected, and that sensor fails, the process halts or goes into timed power.

Ramp 1: During the deposition of a layer, it may be desirable to change the deposition rate. For example, you may want to deposit slowly at first, then increase the rate once an initial thickness is reached. Enabling rate ramps provides that capability. Once enabled, these parameters are added to the list.

Start Thickness: The deposited thickness at which the new rate will begin.

Ramp Time: Time allowed for the rate to change from initial rate to new rate.

New Rate: The rate of deposition, which is reached at the end of Ramp 1.

Ramp 2: Two rate ramps are available for each layer. The start thickness for Ramp 2 should be greater than the start thickness for Ramp 1.

3.7 Cut/Copy and Insert Menus

Cut/Copy and Insert menus are used to build and edit a sequence of process layers.

The Layer Select Menu below shows a process consisting of four layers. The first three layers will be co-deposited with Layer 1 (note the indentation of layers 2 and 3). The fourth layer will be deposited after layers 1-3 are Codeposited.

<p>To Main</p> <p>Prev Menu</p> <p>Edit</p> <p>Cut / Paste</p> <p>Insert Layer</p>	Process 1 -> Layer 1 -> Film 1	
	Layer	Film
	Layer 1.1	Film 1
	Layer 1.2	Film 2
	Layer 1.3	Film 3
	Layer 2.1	Film 5

Layer Select Menu

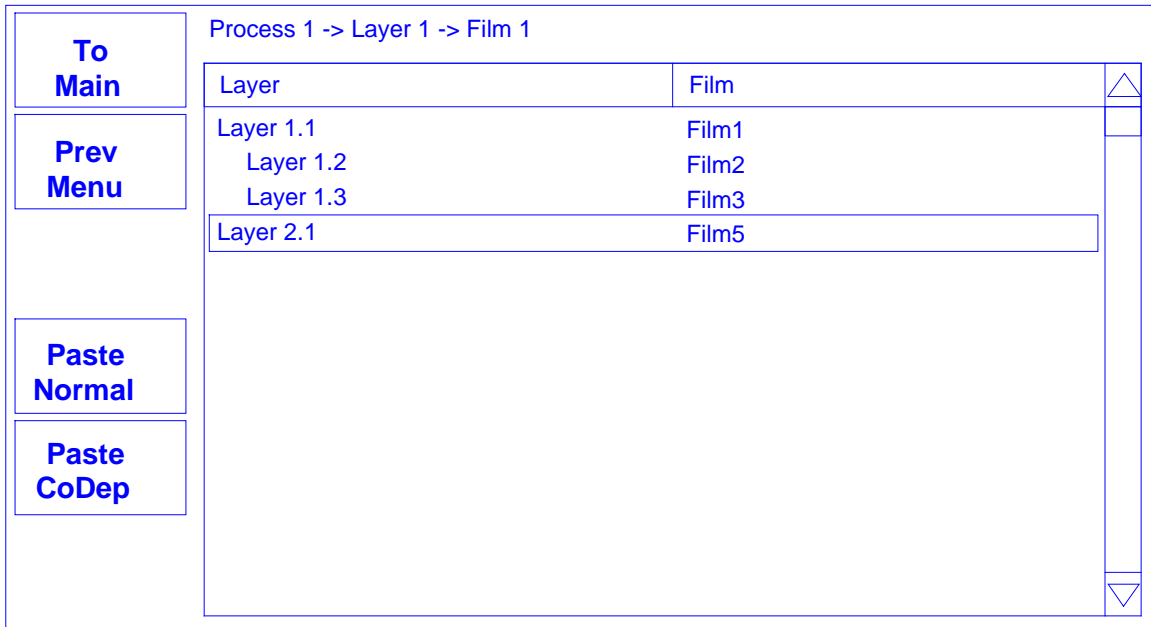
To remove (or duplicate) a layer highlight it , then press Cut/Paste.

<p>To Main</p> <p>Prev Menu</p> <p>Copy</p> <p>Cut</p>	Process 1 -> Layer 1 -> Film 1	
	Layer	Film
	Layer 1.1	Film 1
	Layer 1.2	Film 2
	Layer 1.3	Film 3
	Layer 2.1	Film 5

Cut/Paste Menu

On the Cut/Paste menu, highlight a layer and press Cut to remove the layer. The cut layer is removed from the process and placed on the clipboard. Highlight a layer and press Copy to place a copy on the clipboard without removing the layer.

The display changes to the Insert Layer Menu. The Paste Normal and Paste Codep SoftKey may not be visible if the operation is not legal for the selected layer.



Insert Layer Menu

Remember that layers are always pasted at the highlighted layer. That is, the pasted layer will have the same number as the highlighted layer, and the highlighted layer will move down one layer.

Hint: When building a process it is easiest to add a “dummy” last layer and keep inserting above that layer. When the process is complete, delete the “dummy” layer.

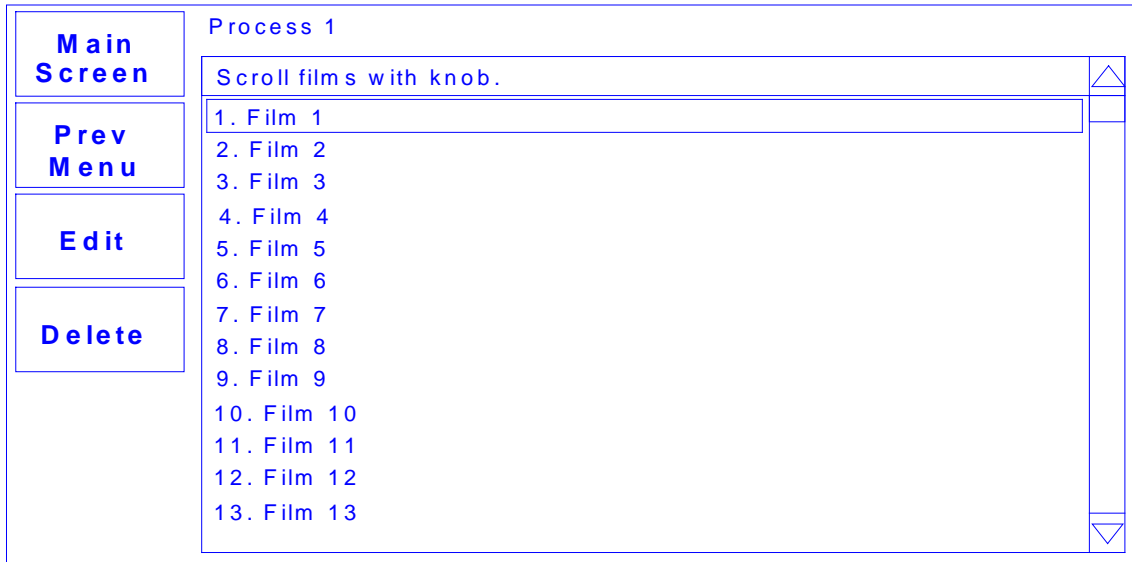
For example, to insert a new Layer 1, highlight Layer 1 and press Paste Normal. The layer is as Layer 1. The existing Layer 1 becomes Layer 2. Layer 2 becomes Layer 3, etc.

To insert a Codep layer with Layers 1-3, highlight Layer 4 and press Insert Codep. The new layer will be inserted as a Codep Layer 4 (indented and below Layer 3). The existing Layer 4 becomes Layer 5.

Note: Each Codep layer must be assigned to a different output and sensor. A warning message is displayed if there is a conflict. Highlight each Codep layer, press Edit, and assign unique sensors and outputs.

3.8 Film Menu

Each film has certain characteristics that determine how it should be deposited. The Film Menus allow you to set parameters that regulate the deposition of each film. These parameters apply any time this film is used (in any process).



Film Select Menu

Main Screen	Returns to the Main Menu.
Prev Menu	Steps back through the film menus: Film Select <--> Film Edit <-> Film Conds/Deposit Controls. On the topmost Film Menu, returns to the Main Menu.
Edit	Displays the Film Edit Menu for the highlighted film.
Delete	Deletes the highlighted film. (Note: Films cannot be deleted if they are used in any process.)

Press Edit to view the setup parameters for the selected film.

The parameters on the Film Edit Menu are those most commonly modified. Additional film parameters are available by pressing Film Conds. and Deposit Controls. An explanation of each parameter is listed at the end of this section.

Process 1 Editing: Film 1			
Parameter	Value	Units	
P Term	50	None	
I Term	0.7	Sec.	
D Term	0.0	Sec.	
Film Tooling	100	%	
Pocket	None		
Crystal Quality	Disabled		
Crystal Stability	Disabled		
Xtal Fail Mode	Halt		
Material	Aluminum		
Density	2.73	gm/cc	
Z Factor	1.08		

Film Edit Menu

- Exit to Main** Returns to the Main Menu.
- Prev Menu** Returns to the Film Select Menu.
- Edit** Selects the highlighted parameter for edit. SoftKey functions change to:
Next: Store parameter and move to next for editing.
Cancel: Stop editing and undo changes to selected parameter.
Enter: Stop editing and save values for selected parameter.
Control Knob: Turn to adjust value. Push to store value and move to next parameter.
- Film Conds.** Displays pre/post conditioning settings (See 2.6).
- Deposit Controls** Displays deposition control settings (See 2.2).

Press Film Conds to display the Film Conditioning Menu.

The Film Conditioning Menu contains the power settings used before and after deposition. Definitions of each parameter appears later in this section.

Process 1 Editing: Film 1			
Parameter	Value	Units	
Ramp1 Power	25.0	%	
Ramp1 Time	0:00:10	h:mm:ss	
Soak1 Time	0:00:05	h:mm:ss	
Ramp2 Power	50.0	%	
Ramp2 Time	0:00:05	h:mm:ss	
Soak2 Time	0:00:05	h:mm:ss	
Feed Power	0.0	%	
Ramp Time	0:00:00	h:mm:ss	
Feed Time	0:00:00	h:mm:ss	
Idle Power	0.0	%	
Ramp Time	0:00:00	h:mm:ss	

Film Conditioning Menu

- Exit to Main** Returns to the Main Menu.
- Prev Menu** Returns to the Film Edit Menu.
- Edit** Selects the highlighted parameter for edit. SoftKey functions change to:
Next: Store parameter and move to next for editing.
Cancel: Stop editing and undo changes to selected parameter.
Enter: Stop editing and save values for selected parameter.
Control Knob: Turn to adjust value. Push to store value and move to next parameter.

The Deposit Controls Menu contains the settings used to control shutters and instrument response during error conditions. Definitions of each parameter appears later in this section.

Process 1 Editing: Film 1			
	Parameter	Value	Units
To Main	Shutter Delay	0:00:00	h:mm:ss
	Capture	0.0	%
	Control Error	(Ignore, Stop, Hold)	
Prev Menu	Setting	Stop	
	Error	0.0	%
Edit	Rate Sampling	(Cont, Time, Acc based)	
	Setting	Continuous	%

Deposition Controls Menu

- Exit to Main** Returns to the Main Menu.
- Prev Menu** Returns to the Film Edit Menu.
- Edit** Selects the highlighted parameter for edit. SoftKey functions change to:
Next: Store parameter and move to next for editing.
Cancel: Stop editing and undo changes to selected parameter.
Enter: Stop editing and save values for selected parameter.
Control Knob: Turn to adjust value. Push to store value and move to next parameter.

A description of each film parameter follows:

P Term: The proportional term sets the gain of the control loop. High gains yield more responsive (but potentially unstable) loops. Try a value of 50, then gradually increase/decrease the value to respond to step changes in rate setpoint.

I Term: The integral term controls the time constant of the loop response. A small I term, say .5 to 1 seconds, will smooth the response of most loops.

D Term: The differential term causes the loop to respond quickly to changes. Use 0 or a very small value to avoid oscillations.

Film Tooling: Compensates for sensor sensitivity to the selected material. Use Xtal Tooling in the System Params menu to compensate for each sensor individually.

Pocket: Indicates which pocket (1-8) should be used. For this parameter to have an effect, you must assign the Pocket Relays and Pocket Ready input in System Parameters I/O setup (see section 3.7).

Crystal Quality: The maximum allowed rate deviation, from the rolling average of the previous 16 rate readings. Each time the rate deviation exceeds the selected percent value, a counter is incremented. Each time the deviation is within the selected value, the counter is decremented (to 0 minimum). If the counter reaches 100 during a process, the process is aborted. Crystal Quality settings from 0 to 9 indicate:

0	Disabled	5	12.5%
1	30.0%	6	10.0%
2	25.0%	7	7.5%
3	20.0%	8	5.0%
4	15.0%	9	2.5%

Note: *The Crystal Quality setting is very sensitive to PID loop tuning. It is best to leave Crystal Quality disabled until you are confident of your process and PID settings.*

Crystal Stability: As material is deposited on the crystal, the frequency normally decreases. However arcing, mode hopping, or external stresses may cause the crystal frequency to increase. If the accumulated value of these positive frequency shifts (or a single large positive shift) exceeds a threshold during a process, a crystal fail condition is indicated.

0	Disabled	5	200 Hz
1	5000 Hz (1250 Hz single shift)	6	200 Hz (100 Hz single shift)
2	1000 Hz	7	100 Hz
3	500 Hz	8	100 Hz (50 Hz single shift)
4	400 Hz	9	25 Hz

Xtal Fail Mode: Programs the action when the last sensor assigned to a film fails. Selecting Halt stops the process. When Timed Power is selected, the instrument uses the last valid rate, thickness, and power readings to calculate the time required to reach final thickness. The power is fixed at the last valid reading and deposition continues for the calculated time. Because there are no sensor readings, this is only a rough estimate. The more stable the process, the more accurate the estimate.

Material: Selects a material assigned to this film. As materials change, their density and Z-Factor are updated.

Density: Sets the density for this material. Material density has a significant impact on deposition calculations.

Z-Factor: Sets the Z-Factor, an empirically determined measure of a material's effect on quartz crystal frequency change.

Ramp 1: Ramp power sets the power level desired at the end of the ramp phase, in % of Scale 1,2. Ramp time sets the time to ramp linearly from the initial power to the Ramp power. Soak time sets the time the output remains at the ramp power level.

Ramp 2: Ramp 2 functions are the same as Ramp 1. Typically, Ramp 2 power is set near the power level required to achieve the desired initial deposition rate.

Feed: The feed phase holds output power at the level and time required to wire feed new material.

Idle: Idle power ramps output power back to zero, or holds the material at a state that is ready for deposition (usually the same as Ramp 2 power).

Shutter Delay: It is often desirable to obtain deposition control before the substrate shutter opens. Enabling shutter delay requires that the system reach a specific capture accuracy before the shutter opens. If the capture accuracy is not reached within the shutter delay time, the process halts. Otherwise, the substrate shutter opens and deposition begins when control accuracy has been maintained for 5 seconds. The thickness reading is zeroed at the end of the shutter delay period.

Capture: The control accuracy (%) that must be reached to end the shutter delay.

Control Error: If the control loop cannot maintain the desired deposition rate, due to loss of source material, excess rate ramps, or equipment malfunction, a control error occurs. The error condition can be ignored, the process stopped (output power to 0%), or the output power held at the same level as when the error occurred. If hold is selected, PID control is abandoned, but the process will continue to be monitored for thickness setpoint.

Rate Sampling: Rate sampling can extend the life of crystals. With rate sampling, the deposition rate is sampled for a period of time, then the sensor shutter is closed. Power is then held at the same level as the final power setting during the sample period.

- Continuous selects no sampling, the sensor shutter remains open during deposition.
- Time based sampling opens the shutter for a fixed period of time, then closes it for a fixed time.
- Accuracy based sampling opens and closes the shutter at the rate required to maintain the desired accuracy during the hold phase.

3.9 System Parameters Menu

The System Parameters Menu contains settings that affect the basic operation of the SQC-300. System parameters generally pertain to the physical setup of your vacuum system equipment.

Process 1 -> Editing -> Film 1			
To Main	Parameter	Value	Units
	Period	1.00	Sec
Edit	Simulate Mode	On	On/Off
	Xtal Tool 1	100	%
Input Setup	Xtal Tool 2	100	%
	Xtal Tool 3	100	%
Relay Setup	Xtal Tool 4	100	%
	Scale 1	0.5	Volts
	Scale 2	0.5	Volts
	Scale 3	10.0	Volts
	Scale 4	10.0	Volts
	Multi Xtal Count 1	0	
	Multi Xtal Count 2	0	

Edit System Params Menu

- Exit to Main** Returns to the Main Menu.
- Edit** Selects the highlighted parameter for edit. SoftKey functions change to:
Next: Store parameter and move to next for editing.
Cancel: Stop editing and undo changes to selected parameter.
Enter: Stop editing and save values for selected parameter.
Control Knob: Turn to adjust value. Push to store value and move to next parameter.
- Input Setup** Displays menu for mapping digital inputs to process events.
- Relay Setup** Displays menu for mapping relays to process events.

Descriptions of each System Parameter follows:

Period: Sets the measurement period between .1 second (10 readings per second) and 1 second. A longer period gives higher reading accuracy, especially in low rate and low density applications.

<u>Period</u> (seconds)	<u>Frequency</u> <u>Resolution</u> (Hz)
.10	.03
.25	.01
.50	.005
.75	.004
1.00	.003

Simulate Mode: Normal mode uses the quartz crystals as inputs to the SQC-300 for PID calculations and source output control. Simulate mode simulates the quartz crystals based on the crystal frequencies set on this. Simulate mode is useful for debugging process recipes.

System Tooling: Adjusts for overall sensor deposition rates that differ from the measured substrate deposition rate.

Xtal Tool: Adjusts for sensor deposition rates that differ from the measured substrate deposition rate, because of sensor location. If the rate/thickness reading is low, then increase the tooling value. If the rate/thickness reading is high, then decrease the tooling value.

Scale: The input voltage required by the deposition source power supply to produce 100% output power. Positive or negative Scale values are possible.

Multi Xtal Count: Specifies the number of crystal positions available in a multi-crystal sensor head. For a six-sensor head, set the value to six. For standard single or dual crystal sensor heads, leave the value at 0.

Min/Max Frequency: The frequency values for the quartz crystal sensors used as inputs to the SQC-300. The maximum frequency should be set to the frequency of a new crystal, typically 6 MHz. Sensor readings outside the min/max values cause an error.

Pocket Relay: Select Single to assign a single relay to each source pocket. Select Multi to allow relays to represent the BCD encoded value of the selected pocket.

For example, assume that a film has its Pocket parameter set to 3. In I/O Setup, set Relay 1, 2, & 3 to Pocket 1, 2, & 3. Then if this parameter is set to Single, Relay 3 will close when deposition begins. If this parameter is set to Multi then Relays 1 & 2 will close (representing a binary 3).

Pocket Wait: This parameter has two functions, depending on the setting of the Pocket Ready signal in I/O setup. If no Pocket Ready input is programmed for an output, then this is the time the program waits for the indexer to complete its move. After the wait time, deposit begins.

If a Pocket Ready input is programmed for an output, then this is a timeout value. If the pocket ready signal is not received within Time Wait, then an error occurs.

Dev Graph Limit: Sets the upper limit for the Rate Deviation graph Y axis.

Rate Alarm Low: Sets the % deviation below rate setpoint that causes an audible alarm.

Rate Alarm High: Sets the % deviation above rate setpoint that causes an audible alarm. The tone of the high rate alarm is lower than that of the low rate alarm.

Password Enable: If Password is enabled, the Quick Start, Film and System Menus require a password. The Process Menu can be used to select a process, but a password is required to make any changes on the Process Menu.

Password: If password is enabled, this parameter sets the sequence of SoftKeys to press to enter menus. Press the desired sequence to set the password.

Note: *Holding down the top and bottom switch while powering up the SQC-300 sets the password to 1111.*

System Time: Sets the SQC-300 clock to your local time. System time is battery backed up. Does not compensate for daylight savings time.

System Date: Sets the SQC-300 date to your local time. System date is battery backed up.

3.10 Relay and Input Setup

The Input and Relay SoftKeys of the System Parameters Menu allow you to map the eight digital inputs and the eight digital outputs (16 of each if the option card is installed).

The Relay screen has an additional Softkey that allows each relay to be toggled manually. Relays are returned to their proper defined state on exit from the Relay screen.

Process 1 -> Layer 1 -> Film 1	
Parameter	Value
Input 1	None
Input 2	None
Input 3	None
Input 4	None
Input 5	None
Input 6	None
Input 7	None
Input 9	None
Input 10	None
Input 11	None
Input 12	None
Input 13	None

I/O Mapping Menu

To Main

Returns to the Main Menu.

Prev Menu

Returns to the System Parameters Menu.

Edit

Selects the highlighted parameter for edit. SoftKey functions change to:

Next: Store parameter and move to next for editing.

Cancel: Stop editing and undo changes to selected parameter.

Enter: Stop editing and save value for selected parameter.

Control Knob: Turn to adjust value. Push to store value and move to next parameter.

In the I/O Setup Menu, any number of “events” can be mapped to the physical inputs and relays. Options are set by selecting a relay or input and then turning the control knob to select the desired event. The following table explains each event:

Inputs

Start Process
 Abort Process
 Start Layer
 Stop Layer
 Start Next Layer
 Force Final Thickness
 Start Process 1-25
 Soak Hold
 Zero Thickness
 Zero Time
 Output Pocket Ready
 Multi Xtal Ready
 None

Explanation (low to high transition causes)

Start the process at Layer 1.
 Abort the process. Can only restart at Layer 1.
 Start the active layer.
 Stop the active layer.
 Start the next layer.
 End deposition.
 Start the selected process.
 Delay the start of deposition.
 Reset thickness reading to zero.
 Reset time setpoint counter to zero.
 The output's source indexer is on the desired pocket.
 A multi-crystal sensor head is on the selected crystal.
 The input is not assigned.

Relays

Source 1-4 Shutter
 Sensor 1-4 Shutter
 Sensor 1-4 Fail
 All Crystal Good
 All Crystal Fail
 Process Hold
 Deposit Phase
 PreCond Phase
 SoakHold Phase
 Process Active
 Manual Mode
 Max Power
 Process Stopped
 Time Setpoint
 Thickness Setpoint
 Final Thickness
 Dual Crystal Shutter
 Multi Xtal Move 1-4
 Output Pocket 1-8
 None

Explanation (closes when)

Deposit phase for films set to Output.
 Shutter Delay and Deposit phases of films set to Sensor.
 Sensor is assigned to this layer, and has failed.
 All sensors assigned to this layer are OK.
 All sensors assigned to this layer have failed.
 Process is stopped (waiting for Start Layer).
 Process is in Deposit phase.
 Process is in Ramp1, Soak1, Ramp2, or Soak2 phase.
 Process is in Soak/Hold phase.
 Process is running (not stopped).
 Process is in Manual mode (not under PID control).
 Active output is at maximum power (out of material?).
 Process is stopped (not running).
 The process has been in Deposit phase the indicated time.
 Thickness setpoint reached. Resets on start of next Layer.
 Final thickness reached. Resets on start of next Layer.
 Primary sensor failed, switch to secondary.
 1 sec. pulse to move a multi-crystal head to next position.
 Source pocket # (Single mode) or BCD bit # (Multi mode)
 The relay is not assigned to any event.

Chapter 4 - Maintenance

4.0 Introduction

This section covers maintenance, cleaning, software upgrades, and the installation of optional accessories.

WARNING: *There are no adjustments or user-serviceable parts inside the SQC-300 Series controllers. 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.

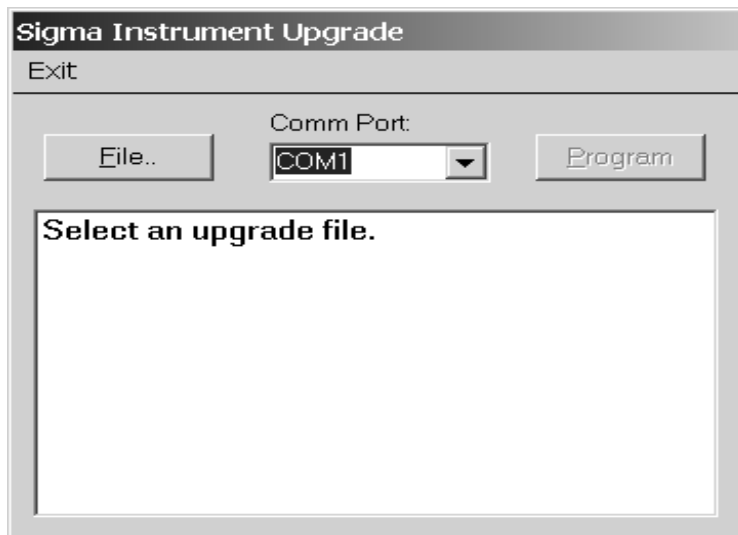
4.2 Software Upgrades

The SQC-300 firmware (Flash software) can be upgraded through its RS-232 port. The upgrade program, SigmaFlash.exe, is on the Utility CDROM shipped with the SQC-300.

The latest firmware file (SQC300_VERSION.BIN) can be found on our web site, www.sig-inst.com. Compare the version of the web site's file with the version shown on the SQC-300 at power on. Upgrade only if the BIN file on our web site is a higher number.

To upgrade the SQC-300 firmware:

1. Download the BIN file from our web site to your computer.
2. Start the SigmaFlash program.



3. Click File... and load the BIN file that you downloaded.
4. Connect the SQC-300 to your computer with the cable provided (a straight-thru RS-232 cable). Select the computer Comm port in the dropdown box in SigmaFlash.
5. Be sure the SQC-300 is turned OFF.
6. Click Program, then turn on the SQC-300.
7. SigmaFlash should find the SQC-300 and load the new program.
6. When the upgrade is complete, the SQC-300 will restart. Verify that the SQC-300 startup screen shows the new firmware version.

4.3 Option Card Installation

The option card adds two additional sensor inputs, two control outputs, and 8 digital I/O signals to the SQC-300. To install the option card follow these steps.

1. Unplug the SQC-300 from the main power!
2. Remove (and save) the eight screws securing the top cover. Remove the cover.
2. Remove the three screws securing the option cover plate to the back panel.
3. Remove the screws from the two 5/8" standoffs near the rear of the main PCB.
4. Plug the short ribbon cable into the connector on the main PCB.
5. Slide the option card PCB into the back panel.
6. Secure the option card PCB to the main PCB with two 2" screws and lockwashers.
7. Screw the four BNC hex nuts to the back panel.
8. Screw the two jack screws and washers into the back panel I/O connector.
9. Replace the cover and attach with the eight screws saved in step 1.
10. At turn on the SQC-300 will now display four channels on the main display.

4.4 Half Rack Adapter Installation

The Half Rack Adapter option (PN 900-016) adapts the SQC-310 model to many other 5 1/4" high half rack instruments. The Half Rack Adapter option (PN 900-017) adapts the SQC-330 model to many other 3 1/2" high half rack instruments.

The option consists of two standard rack mount ears and an adapter bracket. Attach one of the standard rack mount ears to the SQC-300 with the 10-32 flat head screws supplied. Attach the adapter bracket to the other side of the SQC-300.

Place the other instrument so that its rack mount ear matches the two threaded 10-32 holes on the adapter bracket. Attach the other instrument to the adapter bracket with two standard 10-32 rack mount screws (not supplied).

4.5 Full Rack Extender Installation

The Full Rack Extender option (PN 900-007) mounts an SQC-310 into a full width 19" rack space. A Full Rack Extender option (PN 900-008) mounts an SQC-330 into a full width 19" rack space

Assemble the two 3" x 5..." Extender Kit side panels and the larger front and rear panels into a box configuration using the eight 6-32 flat-head screws.



Thread two 10-32 shoulder screws from the inside of one of the box sides until the threads extend fully to the outside. Now attach the Extender Kit to the SQC-300 by threading the shoulder screws into the matching holes in the SQC-300 covers.

Attach the rack mounting ears with the 10-32 flat-head screws provided. Carefully lift the assembly into a full width, 5¼" high rack space. Attach the assembly to the rack with 10-32 screws (not provided).

Chapter 5 - Communication s

5.0 Introduction

The SQC-300 series communicates with a host computer through three possible protocols:

1. RS-232: 19200 baud, 8 data bits, and no parity
2. USB: PID 8292
3. Ethernet (option): Port 2101, Address 192.168.1.200.

5.1 SQC300 COMM.EXE

SQC300 Comm .exe is found on the Utility and Demo disk supplied with your SQC-300. A current version may be also be downloaded from www.sig-inst.com.

The program provides instrument control and data graphing. It also allows you to set process, layer, film, and material parameters, download them to the SQC-300 and save them to disk. Contact Sigma Instruments if you would like the vb source code.

5.2 Communications Protocol

The SQC-300 communicates with a host computer via a serial ASCII protocol at 19200 baud, 8 data bits, and no parity. The SQC-300 only responds to commands received. It never initiates communications.

The command protocol sent to the instrument is:

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

The sync character is always an exclamation point '!'. Following the sync character is the length character. This is the number of characters in the packet (not counting the sync, length, and CRC characters). The length character has a decimal 34 added to it so there cannot accidentally be a sync character (!) embedded in the packet.

Following the length character are the command and data characters as detailed later in this section. After the data come two CRC characters.

Note: *If you do not wish to use CRC checking in your application, just send two Null characters (CHR\$0) for the CRC. The SQC-300 will ignore the CRC. The SQC-300 will still return a CRC in its response, but you can ignore it.*

The CRC is computed using the following algorithm:

- The CRC is initialized to 3FFF hex.
- Each character in the message is examined, bit by bit, and added to the CRC in the following manner:
- The character is exclusive OR'd with the CRC.

- The CRC is shifted right one bit position.
- If a character's least significant bit is a 0 then the CRC is exclusive OR'd with 2001h
- Steps b and c are repeated for each of the 8 bits in the character.

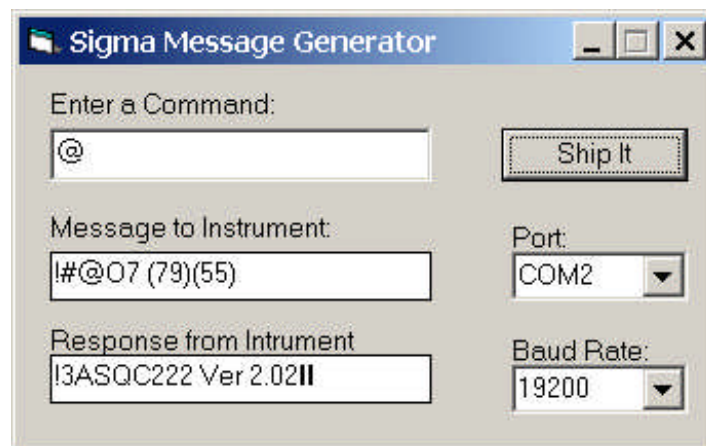
The CRC contains 14 significant bits. This is split into two characters of 7 bits each, and then a decimal 34 is added to offset the character outside the range of the Sync Character.

Once a command is received by the SQC-300, it responds with a Response Status character as shown below:

Response Status	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

If the response status is "A", the requested data follows the status character.

An example application, MessageGen is supplied on the Utility CD to assist in developing your communications program. MessageGen allows you to type in the base command (without sync, length, and CRC characters) and view the complete command sent to the SQC-300, and the complete response.



In this example, the complete Get Model command ("@") is 5 characters long: A sync character (!), the length (34 + 1 = "#"), the command ("@"), and the two CRC characters ("07"). The two values shown in parenthesis after the sync characters are the ASCII value of the CRC characters. They are informational only, and were not actually sent to the instrument.

The format of the response is identical, except that the third character (after sync and length characters) is the Response Status character ("A").

5.3 SQC-300 Commands**Get Model**

Command: @

Description: Returns the model number and software version number.

Parameters: None

Example: The @ command returns "SQC-300 Ver 3.00"

Get/Set Film Parameters

Command: A

Description: There are four film commands. A1 sets/gets the film name. A2 sets/gets the main film edit screen parameters. A3 sets/gets the film conditioning parameters. A4 sets/gets the deposit controls parameters.

To Get Film Parameters send the command (i.e. A1), a space, the film number, a question mark, then a series of spaces and parameter numbers. You may include as many parameters as you want, in whatever order you want. The format of the return string is a series of parameter numbers, a comma, and its value, separated by spaces.

To Set Film Parameters send the command, a space, the film number, then a series of parameter numbers, a comma, and the parameter value.

Parameters: A1: FilmName

A2:	1	P Term	7	Crystal Quality
	2	I Term	8	Crystal Stability
	3	D Term	9	Xtal Fail Mode
	4	Material #		
	5	Pocket		
	6	Tooling		

A3:	1	Ramp1 Power	7	Idle Power
	2	Ramp1 Time	8	Idle Ramp
	3	Soak1 Time	9	Feed Power
	4	Ramp2 Power	10	Feed Ramp
	5	Ramp2 Time	11	Feed Time
	6	Soak2 Time		

A4:	1	Shutter Delay	5	Rate Sampling (0,1,2)
-----	---	---------------	---	-----------------------

2	Capture	6	Sample Accuracy
3	Control Error (0,1,2)	7	Sample Hold
4	Control Percent	8	Sample Time

Example: To Get the P I D parameters of Film 1, send: A2 1? 1 2 3

The return string would be of the form: 1,50 2,5 3,0

To Set the PID parameters of Film 1, send: A2 1 1,50 2,5 3,0

Note: *Numeric film parameter values sent and received by the SQC-300 are integers. To convert between the integer value and the parameter's actual value, you must multiply or divide by the number of decimal digits in the displayed parameter.*

In the examples above the P term is displayed as an integer value, so no conversion is required. However, the I Term is displayed with one decimal digit (i.e. 0.5). A Get response of 5 actually represents a parameter value of .5. Similarly, a Set value of 5 for the I Term sets its value in the SQC-300 to .5.

Get/Set System Parameters

Command: B

Description: Gets/Sets the system parameters screen values. The format is similar to Get/Set Film Parameters. See the examples below.

Parameters:	1	Period	8	Scale 1
	2	System Tooling	9	Scale 2
	3	Xtal Tool 1	10	Scale 3
	4	Xtal Tool 2	11	Scale 4
	5	Simulate Mode	12	Xtal Tool 3
	6	Min. Frequency	13	Xtal Tool 4
	7	Max. Frequency		

Example: To Get the Xtal Tool 1 and Xtal Tool 2, send: B? 3 4

The return string would be of the form: 3,100 4,100

To Set the parameters you would send: B 3,100 4,100

Get/Set Process Parameters

Command: C

Description: Gets/sets the four process parameters. In the parameters list below, Number Layers is the number of layers in a process, counting Codep layers as 1 layer. Actual Layers is the total number of layers. For example, a process with one Codep layer (using two films) would have Number Layers=1 and Actual Layers=2.

The First Layer is the layer number of the first layer in the process. Subsequent layers are found by reading the Next Layer parameter (see the D command, Layer Parameters).

Parameters:	1	Process Name	3	First Layer
	2	Number Layers	4	Actual Layers

Example: To Get Process 1 name, send: C1? 1

The return string would be of the form: AnyName

To Set the parameter, send: C1 1,AnyName

Note: Unlike Get/Set Film Parameters, you can only get/set one process parameter at a time.

Get/Set Layer Parameters

Command: D

Description: Most layer parameters are directly related to a setting on the layer edit screen. You can get/set multiple layer parameters as explained in Film Parameters.

The Next Layer and Codep Layer parameters need some explanation. A process is formed by a "linked list" of layers. We have already seen that Layer 1 in a process is found in the First Layer (process parameter). That layer has a Next Layer (layer parameter) that points to the next layer in the process. This continues until the last layer in the process, where the Next Layer parameter will be -1.

Codep layers are handled similarly. If a layer is one of a set of Codep layers, then it's Next Layer Parameter will be -1. However, it's Codep Layer parameter will be a valid Layer Number. See the example below.

Parameters:	1	Init Rate	13. Ramp1 Enable
	2	Final Thickness	14. Ramp1 Start
	3	Time SetPoint	15. Ramp1 Rate

4	Thickness Limit	16. Ramp1 Time
5	Start Mode	17. Ramp2 Enable
6	Output	18. Ramp2 Start
7	Max. Power	19. Ramp2 Rate
8	Slew rate	20. Ramp2 Time
9	Sensor 1	21. Film Number
10	Sensor 2	22. Next Layer
11	Sensor 3	23. Codep Layer
12	Sensor 4	

Example: Assume that Process 1 has two layers. The first layer being a Codep layer using two outputs. The second a normal layer, using just one output.

Get the Actual Layer count for the process: C1? 4

The response will be 3. Get the First Layer of the process: C1? 3

If the first layer is Layer #1 (of 250 possible layers) the return is: 3,1

Now get the Next Layer for Layer 1: D1? 22

Because this is a Codep layer the response will be: 22,-1

We have to check the Codep Layer parameter: D1? 23

The response might that Layer 2 is the Codep layer: 23, 2

Now read the next Layer for Layer 2: D2? 22

The response might be Layer 3: 22,3

At this point you could read the Next Layer parameter for Layer 3 (it will be -1), or stop (since we already know there are three layers).

Delete All Layers

Command: E

Description: Deletes all 250 layers! Most often used to clear the entire inreument in preparation for downloading a new list.

Parameters: None

Get/Set Material Parameters

Command: F

Description: Gets/Sets the parameters of the 100 stored materials.

Parameters: 1. Material Name 3. Zfactor
 2. Density

Example: To Get Material 1 name, send: F1? 1

 The return string would be of the form: Aluminum

To Set the parameter you would send: F1 1,AnyName

Note: You can only get/set one material parameter at a time.

Get/Set Input Parameters

Command: G

Description: Gets/Sets the logical function of each of the 16 digital inputs.

Parameters:	1	Start Process	32	Soak Hold
	2	Abort Process	33	Zero Thickness
	3	Start Layer	34	Zero Time
	4	Stop Layer	35	Out1 Pocket Ready
	5	Start Next Layer	36	Out2 Pocket Ready
	6	Force Final Thick	37	Out3 Pocket Ready
	7-31	Start Process 1-25	38	Out4 Pocket Ready
			39	Not Used

Example: To Get Input 1 and Input 2 functions, send: G? 1 2

The return string for Start Layer and Stop Layer would be: 1,3 2,4

To Set the same parameters you would send: G1 1,3 2,4

Get/Set Relay Parameters

Command: H

Description: Gets/Sets the logical function of each of the 16 relays.

Parameters:	1	Source 1 Shutter	21	Max. Power
	2	Source 2 Shutter	22	Stopped
	3	Source 3 Shutter	23	Time Setpoint
	4	Source 4 Shutter	24	Thick Limit
	5-8	Sensor 1-4 Shutter	25	Final Thickness
	9-12	Sensor 1-4 Fail	26	Dual Xtal 1/2 Shutter
	13	All Crystals Good	27	Dual Xtal 3/4 Shutter
	14	All Crystals Bad	28-35	Out1 Pocket 1-8
	15	Process Hold	36-43	Out1 Pocket 1-8
	16	Deposit Phase	44-51	Out1 Pocket 1-8
	17	PreCond Phase	52-59	Out1 Pocket 1-8
	18	SoakHold Phase	60	Not Used
	19	Process Active		
	20	Manual Mode		

Example: To Get Relay 1 and Relay 2 functions, send: H? 1 2

The return for Source 1 Shutter and Sensor 1 Shutter would be: 1,1 2,5

To Set the same parameters you would send: H1 1,1 2,5

Get Num Channels

Command: J

Description: Returns the number sensor/output channels installed.

Parameters: None

Example: The J command returns either 2 or 4.

Get Readings

Command: K

Description: Returns the phase time and sensor or output readings for all installed channels.

Parameters: 1 = Output Readings 2 = Sensor Readings

Example: To Get Output readings, send: K1

The return string is of the form:

Time Rate1 Dev1 Thick1 Power1 Rate2 Dev2 Thick 2 etc.

To Get Sensor readings, send: K2

The return string is of the form:

Time Rate1 Thick1 Frequency1 Rate2 Thick 2 etc.

Get Sensor Rate

Command: L

Description: Returns the sensor rate for the requested sensor.

Parameters: Sensor Number

Example: To Get Sensor 1 rate, send: L1

The return string is of the form: 1.00

Get Output Rate

Command: M

Description: Returns the average rate of all sensors assigned to the requested output.

Parameters: Output Number

Example: To Get Output 1 rate, send: M1

The return string is of the form: 1.00

Get Sensor Thickness

Command: N

Description: Returns the thickness reading for the requested sensor.

Parameters: Sensor Number

Example: To Get Sensor 1 thickness, send: N1

The return string is of the form: 1.000

Get Output Thickness

Command: O

Description: Returns the average thickness of all sensors assigned to the requested output.

Parameters: Output Number

Example: To Get Output 1 thickness send: O1

The return string is of the form: 1.000

Get Sensor Frequency

Command: P

Description: Returns the frequency of the requested sensor.

Parameters: Sensor Number

Example: To Get Sensor 1 frequency, send: P1

The return string is of the form: 5543210.0

Get Output Deviation

Command: Q

Description: Returns the % deviation of the requested output.

Parameters: Output Number

Example: To Get Output 1 deviation, send: Q1

The return string is of the form: 1.00

Get/Set Output Power

Command: S

Description: Returns output power. Sets outputs to PID loop mode or manual mode. In manual mode, also sets the output power. Power is sent as an integer value.

Parameters: Output Number, Power

Example: To Get Output 2 power send: S? 2

To Set Output 2 to 50.0% of full scale send: S2 500

Note: This places other outputs in Manual mode at their current power.

To set all outputs to PID loop control send: S0

Set Active Process

Command: T

Description: Sets the currently selected process. If a process is running, it is not changed and an E response status is returned.

Parameters: Process Number

Example: To set the process to Process 1 send: T1

Set Run State

Command: U

Description: Sets the instruments operating state.

Parameters:

0 = Start Process	31 = Soak/Hold
1 = Stop Process	32 = Zero Thickness
2 = Start Layer	33 = Zero Time
3 = Stop Layer	34 = Out 1 Pocket Ready
4 = Next Layer	35 = Out 2 Pocket Ready
5 = Force Final Thickness	36 = Out 3 Pocket Ready
6-30 = Start Process 1-25	37 = Out 4 Pocket Ready

Example: To start process 2, send: U7

Get Run State

Command: V

Description: Returns the Phase #, Process Elapsed Time (as shown on display), Process #, and Active Layer of the active process.

Parameters:

0 = Stopped	10 = Soak 2	20 = Feed Ramp
1 = Crystal Verify	11 = Soak Hold	21 = Feed Soak
2 = Initialize Layer	12 = Shutter Delay	22 = Idle Ramp
3 = Manual Start Layer	13 = Deposit	23 = Start Next layer
4 = Crystal Rotate	14 = Rate Ramp	24 = Crystal Fail
5 = Pocket Rotate	15 = Rate Ramp Deposit	25 = Stop Layer
6 = PreCond (Codep only)	16 = Timed Power	26 = Manual Power
7 = Ramp1	17 = Rate Sample Delay	27 = Pocket Timeout
8 = Soak 1	18 = Rate Sample Sample	28 = Sample Hold
9 = Ramp 2	19 = Crystal Switch	

Example: To read the run state, send: V

The return string for the Deposit Phase, Elapsed Time =15 seconds, Active Process #1, Layer #2 is: 13 15 1 2

Get Power Reset

Command: Y

Description: Gets the status of the power reset flag.

Parameters: None

Example: Y returns 0 if reset has occurred, 1 if not.

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 ₂ O ₃	3.970	0.336	Aluminum Oxide
Al ₄ C 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 ₂ Se ₃	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B ₂ O ₃	1.820	*1.000	Boron Oxide
B ₄ C	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 ₂ O 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 ₂ O ₃	8.900	*1.000	Bismuth Oxide
Bi ₂ S ₃	7.390	*1.000	Bismuth Trisulphide
Bi ₂ Se ₃	6.820	*1.000	Bismuth Selenide
Bi ₂ Te 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 ₈ H ₈	1.100	*1.000	Parlyene (Union Carbide)

Appendix

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-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 ₂ O ₃	5.210	*1.000	Chromium (III) Oxide
Cr ₃ C ₂	6.680	*1.000	Chromium Carbide
CrB	6.170	*1.000	Chromium Boride
Cs	1.870	*1.000	Cesium
Cs ₂ SO 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 ₂ O	6.000	*1.000	Copper Oxide
Cu ₂ S	5.600	0.690	Copper (I) Sulfide (Alpha)
Cu ₂ S	5.800	0.670	Copper (I) Sulfide (Beta)
CuS	4.600	0.820	Copper (II) Sulfide
Dy	8.550	0.600	Dysprosium
Dy ₂ O ₃	7.810	*1.000	Dysprosium Oxide
Er	9.050	0.740	Erbium
Er ₂ O ₃	8.640	*1.000	Erbium Oxide
Eu	5.260	*1.000	Europium
EuF ₂	6.500	*1.000	Europium Fluoride

Appendix

Formula	Density	Z-Ratio	Material Name
Fe	7.860	0.349	Iron
Fe ₂ O 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 ₂ O 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 ₂ O ₃	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium
Ge ₃ N 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	Holmium
Ho ₂ O ₃	8.410	*1.000	Holmium Oxide
In	7.300	0.841	Indium
In ₂ O ₃	7.180	*1.000	Indium Sesquioxide
In ₂ Se ₃	5.700	*1.000	Indium Selenide
In ₂ Te 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

Appendix

Formula	Density	Z-Ratio	Material Name
La	6.170	0.920	Lanthanum
La ₂ O 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 ₂ O ₄	3.600	*1.000	Magnesium Aluminate
MgAl ₂ O 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 ₂ C	9.180	*1.000	Molybdenum Carbide
MoB ₂	7.120	*1.000	Molybdenum Boride
MoO ₃	4.700	*1.000	Molybdenum Trioxide
MoS ₂	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na ₃ AlF ₆	2.900	*1.000	Cryolite
Na ₅ Al ₃ F ₁₄	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 ₂ O ₃	7.500	*1.000	Niobium Trioxide
Nb ₂ O 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	Neodymium
Nd ₂ O ₃	7.240	*1.000	Neodymium Oxide
NdF ₃	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 ₃ N 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 ₂ O 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
S ₈	2.070	2.290	Sulphur
Sb	6.620	0.768	Antimony
Sb ₂ O ₃	5.200	*1.000	Antimony Trioxide
Sb ₂ S ₃	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandium
Sc ₂ O ₃	3.860	*1.000	Scandium Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si ₃ N 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

Appendix

Formula	Density	Z-Ratio	Material Name
Sm	7.540	0.890	Samarium
Sm ₂ O 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 Fluoride
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta ₂ O 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 ₂ O 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 ₃ O ₈	8.300	*1.000	Tri Uranium Octoxide
U ₄ O ₉	10.969	0.348	Uranium Oxide
UO ₂	10.970	0.286	Uranium Dioxide
V	5.960	0.530	Vanadium
V ₂ O 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

Appendix

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 ₂ O ₃	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb ₂ O ₃	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn ₃ Sb 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 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 (+2 optional)
Frequency Range	4.0 MHz to 6.0 MHz
Frequency Accuracy	.001%
Frequency Resolution	.03 Hz @ 10 readings/sec
Rate Accuracy	.5% typical
Rate Display Resolution	.01 or .1 A/s
Thickness Accuracy	.5% typical
Thickness Resolution	.001 kA
Measurement Period	.1 to 1 sec.

Source

Number of Sources	2 (+2 optional)
Control Voltage	0 to $\pm 10V$ into $2k\Omega$ load
Resolution	15 bits

Digital I/O

Digital Inputs	8 (+8 optional)
Functions	User Selected (See Chapter 3)
Input Rating	5VDC, non-isolated

Relay Outputs	8 (+8 optional)
Functions	User Selected (See Chapter 3)
Relay Rating	30Vrms or 30VDC, 2A maximum

General Specifications

Mains Power Supply	100-120/200-240~, $\pm 10\%$ nominal 50/60 Hz, auto detect
Power Consumption	25W
Operating & Transportation 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 <input type="checkbox"/> against harmful ingress of moisture) Pollution Degree II Installation (Overvoltage) Category II <input type="checkbox"/> for transient overvoltages
Storage Environment	-40°C to 70°C
Rack Dimensions (HxWxD)	5.23 in. x 8.4 in. x 10.0 in. 132.8mm x 213.4mm x 254.0mm
Weight	4 pounds (1.8 kg)

Display

Graphs

Readouts

Rate, Deviation, Power
Thickness, Rate, Power

Process Parameters (a Process is a sequence of layers)

Processes

100

Films

50

Layers (total all processes)

1000

Layer Parameters (Layer is a Film, plus these values)

Initial Rate

0.0 to 99.9 A/sec.

Final Thickness

0.0 to 99.999 kA

Time Setpoint

0 to 30000 sec.

Thickness Limit

0.0 to 99.999 kA

Start Mode

Auto/Manual

Output Select

1, 2, 3, 4

Max Power

0.0 to 100.0 %

Slew Rate

0.0 to 100.0 %/sec.

Sensor Select (1 to 4)

On/Off

Rate Ramps

2

Rate Ramp Start

0.0 to 99.999 kA

Rate Ramp Time

0 to 1000 sec.

New Rate

0.0 to 99.9 A/sec.

Film Parameters (Film is a Material, plus these values)

Material

100 stored

Density

0.40 to 99.99 gm/cm³

Z-Factor

0.100 to 9.900

P Term

1 to 9999

I Term

0 to 99.9 sec.

D Term

0 to 99.9 sec.

Tooling

10 to 400

Pocket

1 to 8

Crystal Quality

Disabled to 30%

Crystal Stability

Disabled to 5000 Hz

Crystal Fail Mode

Halt or Timed Power

Ramp1, Ramp2, Feed Ramp, Feed, Idle Ramp Time

0 to 30000 sec.

Soak1, Soak2, Feed, Idle Power

0.0 to 100.0 %

Shutter Delay Time

0 to 200 sec.

Shutter Delay Error

0.0 to 30.0 %

Control Error

Ignore/Stop/Hold

Control Error Setting

0 to 30.0 %

Rate Sampling

Continuous/Time/Accuracy

Sample Time

10.0 to 999.0 sec.

Hold Time

10.0 to 999.0 sec.

C. I/O Connections

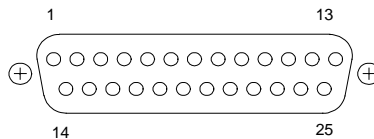
A 25 pin D-sub connector, located on the rear of the SQC-300, provides Input/Output connections. Refer to Section 3.6 for relay and input functional assignments.

Inputs can be activated either by connecting to a switch and shorting to Ground, or they can be driven by a TTL compatible signal.

WARNING: These are not isolated inputs! 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.

The pin assignments for the rear panel mounted I/O connector are shown below:



I/O Connector Wiring

Relay	Pins
Relay 1	14,15
Relay 2	1,2
Relay 3	3,4
Relay 4	5,6
Relay 5	7,8
Relay 6	9,10
Relay 7	11,12
Relay 8	13,25

Input	Pins
Input 1	16
Input 2	17
Input 3	18
Input 4	19
Input 5	20
Input 6	21
Input 7	22
Input 8	23
Ground	24

Interfacing to a Sigma CI-100 Indexer

BCD I/O (Sigma 902-025)

BCD wiring between the CI-100 and SQC 300 Series controllers (referred to below as SQC-3XX) is preferred over Binary I/O wiring because it uses fewer SQC-XXX relays. The cable wiring below interfaces the SQC-3XX series controllers I/O connector to the CI-100 BCD I/O connector:

<u>SQC-3XX</u>	<u>CI-100 BCD I/O</u>	
Pin 14----->-----	Pin 1	OutX Pocket Bit1
Pin 1 ----->-----	Pin 2	OutX Pocket Bit2
Pin 3 ----->-----	Pin 7	OutX Pocket Bit3
Pin 16 -----<-----	Pin 5	OutX Pocket Ready
Pin 15,2,4-----	Pin 6	Common
	Short Pin 3 to Pin 9	Interlock
	Short Pin 4 to Pin 8	Pocket Ready A

On the CI-100 rear panel, set Select On/Off Switch #5 UP and #7 DOWN. On the SQC-3XX System Params Menu, set Pocket Relay to Multi. In the System I/O menu set Relay 1 to OutX Pocket Bit 1, Relay 2 to OutX Pocket Bit 2, and Relay 3 to OutX Pocket Bit 3. In the System I/O Input menu set Input 1 to OutX Pocket Ready.

MDC 991270 and Sycon SRT-400 Indexer compatibility: The pocket select and interlock pins (1, 2, 3, 7) are identical to the MDC and Sycon indexers. For a compatible pocket ready signal (pin 5), ground pin 4 (jumper pin 4 to pin 6, 8, or 9). The pocket position outputs of the MDC/Sycon indexer (pins 4, 8, or 9) are seldom used - contact Sigma Instruments for instructions. Set Select Switch #7 UP.

Binary I/O (Sigma 902-026)

To use binary wiring between the CI-100 and SQC 300 Series controllers for a four pocket crucible:

<u>SQC-3XX</u>	<u>CI-100 Binary I/O</u>	
Pin 1,3,5,14,24 -----	Pin 1,2	Common
Pin 16 -----<-----	Pin 3	OutX Pocket Ready
Pin 15 ----->-----	Pin 4	OutX Pocket 1
Pin 2 ----->-----	Pin 6	OutX Pocket 2
Pin 4 ----->-----	Pin 8	OutX Pocket 3
Pin 6 ----->-----	Pin 10	OutX Pocket 4

On the CI-100 rear panel, set Select Switch #5 Down. On the SQC-3XX System Params Menu, set Pocket Relay to Single. In the System I/O Relay menu set Relay 1 to OutX Pocket 1, Relay 2 to OutX Pocket 2, etc. In the System I/O Input menu set Input 1 to OutX Pocket Ready.

Interfacing to an MDC Sweeper

BCD I/O (Sigma 902-027)

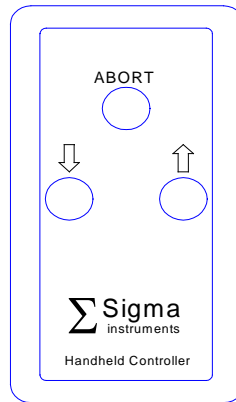
Wiring between the SQC 300 series controllers (referred to below as SQC-3XX)) and an MDC sweeper to select Pattern 1 to 8:

<u>SQC-3XX</u>	<u>Sweeper</u>	
Pin 14----->-----	Pin 8	OutX Pocket Bit1
Pin 1 ----->-----	Pin 7	OutX Pocket Bit2
Pin 3 ----->-----	Pin 6	OutX Pocket Bit3
Pin 5 -----<-----	Pin 12	Process Stopped
Pin 7 -----<-----	Pin 13	SourceX Enable
Pin 15,2,4,6,8-----	Pin 16	Common

On the SQC-3XX System Params Menu, set Pocket Relay to Multi. In the System I/O menu set Relay 1 to OutX Pocket Bit 1, Relay 2 to OutX Pocket Bit 2, and Relay 3 to OutX Pocket Bit 3. Set Relay 4 to Process Stopped and Realy 5 to SourceX Enable.

D. Handheld Remote Controller

The Handheld Controller provides the capability of adjusting output power remotely when the SQC-300 is in Manual Mode.



To use the handheld controller, attach the cable from the handheld controller to the Remote jack on the SQC-300 front panel. Select a Process using the SQC-300 front panel SoftKeys. Press Next Menu until the Auto/Manual SoftKey is displayed. Press Auto/Manual to change to Manual power mode (SoftKey shows Manual/Auto). Press Start to begin the film deposition.

You can now use either the front panel Control Knob or the Handheld Controller to adjust output power. Pressing Abort on the handheld controller stops the layer and returns output power to 0%.

E. 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: Deposition Rate Controller

Product Model: SQC-300 Series

Product Options: All Options

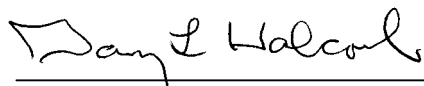
conforms to the following Directives:

73/23/EEC (93/68/EEC)	Low Voltage Directive
89/336/EEC	Electromagnetic Compatibility Directive

uses the following standards:

EN 61010-1	Safety of Electrical Equipment for Measurement, Control, and Laboratory Use
EN 50081-2	Generic Standard for Emissions
EN 55011	Radiated and Conducted Emissions (Class A)
EN 50082-2	Generic Standard for Immunity
EN 61000-4-2	Electrostatic Discharge
EN 61000-4-3	Radiated RF Electro-Magnetic Field
EN 61000-4-4	Electrical Fast Transient/Burst
EN 61000-4-6	Conducted RF
ENV 50204	Radiated RF

and complies with the Essential Health and Safety Requirements.



Gary L. Halcomb
President
