SQC-122
Thin Film Deposition Controller

User's Guide

Version 1.2

Sigma
instruments

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 1 year from the date of shipment, when used in accordance with the instructions in this manual. During the warranty period, Sigma Instruments will, at its option, either repair or replace products that prove to be defective.

Limitation of Warranty

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

Return Policy

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

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1.0 Introduction

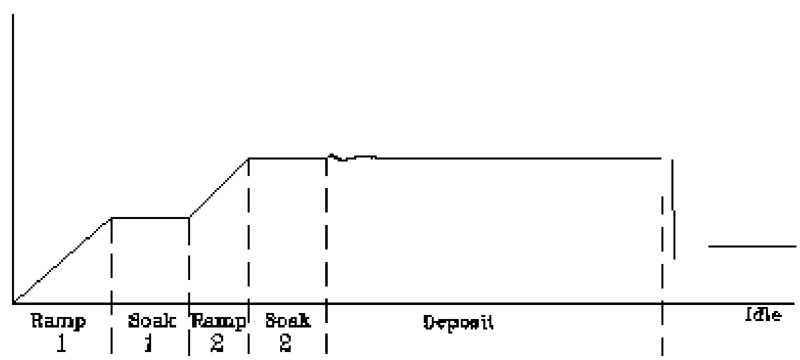
The SQC-122 is a 2-channel, quartz crystal monitor and deposition controller. It measures two 6 MHz quartz crystal sensors, and controls two evaporation sources. Twenty-five processes, consisting of 250 layers and 25 materials, can be stored for easy retrieval. Eight process control relays, and eight digital inputs are easily configured to support a broad range of external functions, including source pocket rotation.

The SQC-122 can also be controlled via the standard RS-232 interface and Windows control program. An optional handheld remote power control is also available

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

1.1 Thin Film Process Overview

The SQC-122 builds the recipes and provides the operating functions required to control all aspects of a thin film deposition process. A typical deposition cycle for a thin film is show below.



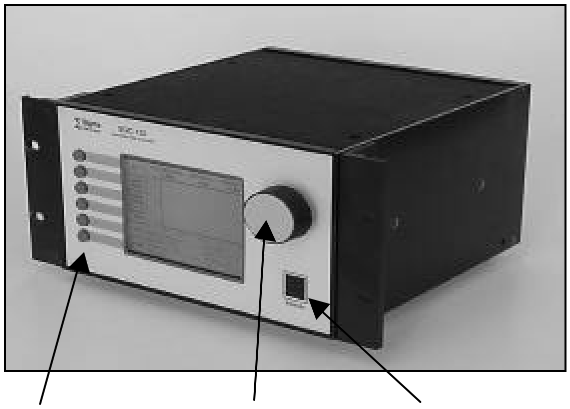
The cycle can be broken into three distinct phases: pre-conditioning (ramp/soak), deposition, and post-conditioning (feed/idle). During pre-conditioning, power is supplied to prepare the evaporation source for deposition. Once the pre-conditioning period expires, material deposition begins. During deposition, the PID loop adjusts the evaporation source power as required to achieve the desired deposition rate. 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 film layer may begin.

1.2 Installation

WARNING: Care should be exercised to route SQC-122 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-122 occupies a 5.25" high, half-rack space. An optional installation kit is available to adapt to a full rack. Install the unit in a 19" rack with the supplied hardware.
Power Connection	***WARNING***: Verify that the Voltage Selector Switch, located next to the power switch, matches your mains supply voltage. ***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-122 sensor inputs. See section 1.4 and 1.5 for details.
Source Output Connections	Connect the BNC cables from the SQC-122 output connectors to your evaporation supply control input. See section 1.4 and 1.5 for details.
Digital I/O Connections	Refer to Appendix C for details on wiring digital I/O to the SQC-122 Relay I/O connectors.
Computer Connection	If you would like to use the Windows software to collect data or program the SQC-122, attach a 9 pin straight-thru cable from the RS-232 connector to your computer's serial port.

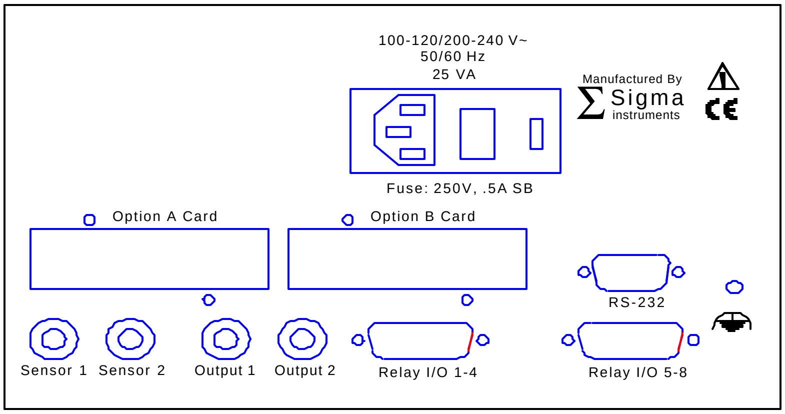
1.3 Front Panel



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.
Remote Jack	Connection jack for the handheld remote control module.

1.4 Rear Panel



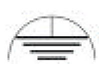
Rear Panel Connections

Sensor 1 & 2 — Connects to quartz crystal sensor remote oscillator.

Output 1 & 2 — Connects the SQC-122 output to your evaporation supply control input.

Relay I/O (1-4)
Relay I/O (5-8) — Connects 8 relays and 8 digital inputs to external equipment for process control. See Appendix C for connections.

RS-232 — Connects to computer for programming and data acquisition.

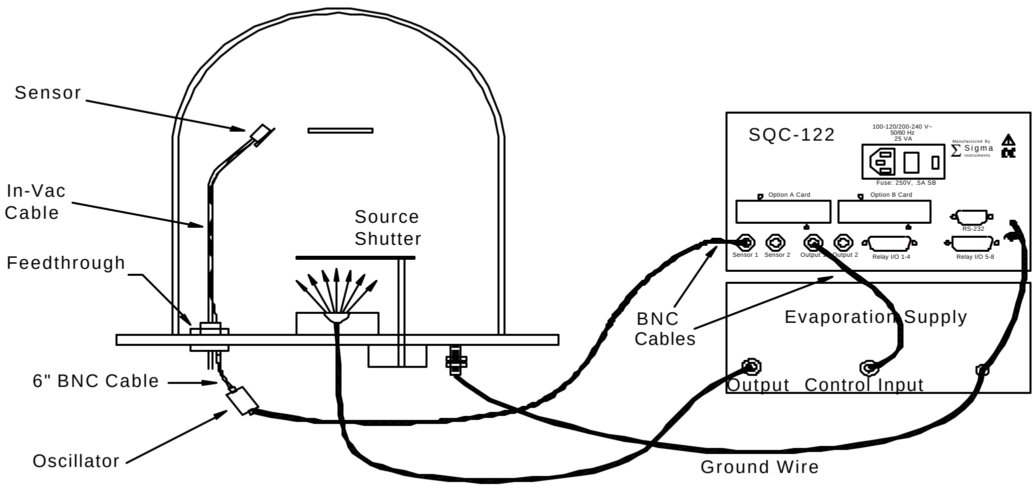
 — Measurement ground terminal useful for common system and cable grounding.

Power Input and Voltage Selector — ***WARNING***: Select 115V for 100-120VAC, 230V for 200-240VAC.

WARNING: Use removable power cords only of the specified type and rating, attached to a properly grounded receptacle.

1.5 System Connections

This section identifies typical system components and their connection:



System Components

Sensor Holds the quartz crystal used to measure rate and thickness. Crystals must be replaced occasionally.

In-Vac Cable A coax 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-122 input. Lengths up to 100’ are acceptable.

Control Output BNC Cable Connects the SQC-122 output to the evaporation source’s control voltage input. Keep length below 10’.

Ground Wire A wire, typically braided, that connects the vacuum system to the SQC-122 ground terminal.

1.6 Process Setup

Follow these steps to build a process from the main (also called “power up”) 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”. If you forget the password, see the System Params Section for password setup.*

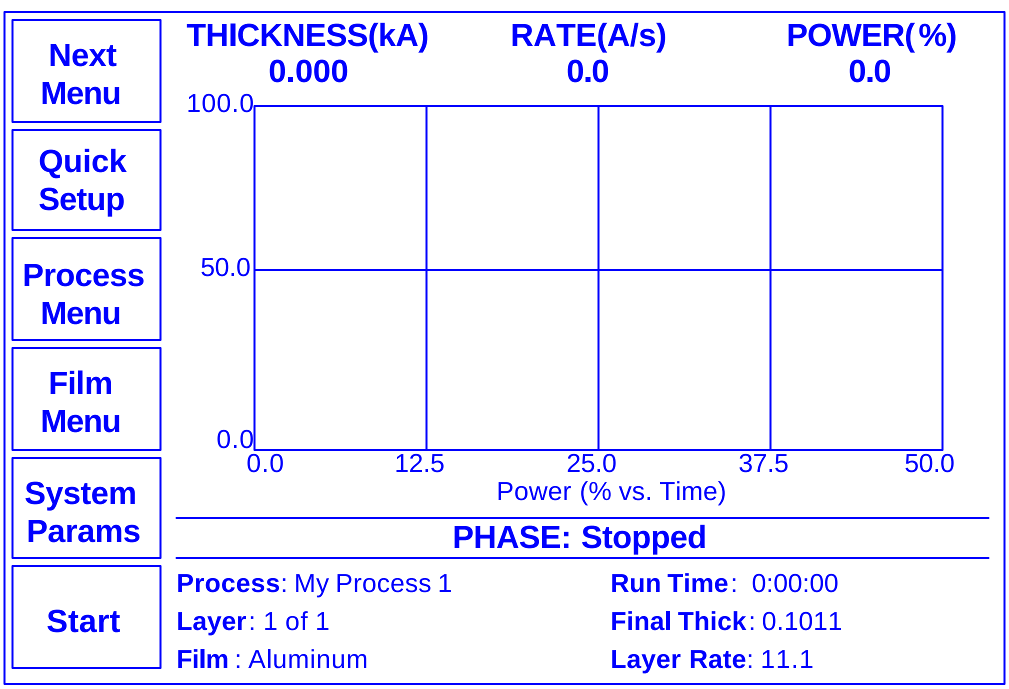
Power On

Move the rear panel power switch to the On (|) position. The SQC-122 will briefly display its initialization information, then go to normal operating mode.

Select Quick Setup

Press the **Quick Setup** softkey to view the quick setup parameters for the current process.

If no Quick Setup option is visible, no processes are defined in the SQC-122. In that case, press **Film Menu,** then scroll the cursor until an <Empty> film is selected. Press **Create** to create a new film, then press **Main Screen**. Now press **Process Menu**, then **Create**, then **Edit**. Select **Insert Layer**, scroll to your new film and press **Enter**. Now press **Prev Menu** twice to return to the Main Menu.



Main Screen

Edit Mode

To edit a setting in any menu, turn the control knob to scroll to the desired setting, then press the **Edit** SoftKey.

In Edit mode, the cursor moves to the setting value and the Softkey functions change to show:

Next: Store the parameter and move to next for 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 Quick Setup parameters, and editing values. When you are comfortable, be sure your values for Layer 1 match those shown below.

THICKNESS(kA)	RATE(A/s)	POWER(%)
0.000	0.0	0.0

Exit to Main

Edit

Next Layer

My Process 1 -> Layer 1 -> Aluminum

Parameter	Value	Units
Init Rate	11.1	A/s
Fnl Thk	0.101	kA
P Term	50	None
I Term	0.7	Sec.
D Term	0.0	Sec.
Sensor 1	On	On/Off
Sensor 2	On	On/Off
Output	Out1	Out1/Out2
Max. Power	76.0	%
Slew Rate	10.0	%
Material	Copper	

Quick Setup Menu

Exit to Main

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

1.7 Depositing a Film

If you have followed this Quick Start chapter, you are ready to deposit 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 Chapter 2.6 for System Parameters Menu information.*

Verify Output Operation	From the Main Menu, press the **Next Menu** SoftKey. Then, press **Auto/Manual** to display Manual/Auto. Slowly turn the control knob to increase the control voltage to your evaporation supply. Verify that the Power(%) reading in the display upper right-hand corner approximates the actual output of your evaporation supply. If not, check your hookup (1.4), and refer to Scale Voltage (3.6).
Verify Sensor Operation	Press **Next Menu** until the Switch Displays option is shown. Press **Switch Displays** to display Sensor1 and Sensor 2 in the lower status section of the screen. At least one sensor should be ON and display a % life of over 50%. If not, check your sensor connections (1.4), and refer to Min/Max Frequency (3.6).
Enter Auto Mode	Press the **Next Menu** key twice to display the output screen. Press **Manual/Auto** until Auto/Manual is displayed.
Show Power Graph	Press **Next Menu** once more. Press the **Next Graph** softkey until the graph shows Power (% vs Time).
Start Process	Press the **Start** key to start the deposition process. Graphing of the output power should start. ***Caution:*** Observe the output power versus your evaporation supply's actual output. If there is a problem, press the **Stop** softkey immediately.

If the rate and thickness readings do no match your expectations, refer to Section 3.5 for information on Density and Z-Factor, and Section 3.6 for Tooling.

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

2.0 Introduction

This chapter describes common tasks associated with operating the SQC-122. It assumes that you understand basic operation of the menus, and parameter setup, as described in Chapter 1. Detailed definitions of unfamiliar setup parameters 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-122, 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 film can be used in several different processes. The SQC-122 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 that it be deposited in a process.

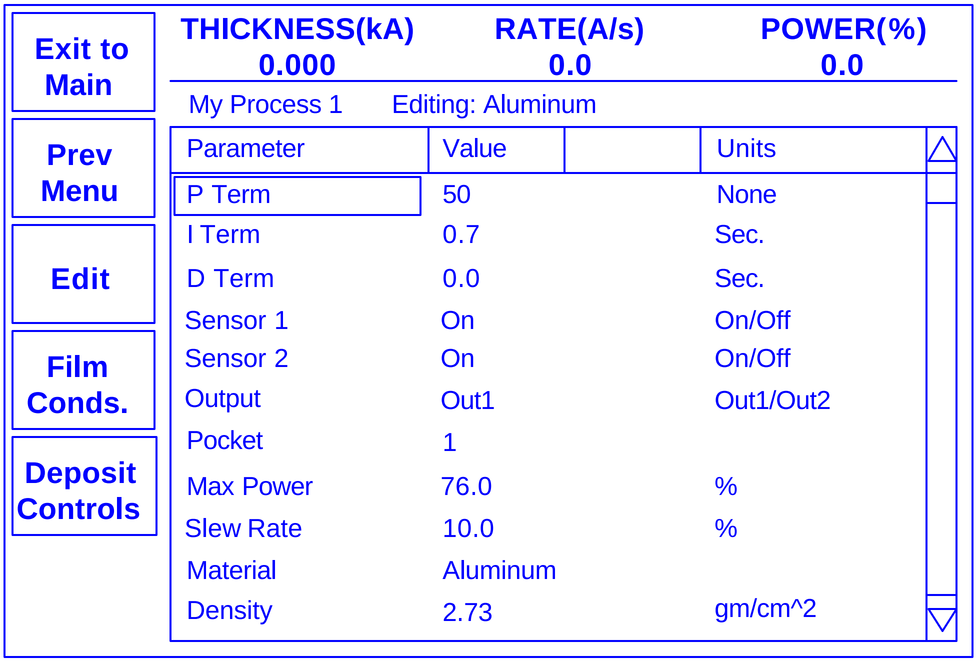
Process: A deposition process is a sequence of layers (i.e. films, materials) to be deposited. The SQC-122 can store up to 25 processes, consisting of a total of 250 layers.

2.2 Defining a Film

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

To define a film, select **Film Menu** on the main screen. 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 (use the SQC-122 setup software to assign descriptive film names). Press **Edit** to display the parameters for this film.

The most commonly modified parameters are shown on the first film parameters screen. Additional parameters can be accessed by pressing Film Conds (film conditioning) or Deposit Controls.



Film Edit Menu

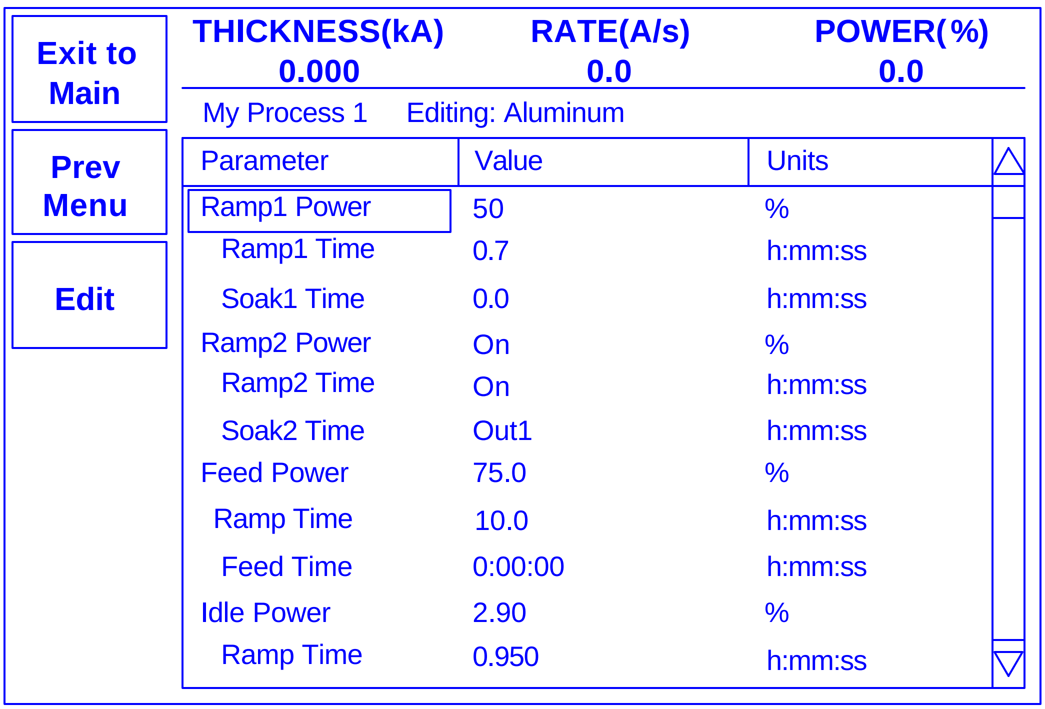
Scroll to the bottom of the parameters list (Z factor), then back up to the Material entry. Press **Edit** and scroll through the list of materials. Notice that the Density and Z Factor are updated automatically as a new material appears. Select the desired material, the press **Enter**. You could change the Density and Z Factor for the selected material now, but it is unlikely those values are wrong. To define a material not stored in the SQC-122, use the SQC-122 setup software.

Once the material is selected, we need to setup the source parameters. Scroll to Output and select the SQC-122 output that is connected to the source evaporation supply. If a source pocket indexer is being used, assign it also. Now assign the Max Power and Slew Rate appropriate for this material and your power supply. These two values are a compromise. They should be large enough to allow adequate power and power rate of change to achieve the desired deposition rate. For now, set both to 100%. Set them to lower values later if you find that very small power changes cause large changes in deposition rate.

The SQC-122 can use either one, or both sensors to measure the film's deposition rate and thickness. Normally, a single sensor can measure multiple layers and different materials. However, some materials may interact to cause short crystal life. In that case, you might want to assign specific sensors to certain materials. If both are selected, an average of the two values is used.

The PID parameters control the response of the SQC-122 to changes in deposition rate. These values are unique to each deposition chamber setup, and to a lesser extent to each material. The P Term is proportional (or gain), the % process change (i.e. rate) divided by the % input change (i.e. power). The I Term (integral) sums the output error (rate deviation) 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. For now, you should probably leave these values at their defaults.

Press **Film Conds** to enter the film conditioning menu. Film preconditioning is used to prepare a material for deposition. When the film deposition is complete, post conditioning ramps power down to an idle level. It may also ramp power to a level appropriate for wire feeding new material. Refer to the Thin Film Process Overview in Chapter 1 for an illustration of pre and post conditioning.

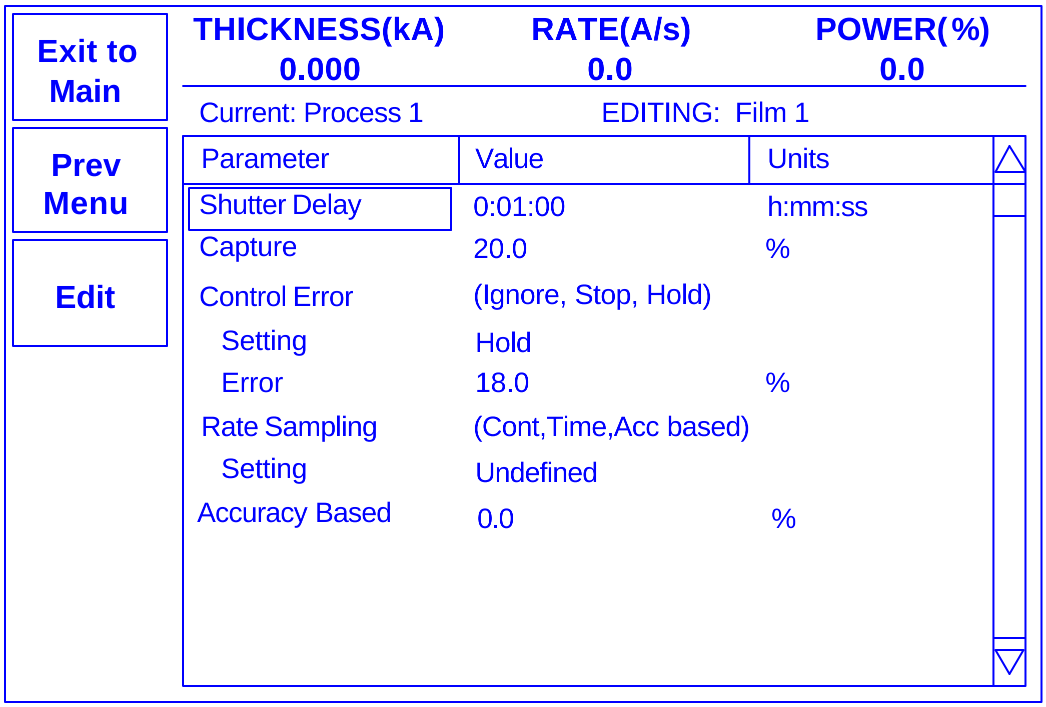


Film Conditioning Menu

Set the Ramp1 Power and Time to values that will slowly bring the material to a near molten state. Set the Soak 1 Time to a value that will allow the material to homogeneously achieve the state. Ramp 2 is used to slowly bring the material to a power level that nearly matches the desired deposition power level. 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. Idle typically ramps output power back toward zero.

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.



Deposition Controls Menu

Shutter delay causes the SQC-122 to delay opening the shutter until the process has stabilized at the desired deposition rate. The time value is the maximum amount of time to wait, before an error is sensed. The accuracy is the % rate deviation that must be achieved to open the shutter. Set Shutter Delay and Capture to zero to disable this feature.

If the SQC-122 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.

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 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!

Each film parameter has been set. Press **Exit to Main** to return to the Main Screen.

2.3 Defining a Process

A process is a sequence of film layers deposited to achieve a particular thin film characteristic. A single process, consisting of a few layers, may be adequate for a dedicated production facility. For research or laboratory use, the SQC-122 can store up to 25 processes to a total of 250 layers.

You should define each of the films that will make up the layers of the process before starting process definition. See the previous section for instructions on defining films.

To define a process, select **Process Menu** on the main screen. A list of 25 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-122 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 a layer, scroll to the desired location in the layer sequence, and press **Insert Layer**. Select a film for this layer from the list of films and press **Enter**. 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.

To edit a layer, highlight it, then press **Edit**. There are only a few parameters associated with a layer: Initial rate, Final Thickness, Time and Thickness Setpoints, and Start Mode. Remember that most setup parameters are set in the Films Menu, and apply to every instance where that film is used. The layer parameters pertain only to this instance of the film, in this process.

Initial rate and final thickness for this layer should be obvious. Keep in mind that the SQC-122 zeroes thickness at the beginning of each layer, it is not a cumulative value. Time Setpoint and Thickness Limit are arbitrary values that will activate a relay when they are reached. Start mode allows you to have this layer in the sequence start immediately on completion of the previous layer (Auto), or wait for a user signal via the front panel, RS-232, or digital input (Manual).

Press **Prev Menu** to return to the list of layers, or **Exit to Main** to return to the Main Screen.

2.4 Sensor Setup

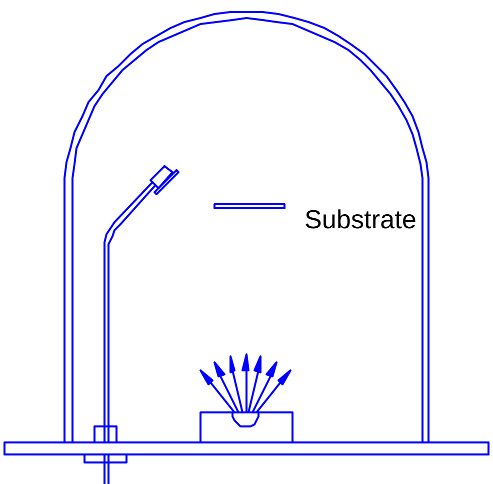
The theory of operation for a quartz crystal sensor is quite simple. The sensor initially oscillates at its natural frequency, typically 6MHz. As material is deposited on the substrate, it is also deposited on the sensor. Depending on the density of the deposited material, and the amount of material deposited, the sensor's frequency will drop from its initial frequency. The rate and thickness can be calculated from this frequency shift.

Sensor setup involves selecting the sensor to be used, setting the Min/Max crystal frequencies, and adjusting the Tooling Factor. Sensors are assigned individually to each film, as described in Section 2.2, Defining a Film. The remaining sensor parameters are in the System Params menu.

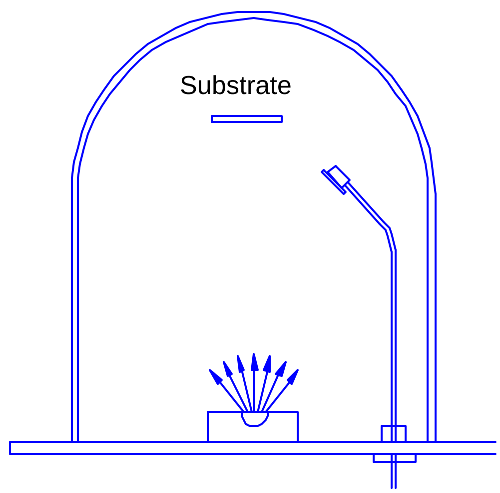
In the **System Params** menu, Max Frequency is the initial frequency of a new crystal, typically 6.0e+06 Hz (6 MHz). Due to manufacturing tolerances, some crystals may oscillate above 6MHz initially. Setting the Max Frequency slightly above the nominal value, to say 6.1MHz, will avoid this problem with no effect on instrument accuracy.

Min Frequency is the frequency where the SQC-122 will flag a sensor as bad. For a 6MHz crystal, the Min Frequency is typically 5 MHz. Crystal failure is often predicted by brief periods "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 5MHz. It is good practice to set the Min Frequency to a value that indicates crystal failure before most crystals actually fail.

Sensor Tooling adjusts for the difference in deposition rate between the sensor and the substrate being coated.



Tooling
Over 100%



Tooling
Under 100%

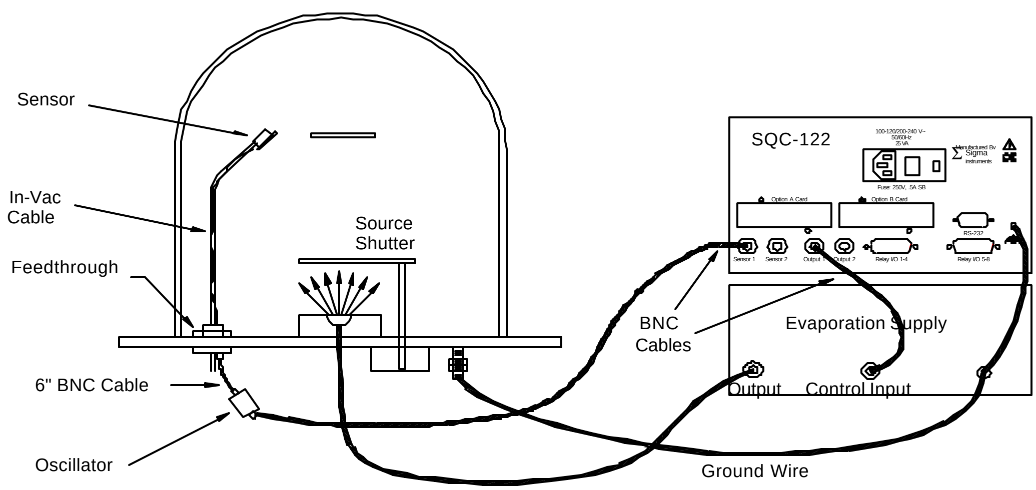
In the illustration above (left), the sensor will measure less rate or thickness than actually deposited, because of its positioning. In the right illustration, the sensor will measure high. Tooling is the ratio of the actual substrate deposition rate or thickness, to that measured by the sensor. Lets assume that at the end of deposition the sensor measures a thickness of 1.000 kA. But, suppose the actual substrate is deposited to 1.100 kA (as determined by some other means). Then the tooling for this sensor would be:

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

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.

Once the sensor parameters are set, test your sensor setup to assure reliable readings at the SQC-122. A typical single sensor setup is shown below:



On the SQC-122, press **Next Menu** until the Switch Displays option is shown. Press **Switch Displays** until Sensor 1 and Sensor 2 are shown in the lower right corner of the screen. Any connected sensor (whether programmed On or Off) should display its % 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 5.5MHz “test crystal adapter” with each oscillator. If the % Life reading is not correct, remove the 6” BNC from the oscillator, and replace it with the test crystal and adapter. For a typical setup of 6MHz Max Frequency and 5MHz Min Frequency, the % life display should be near 50%. Use the test crystal and the Sensor 1 and Sensor 2 inputs of the SQC-122 to verify your sensor setup and cabling.

2.5 Source Setup

The SQC-122 controls deposition rate by varying the control voltage to an external evaporation (source) supply. The previous illustration for sensor wiring also shows source supply wiring.

The SQC-122 control voltage output range is set in the **Systems Params** menu. For the supply connected to Output 1, set Scale 1 to the control voltage that corresponds to 100% output on the source supply. The SQC-122 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 customize response to that film.

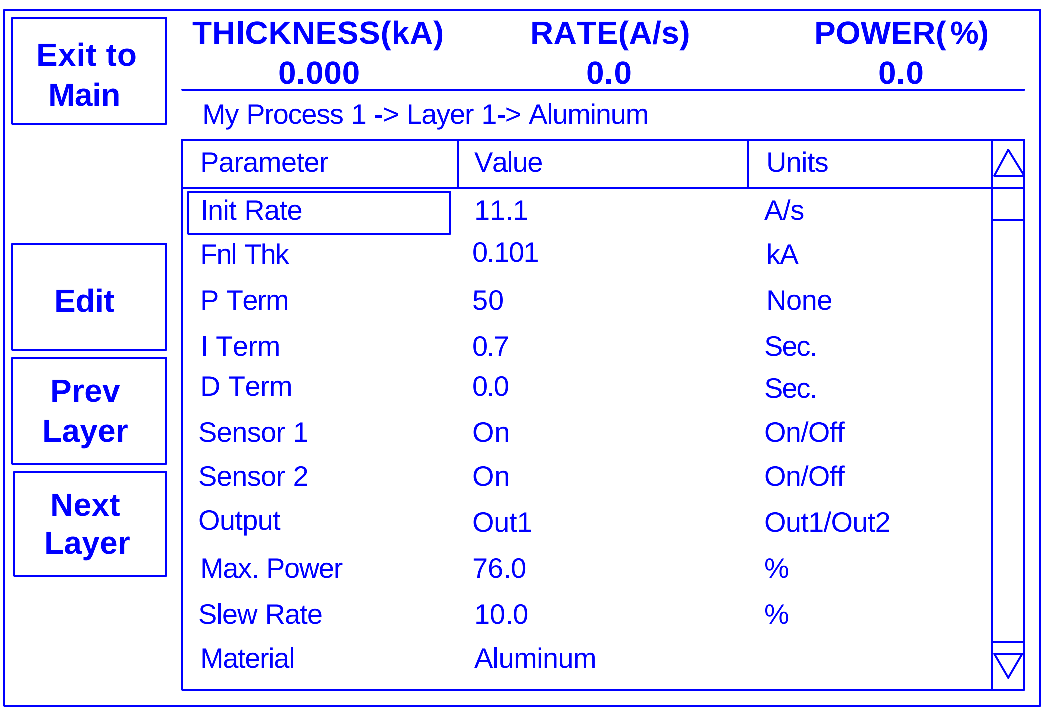
2.6 Running a Process

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. The next section, on Loop Tuning, describes a method for initial process startup and optimization. This section describes the steps to select, start, and stop a process.

To select a process, the status bar must be showing Phase: Stopped. If any other phase is displayed, press the **Abort** Softkey.

Press **Process Menu**, then use the scroll knob to highlight the desired process. If the third SoftKey shows Edit when a process is highlighted, then it is already the current process. Otherwise, press **Select** to set the highlighted process as the current process. You can press Edit to review the current process layers and their associated films. Press **Main Screen** to return to the main operating screen.

Press **Quick Setup**, then **Next Layer** to review the most commonly adjusted parameters for each layer in the current process.



Quick Setup Menu

Press **Exit To Main** to return to the main operating screen.

While we're on the Main Menu screen, and before starting the selected process, let's cover the capabilities of the Next Menu screens.

***Note**: It is best (and safest!) to place the SQC-122 in Simulate mode when a process is first run. Press **System Params** and set **Simulate Mode to ON**. Unless you are sure the SQC-122 is in Simulate mode, DO NOT press the Auto/Manual SoftKey during the discussion that follows.*

Press **Next Menu** once to view the first Next Menu screen. This screen provides two important operator functions: Zero Thickness and Auto/Manual mode.

The **Zero** SoftKey can be used to zero the thickness reading at any time. It is not normally needed, since the SQM-142 automatically zeroes the thickness at the beginning of each layer. It is, however, useful when simulating a process and when operating in Manual Mode.

The **Auto/Manual** key alternates between Automatic (PID) output control and Manual (user) output control. Auto/Manual indicates the process is in automatic control, and a key press will change to Manual control. Manual/Auto indicates Manual control; a key press changes to Automatic mode.

In Manual mode, whether the process was stopped or running, the SQC-122 immediately starts the deposition phase for the current layer. However, the PID loop is disabled and output power is controlled by the front panel control knob. You will usually want to display the Rate Graph, then manually adjust the output power to the desired deposition rate. It is easy to exceed a layer's Final Thickness setpoint in Manual mode, so watch the Thickness reading carefully. If you exceed the layer's Final Thickness, you must manually lower power to stop deposition for that layer. Manual mode is particularly useful for determining preconditioning power levels, and loop gain (discussed later in Loop Tuning).

Moving from Manual mode to Auto mode places the SQC-122 into automatic (PID) control. The PID control loop will try to achieve rate setpoint, so there may be a rapid change in output power.

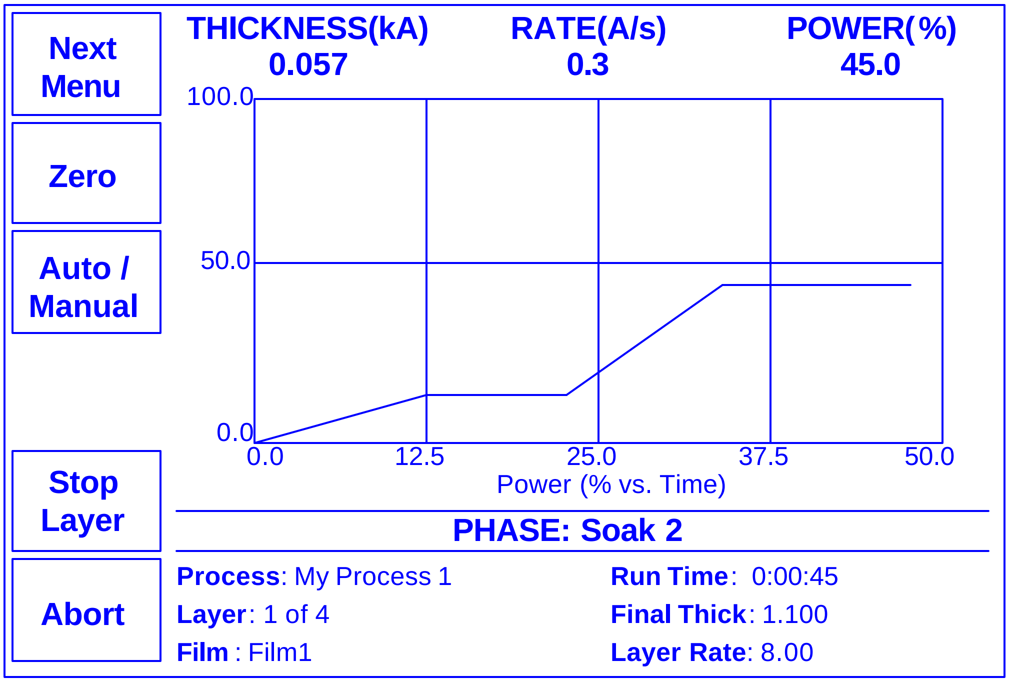
Next Graph selects which of three available graphs is displayed. The Power Graph is useful during preconditioning. The Rate graph clearly shows the response of the control loop to process changes, such as when moving from preconditioning to deposition. The Rate Deviation Graph shows the normal, or steady-state, performance of the control system during deposition. During normal deposition, the graph automatically displays the most useful graph.

Switch Displays toggles the process data display in the lower portion of the screen. You might want to select the Crystal Life display to predict the number of remaining runs, or to troubleshoot erratic performance.

Enough preliminaries let start the process!

Press **Start** from any of the main screen menus 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.

***Note**: Don't confuse Manual and Auto Start Mode with the Manual/Auto SoftKey. Manual Start is a Process setup parameter that tells the SQC-122 to wait for operator intervention before starting a Layer.*

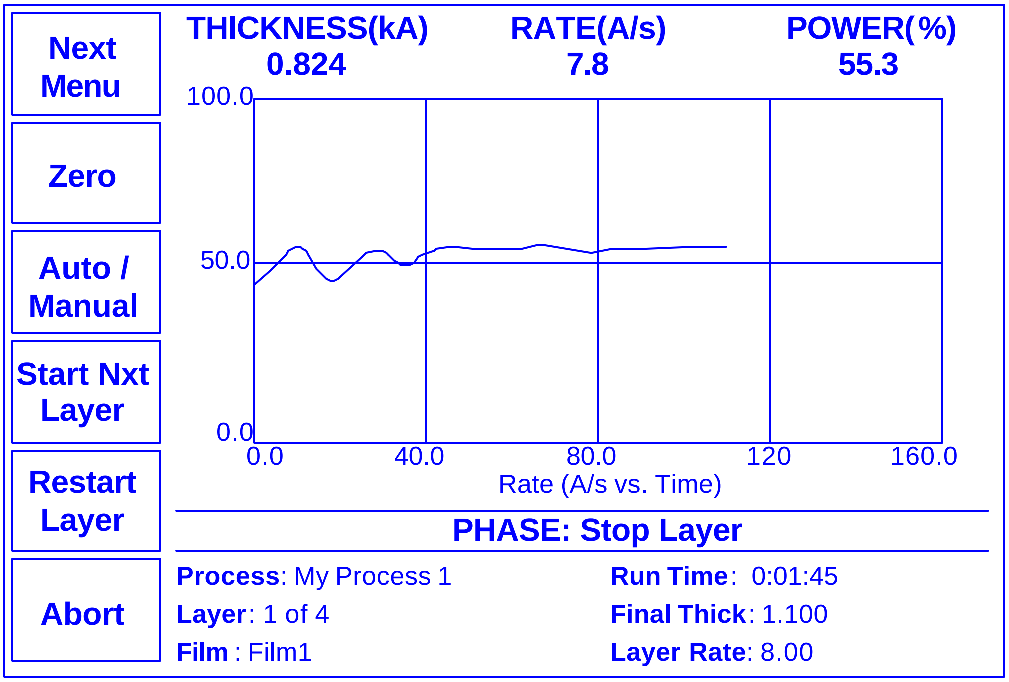


Preconditioning

When Start is pushed, 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 (see above). Pressing **Stop Layer** temporarily halts the current layer and displays two restart options, Start Nxt Layer and Restart Layer (see below).



Layer Stopped

Restart Layer repeats the stopped layer, beginning with preconditioning. **Start Nxt Layer** skips the remainder of the current layer and immediately starts the next layer.

Note: *Pressing the Abort SoftKey at any time completely aborts the process. You can only restart the process at Layer 1!*

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”, the some parameters will not be correct for your process (particularly, PID). However, you can become familiar with the effect of each parameter in this simulate 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 Parms menu and turn Simulate OFF and start testing your process. Use the next section to finalize the loop PID settings.

2.7 Loop Tuning

This section will help you adjust your control loop PID parameters to achieve a stable deposition process. There is no one way to determine PID parameters, and no one set of settings that is "best." There

Setup 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. Select the new process 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-122 Power(%) reading. If the readings don't agree, check your wiring and process setup. In particular, verify that the System Params 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_{0R}.

Determine Open Loop Response Time: Calculate1/3 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. <u>Twice</u> the measured time is the step response time, $TIME_{SR}$. $TIME_{SR}$ is typically .7 to 1.5 for E-Beam evaporation, 5 to 20 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. You might want to switch to the Rate graph for a clearer view of loop performance.

Set Preconditioning: The power level you recorded as PWR_{0R} is the power where deposition is just begins. That's a good value for Ramp 1 power. 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 be similar for other materials. Only the P Term may need slight adjustments.

3.0 Introduction

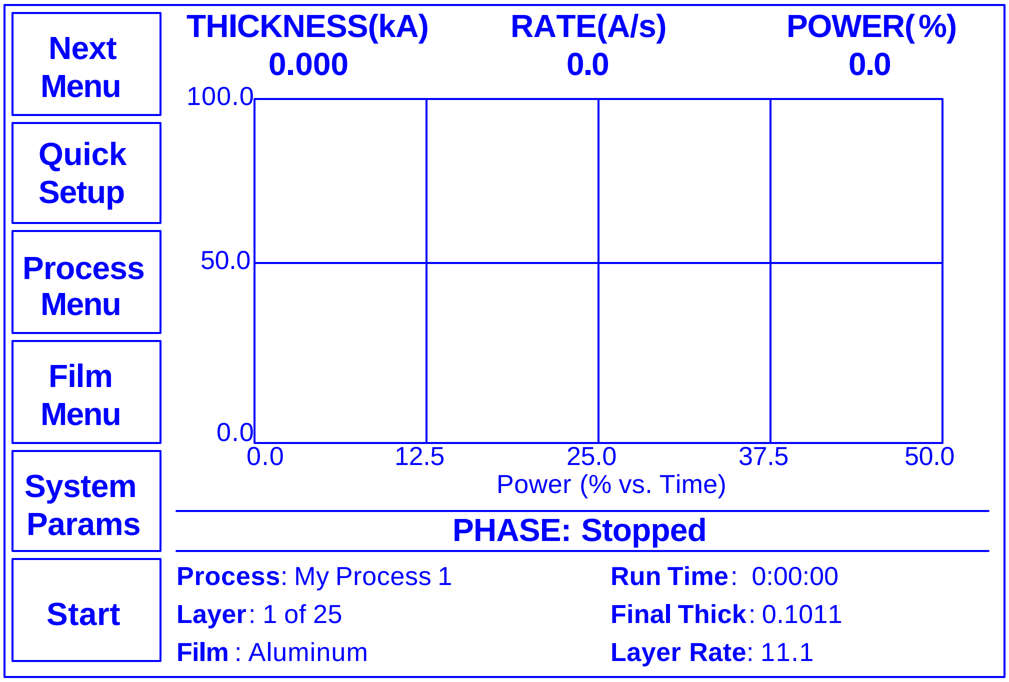
SQC-122 operation during deposition is accomplished by pressing one of the six SoftKeys along the left of the display. Five menus provide access to all programmable and operating functions:

Main Menu	The Main Menu is displayed at power up. It provides the softkey functions and display information necessary to run a thin film deposition. No matter where you are in the SQC-122 menus, you can return immediately to the Main Menu by pressing the first softkey. On the Main Menu, you can view additional sub-menus by repeatedly pressing the Next Menu softkey.
Quick Setup Menu	Provides immediate access to the most commonly adjusted parameters for the current process and layer.
Process Menu	A process is a sequence of layers of deposited film(s). Each layer in a process has a specific film, final thickness, and deposition rate(s) associated with it. These are accessed from the Process Menu.
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 Parameters Menu	System parameters control the overall operation of the SQC-122. 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 menu, and its settings.

3.1 Main Menu

The default, power-up Main Screen display is shown below.



Main Screen

The current Thickness, Rate, and output Power values are always displayed along the top of the screen.

The graph displays either Rate, Rate Deviation, or output Power. The next section of the manual describes graph selection.

The status bar below the graph displays the current deposition phase. In Manual mode, Manual Power is displayed in the status bar. In Auto mode, the status bar will automatically sequence through the pre-condition, deposit, and feed/idle phases for each layer, as defined by the Process setup.

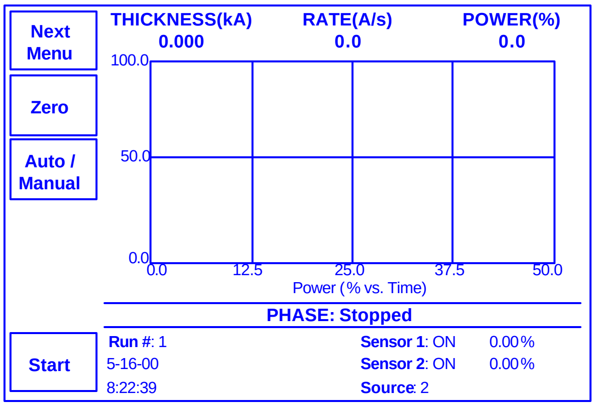
Below the status bar, important settings for the current process are shown. The next section explains other parameters that can be displayed in this screen area.

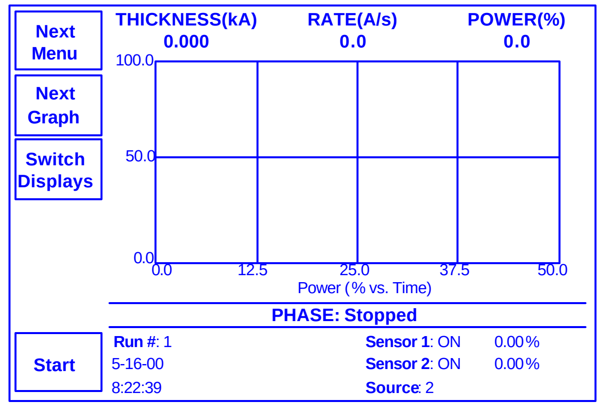
The Main Screen SoftKeys undergo subtle changes based the current process status, and the Next Menu selection. The table below describes the function of each of the possible Softkeys on the Main Screen

Next Menu	Displays additional Main Menu options as described in Section 3.2.
Quick Setup	Displays the Quick Setup Menu of commonly changed process values.
Process Menu	Create, delete, and edit up to 25 processes. Also used to select the currently active process. When a process is running, this selection is not available.
Film Menu	Create, delete, and edit up to 25 films. A film is basically a material, and may appear in several processes.
System Params	Sets system-wide operating parameters. Also used to “map” the 8 digital input and 8 relays to process functions.
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 the Start Layer SoftKey.
Restart / StartNxt Layer	During deposition, it may be necessary to halt a layer to correct a problem. These two SoftKeys allow the operator to either restart the current layer or skip to the next layer.
Stop Layer	Temporarily halts deposition. Deposition is restarted with the Restart or Start Nxt keys.
Start/Abort	Starts or aborts sequencing through the current process layers and deposition cycles. Abort sets both outputs to zero, and abandons the current process.

3.2 Next Menu Screens

The Next Menu function provides access to two sub-menus of the Main Menu that control display and operating mode preferences.





Next Menu Screens

Zero	Zeros the thickness reading. Useful for resetting or extending the current deposition layer.
Auto / Manual	Toggles between Auto and Manual power control. When Auto/Manual is shown, output power is set by the SQC-122 to achieve the programmed deposition rate. When Manual/Auto is shown, the control knob sets the output power.
Next Graph	Cycles through options for the main display. Choose between Rate, Rate Deviation, and Power graphs.
Switch Displays	Toggles between data display options at the bottom of the SQC-122 screen. Note the differences between the screens above and the Main Menu screen shot in the previous section.

3.3 Quick Setup Menu

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

Exit to Main | **THICKNESS(kA)** 0.000 | **RATE(A/s)** 0.0 | **POWER(%)** 0.0

My Process 1 -> Layer 1-> Aluminum

Parameter	Value	Units
Init Rate	11.1	A/s
Fnl Thk	0.101	kA
P Term	50	None
I Term	0.7	Sec.
D Term	0.0	Sec.
Sensor 1	On	On/Off
Sensor 2	On	On/Off
Output	Out1	Out1/Out2
Max. Power	76.0	%
Slew Rate	10.0	%
Material	Aluminum	

Edit

Prev Layer

Next Layer

Quick Setup 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.

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.

Sensor 1: Allows quartz crystal Sensor 1 to be turned on or off for the selected layer. If more than one sensor is assigned to a layer, their readings are averaged. If multiple sensors are assigned to a layer, and one fails, it is excluded from measurements.

Sensor 2: Allows quartz crystal Sensor 2 to be turned on or off.

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.

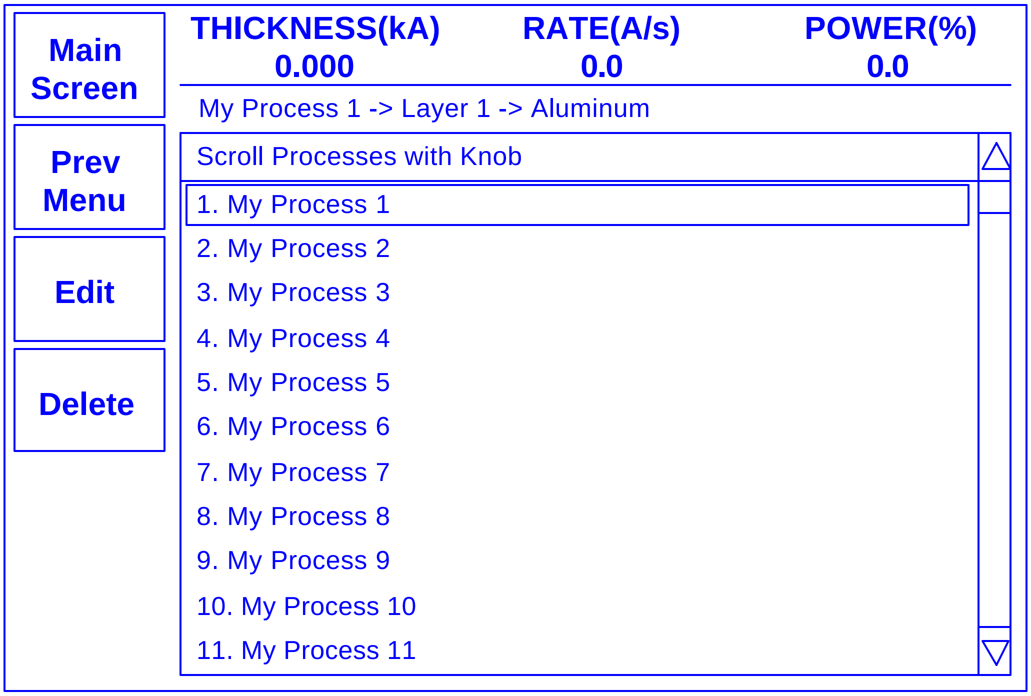
Material: Selects a material assigned to this film. As materials change, their density and Z factor are updated.

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.

3.4 Process Menus

There are several tiers of Process Menus. 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 Menu.

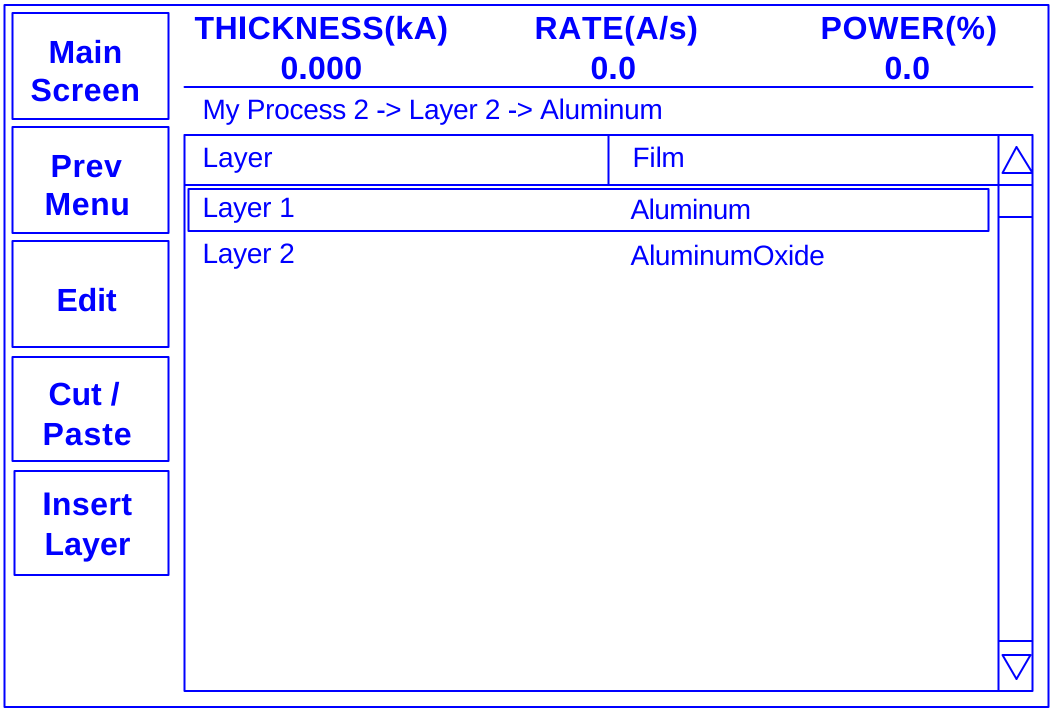
Prev Menu Steps back through the sequence of process menus: Process Select <–> Layer Select <–> Layer Edit. On the topmost Process Menu, returns to the Main Menu.

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.

Control Knob Scrolls through the list of processes. When pressed, selects or begins editing of the highlighted process.

The second Process Menu shows the sequence of layers that will be deposited in the current process.



Layer Select Menu

Main Screen Returns to the Main Menu.

Prev Menu Returns to the Process Select Menu.

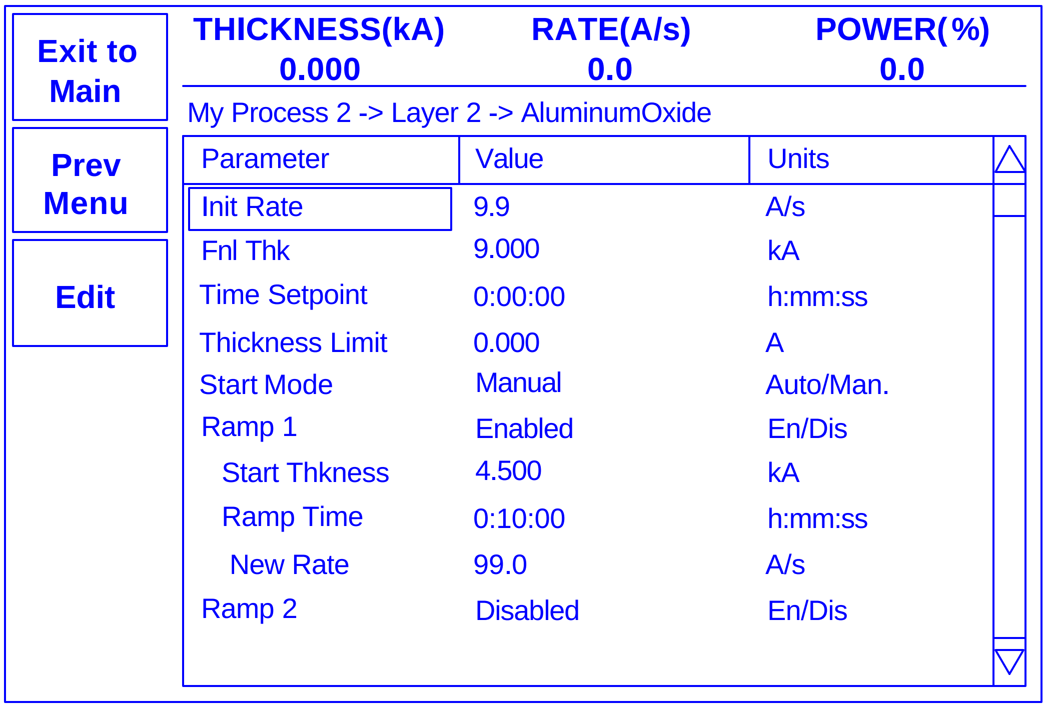
Edit Displays the Layer Edit Menu for the highlighted layer (see 3.4).

Cut / Paste Used to develop the sequence of layers in a process. 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.

Insert Layer Shows the list of 25 films. Select a film, then press Enter to insert the film as a new layer.

Control Knob Scrolls through the list of layers in the Layer Select Menu, and through the list of films in the Insert Layer mode. When pressed, begins editing of the highlighted layer.

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



Edit Layer Menu

Exit To Main	Returns to the Main Menu.
Prev Menu	Returns to the Layer 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.
Control Knob	Scrolls through the list of layer parameters.

A description of each parameter on the Edit Layer 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.

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.

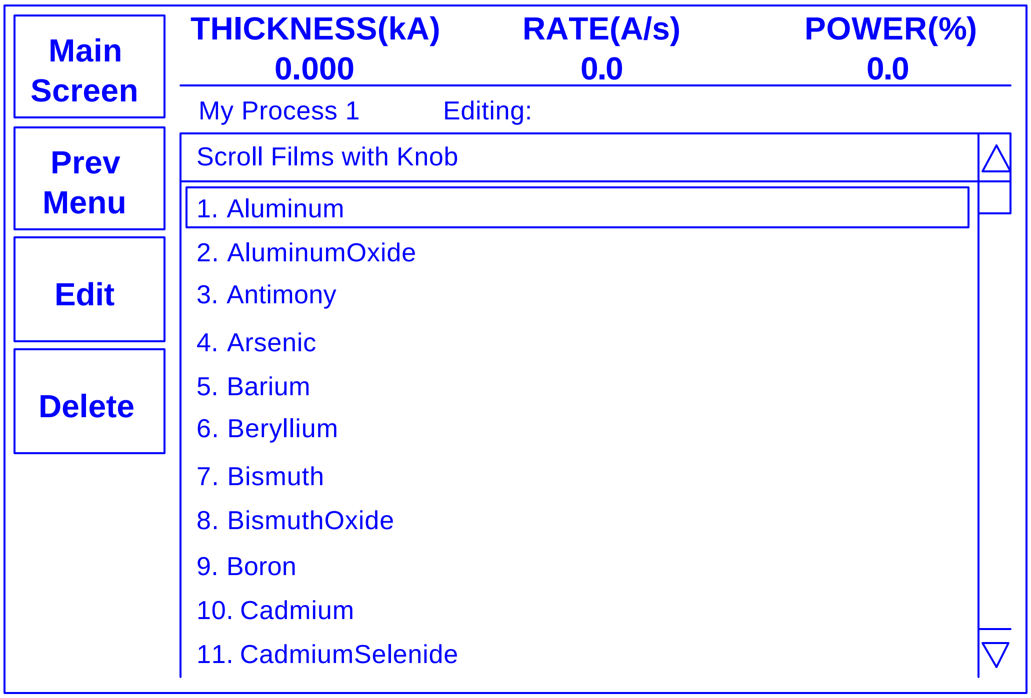
Ramp Time: - Time allowed for the rate to change from initial rate to new rate.

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 Ramp2 should be greater than the start thickness for Ramp 1.

3.5 Film Menus

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 in a certain process.



Film Select Menu

Main Screen — Returns to the Main Menu.

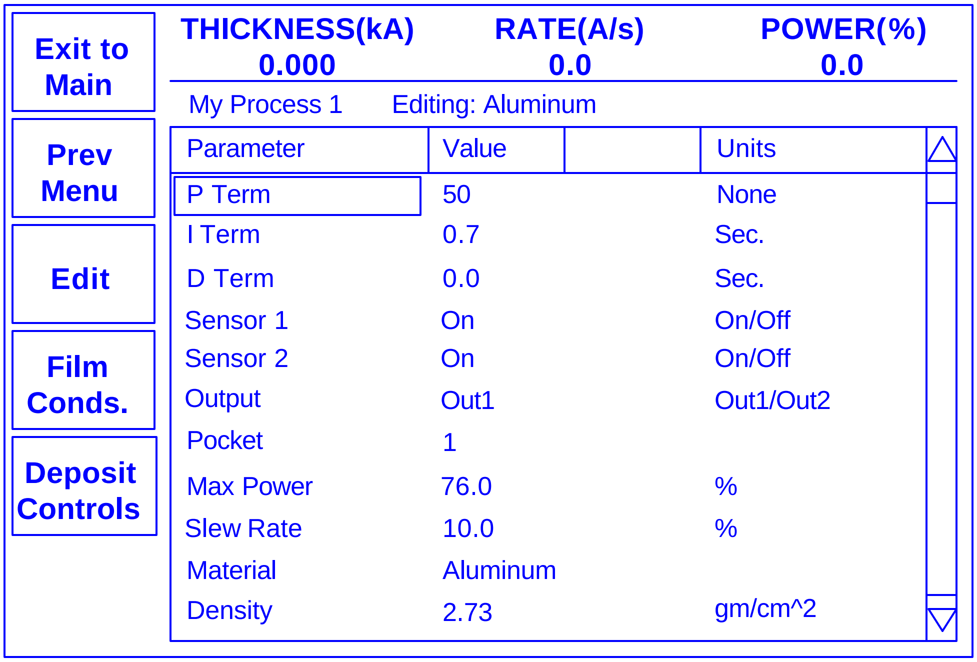
Prev Menu — Steps back through the film menus: Film Select <–> Film Edit <-> Film Conds/Deposit Controls. On the topmost Film Menu, returns to the Main Menu.

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.)

Control Knob — Scrolls through the list of films. When pressed, begins editing of the highlighted film.

The material to be deposited is the most significant film parameter. However, a film definition also includes the setup parameters shown below:



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 3.5).
Deposit Controls	Displays deposition control settings (See 3.5).
Control Knob	Scrolls through the list of film parameters.

The Film Conds SoftKey displays these additional film conditioning settings: (Refer to section 3.5 for definitions).

	THICKNESS(kA)	RATE(A/s)	POWER(%)
Exit to Main	0.000	0.0	0.0
Prev Menu	My Process 1	Editing: Aluminum	
Edit			

Parameter	Value	Units
Ramp1 Power	50	%
Ramp1 Time	0.7	h:mm:ss
Soak1 Time	0.0	h:mm:ss
Ramp2 Power	On	%
Ramp2 Time	On	h:mm:ss
Soak2 Time	Out1	h:mm:ss
Feed Power	75.0	%
Ramp Time	10.0	h:mm:ss
Feed Time	0:00:00	h:mm:ss
Idle Power	2.90	%
Ramp Time	0.950	h:mm:ss

Film Conditioning Menu

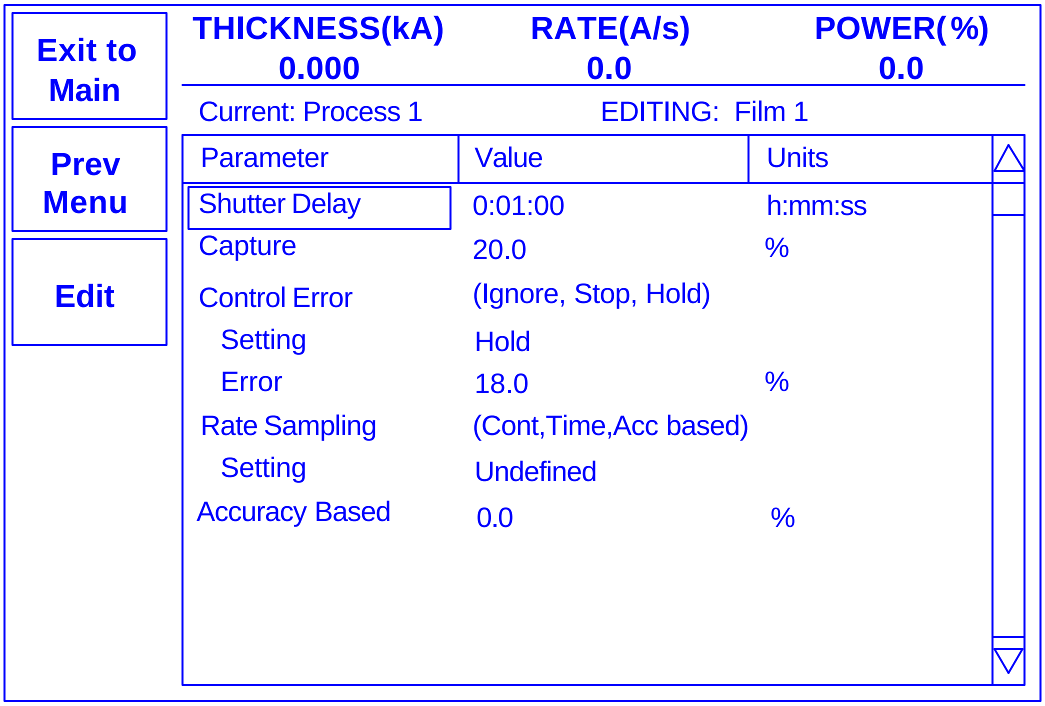
Exit To Main Returns to the Main Menu.

Prev Menu Returns to the Edit Film 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.

Control Knob Scrolls through the list of film conditioning parameters.

The Deposit Controls SoftKey displays these additional film settings: (Refer to 3.5 for deposition control definitions.)



Deposition Controls Menu

[

Exit To Main Returns to the Main Menu.

Prev Menu Returns to the Edit Film 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.

Control Knob Scrolls through the list of deposition control parameters.

A description of each film parameter follows:

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.

Sensor 1: Allows quartz crystal Sensor 1 to be turned on or off for the selected layer. If more than one sensor is assigned to a layer, their readings are averaged. If multiple sensors are assigned to a layer, and one fails, it is excluded from measurements.

Sensor 2: Allows quartz crystal Sensor 2 to be turned on or off.

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

Pocket Number: Indicates which pocket (0-7) should be used. At the beginning of each layer the SQC-122 will set up to three relays with the BCD value of the pocket to be used for this film. You must assign the Pocket relays and Pocket Ready input in system setup, see 3.6.

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.

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 holds the material at a state that is ready for deposition, typically 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 control accuracy before deposition begins. If the accuracy is not reached, 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.

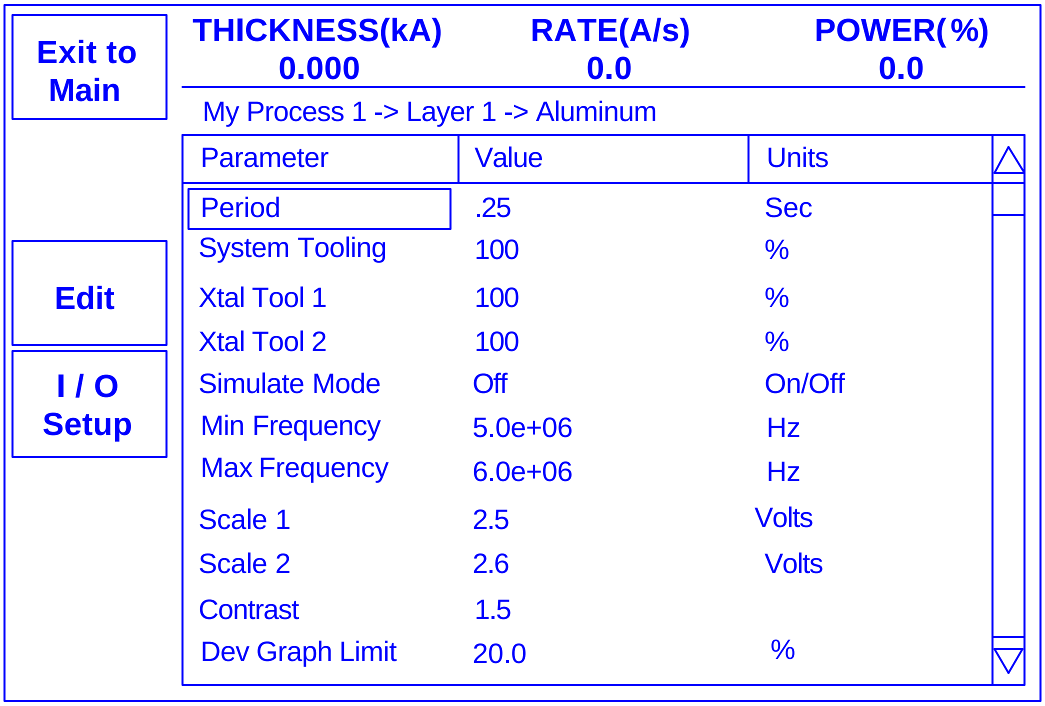
Capture: The control accuracy that must be reached to end the shutter delay.

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.

3.6 System Parameters Menu

The System Parameters Menu contains settings that effect the basic operation of the SQC-122. System parameters generally pertain to the physical setup of your vacuum system equipment.



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.

I / O Setup Displays menu for mapping of inputs and outputs.

Control Knob Scrolls through the list of system parameters.

Descriptions of each system parameter follows:

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

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

Xtal Tooling 1/2: Adjusts for sensor deposition rates that differ from the measured substrate deposition rate, because of sensor location. For example, if the sensor sees only 50% of the substrate rate, set the value to 50%.

Simulate Mode: Normal mode uses the quartz crystals as inputs to the SQC-122 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.

Min/Max Frequency: The frequency values for the quartz crystal sensors used as inputs to the SQM-142. The maximum frequency should be set to the frequency of a new crystal, typically 6MHz. Sensor readings outside the min/max values cause an error.

Scale 1 and Scale 2: The input voltage required by the deposition source power supply to produce 100% output power. Positive or negative Scale 1/2 values are possible.

Contrast: Sets display contrast.

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

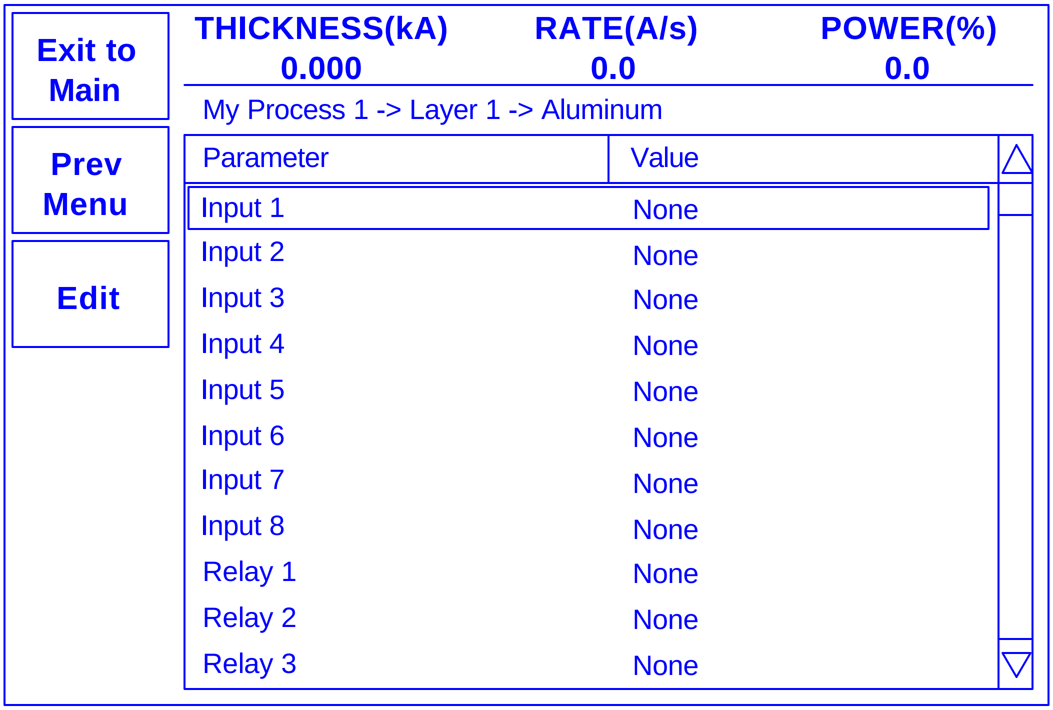
Password Enable: If Password is enabled, the Quick Start, Film and System Menus require a password. The Process Menu can be used to select a process, but a password is required to make any changes on the Process Menu.

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. Holding down the top and bottom switch while powering up the SQC-122 sets the password to “1111”.

System Time: Sets the SQC-122 clock to your local time. System time is battery backed up. Does not compensate for daylight savings time.

System Date: Sets the SQC-122 date to your local time. System date is battery backed up.

The I / O Setup SoftKey displays a menu allowing you to map the eight digital inputs and the eight digital outputs.



I / O Mapping Menu

Exit 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.

Control Knob Scrolls through the list of inputs and relays.

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

Relays	**Explanation (closes when)**
Source 1 Shutter	Deposit phase for films set to Output 1.
Source 2 Shutter	Deposit phase for films set to Output 2.
Sensor 1 Shutter	Shutter Delay and Deposit phases of films set to Sensor 1.
Sensor 2 Shutter	Shutter Delay and Deposit phases of films set to Sensor 2.
All Crystal Fail	All sensors assigned to this film have failed.
Sensor 1 Fail	Sensor 1 is assigned to this film, and has failed.
Sensor 2 Fail	Sensor 2 is assigned to this film, and has failed.
PreCond Phase	Process is in Ramp1, Soak1, Ramp2, or Soak2 phase.
Deposit Phase	Process is in Deposit phase.
SoakHold Phase	Process is in Soak/Hold phase.
Process Active	Process is running (not stopped).
Stopped	Process is stopped (not running)
Manual Mode	Process is in Manual mode (not under PID control).
Max Power	Active output is at maximum power (out of material?)
Time Setpoint	The process has been in Deposit phase indicated time.
Thickness Setpoint	Thickness setpoint reached. Resets on start of next Layer.
Final Thickness	Final thickness reached. Resets on start of next Layer.
Pocket Bit 0	First BCD bit of source pocket to be used.
Pocket Bit 1	Second BCD bit of source pocket to be used.
Pocket Bit 2	Third BCD bit of source pocket to be used.
None	This relay is not assigned to any event.

Inputs	**Explanation (high input causes)**
Abort Process	Abort the process. Can only restart at Layer 1.
Start Process	Start the process at Layer 1.
Stop Layer	Stop the active layer.
Restart Layer	Start the active layer.
Start Next Layer	Start the next layer.
Soak Hold	Delay the start of deposition.
Force Final Thickness	End deposition.
Zero Thickness	Reset thickness reading to zero.
Zero Time	Reset time setpoint counter to zero.
Start Process 1-25	Start the selected process..
Pocket Ready	The source indexer is on the desired pocket.
None	This input is not assigned.

A. Material Parameters

Material	Density	ZFactor
Aluminum	2.73	1.08
Aluminum Oxide	3.97	1
Antimony	6.62	0.768
Arsenic	5.73	0.966
Barium	3.5	2.1
Beryllium	1.85	0.543
Bismuth	9.8	0.79
Bismuth Oxide	8.9	1
Boron	2.54	0.389
Cadmium	8.64	0.682
Cadmium Selenium	5.81	1
Cadmium Sulfide	4.83	1.02
Cadmium Teluridium	5.85	0.98
Calcium	1.55	2.62
Calcium Fluoride	3.18	0.775
Carbon Diamond	3.52	0.22
Carbon Graphite	2.25	3.26
Cerium Fluoride	6.16	1
Cerium Oxide	7.13	1
Chromium	7.2	0.305
Chromium Oxide	5.21	1
Cobalt	8.71	0.343
Copper	8.93	0.437
Copper Sulfide	4.6	0.82
Copper Sulfide B	5.8	0.67
Copper Sulfide A	5.6	0.69
Dysprosium	8.54	0.6
Erbium	9.05	0.74
Gadolinium	7.89	0.67
Gallium	5.93	0.593
Gallium Arsenide	5.31	1.59
Germanium	5.35	0.516
Gold	19.3	.381
Hafnium	13.1	0.36
Hafnium Oxide	9.63	1
Holnium	8.8	0.58
Indium	7.3	0.841
Indium Intimnide	5.76	0.769
Indium Oxide	7.18	1
Iridium	22.4	0.129
Iron	7.86	0.349
Lanthanum	6.17	0.92
Lanthanum Fluoride	5.94	1
Lanthanum Oxide	6.51	1
Lead	11.3	1.13
Lead Sulfide	7.5	0.566
Lithium	0.53	5.9
Lithium Fluoride	2.64	0.774
Magnesium	1.74	1.61
Magnesium Fluoride	3	1

Material	Density	ZFactor
Manganese	7.2	0.377
Manganese Sulfide	3.99	0.94
Mercury	13.46	0.74
Molybdenum	10.2	0.257
Neodymium Fluoride	6.506	1
Neodymium Oxide	7.24	1
New	1	1
Nickel	8.91	0.331
Niobium	8.57	0.493
Niobium Oxide	4.47	1
Palladium	12	0.357
Platinum	21.4	0.245
Potassium Chloride	1.98	2.05
Rhenium	21.04	0.15
Rhodium	12.41	0.21
Samarium	7.54	0.89
Scandium	3	0.91
Selenium	4.82	0.864
Silicon	2.32	0.712
Silicon Dioxide	2.2	1.07
Silicon Oxide	2.13	0.87
Silver	10.5	0.529
Silver Bromide	6.47	1.18
Silver Chloride	5.56	1.32
Sodium	0.97	4.8
Sodium Chloride	2.17	1.57
Sulfur	2.07	2.29
Tantalum	16.6	0.262
Tantalum Oxide	8.2	0.3
Tellurium	6.25	0.9
Terbium	8.27	0.66
Thallium	11.85	1.55
Thorium Fluoride	6.32	1
Tin	7.3	0.724
Titanium	4.5	0.628
Titanium Oxide	4.9	1
Titanium Oxide IV	4.26	0.4
Tungsten	19.3	0.163
Tungsten Carbide	15.6	0.151
Uranium	18.7	0.238
Vanadium	5.96	0.53
Ytterbium	6.98	1.13
Yttrium	4.34	0.835
Yttrium Oxide	5.01	1
Zinc	7.04	0.514
Zinc Oxide	5.61	0.556
Zinc Selenide	5.26	0.722
Zinc Sulfide	4.09	0.775
Zirconium Oxide	5.6	1.001

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 SiO_2) to obtain the material's Z factor.

Z Factor corrects for stresses placed on the quartz sensor by the deposited material. Its impact is most pronounced as the sensor's frequency shifts significantly from its initial frequency.

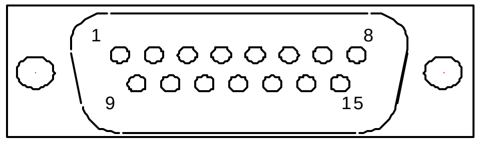
B. Specifications

Measurement	
Number of Sensors	2
Frequency Range	4.0MHz to 6.0Mhz
Frequency Accuracy	.01% @ 2 rdgs/sec.
Frequency Resolution	.1 Hz
Rate Accuracy	.5% typical
Rate Resolution	.01/.1 Å/s
Thickness Accuracy	.5% typical
Thickness Resolution	1 Å
Measurement Period	.1 to 1 sec
Source	
Number of Sources	2
Control Voltage	0 to ±10V into 2K load
Resolution	15 bits
Digital I/O	
Digital Inputs	8
Functions	Shutter, Thickness Setpoint, Time Setpoint, All Crystal Fail
Input Rating	5VDC, non-isolated
Relay Outputs	8
Functions	Source Shutter, Close Shutter, Zero Thickness, Zero Time
Relay Rating	30Vrms or 30VDC, 2A maximum
General Specifications	
Mains Power Supply	100-120/200-240~, ±10% nominal 50/60HZ
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 against harmful ingress of moisture) Pollution Degree II Installation (Overvoltage) Category II for transient overvoltages
Storage Environment	-40°C to 70°C
Rack Dimensions (HxWxD)	88.5mm x 212.7mm x 196.9mm
Weight	13.2 kg (6 lbs)

Display	
Graphs	Rate, Deviation, Power
Readouts	Thickness, Rate, Power
Process Parameters (a Process is a sequence of layers)	
# Processes	25
# Films	25
# Layers (total all processes)	250
Layer Parameters (Layer is a Film, plus these values)	
Initial Rate	0.0 to 999.9 Å/sec.
Final Thickness	0.0 to 999.9 Å
Time Setpoint	0 to 30000 sec.
Thickness Limit	0.0 to 999.9 Å
Start Mode	Auto/Manual
# Rate Ramps	2
Rate Ramp Start	0.0 to 999.9 Å
Rate Ramp Time	0 to 1000 sec.
New Rate	0.0 to 999.9 Å/sec
Film Parameters (Film is a Material, plus these values)	
Material	100 stored
Density	.0.40 to 99.99 gm/cm^3
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.
Sensor (1,2)	On/Off
Output	1 or 2
Max Power	0.0 to 100.0 %
Slew Rate	0.0 to 100.0 %/sec.
Ramp Time (1,2)	0 to 30000 sec.
Soak Power (1,2)	0.0 to 100.0 %
Soak Time (1,2)	0 to 30000 sec.
Feed Ramp Time	0 to 30000 sec.
Feed Power	0.0 to 100.0 %
Feed Time	0 to 30000 sec.
Idle Ramp Time	0 to 30000 sec.
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
Hold Time	10.0 to 999.0

C. I/O Connections

Two 15-pin D-sub connectors, located on the rear of the SQC-122, provide I/O connections to .



Relay I/O Connectors

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.

Relay I/O 1-4

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

Relay I/O 5-8

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

Refer to Sections 2.3 and 2.4 for relay and input definitions.

D. EC Declaration of Conformity

Manufacturer's Name: Sigma Instruments

Manufacturer's Address: 1318 Duff Drive

Fort Collins, CO 80524 USA

declares that the product:

Product Name: Deposition Rate Controller

Product Model: SQC-122

Product Options: All Options

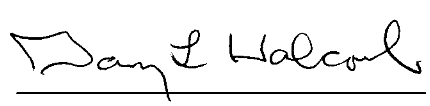
conforms to the following Directives:

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

Fort Collins, Colorado, USA May 2000