# SQC-222
# Thin Film CoDeposition Controller

## User's Guide

**Version 3.08**



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

## Limitation of Warranty

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

## Return Policy

The purchaser may return this product in 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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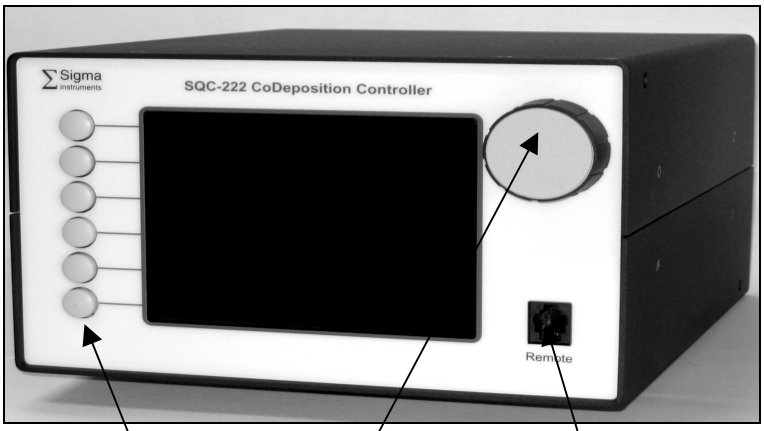
# 1.0 Introduction

The SQC-222 is a multi-channel quartz crystal monitor and deposition controller. It measures two 1 MHz to 6 MHz quartz crystal sensors, and controls up to two evaporation sources. Eight process control relays, and eight digital inputs are easily configured to support a broad range of external functions, including source pocket rotation. The number of sensors, outputs, and digital I/O can be doubled with an optional expansion card.

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

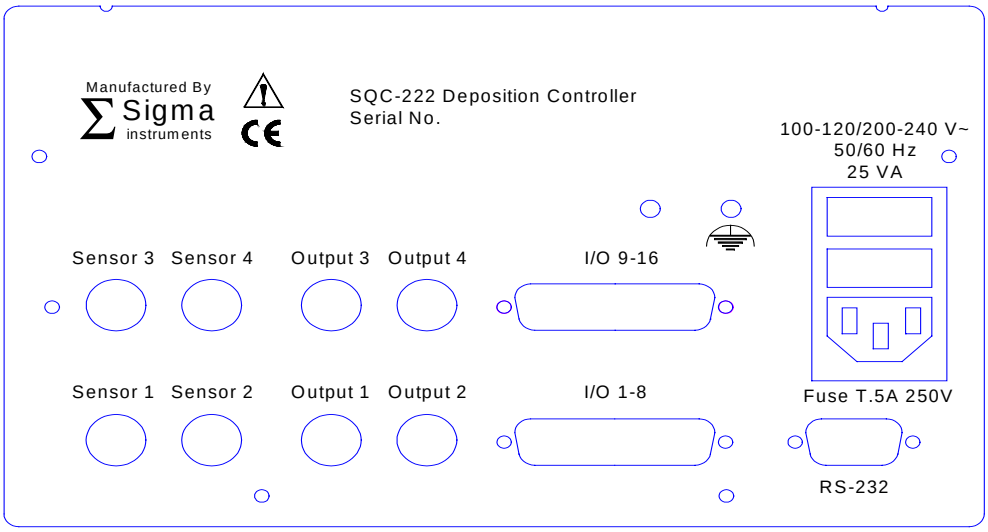



SoftKeys Control Knob Remote Jack

**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 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-222 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 connections. |
| **RS-232** | Connects to a computer for programming and data acquisition. Also used for the PLC I/O option. |
| **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. |

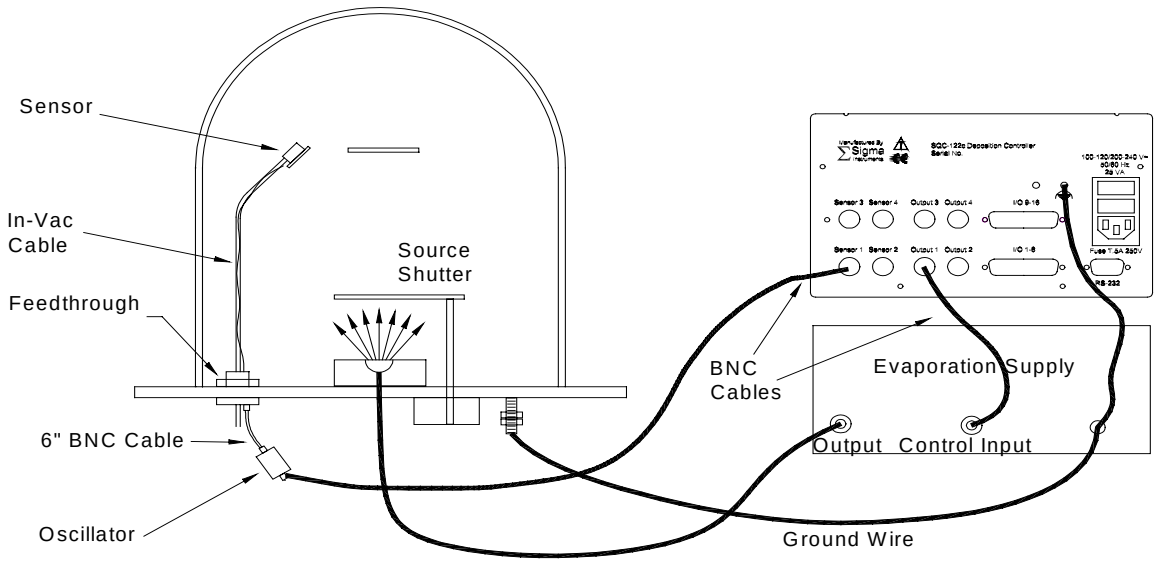
**Power Input and Fuse**

Connects to mains power. The SQC-222 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.

***WARNING***: Use removable 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-222 input. Lengths up to 100’ are acceptable. |
| **Control Output BNC Cable** | Connects the SQC-222 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-222 ground terminal. Important for noise rejection. |

## 1.4 Installation

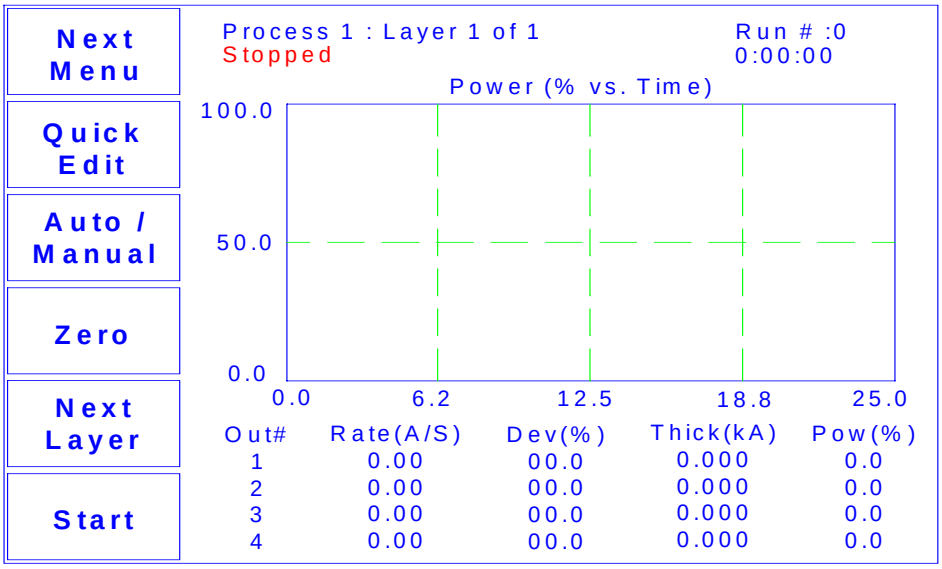
***WARNING***: Care should be exercised to route SQC-222 cables as far as practical from other cables that carry high voltages or generate noise. This includes other line voltage cables, wires to heaters that are SCR-controlled, and cables to source power supplies that may conduct high transient currents during arc down conditions.

| | |
|---|---|
| **Rack Installation** | The SQC-222 occupies a 5.25" 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-222 automatically detects mains voltages of 100-120 and 200-240VAC, 50/60Hz.<br><br>***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-222 sensor inputs. See the previous section for cabling details. |
| **Source Output Connections** | Connect the BNC cables from the SQC-222 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-222 Relay I/O connectors. Appendix C also covers I/O wiring with the optional PLC. |
| **Computer Connection** | If you would like to use the Windows software to collect data or program the SQC-222, attach a 9 pin straight-thru cable from the RS-232 connector to your computer's serial port. A cable is supplied with the SQC-222. |

## 1.5 Menus

At power up the SQC-222 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**

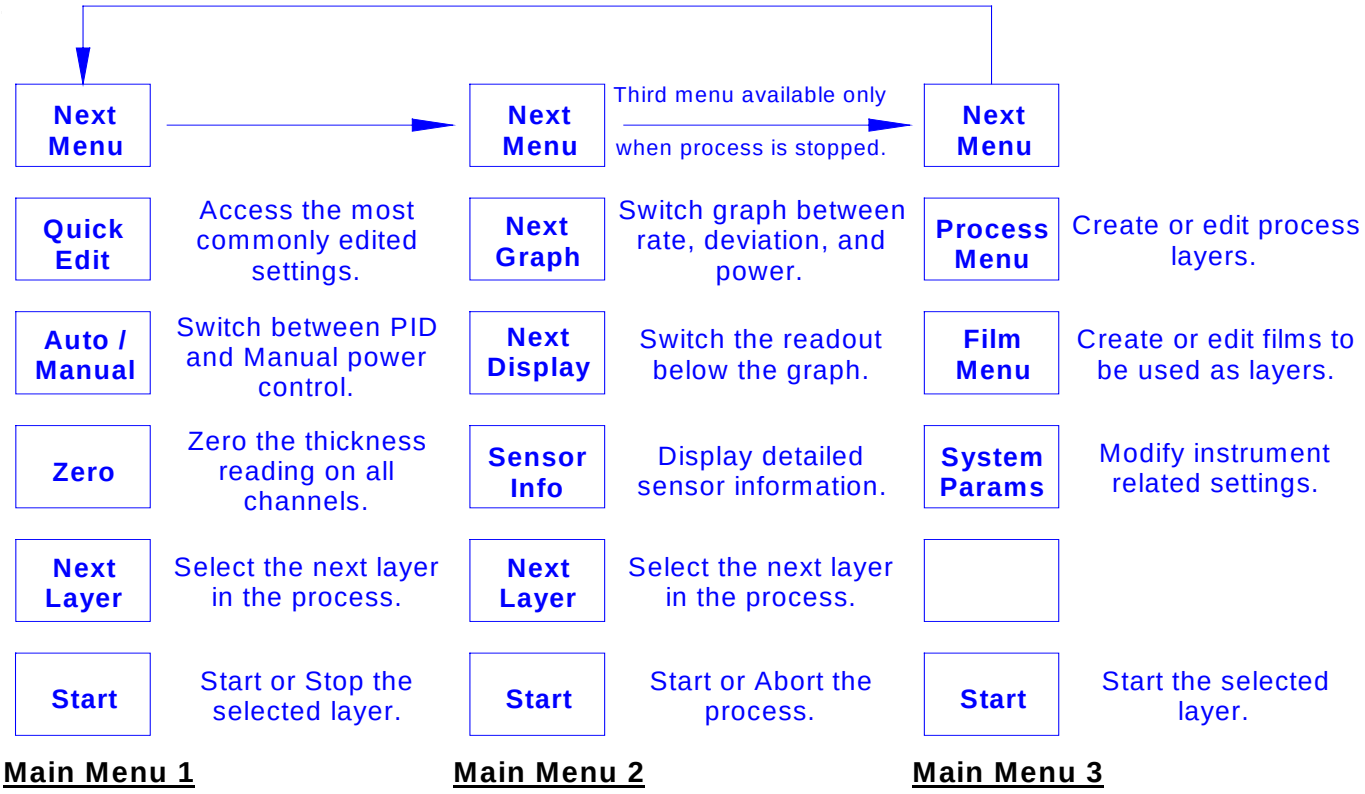
The first line of the Main screen shows the name of the currently selected process. After the process name are the layer that will run when the Start SoftKey is pushed, and the total number of layers in the process. Further to the right is the number of times this process has been run.

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:

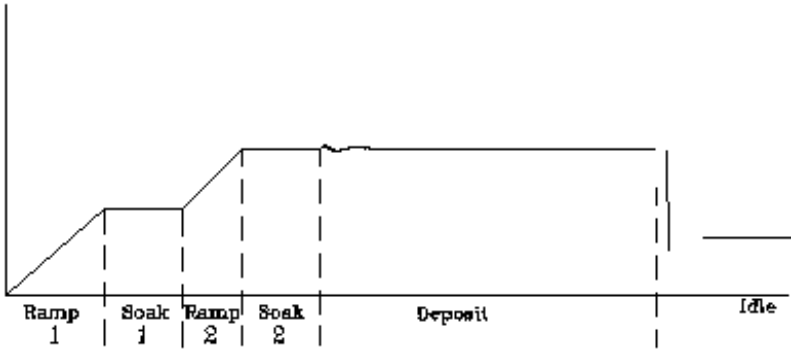



Because Main Menu 3 provides access to functions that can completely redefine a process, it is available only when the process is not running.

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-222 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 CoDeposition 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.

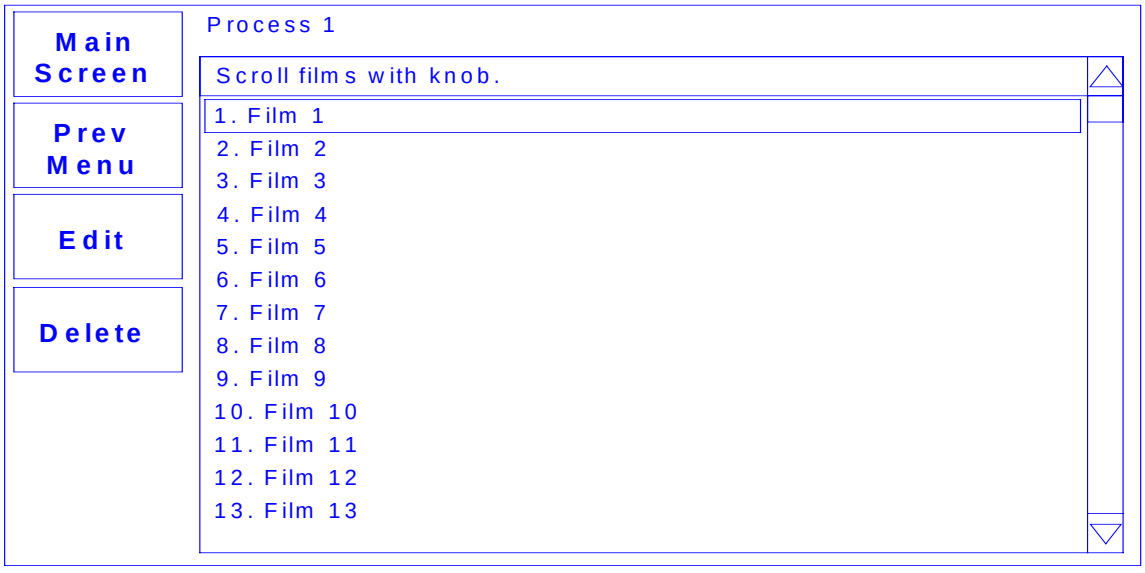
**Create a Film**

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

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.

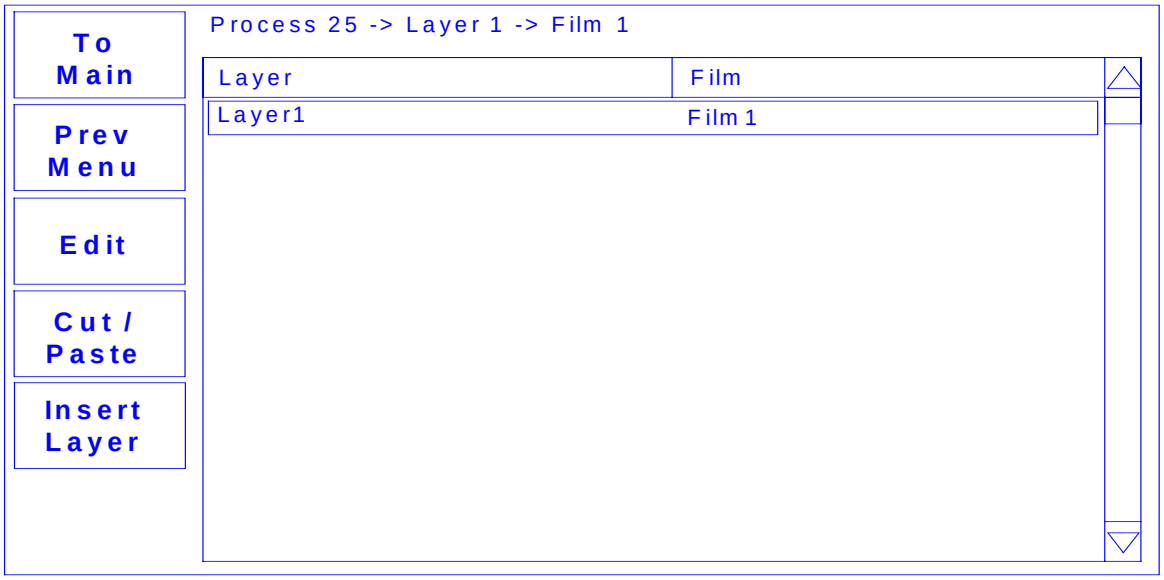
**Edit Process**

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

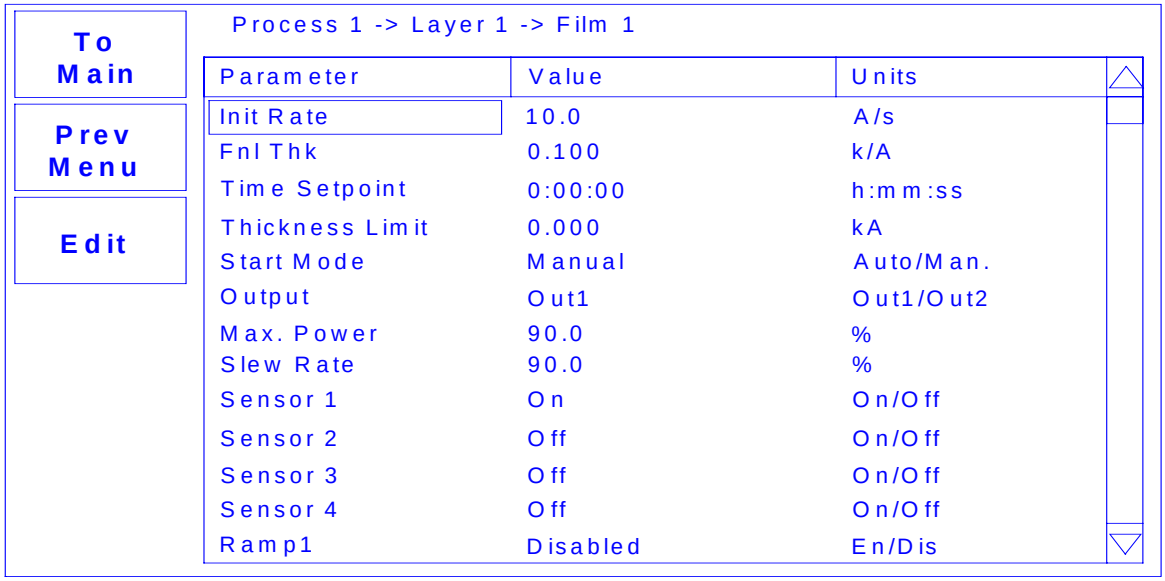



Layer Select Menu

A process consists of one or more layers. Each layer can have a different film, or even multiple films (CoDeposition). 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.




**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.

## 2.0 Introduction

This chapter describes common tasks associated with operating the SQC-222. 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.

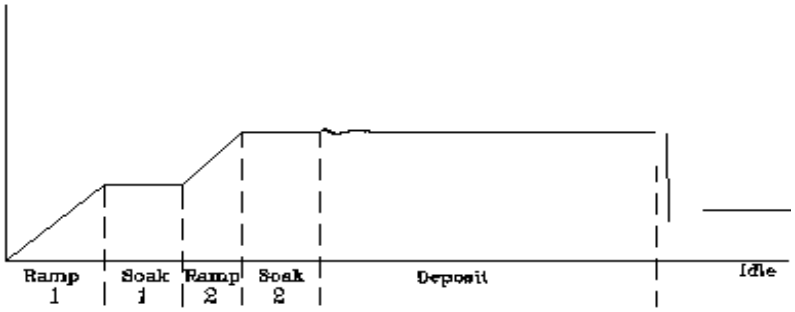
**Material:** A physical material to be deposited. A database of approximately 100 materials is stored in the SQC-222, and additional materials may be added using the setup software. Three parameters completely define a material: Name, Density, and Z-Factor. A table of common materials, their density, 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-222 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. Codeposition 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-222 can store up to 25 processes, consisting of a total of 400 layers.

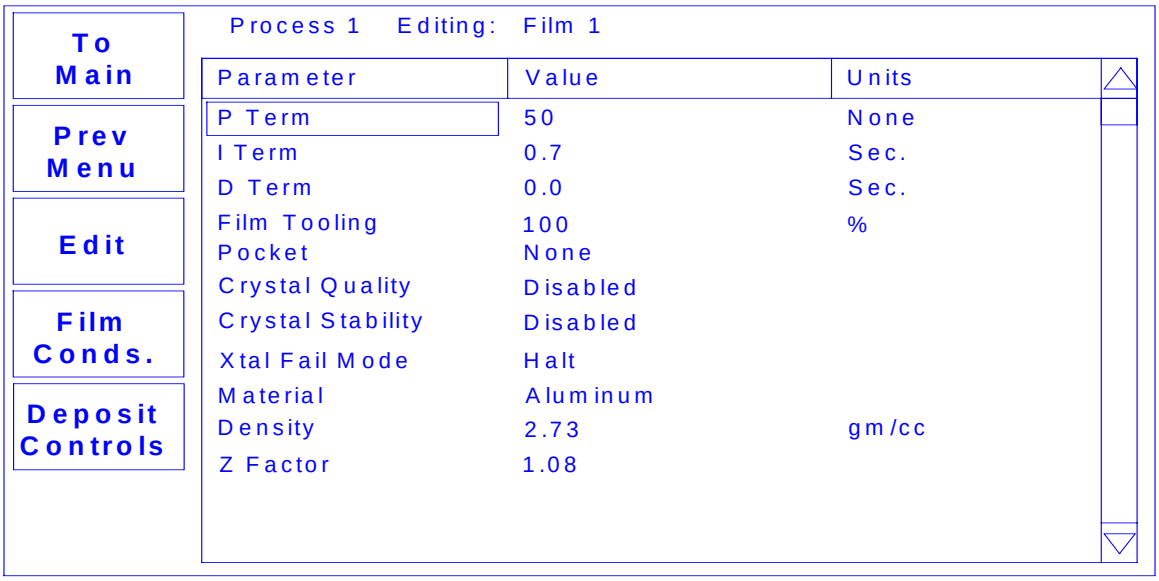
**Phase:** A step in the deposition cycle. Preconditioning phases include Ramp 1, Soak 1, Ramp 2, Soak 2. Deposit phases include indexer rotate, shutter delay, deposition, and deposition rate ramps. Post conditioning phases include Feed Ramp, Feed, and Idle Power.



## 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-222 setup software later to assign descriptive film names). Press **Edit** to display the parameters for this film.




**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.

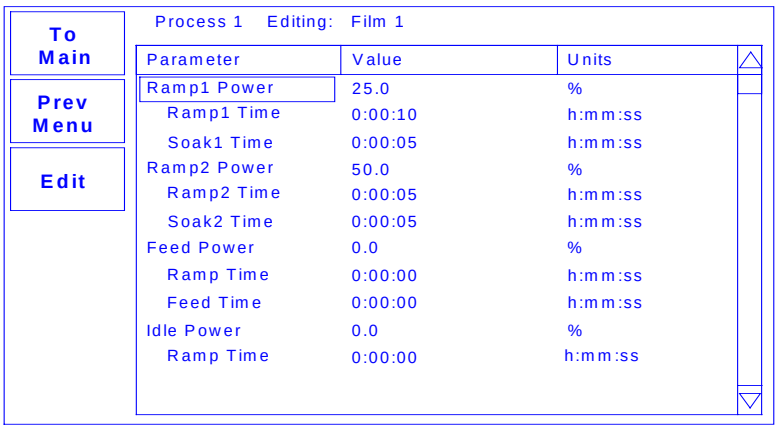
Film Tooling adjusts for differences in actual versus measured thickness for this film (material). This parameter is seldom used, but can adjust for material specific dispersion patterns. See Xtal Tooling in the System Parameters menu for the more commonly used tooling correction.

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-222 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.



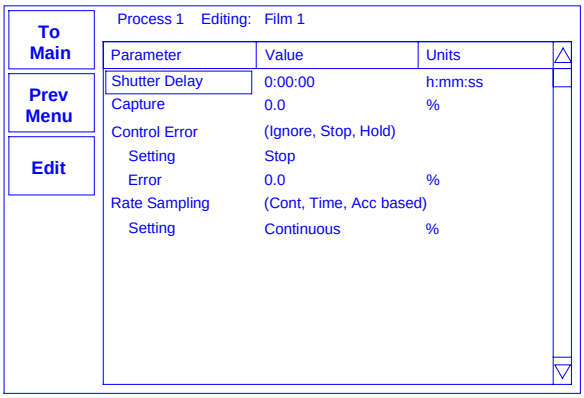

**Film Conditioning Menu**

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.




**Deposition Controls Menu**

Shutter delay causes the SQC-222 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-222 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-222 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 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-222 setup software to assign descriptive process names).

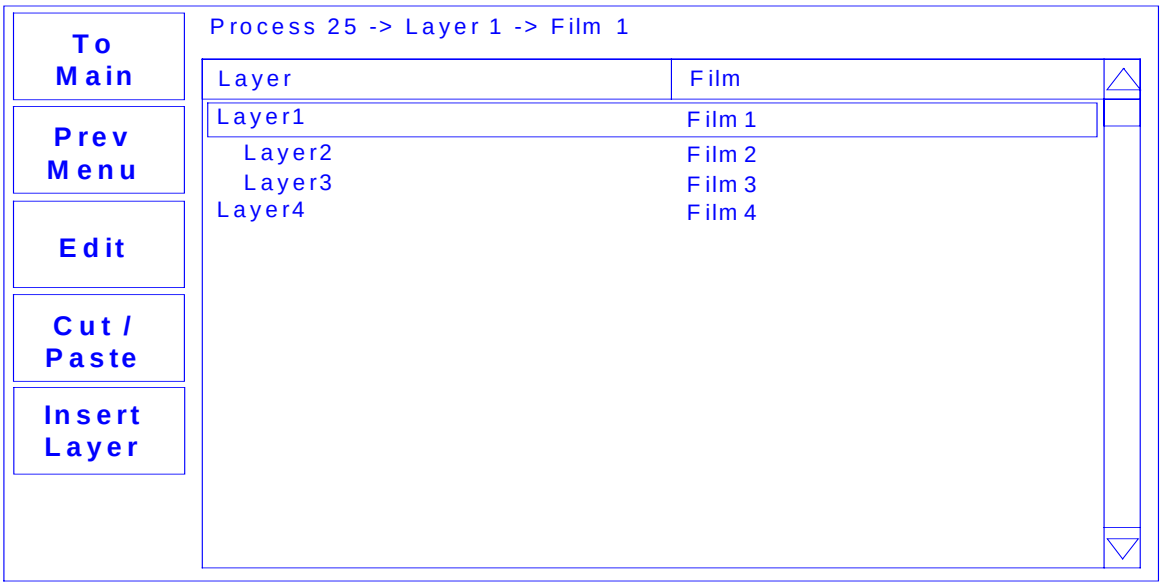
Press **Select**, then **Edit** to display the sequence of layers and films that comprise the selected process.

To add a layer, scroll to the desired location in the layer sequence, and press **Insert Layer**. Select a film from the list and press **Insert Normal** to insert a new layer. Layers are always inserted at 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 film to an existing layer so that materials will be codeposited, highlight the layer after the desired codeposition 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 codeposition film.

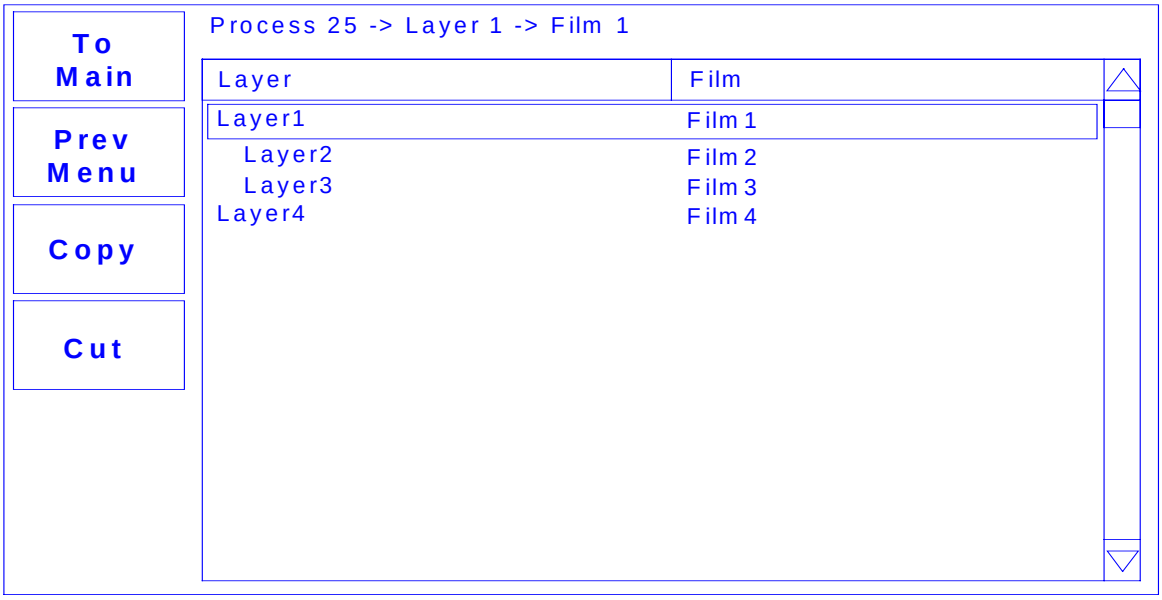
The display below shows two films being codeposited with Film1, then a fourth film being deposited as an additional layer. While layers are always numbered sequentially, the films are sequential only for this example. Any film can be used in any layer.




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**

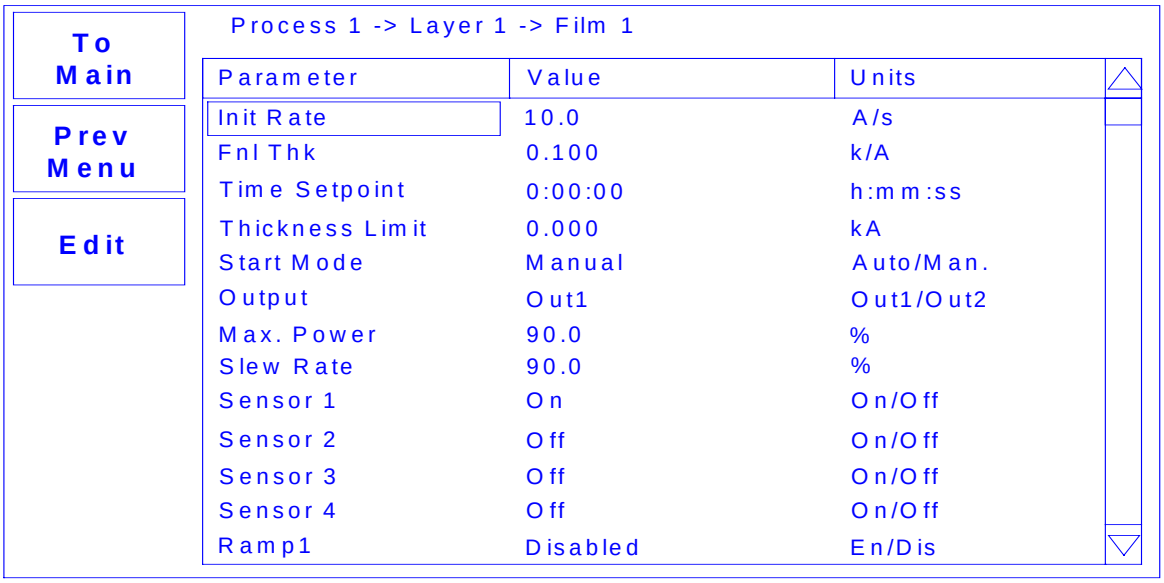
To move or duplicate a layer, highlight it in the Layer Select menu and press **Cut/Paste**. On the Cut/Paste menu, press **Cut** to remove the layer. A copy of the layer is automatically saved to copy/paste memory. Press **Copy** to save a copy to memory without removing the layer. Without leaving the 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**.




**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, RS-232, or digital input 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-222 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-222 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

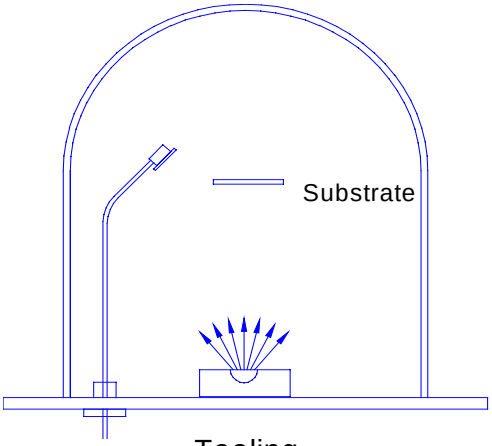
Sensor setup involves selecting the sensor(s) to be used, setting the Min/Max crystal frequencies, and adjusting the Tooling Factor.

In the **System Params** menu, Max Frequency is the initial frequency of a new crystal, typically 6.0e+06 Hz (6 MHz). Due to manufacturing tolerances, some crystals may oscillate above 6MHz initially, which would be detected as a sensor error. Setting the Max Frequency slightly above the nominal value, to say 6.1 MHz will avoid this problem.

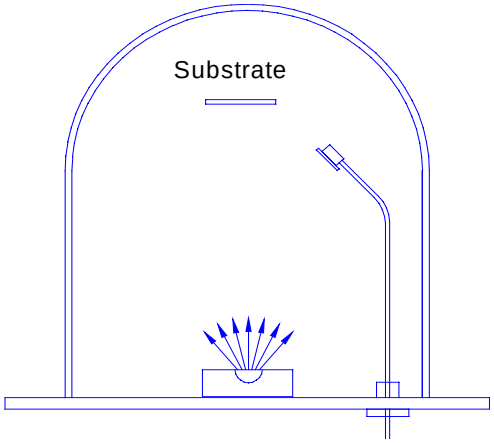
Min Frequency is the frequency where the SQC-222 will flag a sensor as bad. For a 6 MHz crystal, the Min Frequency is typically 5 MHz. Crystal failure is often predicted by periods of "mode hopping," where the crystal briefly makes an abrupt change in frequency, or stops oscillating altogether. Some 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 you 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.

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




Tooling
Over 100%




Tooling
Under 100%

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 kA. But, suppose the actual substrate is deposited to 1.100 kA thickness (as

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

(1.100 / 1.000) x 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-222. 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-222 controls deposition rate by varying the control voltage to an external evaporation (source) supply.

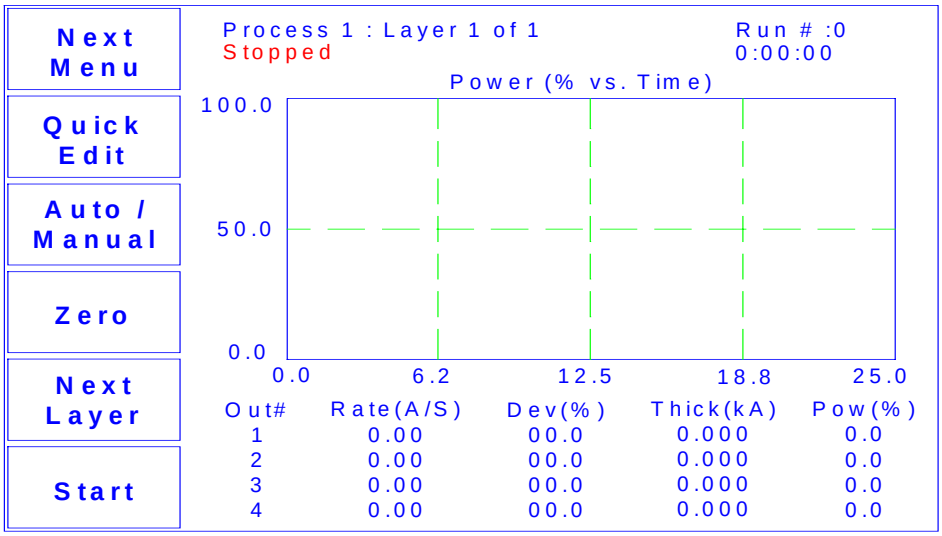
The SQC-222 output voltage range is set in the **Systems Params** menu. For the supply connected to each output, set the Scale to the control voltage that corresponds to 100% output on the source supply. The SQC-222 uses 0 volts as 0% output, and the programmed value as 100% output. Scale values from –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

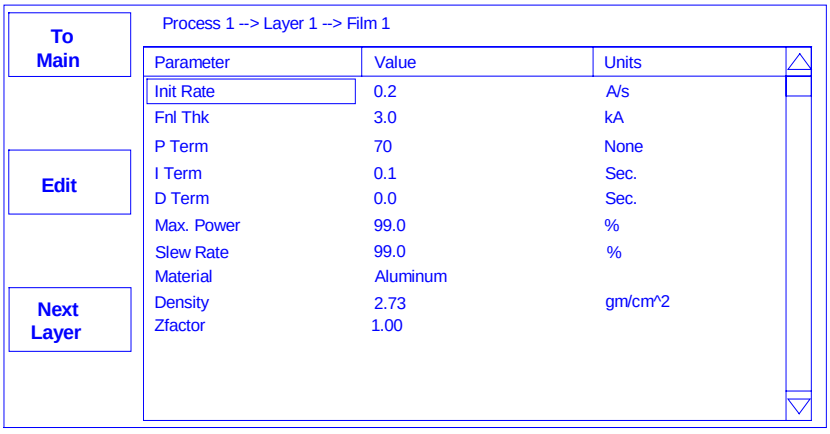
Once a Process is defined with the desired Layers, and the sensors and source supply are properly connected, the deposition process is ready to run. This section describes the steps to select, start, and stop a process.

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.



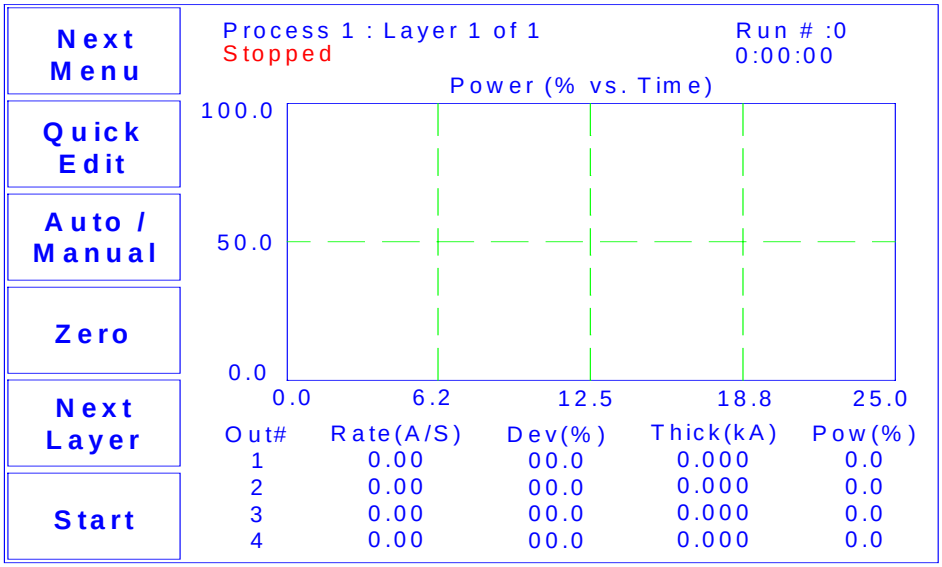

**Main Screen**

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




**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-222 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-222 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 Manual/Auto power SoftKey with a layer's Manual and Auto Start. Manual/Auto Start modes are a Layer setup parameter that tells the SQC-222 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-222 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.

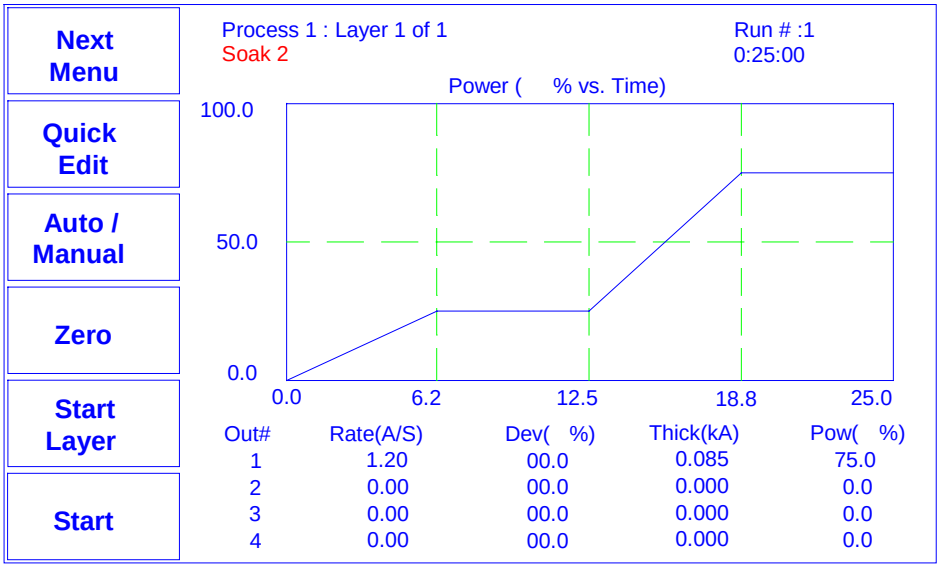
The last SoftKey on this menu is used to Start and Stop the deposition cycle. Press **Start** to start the layer shown on the first line of the screen at the preconditioning phase.

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-222 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!

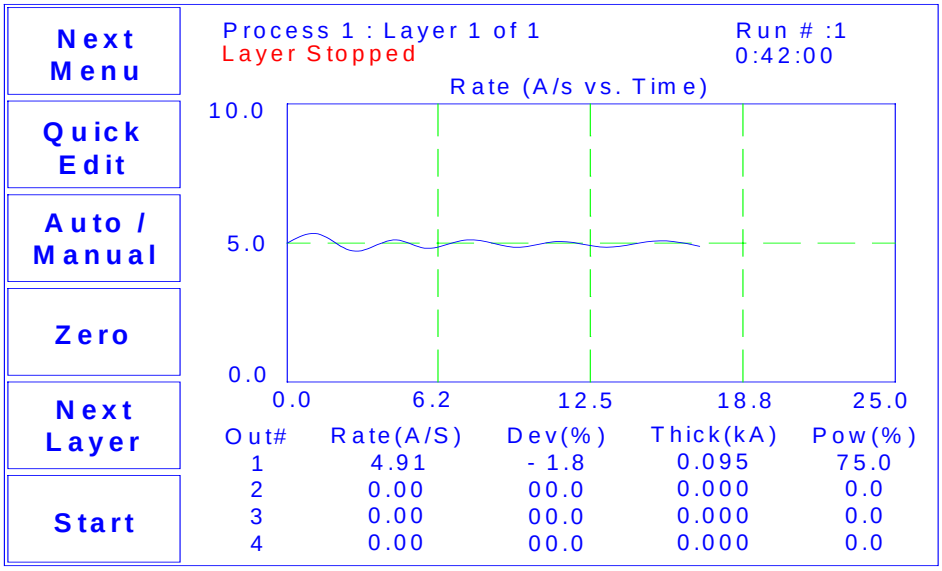
Press **Start** to start deposition. If the first layer Start mode was programmed as Manual, you will need to press the Start Layer SoftKey now to start the layer.




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.




**Layer Stopped**

**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-222 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 $PWR_{0R}$.

**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 $PWR_{0R}$ 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-222 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.

### 2.9.1 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-222 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 then 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 6MHz 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-222, and verify that the SQC-222 is properly grounded. Also check that the crystal is seated properly in the sensor head.

Swap the sensor to the other SQC-222 input. If both SQC-222 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).

### 2.9.2 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.

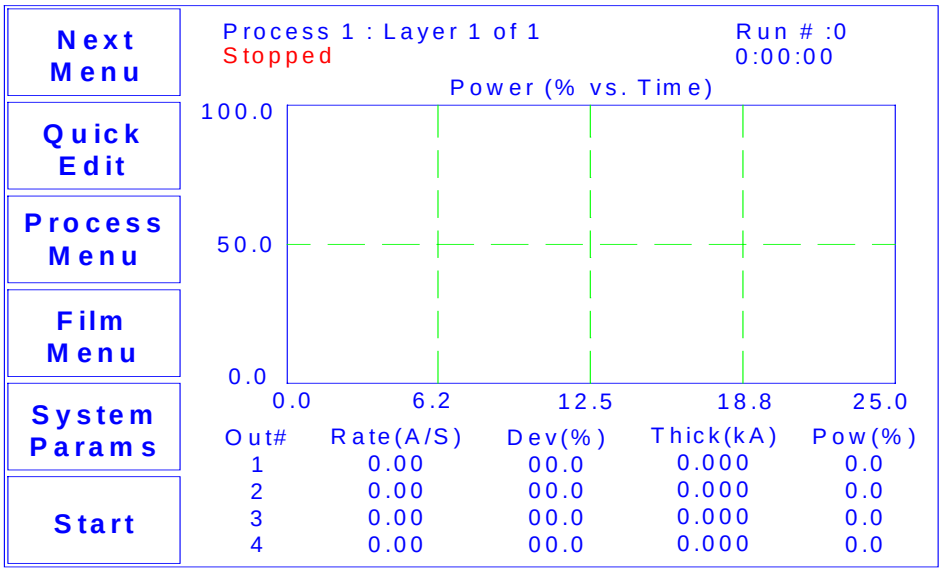
### 2.9.3 Poor Rate Stability:

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.

## 3.0 Introduction

Three menus on the Main Screen control SQC-222 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 power-up screen for the SQC-222 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-222 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

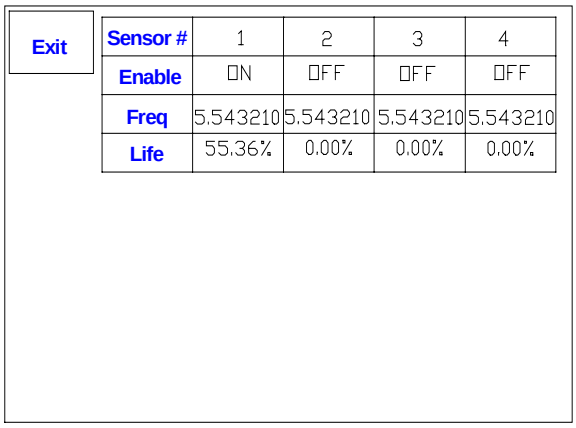
The table below describes the function of each SoftKey on Main Screen, Menu 1.

| | |
|---|---|
| **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-222 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; 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. |




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 is can 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.

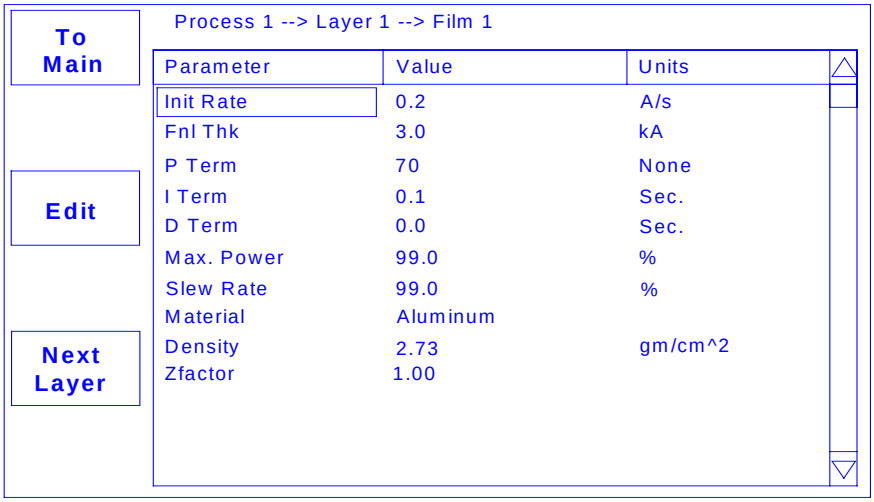
The table below describes the function of each SoftKey on Main Screen Menu 3.

| | |
|---|---|
| **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-222. 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.




**Quick Edit Menu**

| | |
|---|---|
| **To Main** | Returns to the Main Screen Menu 1. |
| **Edit** | Selects the highlighted parameter for edit. SoftKey functions change to:<br>**Next:** Store parameter and move to next for editing.<br>**Cancel:** Stop editing and undo changes to selected parameter.<br>**Enter:** Stop editing and save values for selected parameter.<br>**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.

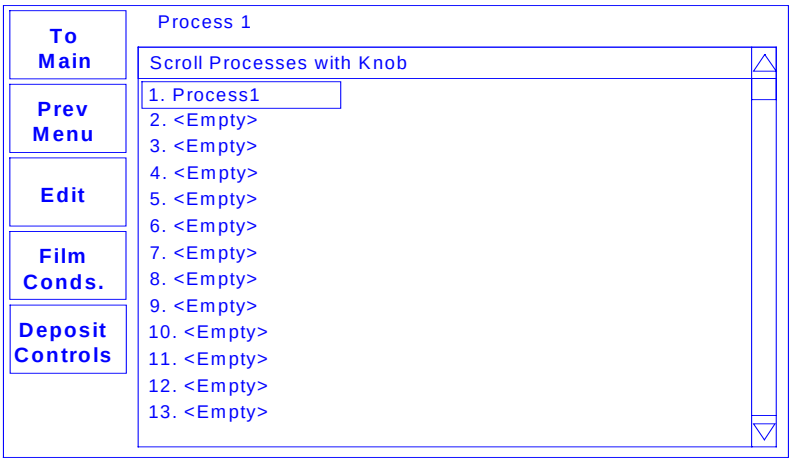
**Material:** Selects a material assigned to this film. As materials change, their density and Z-Factor are updated.

**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 $SiO_2$) to obtain the material's Z-Factor.

## 3.5 Process Menus

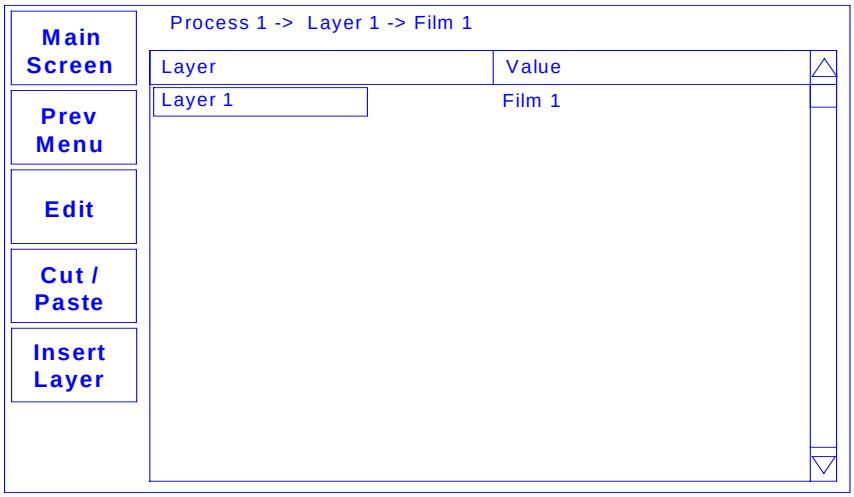
There are several tiers of Process Menus. The first menu (shown below) selects the current process. The current process is the process that is ready to run, and also the process that is selected for editing.




**Process Select Menu**

| | |
|---|---|
| **Main Screen** | Returns to the Main 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).

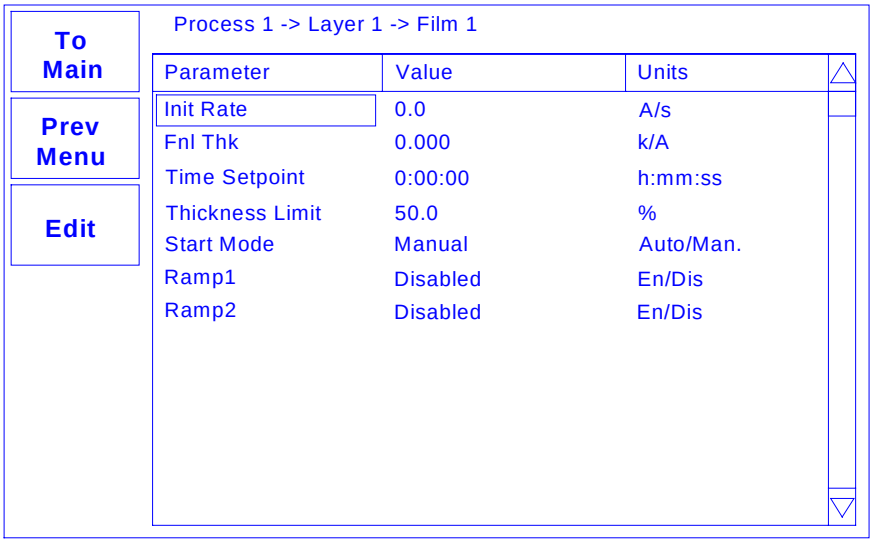
**Cut / Paste** — Used to develop the sequence of layers in a process. Pressing Cut/Paste displays a sub menu.

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 25 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:




**Layer Edit Menu**

| | |
|---|---|
| **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:<br>**Next:** Store parameter and move to next for editing.<br>**Cancel:** Stop editing and undo changes to selected parameter.<br>**Enter:** Stop editing and save values for selected parameter.<br>**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 are a 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.

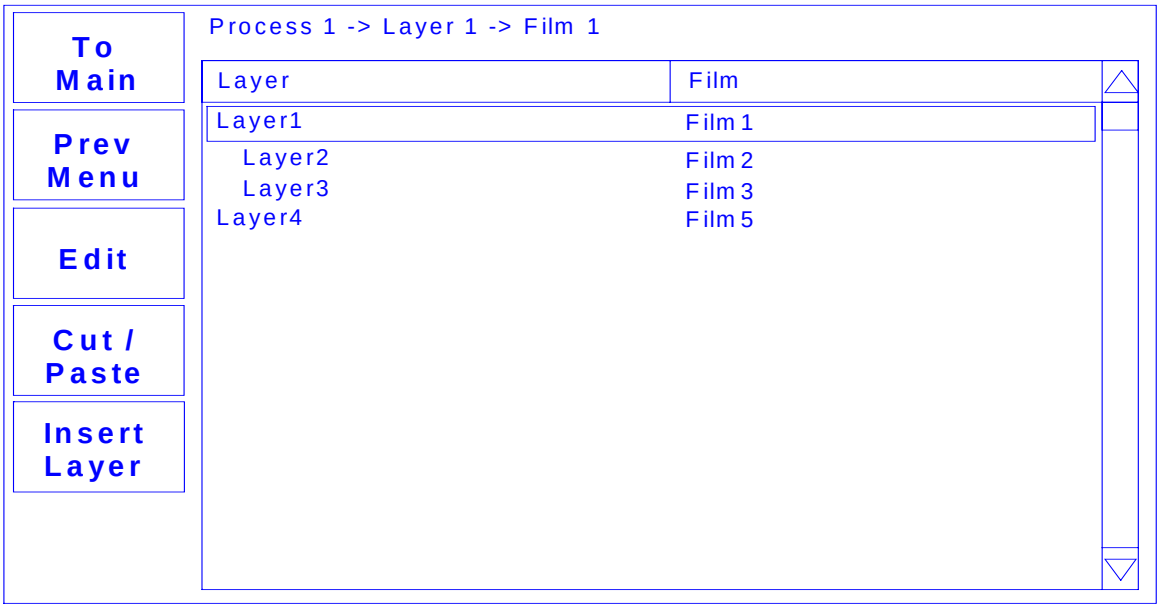
**New Rate:** The rate of deposition, which is reached at the end of Ramp 1.

**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

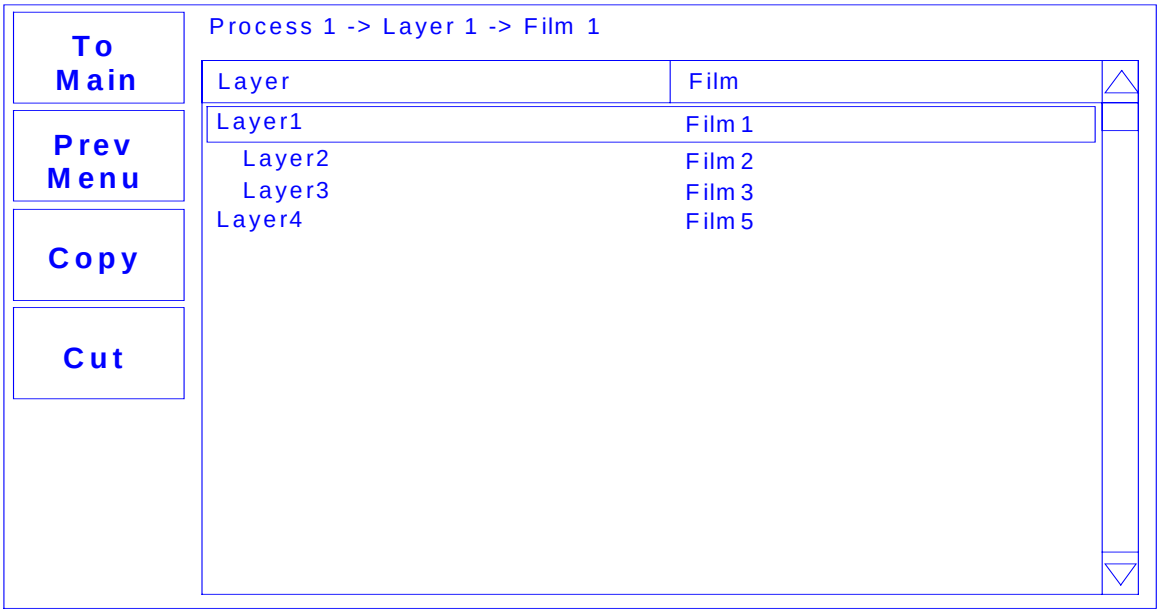
Cut/Copy and Insert menus are used to build and edit a sequence of process layers.

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.




**Layer Select Menu**

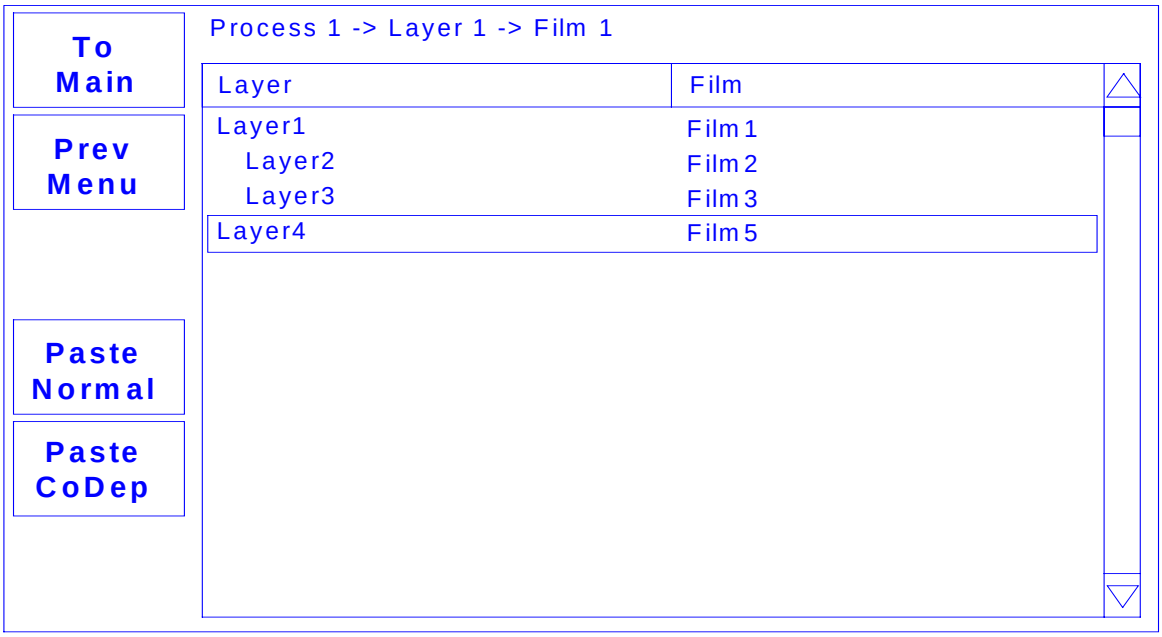
To remove (or duplicate) a layer highlight it , then press Cut/Paste.




**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 is 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.*

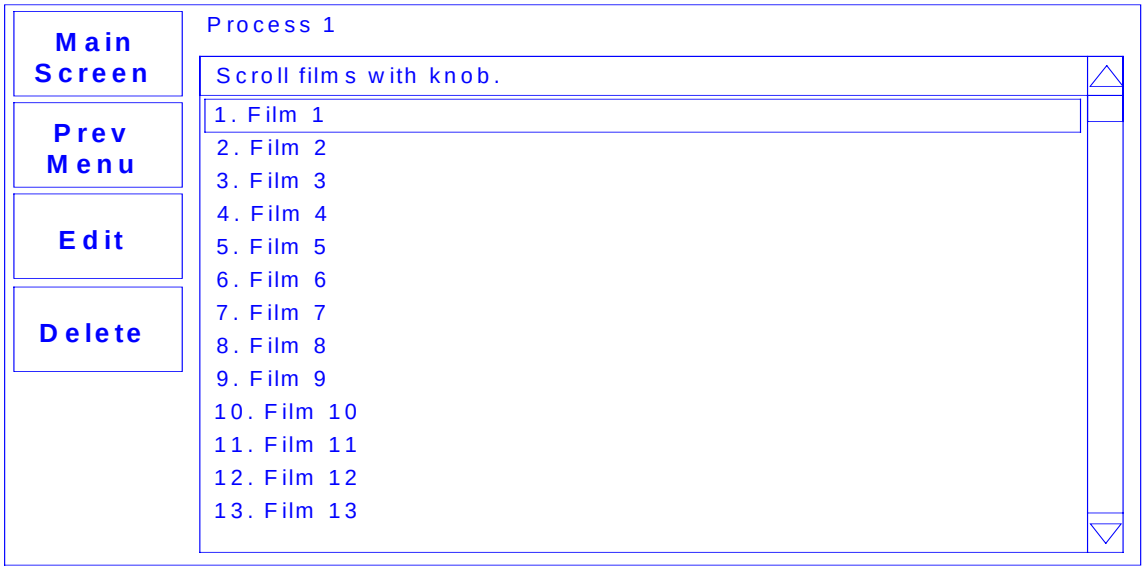
For example, to insert a new Layer 1, highlight Layer 1 and press Paste Normal. The layer is as Layer 1. The existing Layer 1 becomes Layer 2. Layer 2 becomes Layer 3, etc.

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 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. These parameters apply anytime this film is used (in any process).

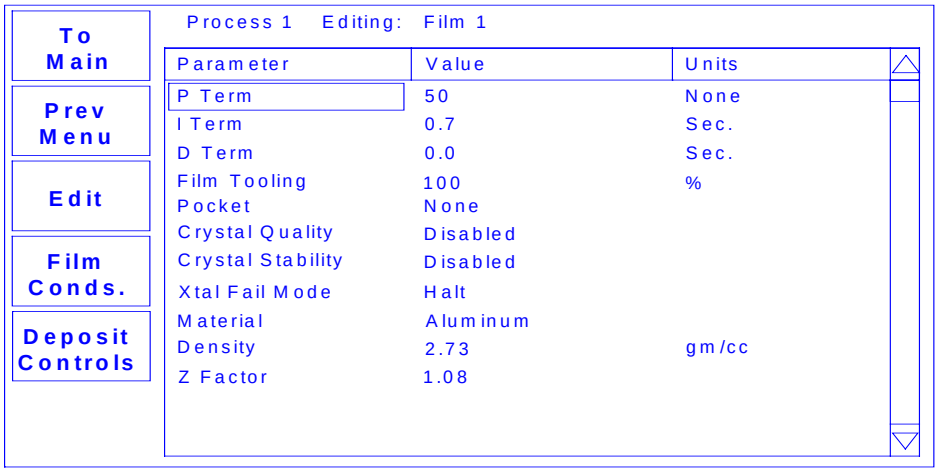



Film Select Menu

| | |
|---|---|
| **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.

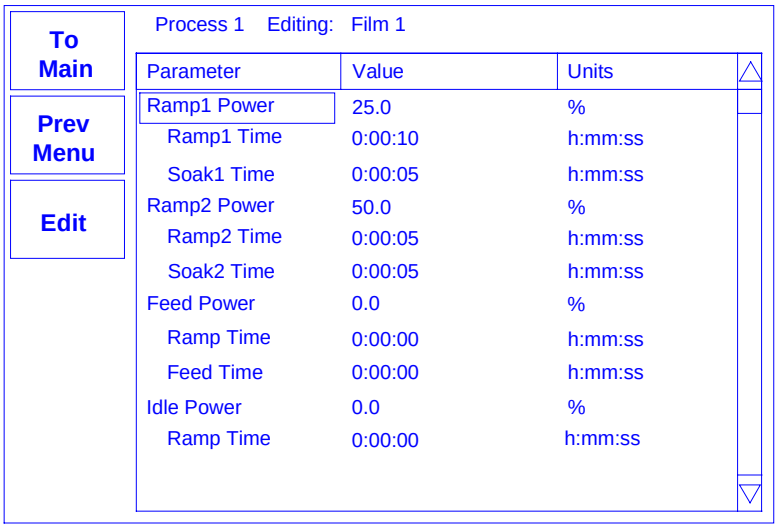



**Film Edit Menu**

| | |
|---|---|
| **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:<br>**Next:** Store parameter and move to next for editing.<br>**Cancel:** Stop editing and undo changes to selected parameter.<br>**Enter:** Stop editing and save values for selected parameter.<br>**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.



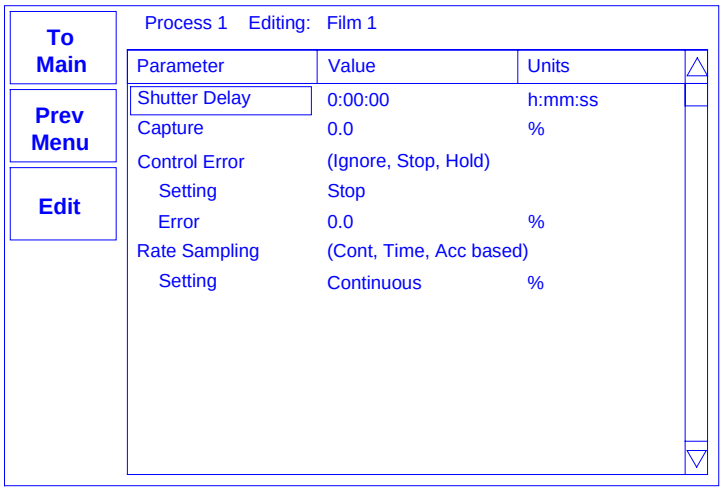

**Film Conditioning Menu**

**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.




**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 (100Hz single shift) |
| 2 | 1000 Hz | 7 | 100 Hz |
| 3 | 500 Hz | 8 | 100 Hz (50Hz single shift) |
| 4 | 400 Hz | 9 | 25Hz |

**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.

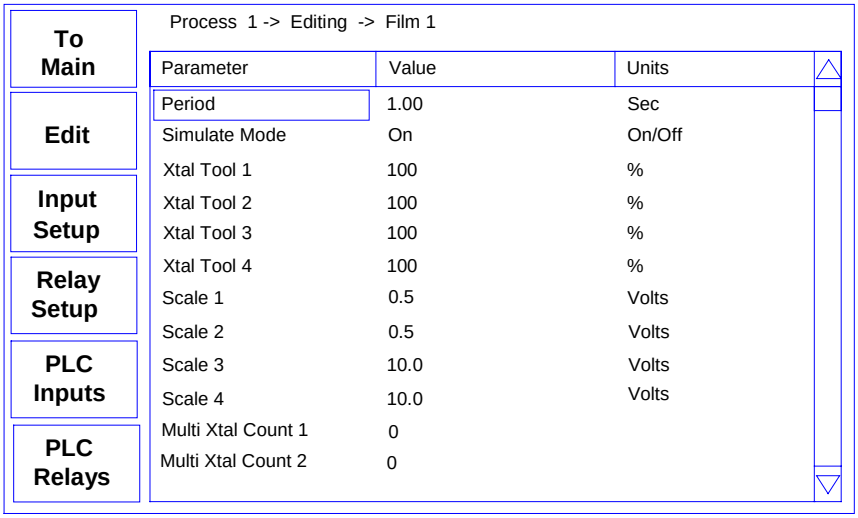
**Control Error:** If the control loop cannot maintain the desired deposition rate, due to loss of source material, excess rate ramps, or equipment malfunction, a control error occurs. The error condition can be ignored, the process stopped (output power to 0%), or the output power held at the same level 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-222. 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.

**Input Setup** Displays menu for mapping digital inputs to process events.

**Relay Setup** Displays menu for mapping relays to process events

**PLC Inputs** Displays menu for mapping PLC inputs to process events. See the PLC appendix for more information.

**PLC Relays** Displays menu for mapping PLC relays to process events. See the PLC appendix for more information.

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.

| Period (seconds) | Frequency Resolution (Hz) |
|---|---|
| .1 | .3 |
| .25 | .12 |
| .5 | .06 |
| .75 | .04 |
| 1 | .03 |

**Simulate Mode:** Normal mode uses the quartz crystals as inputs to the SQC-222 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 1-2:** 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 lower the tooling value

**Scale 1 -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.

**Multi Xtal Count 1-2:** 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-222. 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.

**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.

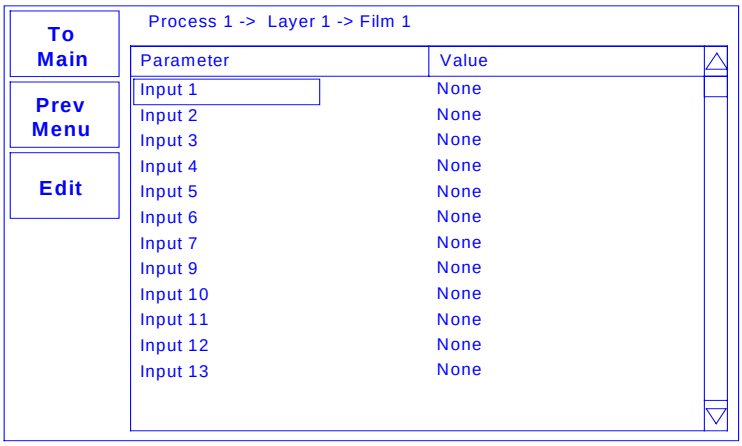
**Password:** If password is enabled, this parameter sets the sequence of SoftKeys to press to enter menus. Press the desired sequence to set the password. Holding down the top and bottom switch while powering up the SQC-222 sets the password to "1111."

**System Time:** Sets the SQC-222 clock to your local time. System time is battery backed up. Does not compensate for daylight savings time.

**System Date:** Sets the SQC-222 date to your local time. System date is battery backed up.

The Input and Relay SoftKeys of the System Parameters Menu allows you to map the eight digital inputs and the eight digital outputs (16 of each if the option card is installed). The I/O can be expanded with more relays and inputs, and significant logic capabilities, by using the external PLC option.

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.




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:

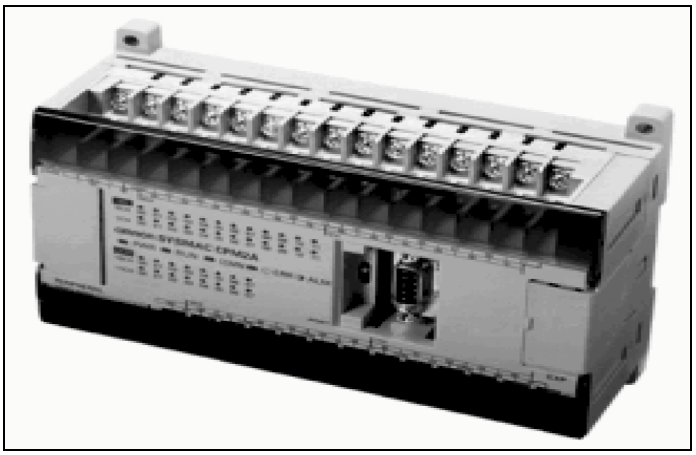
| **Inputs** | **Explanation (low to high transition causes)** |
|---|---|
| Start Process | Start the process at Layer 1. |
| Abort Process | Abort the process. Can only restart at Layer 1. |
| Start Layer | Start the active layer. |
| Stop Layer | Stop the active layer. |
| Start Next Layer | Start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

| **Relays** | **Explanation (closes when)** |
|---|---|
| Source 1-4 Shutter | Deposit phase for films set to Output. |
| Sensor 1-4 Shutter | Shutter Delay and Deposit phases of films set to Sensor. |
| Sensor 1-4 Fail | Sensor is assigned to this layer, and has failed. |
| All Crystal Good | All sensors assigned to this layer are OK. |
| All Crystal Fail | All sensors assigned to this layer have failed. |
| Process Hold | Process is stopped (waiting for Start Layer). |
| Deposit Phase | Process is in Deposit phase. |
| PreCond Phase | Process is in Ramp1, Soak1, Ramp2, or Soak2 phase. |
| SoakHold Phase | Process is in Soak/Hold phase. |
| Process Active | Process is running (not stopped). |
| Manual Mode | Process is in Manual mode (not under PID control). |
| Max Power | Active output is at maximum power (out of material?). |
| Process Stopped | Process is stopped (not running). |
| Time Setpoint | The process has been in Deposit phase the indicated time. |
| Thickness Setpoint | Thickness setpoint reached. Resets on start of next Layer. |
| Final Thickness | Final thickness reached. Resets on start of next Layer. |
| Dual Crystal Shutter | Primary sensor failed, switch to secondary. |
| Multi Xtal Move 1-4 | 1 sec. pulse to move a multi-crystal head to next position. |
| Output Pocket 1-8 | Source pocket # (Single Mode) or BCD bit # (Multi mode) |
| None | This relay is not assigned to any event. |

## 3.10 PLC I/O

The standard I/O of the SQC-222 is adequate for most applications. Applications that require additional I/O points, or extensive I/O logic capabilities, can use the low cost PLC option to extend the instrument's process control capabilities.

An inexpensive Omron CPM2 series PLC extensive I/O processing capabilities through its ladder logic programming.



There are several benefits to using the PLC. First, noisy high voltage wiring can be placed near the control sources, rather than routed to the SQC-222 controller back panel. Only a single serial cable runs from the PLC to the SQC-222. The PLC also provides electrical isolation from the process for the SQC-222. And finally, the PLC's ladder logic programming provides fail-safe process protection and allows I/O to be easily tailored to each end user's installation.

The functions of the standard PLC program supplied by Sigma extend the SQC-222 standard I/O as shown below:

| | | |
|---|---|---|
| PLC Input | 0.00 to 0.11 | Functions mapped by SQC-222 system setup screen |
| | 1.00 | Pocket ready signal from Indexer 1 |
| PLC Relay | 10.00 to 10.07 | Functions mapped by SQC-222 system setup screen |
| | 11.00 to 11.03 | Pocket 1 to 4 select signal for Indexer 1 |

The PLC runs a small ladder logic program that communicates with the SQC-222 through several internal registers on the PLC. These PLC registers contain information about the SQC-222 operating state, the selected sensors and outputs, and indexer status. The ladder logic program can be modified to perform additional I/O, logic and timing functions using Omron's CX-Programmer software. Contact Sigma Instruments for more information on programming your PLC.

For those developing their own PLC program, the SQC-222 updates/reads the internal PLC registers with the events shown below. .

| PLC Register | SQC-222 Function |
|---|---|
| 200 | Layer/Phase Register<br>Bits 0-9 are BCD layer number running<br>Bits 10-15 are BCD Phase# as shown below<br>00 Not Used — 09 ShutterDelay Phase<br>01 Not Used — 10 Deposit Phase<br>02 Not Used — 11 Layer Stopped<br>03 Not Used — 12 Layer Starting<br>04 Process Stopped — 13 Not Used<br>05 Precondition Phase — 14 Feed Ramp Phase<br>06 Not Used — 15 Feed Hold Phase<br>07 Not Used — 16 Idle Ramp Phase<br>08 Not Used — 17 Idle Phase |
| 201 | Sensors/Outputs 1-4 Register (updated each layer)<br>Bits 0-3 are sensors used (1=used, 0=unused)<br>Bits 12-15 are outputs used, 12 is Out1, 13 is Out2, etc. |
| 220 | Source Index Register (updated each layer)<br>Bits 0-3 are BCD of Output 1 source index<br>Bits 4-7 are BCD of Output 2 source index<br>Bits 8-11 are BCD of Output 3 source index<br>Bits 12-15 are BCD of Output 4 source index |
| 221 | Source Indexer Done Flag<br>Bit 0 is Source Indexer 1 (1= Indexer Done, 0=Not Done)<br>Bit 1 is Source Indexer 2<br>Bit 2 is Source Indexer 3<br>Bit 3 is Source Indexer 4 |
| 222 | Relays 1-16<br>Bit 0 is Relay 1, etc. |
| 224 | Inputs 1-12<br>Bit 0 is Input 1, etc. |

## 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 SQM-160. For maintenance or repair, contact

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

## 4.1 Cleaning

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

## 4.2 Software Upgrades

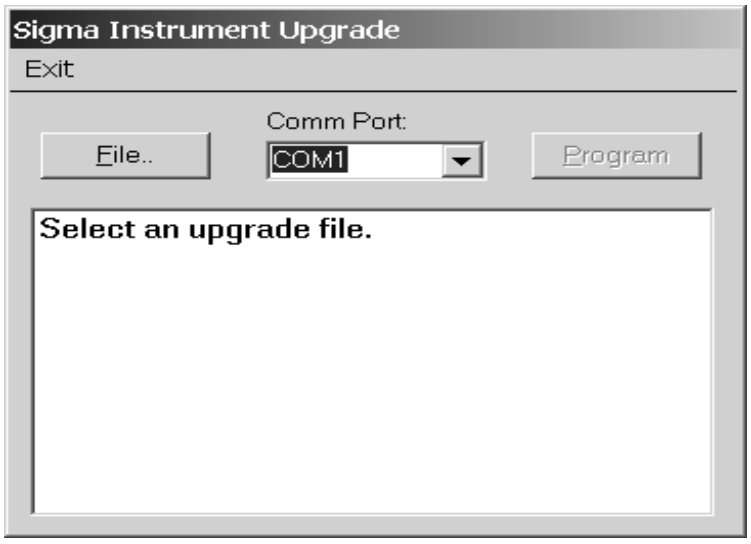
The SQC-222 firmware (Flash software) can be upgraded through its RS-232 port. The upgrade program, SigmaFlash.exe, is on the Utility CDROM shipped with the SQC-222.

The latest firmware file (SQC222.BIN) can be found our web site, www.sig-inst.com. Compare the version of the web site's file with the version shown on the SQC-222 at power on. Upgrade only if the BIN file on our web site is a higher number.

To upgrade the SQC-222 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 SCQ-222 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-222 is turned OFF.

6. Click Program, then turn on the SQC-222.

7. SigmaFlash should find the SQC-222 and load the new program.

6. When the upgrade is complete, the SQC-222 will restart. Verify that the SQC-222 startup screen shows the new firmware version.

## 4.3 Option Card Installation

The option card adds two additional sensor inputs, two control out puts, and 8 digital I/O signals to the SQC-222. To install the option card follow these steps.

1. Unplug the SQC-222 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. Screws 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 and attach with the eight screws saved in step 1.
10. At turn on the SQC-222 will now display four channels on the main display.

## 4.4 Half Rack Adapter Installation

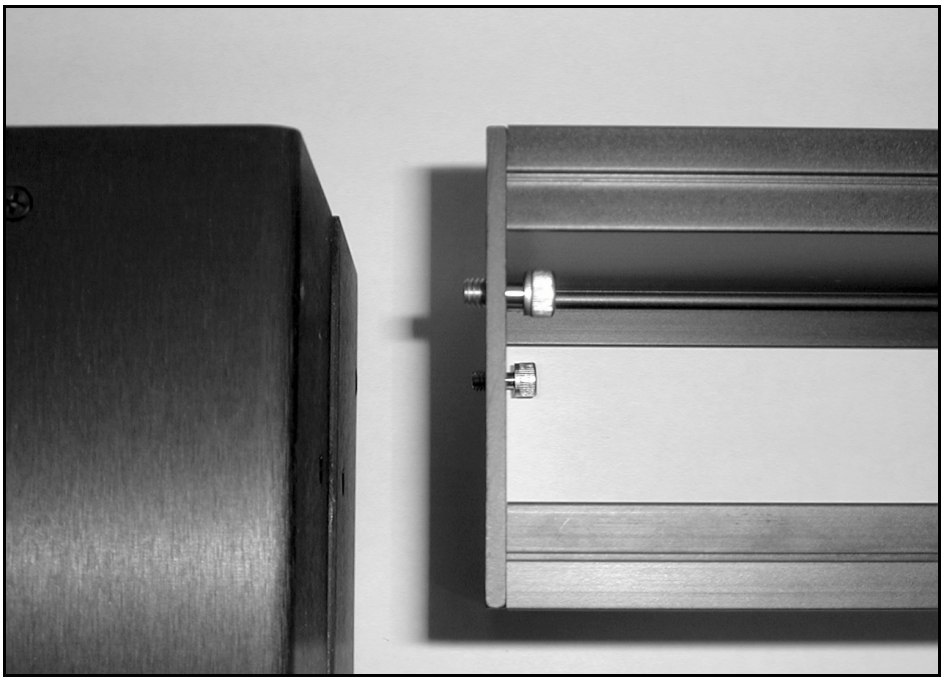
The Half Rack Adapter option (PN 900-016) adapts the SQC-222 to many other 5 1/4" high half rack instruments.

The option consists of two standard rack mount ears and an adapter bracket. Attach one of the standard rack mount ears to the SQC-222 with the 10-32 flat head screws supplied. Attach the adapter bracket to the other side of the SQC-222.

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-222 into a full width 19" rack space. Assemble the two 3" x 5¼" 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-222 by threading the shoulder screws into the matching holes in the SQC-222 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 the 10-32 Phillips screws (not provided).

# 5.0 Introduction

This section covers external control of the SQC-222 by RS-232 commands.

# 5.1 SQC222 COMM.EXE

SQC222 Comm .exe is found on the Utility and Demo disk supplied with your SQC-222. A more current version may be available on 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-222 and save them to disk. This program is written in Visual Basic. Contact Sigma Instruments if you would like the source code for this program.

# 5.2 Communications Protocol

The SQC-222 communicates with a host computer via an ASCII based protocol. The instrument defaults to 19200 baud, 8 data bits, and no parity. The basic protocol is:

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

Once a valid command has been transmitted to the SQC-222, a response is returned. The structure of the packet is identical in both the command and response. In the response, the first character is a Response Status. These are summarized in the following table.

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

The sync character is an exclamation point '!'. Anytime this character is received, the communications buffer of the SQC-222 is reset for a new packet.

Following the sync character is the length character. This is the number of characters in the packet starting with the length and counting the 2 CRC characters. This character has a decimal 34 added to it so there cannot accidentally be a sync character embedded in the packet.

The two character CRC is computed using the following algorithm:

1. The CRC is initialized to 3FFF hex.

2. Each character in the message is examined, bit by bit, and added to the CRC in the following manner:

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

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

## 5.3 Commands

The examples represent the data commands only (less sync, length, and CRC characters) for clarity. The Utility and Demo CDROM includes a demonstration program, MessageGen.EXE, that allows you to view the complete send/receive commands.

**Command:** @

Parameters: None

Description: Returns the model number and software version number. Use this command to test for correct communications with the instrument.

Example: @ SQC222 Ver 1.0

---

**Command: A**

Parameters: [1..9], Values | ?

Description: Film parameters. The parameters available for change or inspection are Label, Density, Tooling, Z-Factor, Final Thickness, Thickness Setpoint, Time Setpoint, Sensor Average

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

Each film's parameters are accessed by using the film's number directly after the Command. The parameters are edited by adding a value after the command film number.

The parameters are inspected by issuing a command, film number, then a question mark.

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

---

**Command: B**

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

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

---

**Command: C**

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

Example: C? 5.000 6.000 0.000 100.00 0.000 1.000 0

---

**Command: J**

Parameters: None.

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

Example: J A2 The unit has two channels available.

**Command: L**

Parameters: [1..6]

Description: Read the current Rate for a channel.

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

---

**Command: M**

Parameters: None.

Description: Read the current Average Rate.

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

---

**Command: N**

Parameters: [1..6]

Description: Read the current thickness for a channel.

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

---

**Command: O**

Parameters: None.

Description: Read the current Average Thickness

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

---

**Command: P**

Parameters: [1..6]

Description: Read the current Frequency for a channel.

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

---

**Command: R**

Parameters: [1..6]

Description: Read the Crystal Life for a channel.

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

---

**Command: S**

Parameters: None.

Description: Zero Average Thickness and Rate.

Example: S A

---

**Command: T**

Parameters: None.

Description: Zero Time

Example: T A Zeroes time display on unit.

---

**Command: U**

Parameters: 0,1, or ?

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

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

| | | |
|---|---|---|
| U0 | A | Shutter is closed. |

**Command: Y**

Parameters: None.

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

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

**Command: Z**

Parameters: None.

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

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

# 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 |

| Material | Density | ZFactor |
|---|---|---|
| Magnesium Fluoride | 3 | 1 |
| 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 |
| 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 |

# B. Specifications

| | |
|---|---|
| **Measurement** | |
| Number of Sensors | 2 (+2 optional) |
| Frequency Range | 4.0 MHz to 6.0 MHz |
| Frequency Accuracy | .001% |
| Frequency Resolution | .05 Hz @ 2 readings/sec |
| Rate Accuracy | .5% typical |
| Rate Resolution | .01 Å/s |
| Thickness Accuracy | .5% typical |
| Thickness Resolution | 1 Å |
| Measurement Period | .1 to 1 sec. |
| **Source** | |
| Number of Sources | 2 (+2 optional) |
| Control Voltage | 0 to ±10V into 2kΩ 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~, ±10% nominal<br>50/60 Hz, auto detect |
| Power Consumption | 25W |
| Operating & Transportation Environment | 0°C to 50°C<br>0 to 80% RH non-condensing<br>0 to 2,000 meters<br>Indoor Use Only<br>Class 1 Equipment (Grounded Type)<br>Suitable for Continuous Operation<br>Ordinary Protection (not protected against harmful ingress of moisture)<br>Pollution Degree II<br>Installation (Overvoltage) Category II for transient overvoltages |
| Storage Environment | -40°C to 70°C |
| Rack Dimensions (HxWxD) | 5.23 in. x 8.4 in. x 10.0 in.<br>132.8mm x 213.4m x 254.0mm |
| Weight | 4 pounds (1.8 kg) |

| | |
|---|---|
| **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) | 400 |
| **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 |
| 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 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. |
| 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

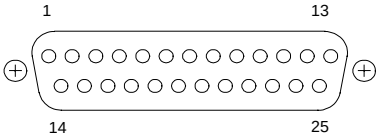
A 25 pin D-sub connector, located on the rear of the SQC-222, provides Input/Output connections. Refer to Section 3.6 for relay and input functional assignments.

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 |

## PLC Connections

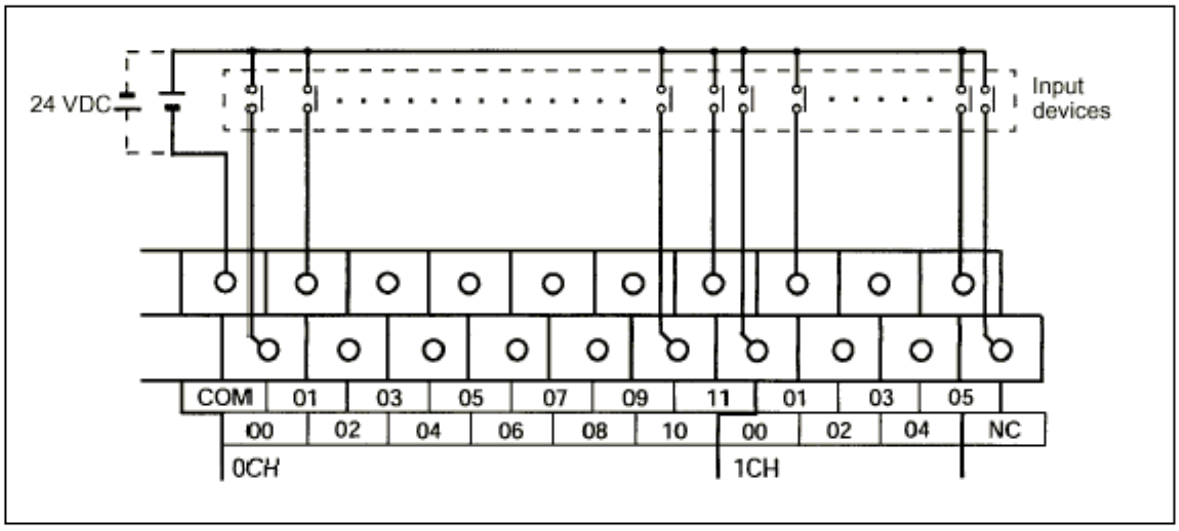
If you are using the optional PLC for I/O, you must first connect the PLC to the RS-232 connector on the SQC-222. The single RS-232 connector of the SQC-222 supports two serial connections – one for the PLC, the other for computer communications. Sigma cable PN 505-053 is a "Y" cable for connecting both. The pinout is shown below.

| Signal | SQC-222 | PLC | Computer |
|---|---|---|---|
| Tx Data 1 | 2 | | 2 |
| Rx Data 1 | 3 | | 3 |
| Tx Data 2 | 7 | 2 | |
| Rx Data 2 | 1 | 3 | |
| Ground | 5 | 9 | 5 |
| | | | |
| Connector | DB-9P | DB-9P | DB-9S |

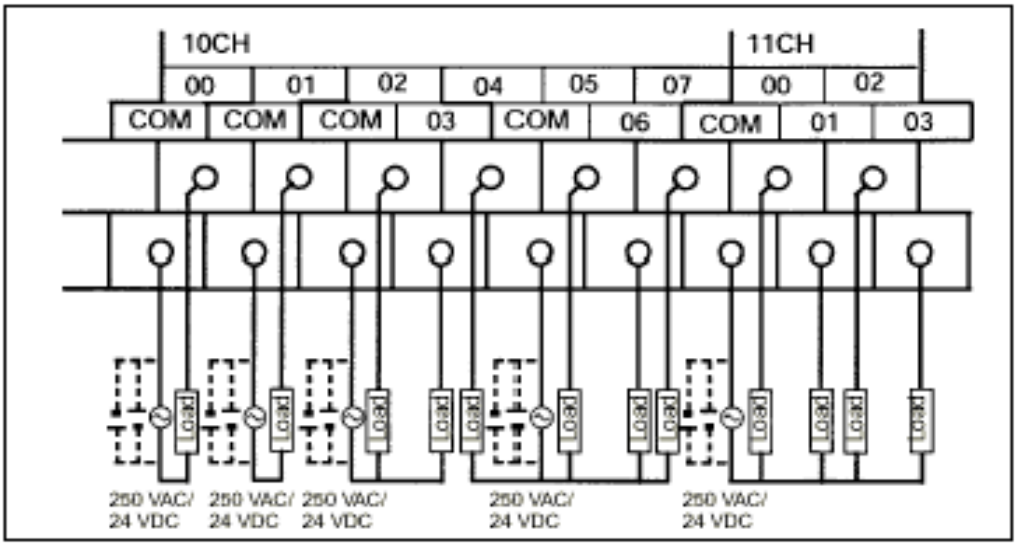
***CAUTION***: *Both the SQC-222 and the Omron PLC use a special RS-232 pinout. Do not use a standard serial cable. Damage to the SQC-222 or the PLC could result.*

Mount the PLC controller near the devices it is controlling and sensing. Connect the PLC to a properly grounded power source. See the PLC User Manual on the Sigma CD-ROM for detailed PLC mounting and connection information. Connect the serial cable from the PLC serial port to the SQC-222 serial port.

**Input Wiring:** PLC Inputs are mapped to events in the SQC-222 System Setup, PLC Inputs menu. SQC-222 Inputs 1 to 12 correspond to Omron Inputs 0.0 to 0.11. Omron PLC input wiring is shown below.



**Output Wiring**: PLC Relays are mapped to output events in the SQC-222 Systems Setup, PLC Relays menu. SQC-222 Relays 1 to 8 correspond to Omron PLC relays 10.00 to 10.07.

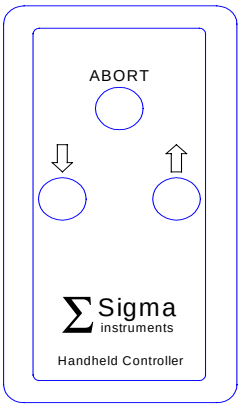



Omron PLC output wiring is illustrated above. Notice that some relays (i.e. 02/03 and 04/05/06/07 share a common terminal).

***Note**: The internal 24VDC, .3A supply of the Omron PLC is NOT adequate to serve as the supply shown in the diagram above.*

# D. Handheld Remote Controller

The Handheld Controller provides the capability of adjusting output power remotely when the SQC-222 is in Manual Mode.




To use the handheld controller, attach the cable from the handheld controller to the Remote jack on the SQC-222 front panel. Select a Process using the SQC-222 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-222

**Product Options:** All Options

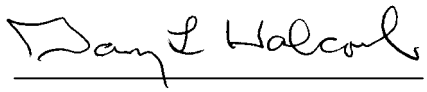
**conforms to the following Directives:**

| | |
|---|---|
| 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