OPERATING MANUAL

STM-2XM

Rate and Thickness Monitor

PN 074-614-P1C

INFICON

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

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

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

Equipment Description: STM-2XM Rate/Thickness Monitor (including its accessories and options)

Applicable Directives:
2014/35/EU (LVD)
2014/30/EU (General EMC)
2011/65/EU (RoHS2)

Applicable Standards:

Safety:	EN 61010-1: 2010 Safety Requirements for Electrical Equipment For Measurement, Control, And Laboratory Use. PART 1: General Requirements
Emissions:	EN 61326-1: 2013 (Radiated & Conducted Emissions) (EMC – Measurement, Control & Laboratory Equipment) CISPR 11/EN 55011 Edition 2009-12 Emission standard for industrial, scientific, and medical (ISM) radio RF equipment FCC Part 15 Class A emissions requirement (USA)
Immunity:	EN 61326-1: 2013 (Industrial EMC Environments) (EMC – Measurement, Control & Laboratory Equipment)
RoHS2:	Fully Compliant

CE Implementation Date: Sept 10, 2014 (REVISED 5/29/15)

Authorized Representative: Steven Schill

Thin Film Business Line Manager
INFICON, Inc.

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NOTE: These instructions do not provide for every contingency that may arise in connection with the installation, operation or maintenance of this equipment. Should you require further assistance, please contact INFICON.

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Table Of Contents

Chapter 1
Introduction and Specifications

1.1 Introduction

STM-2XM rate and thickness monitor (see Figure 1-1) will manage single sensor processes as well as codeposition and alloy processes through five modes of operation:

- Simple mode (single film mode)
- Backup mode (crystal switching)
- Averaging mode
- Alloy mode
- Independent mode

Independent mode allows STM-2XM to function as two completely separate monitors with shutter delay. To extend crystal life for thicker films, the Alloy mode provides a linked shutter delay.

Time/Power allows films to complete even with a crystal failure. STM-2XM displays accumulated film mass or thickness and can also display a graph of rate, thickness, or rate deviation.

STM-2XM has eight programmable digital inputs, eight programmable digital outputs, and four analog outputs.

Figure 1-1 STM-2XM rate/thickness monitor

1.1.1 Related Manuals

Sensors are covered in separate manuals. PDF files of these manuals are contained in the Thin Film Manuals CD (PN 074-5000-G1), part of the Ship Kit.

- PN 074-154—Bakeable Sensor
- PN 074-156—Front Load Sensor, Single/Dual
- PN 074-157—Sputtering Sensor
- PN 074-609—Cool Drawer Sensor, Single/Dual

1.2 Instrument Safety

1.2.1 Definition of Notes, Cautions and Warnings

When using this manual, please pay attention to the NOTES, CAUTIONS, and WARNINGS found throughout. For the purposes of this manual they are defined as follows:

NOTE: Pertinent information that is useful in achieving maximum STM-2XM efficiency when followed.

CAUTION

Failure to heed these messages could result in damage to STM-2XM.

WARNING

Failure to heed these messages could result in personal injury.

WARNING - Risk Of Electric Shock

Dangerous voltages are present which could result in personal injury.

1.2.2 General Safety Information

WARNING - Risk Of Electric Shock

Dangerous voltages may be present whenever the power cord or external input/relay connectors are present.

Refer all maintenance to qualified personnel.

CAUTION

STM-2XM contains delicate circuitry which is susceptible to transient power line voltages. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.

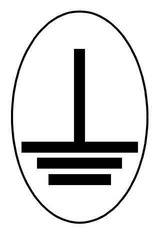
1.2.3 Earth Ground

STM-2XM is connected to earth ground through a sealed three-core (three-conductor) power cable, which must be plugged into a socket outlet with a protective earth terminal. Extension cables must always have three conductors including a protective earth terminal.

WARNING - Risk Of Electric Shock

Never interrupt the protective earth circuit.

Any interruption of the protective earth circuit inside or outside STM-2XM, or disconnection of the protective earth terminal is likely to make STM-2XM dangerous.



This symbol indicates where the protective earth ground is connected inside STM-2XM. Never unscrew or loosen this connection.

CAUTION

There are no user serviceable components within the STM-2XM case.

Refer all maintenance to qualified personnel.

1.3 How To Contact INFICON

Worldwide customer support information is available under **Support >> Support Worldwide** at www.inficon.com:

- Sales and Customer Service
- Technical Support
- Repair Service

If experiencing a problem with STM-2XM, please have the following information readily available:

- The Sales Order or Purchase Order number of the instrument purchase.
- The version of STM-2XM firmware.
- The version of Windows operating system.
- A description of the problem.
- An explanation of any corrective action that may have already been attempted.
- The exact wording of any error messages that may have been received.

1.3.1 Returning STM-2XM

Do not return any component of STM-2XM to INFICON before speaking with a Customer Support Representative and obtaining a Return Material Authorization (RMA) number. STM-2XM will not be serviced without an RMA number.

Packages delivered to INFICON without an RMA number will be held until the customer is contacted. This will result in delays in servicing STM-2XM.

If returning STM-2XM with a crystal sensor or another component potentially exposed to process materials, prior to being given an RMA number, a completed Declaration Of Contamination (DOC) form will be required. DOC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the component be sent to a designated decontamination facility, not to the factory.

1.4 Specifications

1.4.1 Measurement

Sensor Inputs	2
Compatible Sensors	Single/shuttered single or dual QCM sensor
Measurement Frequency Range	6.0 to 5.0 MHz (fixed)
Frequency Resolution	± 0.03 Hz @ 6 MHz
Reference Frequency Stability	± 2 ppm
Thickness and Rate Resolution/Measurement	± 0.037 Å @ tooling/density = 100/1 Fundamental frequency = 6 MHz
Measurement Interval	0.10 s

1.4.2 Film Parameters

Stored Films	15
Name	8 characters, 0 to 9, A to Z, _ and [space]
Density	0.4 to 99.99 g/cm^3
Z-Ratio	0.100 to 9.999
Tooling	10 to 999.9%
Setpoint Thickness	0.000 to 999.999 kÅ
End Thickness	0.000 to 999.999 kÅ
Use Backup Crystal	Yes/No
Setpoint Time	0:00:00 to 9:59:59 h:mm:ss
Deposit Rate	0.0 to 999.9 Å/s
Coast Enable	Yes/No
Crystal Life Minimum	0 to 99%
Force Crystal Fail	Yes/No
Temporal Average	1 to 50
Good Rate Tolerance	0 to 50

1.4.3 System Parameters

Operation Modes	Simple mode (single film mode) Backup mode (crystal switching) Averaging mode Alloy mode Independent mode
Test Mode	On/Off
Active Source	Channel 1/Channel 2
Display Mode	Thickness/Mass

Plot Type . . . . None/Rate Deviation/Rate/Thickness

Plot Time Interval . . . . 0:00:00 to 9:59:59 h:mm:ss

LCD Contrast . . . . 10 to 85

LCD Brightness . . . . 1 to 99

Beeper . . . . On/Off

Communications Protocol . . . . Sycon 9600 (Sycon Protocol @ 9.6 Kbps)
SMDP L (SMDP Protocol @ 9.6 Kbps)
SMDP M (SMDP Protocol @ 38.4 Kbps)
SMDP H (SMDP Protocol @ 115.2 Kbps)

SMDP Address. . . . . 16 to 254

1.4.4 Digital I/O

Digital Inputs. 8

Digital Input Functions . . . . Open Shutter
Close Shutter
Zero Thickness
Disabled
Select crystal as active (dual mode)

NOTE: To select crystal one, use on a Channel 1 input (1.x). To select crystal two, use on a Channel 2 input (2.x).

Allow sync

NOTE: Allows simultaneous shutter delay of both films.

Digital Outputs 8

Digital Output Functions	Manual (front panel) Source shutter Substrate shutter Sensor shutter Crystal fail Setpoint time Setpoint thick Forced active Controlled via serial communications Rate is steady and within tolerance
Analog Outputs	4
Analog Output Functions	Rate: Rate 1000 Å/s, 10.00 µg scale Rate 10.0 Å/s, 0.10 µg scale Rate deviation: Rate deviation 1000 Å/s, 10.00 µg scale Rate deviation 10.0 Å/s, 0.10 µg scale Thickness: Thickness recorder 999 Å scale Thickness recorder 99.9 Å scale Disabled Controlled via serial communications Fixed positive/negative full scale
Analog Output Rating	-10 to +10 V, 10 mA
Analog Output Interval	6 mV
Relay Rating	up to 48 V (dc) • V (ac), 2 A

1.4.5 Power

Rated Supply Voltage	100 to 240 V (ac) ± 10%, 50/60 Hz, 2.5 VA
Fuse Rating	1 A 250 V, 5 x 20 mm, Fast-acting
Mains Power Cable Rating	
STM-2XM-G1	10 A 125 V
STM-2XM-G2	10 A 250 V
Power Consumption	less than 10 W
Overvoltage	Category II
Temporary Overvoltage	
Short Term	1200 V, < 5 s
Long Term	250 V, > 5 s

1.4.6 Operating Environment

Usage . . . . Indoor use only
Operating Temperature . . . . 0 to 50°C (32 to 122°F)
Storage Temperature . . . . -10 to 60°C (14 to 140°F)
Humidity . . . . Up to 85% RH, non-condensing
Altitude . . . . Up to 2000 meters
Pollution Degree. 2

1.4.7 Size and Weight

Rack Dimensions (HxWxD) . . . . 8.9 x 24.1 x 25.4 cm (3.5 x 9.5 x 10 in.)
Weight . . . . 1.25 kg (2.75 lb.)

1.5 Unpacking and Inspection

1. If STM-2XM has not been removed from its packaging, do so now.
2. Carefully examine STM-2XM for damage that may have occurred during shipping. It is especially important to note obvious rough handling on the outside of the container. *Immediately report any damage to the carrier and to INFICON.*
3. Do not discard the packaging material until inventory has been taken and installation has been successful.
4. Refer to the invoice to take inventory (see section 1.6).
5. To install STM-2XM, see Chapter 2, Installation.
6. For additional information or technical assistance, contact INFICON (refer to section 1.3 on page 1-5).

1.6 Parts and Options Overview

1.6.1 Base Configurations

STM-2XM with US Power Cord . . . . PN STM-2XM-G1
STM-2XM with
European Power Cord . . . . PN STM-2XM-G2
Thin Film Manuals CD . . . . PN 074-5000-G1

1.6.2 Accessories

3 m (10 ft.) Oscillator Kit . . . . PN 783-500-109-10
7.6 m (25 ft.) Oscillator Kit . . . . PN 783-500-109-25
15.2 m (50 ft.) Oscillator Kit . . . . PN 783-500-109-50
22.9 m (75 ft.) Oscillator Kit . . . . PN 783-500-109-75

NOTE: Each sensor requires an oscillator kit to interface to STM-2XM.

Oscillator kits include:

Oscillator. . . . . PN 783-500-013

15.2 cm (6 in.) BNC cable . . . . . PN 782-902-011

One of the following:

3 m (10 ft.) BNC Cable . . . . . PN 782-902-012-10

7.6 m (25 ft.) BNC Cable . . . PN 782-902-012-25

15.2 m (50 ft.) BNC Cable . . PN 782-902-012-50

22.9 m (75 ft.) BNC Cable . . PN 782-902-012-75

These kits are designed for use with the standard in-vacuum cables ranging in length from 15.2 cm (6 in.) to 78.1 cm (30.75 in.).

48.3 cm (19 in.) rack mount kits are available in the following configurations:

One STM-2XM . . . . PN 783-014-008
Two STM-2XM . . . . PN 783-014-009

1.6.3 Sensors

Front Load Single Sensor . . . . PN SL-XXXXX

Front Load Dual Sensor . . . . PN DL-AXXX

Cool Drawer Single Sensor . . . . PN CDS-XXFXX

Cool Drawer Dual Sensor . . . . PN CDD-XFXX

Sputtering Sensor. . . . . PN 750-618-G1

UHV Bakeable Sensor . . . . PN BK-AXF

NOTE: "X" in part number indicates customer-selectable option, see www.inficon.com for Sensor Datasheets.

NOTE: Shuttered sensors require a feedthrough with an air line and solenoid valve PN 750-420-G1.

NOTE: Multi-crystal (rotary) sensors should not be used with STM-2XM.

Chapter 2
Installation

2.1 Installation Requirements

2.1.1 Parts Requirements

- STM-2XM Monitor

CAUTION

Use the supplied mains power cable.

If this cable must be replaced, the replacement cable must meet or exceed the ratings of the supplied cable.

- One crystal sensor/feedthrough
- One oscillator kit for each crystal sensor
- Quartz crystals appropriate for the application

CAUTION

To maintain proper STM-2XM performance, use only the 15.2 cm (6 in.) BNC cable that is included to connect the oscillator to the crystal sensor.

The length of the in-vacuum cable (Front Load and Sputtering Sensors) or electrical conduit tube (Cool Drawer and Bakeable Sensors) should not exceed 78.1 cm (30.75 in.).

2.1.2 Ground Requirements

CAUTION

A ground post is provided on the rear panel. This point should be connected to the common ground with a grounding strap.

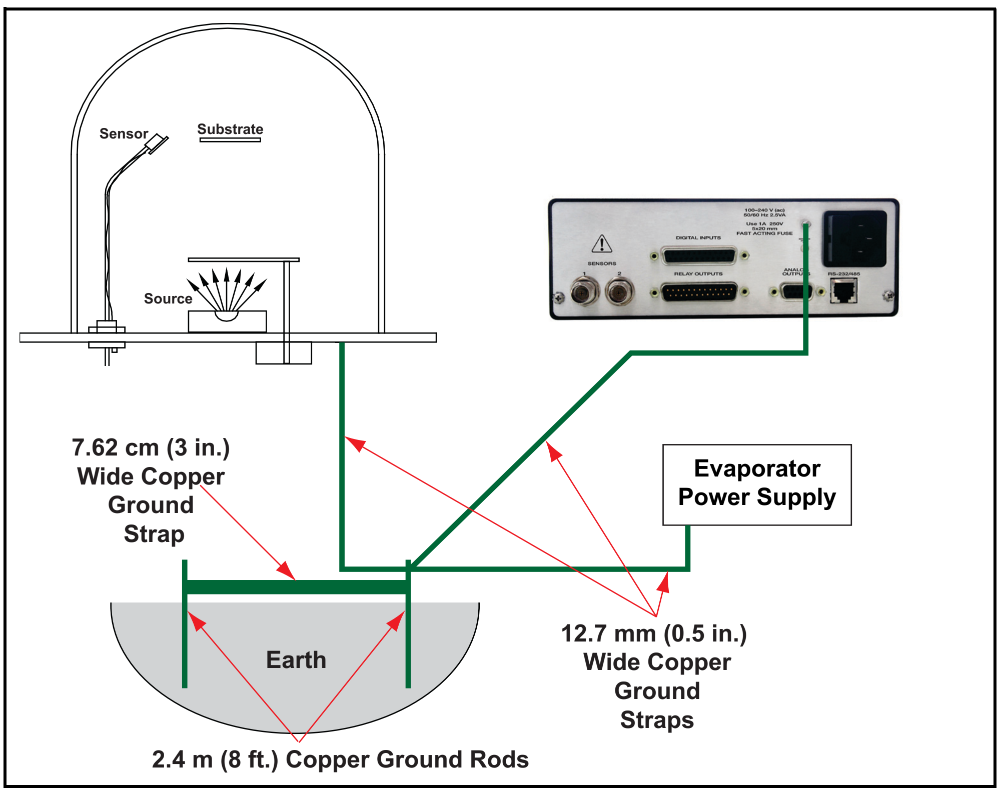
Use low impedance cables or straps to connect the chassis of all control components to a common ground point on the vacuum chamber. The common ground point must be connected to earth ground (see section 2.1.3, Connection to Earth Ground, on page 2-3).

Solid copper straps are recommended, where RF is present. Use a strap of the shortest possible length, minimum width of 12.7 mm (0.5 in.), approximately 0.56 mm (0.22 in.) thick. This is particularly important in high-noise electron beam (e-beam) systems. See Figure 2-1 for the recommended grounding method.

NOTE: The oscillator is grounded to STM-2XM and crystal sensor through the BNC cables.

The crystal sensor is typically grounded to the wall of the vacuum system. If the sensor feedthrough is not properly grounded to earth through the vacuum system, connect a copper strap between the feedthrough and the common ground point on the vacuum system.

Figure 2-1 Recommended grounding



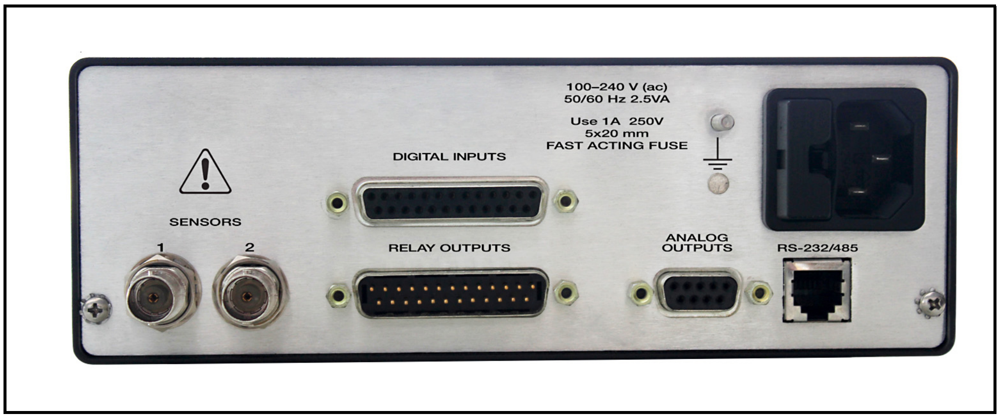
2.1.3 Connection to Earth Ground

If an earth ground is not established:

1. Where soil conditions allow, drive two 2.4 m (8 ft.) copper clad steel rods into the ground 1.8 m (6 ft.) apart. Follow local regulations and codes.
2. Pour a copper sulfate or a salt solution around each rod to improve the ground conductivity.
3. Measure the resistance. A near zero resistance between the two rods indicates that a good earth ground is achieved.
4. After verifying a near zero resistance between the rods, connect the rods together with a 7.62 cm (3 in.) wide copper strap.

2.2 Rear Panel

Figure 2-2 STM-2XM rear panel



CAUTION

Connecting cables must be routed away from any potential source of electrical noise.

2.2.1 Sensors

The Sensors input provides the remote sensor oscillator interface to STM-2XM, providing both the signal and power path to the oscillator.

NOTE: Sensors connection requires coaxial cable type RG58 or RG59. The maximum BNC cable length connecting the oscillator to STM-2XM is 30 m (98 ft.).

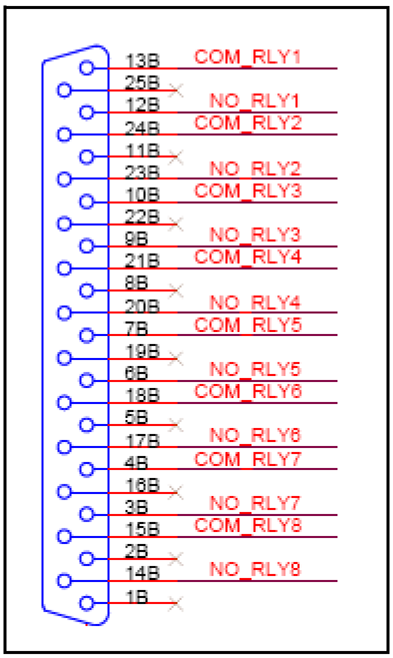
2.2.2 Relay Outputs

STM-2XM has eight normally open (NO) relay contact outputs. These outputs are intended for low voltage (see section 1.4.4, Digital I/O, on page 1-7).

Table 2-1 Relay output contact pin numbers

Relay	Contacts on pins
1	12,13
2	23,24
3	9,10
4	20,21
5	6,7
6	17,18
7	3,4
8	14,15

Figure 2-3 Relay output contact pin numbers



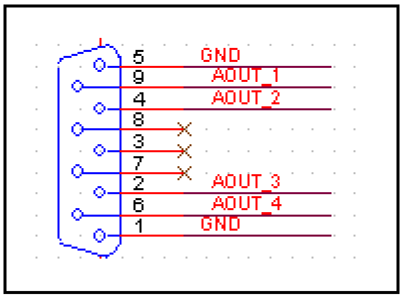
2.2.3 Analog Outputs

For functions associated with the analog outputs, see section 1.4.4, Digital I/O, on page 1-7.

Table 2-2 Analog output contact pin numbers

Analog Output	Connections
1	9(+), relative to pin 5 or 1
2	4(+), relative to pin 5 or 1
3	2(+), relative to pin 5 or 1
4	6(+), relative to pin 5 or 1

Figure 2-4 Analog output contact pin numbers



2.2.4 Remote Inputs

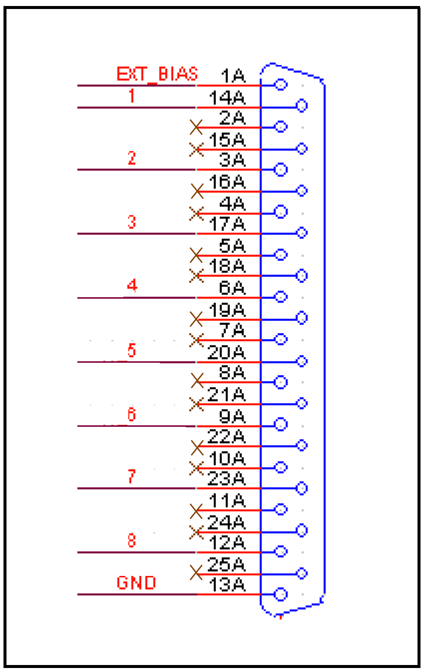
STM-2XM has eight remote digital inputs that are activated by contact closure to ground.

For the specific functions associated with the inputs, see section 1.4.4 on page 1-7.

Table 2-3 Remote input pin numbers

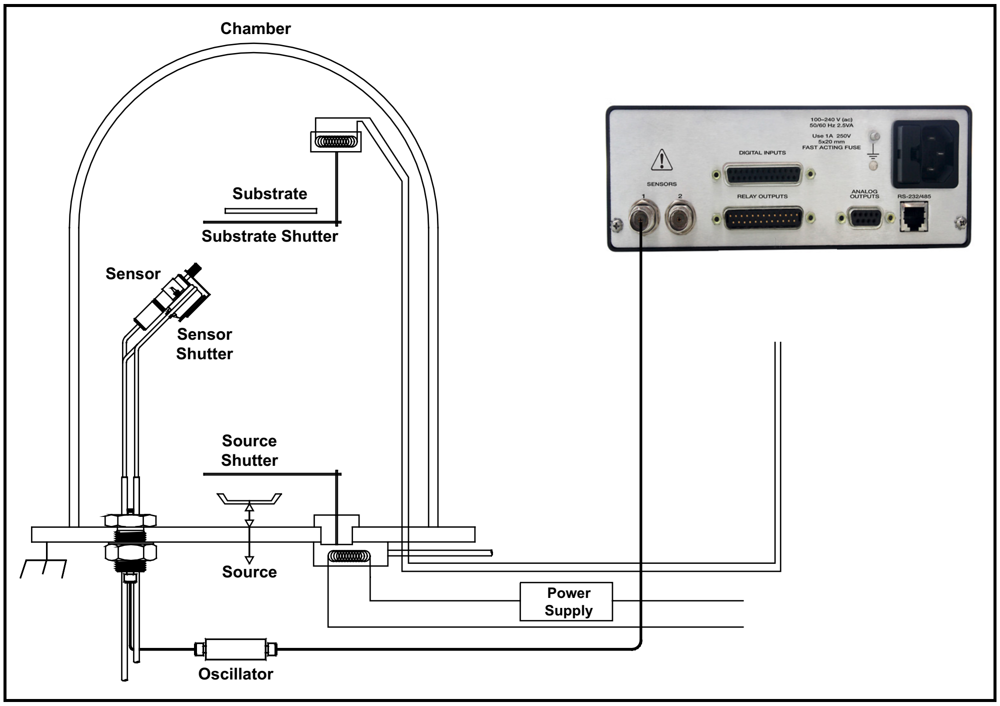
Input	Contact on pins
Input 1	14,13
Input 2	3,13
Input 3	17,13
Input 4	6,13
Input 5	20,13
Input 6	9,13
Input 7	23,13
Input 8	12,13

Figure 2-5 Remote input pinout



2.3 Basic Vacuum System Components

Figure 2-6 Basic vacuum system components



Substrate

The substrate is the object being coated.

Source

The source is the object that emits the evaporant. STM-2XM provides support for two sources.

Sensor

The sensor is the component that detects the evaporant. The sensor can only detect evaporant that accumulates on the sensor crystal. To account for differences in evaporant between the sensor and substrate, tooling adjustments are used (see section 7.3 on page 7-2). STM-2XM provides support for two sensors.

Source Shutter (optional)

The source shutter blocks the evaporant stream from the source. With the source shutter closed, the evaporant from the source cannot reach the substrate or the sensors. The front panel shutter buttons and the End Thickness setpoint activate the source shutter.

Substrate Shutter (optional)

The substrate shutter blocks the evaporant stream from reaching the substrate. A closed substrate shutter will not allow material to reach the substrate but will allow evaporant to reach the sensor(s). With a substrate shutter installed, it is possible to have a shutter delay, where the rate can be pre-established before exposing the substrate to the evaporant stream. STM-2XM automatically accounts for a substrate shutter (if programmed) and will not display thickness accumulation while the substrate shutter is closed. The displayed rate is always "live" even if the substrate shutter is closed.

NOTE: If STM-2XM is programmed to use a substrate shutter, it ignores changes in substrate thickness when the substrate shutter is closed. Therefore, program STM-2XM for a substrate shutter only if a substrate shutter actually exists in the system.

Sensor Shutter (optional)

The sensor shutter blocks the evaporant stream from the sensor. Shuttered sensors are required for rate sampling, where the sensor monitors the source for a portion of the deposition. Shuttered sensors are also used in multiple-sensor, multi-layer systems to keep the sensor from being contaminated with incompatible materials on different layers.

In-Vacuum Cable

The in-vacuum cable connects the sensor to the feedthrough.

Feedthrough

A feedthrough provides isolation between vacuum and atmosphere for electrical and cooling lines.

15.2 cm (6 in.) BNC Cable

A BNC cable provides a flexible connection from the feedthrough to the oscillator.

Oscillator

The oscillator contains the electronics to operate the quartz crystal. The length from the oscillator to the crystal should be under 1 m (40 in.).

BNC Cable

A BNC cable connects the oscillator to STM-2XM.

Ground Wire

The ground wire is preferably a solid copper ground strap that connects the earth-grounded vacuum system to the STM-2XM ground terminal (refer to section 2.1.2, Ground Requirements, on page 2-2).

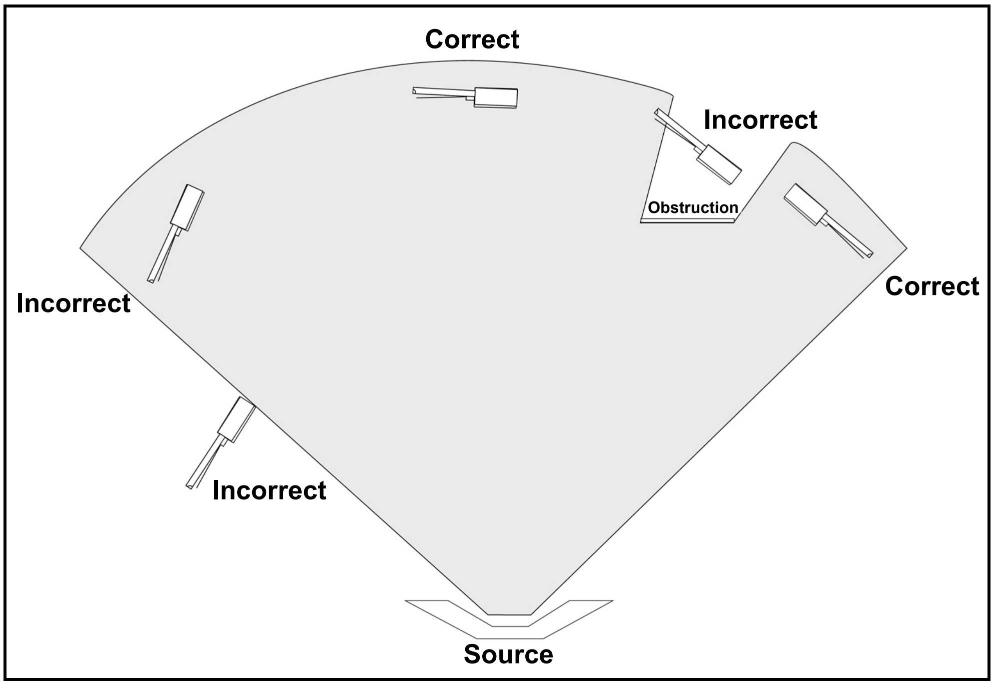
2.4 Deposition System Installation

2.4.1 Sensor Head Installation

Install the sensor as far as possible from the evaporation source (a minimum of 25.4 cm (10 in.)) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 2-7 shows proper and improper methods of installing sensors.

NOTE: For best process reproducibility, rigidly support the sensor so that it cannot move during maintenance and crystal replacement.

Figure 2-7 Sensor installation guidelines



To guard against spattering, use a source shutter to shield the sensor during initial soak periods. If the crystal is hit with a particle of molten material, it may be damaged and stop oscillating. Even in cases when the crystal does not completely stop oscillating, it may immediately become unstable or instability may occur shortly after deposition begins.

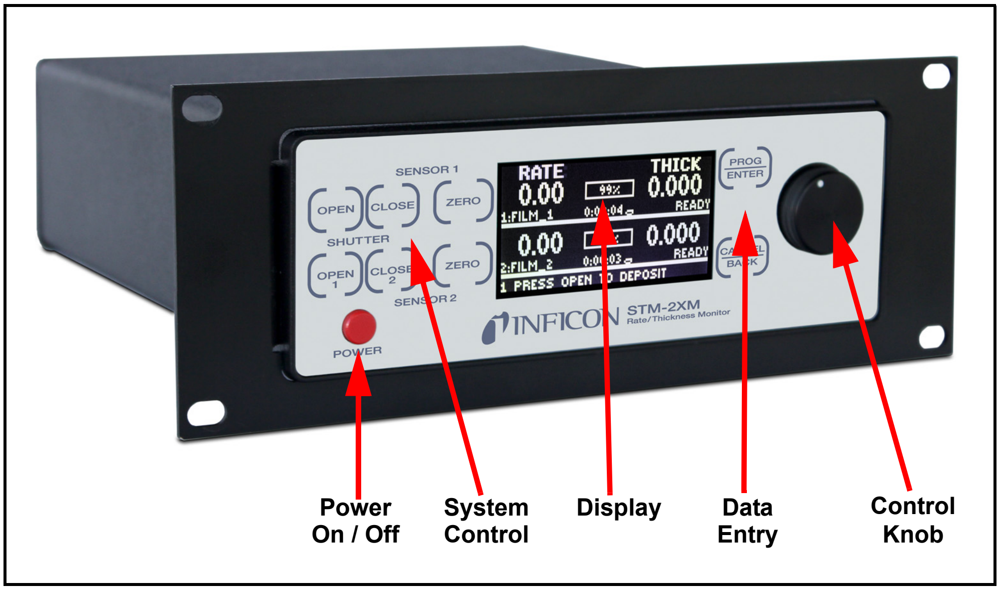
Plan the installation to ensure that there are no obstructions blocking a direct path between the sensor and the source. Install sensors in such a manner that the center axis of the crystal is aimed directly at the source to be monitored. Verify that the angle of the sensor location (with reference to the source) is well within the evaporant stream. If the sensor is not perpendicular to the source, the coating on the crystal will be tapered and diminished crystal life can result.

NOTE: In many cases installing multiple sensors to monitor one source can improve thickness accuracy for the product. The recommendations for multiple sensors are the same as for a single sensor installation, and the locations chosen should be as defined above.

Chapter 3
Operation

3.1 Front Panel Description

Figure 3-1 Front panel



The STM-2XM front panel is divided into two functional groups:

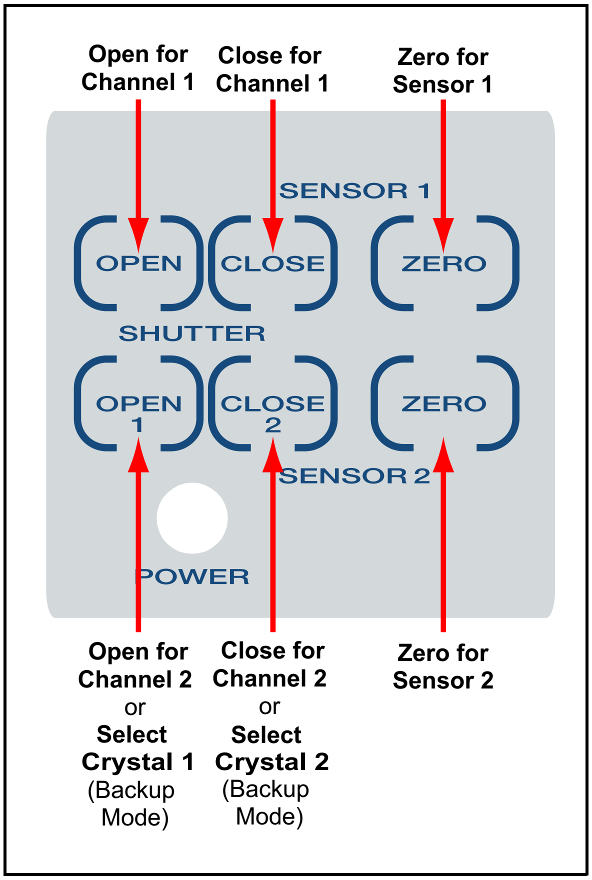
- Buttons to the left of the display are for system control.
- The control knob and buttons to the right of the display are for data entry and programming.

An audible beep will accompany each button activation. The beeper may be disabled if desired (see section 3.2.1.2 on page 3-11).

3.1.1 System Control Buttons

NOTE: All button functions can be duplicated with remote inputs.

Figure 3-2 Button functions



OPEN . . . . Press OPEN to open the source/substrate shutter. When OPEN is pressed, all setpoints (setpoint time, setpoint thickness, and end thickness) are cleared and the film will enter the deposit state.

NOTE: Pressing OPEN while STM-2XM is in the deposit state has no effect.

CLOSE . . . . Press CLOSE to close the source/substrate shutter and terminate the deposition. STM-2XM will then enter the Ready state.

NOTE: Pressing CLOSE while STM-2XM is in the Ready state has no effect.

ZERO . . . . Press ZERO to zero the substrate thickness. When ZERO is pressed, the thickness displayed is cleared.

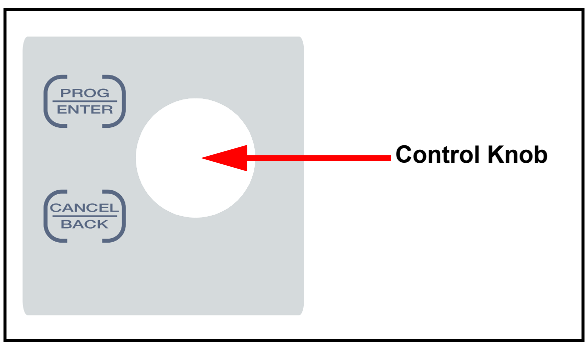
NOTE: If ZERO is pressed during the deposit state, the setpoint thickness will activate when the film thickness on the display reaches the programmed setpoint thickness.

Mode-Dependent Button Functions

- Sensor 2 ZERO is only used in the independent mode.
- Channel 2 OPEN is used to select Crystal 1 in the backup mode.
- Channel 2 CLOSE is used to select Crystal 2 in the backup mode.

3.1.2 Data Entry and Programming Buttons

Figure 3-3 Data entry and programming buttons



PROG/ENTER . . . . Provides access to the main menu and subsequent menus

Saves parameters after edit

Advances to the next list item in a sub-menu after an edit has been saved

CANCEL/BACK . . . . Returns to previous menu or Runtime screen

Control Knob . . . . Scrolls up/down menu items

Scrolls through fixed choices

Increments value-based parameters

For parameters requiring multiple numeric placeholders (density, Z-Ratio, thickness, time, and rate), the control knob will:

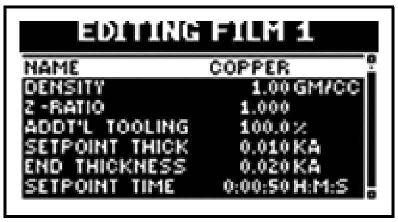
- increment the selected numeric placeholder when rotated clockwise
- select the next numeric placeholder when rotated counterclockwise

3.1.3 Changing a Parameter

There are two types of parameters, enumerated and numeric. Enumerated parameters have a list of fixed choices. Numeric parameters allow a number to be entered. To change a parameter:

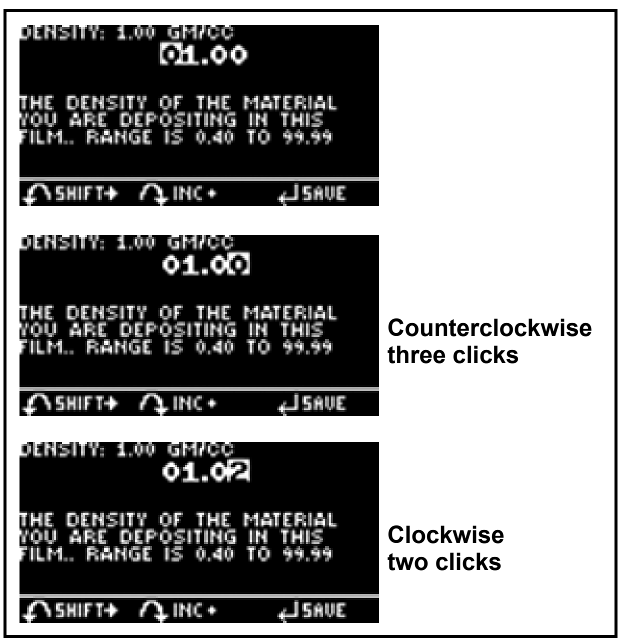
1. Press **PROG/ENTER**.
2. Rotate the control knob to select **Edit Active Film**.
3. Press **PROG/ENTER** to display the **Editing Film** menu for the active film (see Figure 3-4).

Figure 3-4 Editing film settings



To edit the density, for example, rotate the control knob clockwise to select **DENSITY**, then press **PROG/ENTER**. The **DENSITY** numeric parameter editor will be displayed (see Figure 3-5).

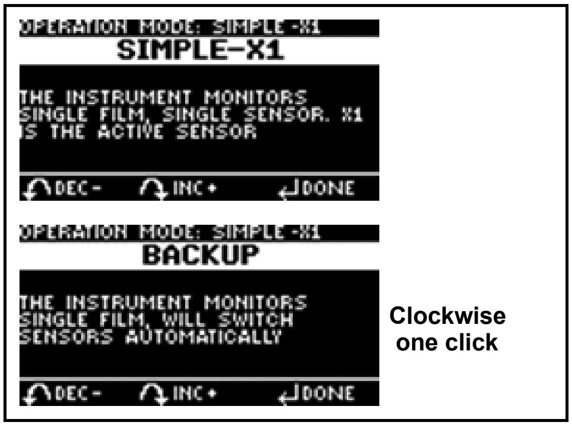
Figure 3-5 Numeric parameter editor



- Numeric parameters are changed one digit at a time.
- Each digit may only be incremented, and rolls over from 9 to 0.
- To select the next digit, rotate the control knob counterclockwise.
- To increment the selected digit, rotate the control knob clockwise.
- When finished, press the **PROG/ENTER** button.
- To cancel the entry, press the **CANCEL/BACK** button.

When changing an enumerated type, rotate the control knob to the appropriate item, and press **PROG/ENTER** to save the selection and return to the previous screen (see Figure 3-6).

Figure 3-6 Enumerated entry



NOTE: The help message changes appropriately with the choice.

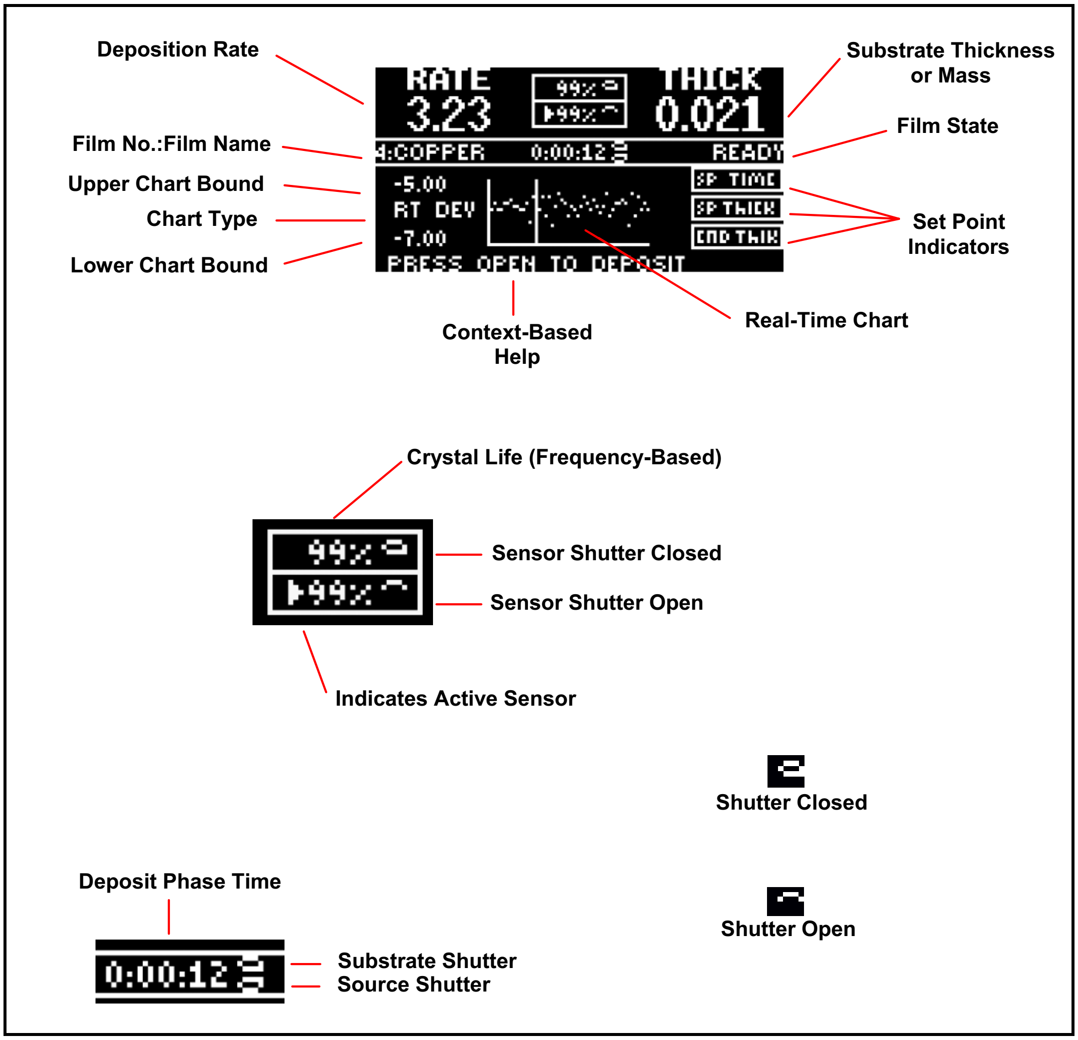
Pressing **CANCEL/BACK** will cancel the entry and set it back to the previous setting.

WARNING

Enumerated choices take effect immediately.

3.1.4 Runtime Screen

Figure 3-7 STM-2XM Runtime screen component status



3.2 Programming

3.2.1 Main Menu

To program STM-2XM, press **PROG/ENTER**. The **MAIN MENU** will display.

Figure 3-8 Main menu

Use the control knob to select a menu item, then press **PROG/ENTER**. Press **CANCEL/BACK** to return to the Runtime screen.

Set Active Film . . . . 1 to 15. Sets the active film.

Edit Active Film . . . . Lists programmable parameters for the currently active film. For a description of the settings on the film page, see section 3.2.1.1.

System Settings . . . . Displays the **SYSTEM PARAMS** menu. For a description of the system settings, see section 3.2.1.2 on page 3-11.

Status/Diagnostics . . . . Displays STM-2XM status and diagnostics. For example, displays the raw frequency of the crystal, the status of the inputs and outputs, and other useful information.

Edit Any Film . . . . Displays a selection box that allows the choice of the film to edit, and then displays the settings menu for the selected film.

Setup . . . . Displays the **HARDWARE SETUP** menu, where STM-2XM system hardware is programmed, including sensors, shutters, tooling, and relays. The settings on this menu must be accurate to allow STM-2XM to operate properly. For example, if STM-2XM is programmed for a substrate shutter, and one does not exist in the system, STM-2XM will provide false readings because it will not count any material accumulated on the substrate during the Ready phase. For a description of hardware settings, see section 3.2.1.3 on page 3-13.

3.2.1.1 Edit Film

All parameters are listed, but during actual operation STM-2XM will show only the parameters that are relevant to its configuration and mode.

Name . . . . Name of the film, displayed on the monitor screen.

Density . . . . Density of the film material. Used to accurately calculate thickness. The density of common materials is found in Appendix A, Material Table.

NOTE: Density is not used in Mass mode.

Z-Ratio . . . . Z-Ratio of the film material. Used to accurately calculate thickness. The Z-Ratio of common materials is found in Appendix A, Material Table.

Additional Tooling . . . . Tooling applied in addition to the tooling in the setup menu.

NOTE: This only affects the film being edited and not all films.

Setpoint Thickness . . . . Thickness/mass at which the setpoint thickness relay (if programmed) will close.

NOTE: Each time a film is started, the setpoint thickness condition is cleared, and will be activated when the thickness of the specific film (not necessarily the total displayed thickness) reaches the setpoint.

End Thickness . . . . Thickness/mass at which the deposit state automatically terminates.

NOTE: Each time a film is started, the end thickness condition is cleared. This will be activated when the thickness of the specific film (not necessarily the total displayed thickness) reaches the setpoint.

Use Backup Xtal . . . . Available in Backup Mode.

Allows the sensor to switch automatically if the active crystal fails.

Setpoint Time . . . . Thickness/mass at which the setpoint time relay (if programmed) will close.

Deposit Rate . . . . Desired rate for the film. Used for the rate deviation graph (and analog output) and to ensure the Rate digital output is steady and within tolerance.

Shutter Delay . . . . Activates a shutter delay for the film. During a shutter delay, STM-2XM will monitor the rate from the source but will keep the substrate shutter closed. OPEN stops shutter delay and starts the deposit phase.

NOTE: Available only if the appropriate shutter setup is present.

Rate Sampling . . . . When using rate sampling, the sensor shutter opens and closes during deposit to reduce the exposure of the crystal to the evaporant stream during deposition. This feature is intended to extend crystal life for processes with stable rates.

NOTE: Available only if the appropriate shutter setup is present.

Rate Sampling Period . . . . Determines how often STM-2XM samples and holds during Rate Sampling. Rate Sampling Period minus Rate Sampling Dwell time yields an approximate hold time (how long STM-2XM will keep the sensor shutter closed).

Rate Sampling Dwell . . . . Determines the amount of time STM-2XM will keep the sensor shutter open.

Time Power Enable . . . . STM-2XM will use the last known steady rate and continue to accumulate thickness/mass at this rate if a crystal fail occurs. This allows films to be completed even in the event of a crystal failure.

Xtal Life Min . . . . Adjustable to enter the percent life at which the crystal will fail. This sets the minimum acceptable crystal life before a forced failure.

Auto Fail/Force Switch Xtal. . . . . . If the sensor(s) used by this film have a life lower than Xtal Life Min, and the Auto Fail parameter is true, then the crystal is failed. Used to switch to a backup sensor at a given crystal life.

Temporal Average . . . . Number of measurement samples to average as the effective rate. More samples yield a more accurate rate, however, rate and thickness will not update as quickly at higher sampling rates.

The effective frequency accuracy is 0.03 Hz per measurement divided by the square root of the number of temporal average samples.

Good Rate Tolerance(%) . . . . Set as a percentage of rate deviation. When set for good rate, a relay will activate only within tolerance, when the good rate condition is true.

For example, if Good Rate Tolerance is set to 10% and the target rate is set to 10 Å/s, when the rate is between 9 and 11 Å/s (10%), the good rate relay would be active.

NOTE: A relay must be programmed to use this feature.

3.2.1.2 System Settings

Operational Mode . . . . Sets STM-2XM mode of operation (see section 3.3, STM-2XM Operating Modes, on page 3-18). (See Table 3-1.)

NOTE: Mode availability is determined by the Sensor Setup parameter (see section 3.2.1.3 on page 3-13). (See Table 3-2.)

Table 3-1 Modes of operation

Mode	Description	Notes
Simple X1	Single film, single channel in use	Sensor 1 active only.[1]
Simple X2	Single film, single channel in use	Sensor 2 active only.[1]
Backup	Single film, dual channel with single channel in use	Crystal switching mode.
Averaging	Single film, dual channel in use spatially averaged	Used for large chambers or systems with a moving substrate.
Alloy	Two films codeposited, dual channel in use	Codeposition of two materials onto a substrate at the same time.
Independent	Two films cluster deposition, dual channel in use	Allows STM-2XM to be used as two separate instruments. Recommended for cluster tools and research systems.

[1] Analog/shutter outputs selected by changing the active source.

Test Mode . . . . Test mode provides simulated sensor readings.

NOTE: If STM-2XM is reset, test mode is turned off automatically.

Active Source
(Active Channel) . . . . For single film modes, this selects where the analog and digital outputs and inputs are connected (refer to section 2.2 on page 2-3).

Display Mode . . . . Displays thickness in kiloangstoms (kÅ) or mass in micrograms per square centimeter (μg/cm^2).

Plot type. . . . . .Available in single film modes.

Displays the graph on the Runtime screen as None, Rate Deviation, Rate, or Thickness.

Plot time scale. . . . . .Sets the horizontal axis size. Defines the amount of time covered by the plot before it is overwritten.

LCD Contrast
LCD Brightness. . . . . .Adjusts the appearance of the screen. Set the brightness to 100%, and then adjust the contrast until the display is easily read. Brightness can be programmed to a desired level.

NOTE: The screen dims when STM-2XM is idle.

Beep [on/off] .Turns the button/control knob beeper on or off.

Comm Protocol. . . . . .Serial communications mode to STM-2XM, Sycon 9600 (9.6 Kbps), SMDP L (9.6 Kbps), SMDP M (38.4 Kbps), and SMDP H (115.2 Kbps).

If the protocol selected is Sycon 9600, STM-2XM performs serial communication with Sycon protocol at 9600 baud, using RS-232 electrical levels.

If the protocol selected is SMDP, STM-2XM performs serial communication using SMDP protocol at 9600, 38400, or 115200 baud.

SMDP address. . . . . .Serial communication mode for STM-2XM. If the SMDP address is 16, STM-2XM uses RS-232 electrical signaling; otherwise STM-2XM uses RS-485 signaling.

3.2.1.3 Setup Parameters

CAUTION

Changes in the Setup menu occur immediately. Relays and analog outputs can activate unexpectedly during programming.

Sensor setup . . . . Main parameter that effects the choices/modes available (see Table 3-2).

Table 3-2 Sensor setup parameter

Sensor Setup[1]	Available Modes	Rate Sampling Capable	Backup Capable
1:Single unshuttered	Simple	No	No
2:Single shuttered	Simple	Yes	No
3:Dual w/single shutter	Simple	Yes	Yes
4:Dual unshuttered	Simple, Averaging, Alloy, Independent	No	If mode is Simple
5:Dual w/dual shutters	Simple, Averaging, Alloy, Independent	Yes	If mode is Simple

[1] Single indicates 1 channel and Dual indicates 2 channels.

Tooling, X1:SRC1 . . . . The ratio between substrate thickness using Source 1 and Sensor 1 thickness. (See section 7.3, Determining Tooling, on page 7-2.)

Tooling, X2:SRC1 . . . . The ratio between substrate thickness using Source 1 and Sensor 2 thickness. (See section 7.3, Determining Tooling, on page 7-2.)

NOTE: In independent chambers, set this value to zero.

Tooling, X1:SRC2 . . . . The ratio between substrate thickness using Source 2 and Sensor 1 thickness. (See section 7.3, Determining Tooling, on page 7-2.)

NOTE: In independent chambers. Set this value to zero.

Tooling, X2:SRC2 . . . . The ratio between substrate thickness using Source 2 and Sensor 2 thickness. (See section 7.3, Determining Tooling, on page 7-2.)

Weight Ratio . . . . Available only in spatial averaging mode.

This parameter describes the percentage of time the substrate is near Sensor 1. In moving substrate systems, if the substrate spends more time near one sensor than the other, this needs to be accounted for in the computations. If the substrate spends 90% of time near Sensor 1, this parameter should be programmed for 90%. If the substrate is fixed, the default value is 50%.

Substrate Shutr . . . . Configures the substrate shutter delay operation. (See Table 3-3.)

Table 3-3 Substrate shutter setup parameters

Substrate Shutter Setup	Shutter Delay Thick Hold
None	N
CH1: Substrate	Only for film on Channel 1
CH2: Substrate	Only for film on Channel 2
Shared substrate	Only allows shutter delay for one film at a time
Dual substrate	Allows dual shutter delay (alloy shutter delay)

Anal. Scl Mode . . . . Thickness, Mass

Analog Out 1 to 4 . . . . Determines the function of each of the analog outputs (refer to section 2.2.3 on page 2-5 for details on wiring analog outputs). (See Table 3-4.)

Table 3-4 Analog output functions

Setting	Description
None	Output is disabled
Pos Fscl	+10 V Fixed
Neg Fscl	-10 V Fixed
Remote	Output is computer set value
Ch1 Rdev 1k	Rate Deviation, Channel 1, 1000 Å/s
Ch1 Rdev 10	Rate Deviation, Channel 1, 10 Å/s
Ch1 Rate 1k	Rate, Channel 1, 1000 Å/s
Ch1 Rate 10	Rate, Channel 1, 10 Å/s
Ch1 Thickns[1]	Thickness Recorder, Channel 1, 999 Å
Ch1 Mgthick[1]	Thickness Recorder, Channel 1, 99.9 Å
Ch2 Rdev 1k	Rate Deviation, Channel 2, 1000 Å/s
Ch2 Rdev 10	Rate Deviation, Channel 2, 10 Å/s
Ch2 Rate 1k	Rate, Channel 2, 1000 Å/s
Ch2 Rate 10	Rate, Channel 2, 10 Å/s
Ch2 Thickns[1]	Thickness Recorder, Channel 2, 999 Å
Ch2 Mgthick[1]	Thickness Recorder, Channel 2, 99.9 Å

[1] Sawtooth mode

Relay 1 to 8 . . . . Determines the function of each of the digital (relay) outputs (refer to section 2.2.2 on page 2-4 for details on wiring digital outputs). (See Table 3-5.)

Table 3-5 Relay functions

Setting	Description
None	Relay is inactive
Forced ON	Relay is always active
Remote	Relay is controlled with remote communications
Ch 1 FP Keys	Relay is toggled using Sensor 1 OPEN/CLOSE buttons
Ch 2 FP Keys	Relay is toggled using Sensor 2 OPEN/CLOSE buttons
Srce 1 Shtr	Relay activates Channel 1 source shutter
Srce 2 Shtr	Relay activates Channel 2 source shutter
Subs 1 Shtr	Relay activates Channel 1 substrate shutter
Subs 2 Shtr	Relay activates Channel 2 substrate shutter
Sens 1 Shtr	Relay activates Sensor 1 shutter
Sens 2 Shtr	Relay activates Sensor 2 shutter
Xtal 1 Fail	Relay activates when Sensor 1 fails
Xtal 2 Fail	Relay activates when Sensor 2 fails
Stpt 1 Time	Relay activates when Channel 1 setpoint time has elapsed
Stpt 2 Time	Relay activates when Channel 2 setpoint time has elapsed
Stpt 1 Thik	Relay activates when Channel 1 setpoint thickness has been reached
Stpt 2 Thik	Relay activates when Channel 2 setpoint thickness has been reached
Ch1 Rate OK	Relay activates when Channel 1 rate is steady and within tolerance
Ch2 Rate OK	Relay activates when Channel 2 rate is steady and within tolerance
Xtl 1 N.C.	Relay is Normally Closed and opens to use Sensor 1
Xtl 2 N.C.	Relay is Normally Closed and opens to use Sensor 2

Input 1.1 to 1.4
Input 2.1 to 2.4 . . . . Determines the function of each of the digital (relay) outputs for Sensor 1 (1.X) and Sensor 2 (2.X) (refer to section 2.2.4 on page 2-6 for details on wiring remote inputs). (See Table 3-6.)

Table 3-6 Input functions

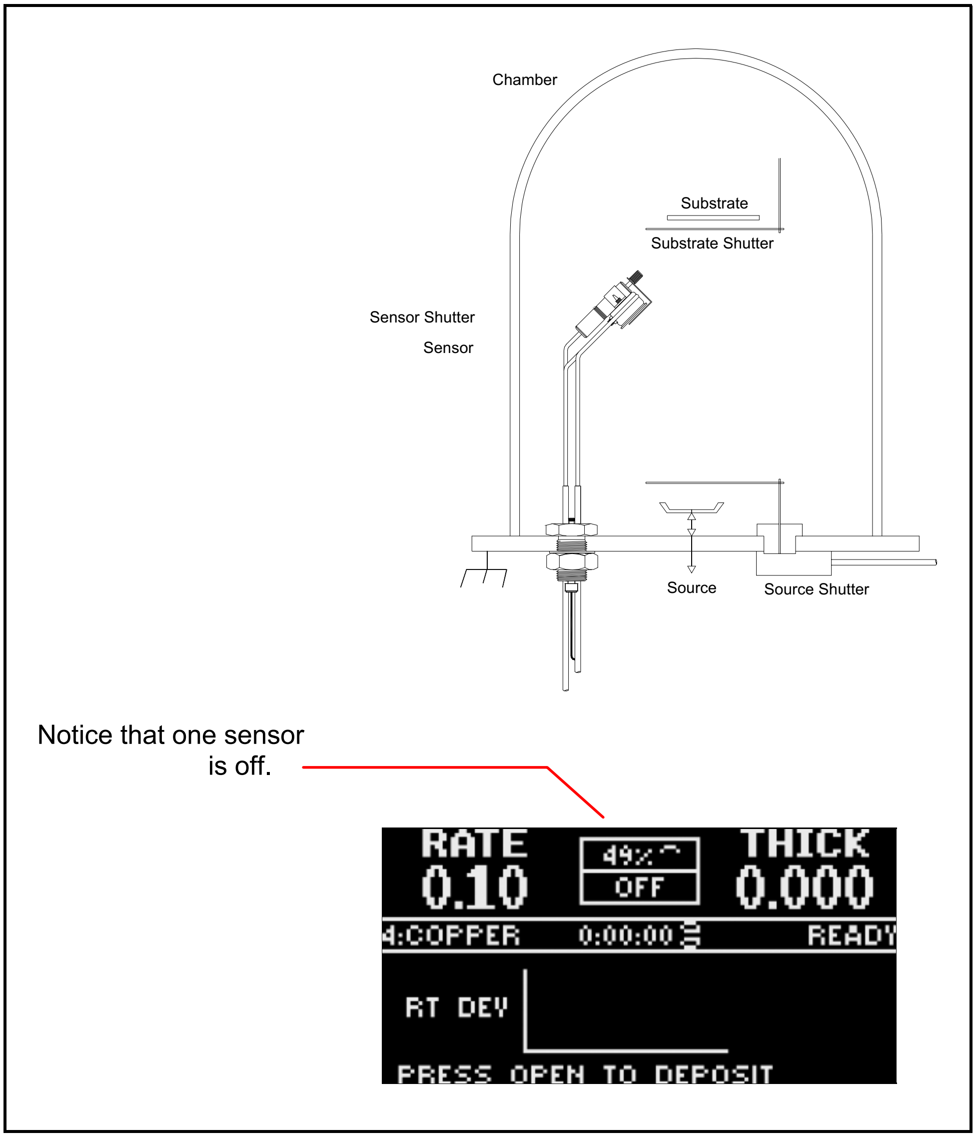
Setting	Description
None	Input is ignored
Zero Thick	Zero accumulated thickness
Open Source	Open source shutter and in deposit mode
Close Source	Closed source shutter and in monitor mode
Select Xtal	Switch active crystal
Terminal Thk	Source final thickness
2 Chnl Fnltk	All channels final thickness (alloy mode)
Alloy Syncup	Open substrate shutter and sync start channels (alloy mode)

3.3 STM-2XM Operating Modes

3.3.1 Simple

In simple mode, STM-2XM can read one sensor and can control a shutter for one source. The deposition process is a single material per layer.

Figure 3-9 Simple mode

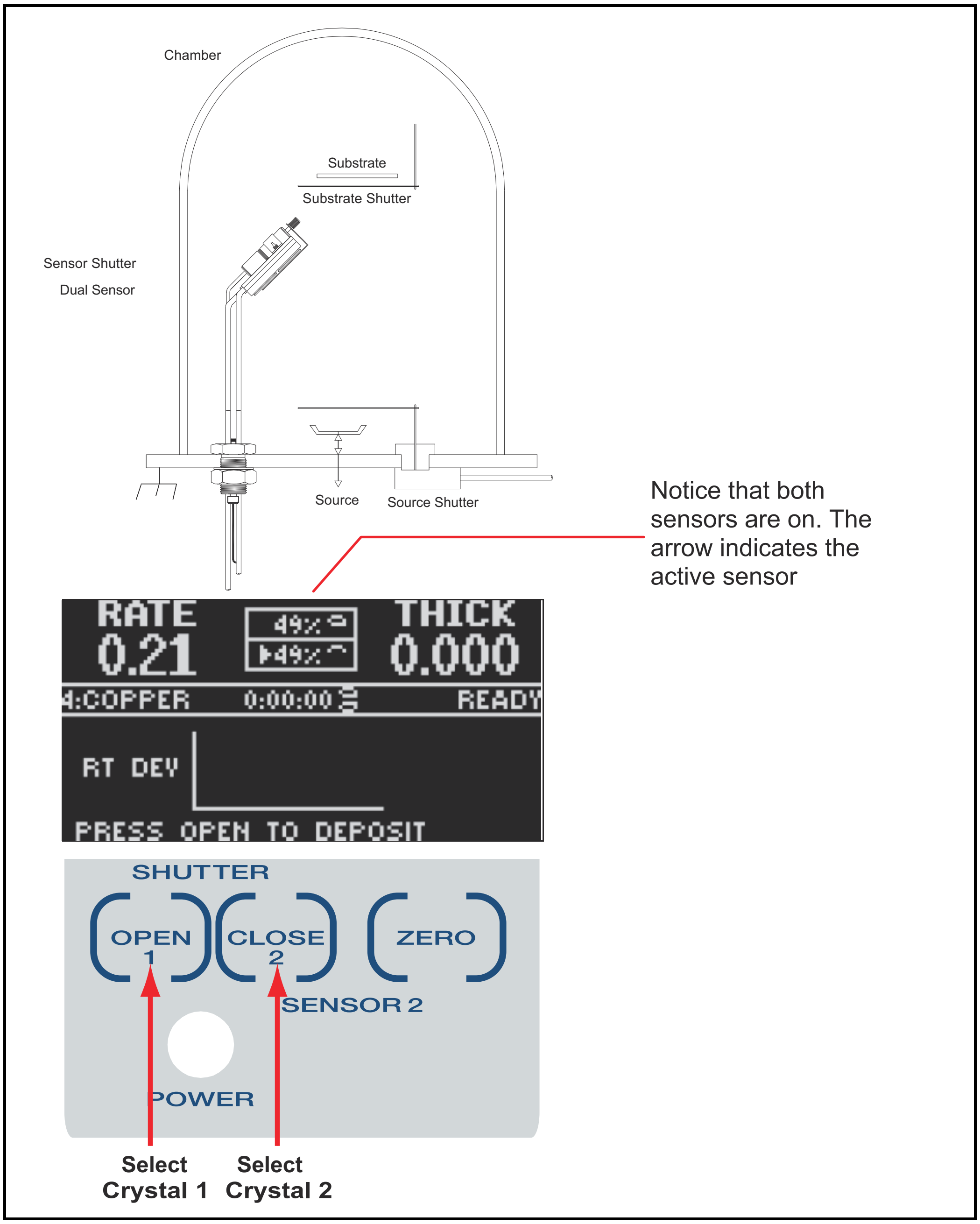


3.3.2 Backup

In backup mode, STM-2XM is a single layer, single source monitor using two sensors; one sensor is a backup for the other sensor. If the active sensor fails, STM-2XM automatically switches to the backup sensor. The active sensor can be switched manually by pressing the lower **OPEN** and **CLOSE** buttons on the front panel (refer to section 3.1.1 on page 3-2).

NOTE: The 1 and 2 on these buttons indicate which sensor will be selected (see Figure 3-10).

Figure 3-10 Backup mode

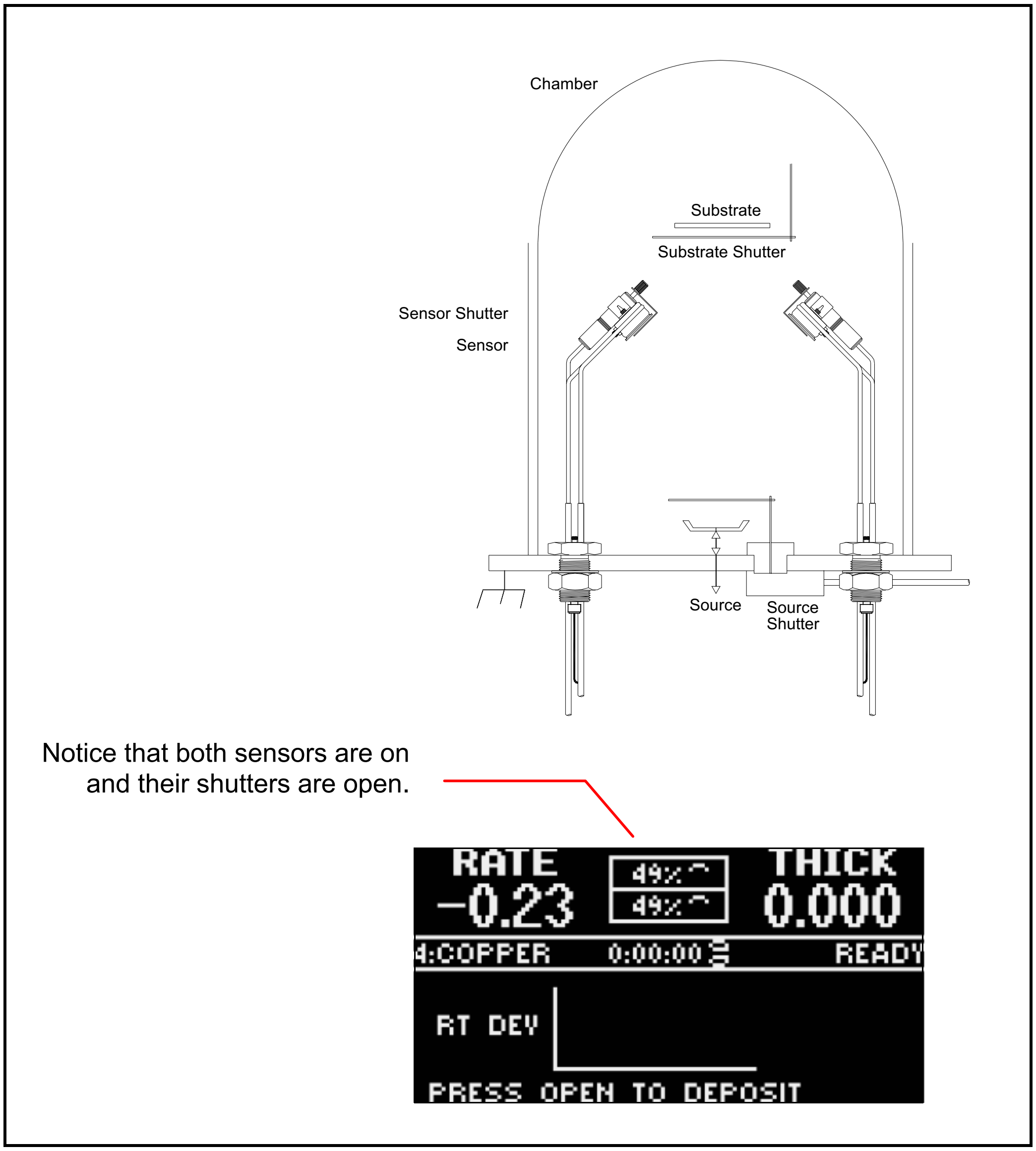


3.3.3 Averaging

The averaging mode is spatial averaging for two sensors. STM-2XM calculates weighted averages of two sensors to determine the film rate and thickness. Both sensors must be active and monitored at the same time. The effective rate/ thickness is the average of the readings between Sensor 1 and Sensor 2.

NOTE: Averaging mode requires two operational sensors.

Figure 3-11 Averaging mode



3.3.4 Alloy

In alloy mode, two different materials are deposited onto the substrate at the same time. STM-2XM associates a material with a sensor. Make sure to shield the sensors so that each sensor monitors only one source.

In alloy mode, Sensor 1 (X1) is associated with Channel/Source 1 (top line on the Runtime screen) and Sensor 2 (X2) is associated with Channel 2/Source 2 (bottom line on the Runtime screen) (see Figure 3-12).

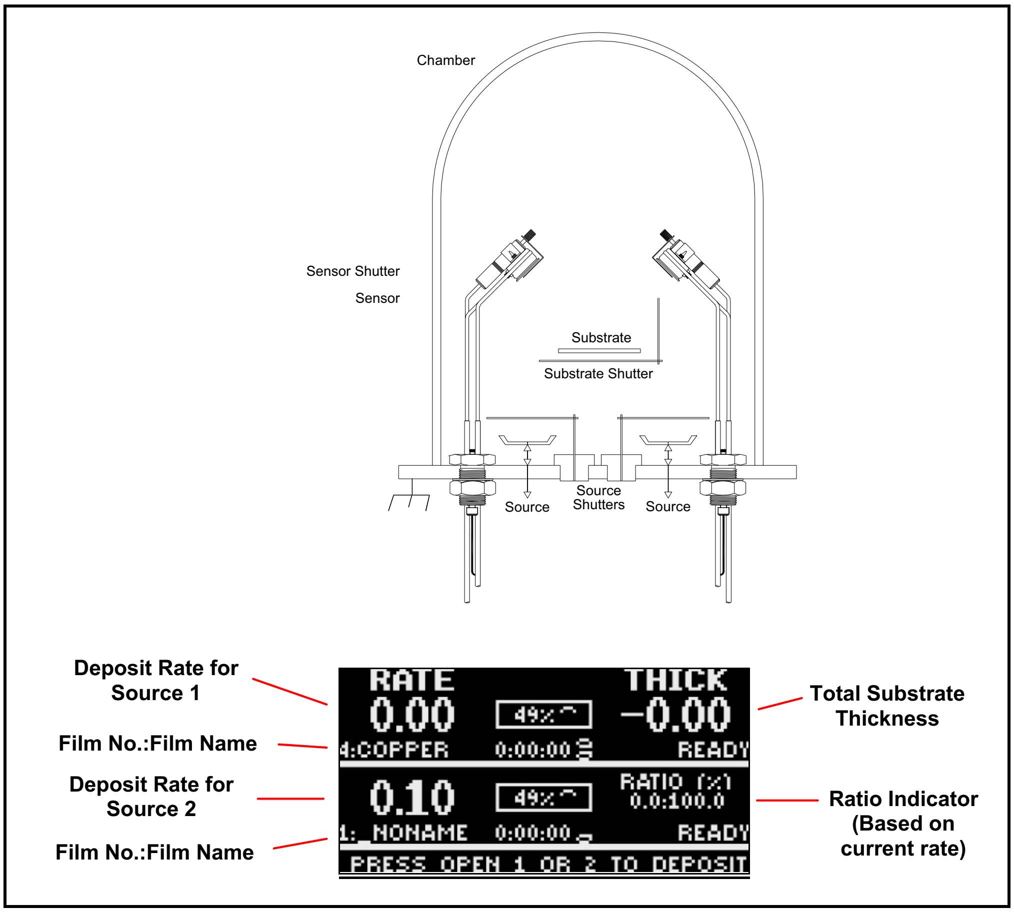
In alloy mode, STM-2XM links the source or substrate shutters together, so that the evaporants are properly codeposited on the substrate. Each channel (or both) may still have a shutter delay phase. In this case, when the channel(s) are programmed with shutter delay, they both enter the deposit phase at the same time by pressing either of the two **OPEN** buttons. Also, each channel may independently be programmed for rate sampling.

In alloy mode, the setpoint thickness of each source channel is independent.

The Ratio Indicator displays the ratio as measured at the instant, not an overall ratio.

NOTE: The chart is not available in Alloy Mode.

Figure 3-12 Alloy mode

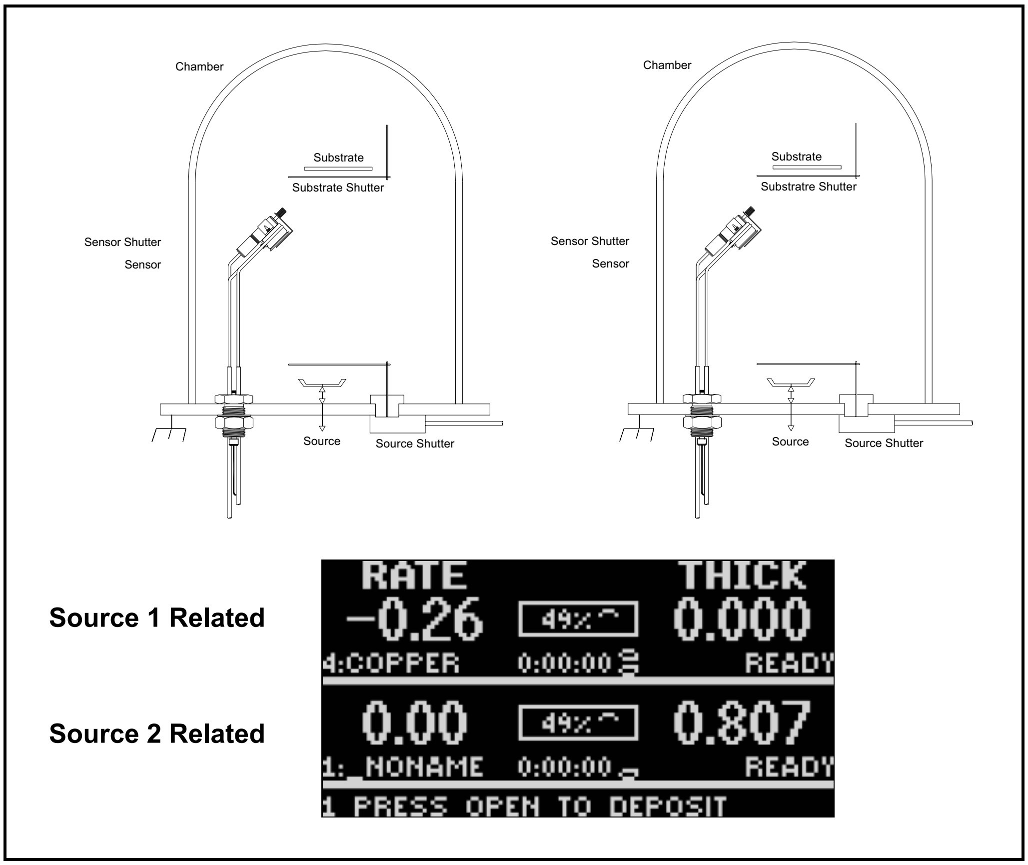


3.3.5 Independent

In independent mode, STM-2XM acts like two separate simple monitors. The source shutters are operated independently, and the films can be deposited independently. The two channels are completely independent. Sensor 1 (X1) is associated with Channel/Source 1 (top line on the screen) and Sensor 2 (X2) is associated with Channel 2/Source 2 (bottom line on the screen).

NOTE: The chart is not available in Independent Mode. The setpoint indicators on the Runtime screen (refer to Figure 3-7 on page 3-6) are also not available in Independent mode.

Figure 3-13 Independent mode



3.4 Operation

3.4.1 No Shutter Delay

Press **OPEN**. STM-2XM transitions from Ready to Deposit. The setpoint time, setpoint thickness, and end thickness indicators are cleared. When the accumulated thickness reaches the End Thickness value for the active film (refer to section 3.2.1.1 on page 3-8), STM-2XM automatically closes the source shutter and transitions back to the Ready phase.

NOTE: The substrate thickness is not zeroed when the deposit phase is entered. This allows multiple layers to be deposited and the accumulated total substrate thickness to be displayed (also known as thickness summing). Zero the thickness by pressing **ZERO** before pressing **OPEN** to display the thickness of a single layer.

3.4.2 Shutter Delay

From the Ready phase, press **OPEN**. STM-2XM will enter the shutter delay phase (SHUT_DLY). The substrate shutter remains closed but the source shutter (if installed) opens. This allows for preconditioning of the source and establishing a steady rate prior to opening the substrate shutter.

While in shutter delay the Open indicator blinks. When ready to start depositing, press **OPEN** again. STM-2XM will open the substrate shutter and enter the deposit phase.

NOTE: Setpoint time, setpoint thickness, and end thickness indicators are cleared at the beginning of the shutter delay phase.

3.4.3 Test Mode

Test mode allows STM-2XM settings and operation to be tested without performing an actual deposition. Setting Test mode On provides a simulated rate, to simulate the effects of a real deposition.

CAUTION

In Test mode, all setpoints, inputs, and outputs are active.

In Test mode, STM-2XM simulates attached sensors, and provides a simplified way to become familiar with the STM-2XM front panel indicators and programming.

It is possible to open or close the shutter to simulate deposition and zero readings. It is also possible to test the Time and Thickness Setpoint relays and indicators.

3.4.4 Rate Sampling

STM-2XM rate sampling allows for long depositions by limiting the time the sensor is exposed to the evaporant. STM-2XM samples rate for a period of time, then closes the sensor shutter and assumes the rate is constant. STM-2XM continuously opens and closes the sensor shutter according to the times programmed. While depositing, when STM-2XM closes the sensor shutter, STM-2XM enters a HOLD phase, and the locked-in rate blinks. STM-2XM will not enter the HOLD phase unless the measured rate is at least 50% of the programmed deposit rate for the film or 0.5 Å/s (whichever is greater). This prevents STM-2XM from jumping into the HOLD phase before the rate has been established.

3.5 Film States

FAIL TPW . . . . Crystal failed; completed time power (thickness was incremented at last known rate and shutter was held open until End Thickness was reached).

X FAIL . . . . Crystal failed; film was aborted; all shutters are closed. If the crystal recovers while in the X FAIL phase, STM-2XM will transition to the Ready phase.

READY. . . . . Sensor shutters are open, but all other shutters are closed. Monitor is ready; press OPEN to open source/substrate shutters.

SHUT DLY . . . . Sensor and source shutters are open but substrate shutter is closed. This allows a rate to be established. Pressing OPEN will transition the film to Deposit (opening the substrate shutter).

COAST. . . . . Crystal failed, but STM-2XM is incrementing thickness at the last known rate and keeping the source/substrate shutters open. Once the end thickness is reached, the film will transition to the FAIL_TPW state.

DEPOSIT . . . . All shutters are open and STM-2XM is monitoring the evaporant onto the target. This is the normal mode.

HOLD . . . . Sensor shutters are closed during deposit, and STM-2XM is incrementing thickness at the last known rate.

NOTE: STM-2XM will not enter the HOLD phase unless the measured rate is at least 50% of the programmed deposit rate for the film or 0.5 Å/s. STM-2XM uses the greater of the two values.

STABILIZ . . . . After being in the HOLD phase, the sensor shutter(s) are opened and STM-2XM waits until the reading stabilizes before accumulating the measured rate.

Chapter 4
Software

4.1 Introduction

STM-2XM is capable of RS-232 and RS-485 serial communication. To connect STM-2XM to a computer via RS-232, use the serial cable included in the ship kit, PN 783-506-000-P1.

STM-2XM can be programmed offline and the offline settings can be saved. STM-2XM supports Sycon protocol for backwards compatibility, SMDP protocol for faster communication, and multiple instruments on the same RS-485 link (see Chapter 5, Communications).

To use INFICON STM-2XM FilmMaker software, first install the Protocol Server (see section 4.2.1). Then install the INFICON STM-2XM FilmMaker software (see section 4.2.2).

4.2 Installing INFICON STM-2XM FilmMaker Software

INFICON STM-2XM FilmMaker Software supports one STM-2XM.

4.2.1 Installing the Protocol Server

1. Insert the **Thin Film Manuals CD** into the CD drive of the computer that will be connected to STM-2XM.
2. Click **Windows Explorer** or **File Explorer >> Computer >> (CD drive letter:) >> Common Software**.
3. Double click **setup_smdp_svr_lv.exe**. The **Zip Self-Extractor** window will display.
4. Click **Unzip**. The **SMDP Serial Protocol Server** window will display.
5. On the **Destination Directory** pane, click **Browse** to select the location all software will be installed.
6. Click **Next**.
7. Read the license agreement.
8. Click **I accept License Agreement(s)**.
9. Click **Next**.
10. Review the summary of information.
11. Click **Next**. **Installation Complete** will display.

12 Click **Next**. The **Setup Wizard** pane will display.

13 Click **Next**. The **Confirm Installation** pane will display.

14 Click **Next**.

15 Read the license agreement.

16 Click **I Agree**.

17 Click **Next**. **Installation Complete** will display.

18 Click **Close**.

19 Click **Close** on the **Zip Self-Extractor**.

4.2.2 Installing INFICON STM-2XM FilmMaker Software

1 Insert the **Thin Film Manuals CD** into the CD drive of the computer that will be connected to STM-2XM.

2 Click **Windows Explorer** or **File Explorer >> Computer >> (CD drive letter:) >> STM-2XM >> TOOLS >> FilmMaker**.

3 Double click **setup_INFICON_2xm_filmmaker.exe**. The **Zip Self-Extractor** window will display.

4 Click **Unzip**. The **INFICON 2XM FilmMaker** window will display.

5 On the **Destination Directory** pane, click **Browse** to select the location all software will be installed.

6 Click **Next**.

7 Review the summary of information.

8 Click **Next**. **Installation Complete** will display.

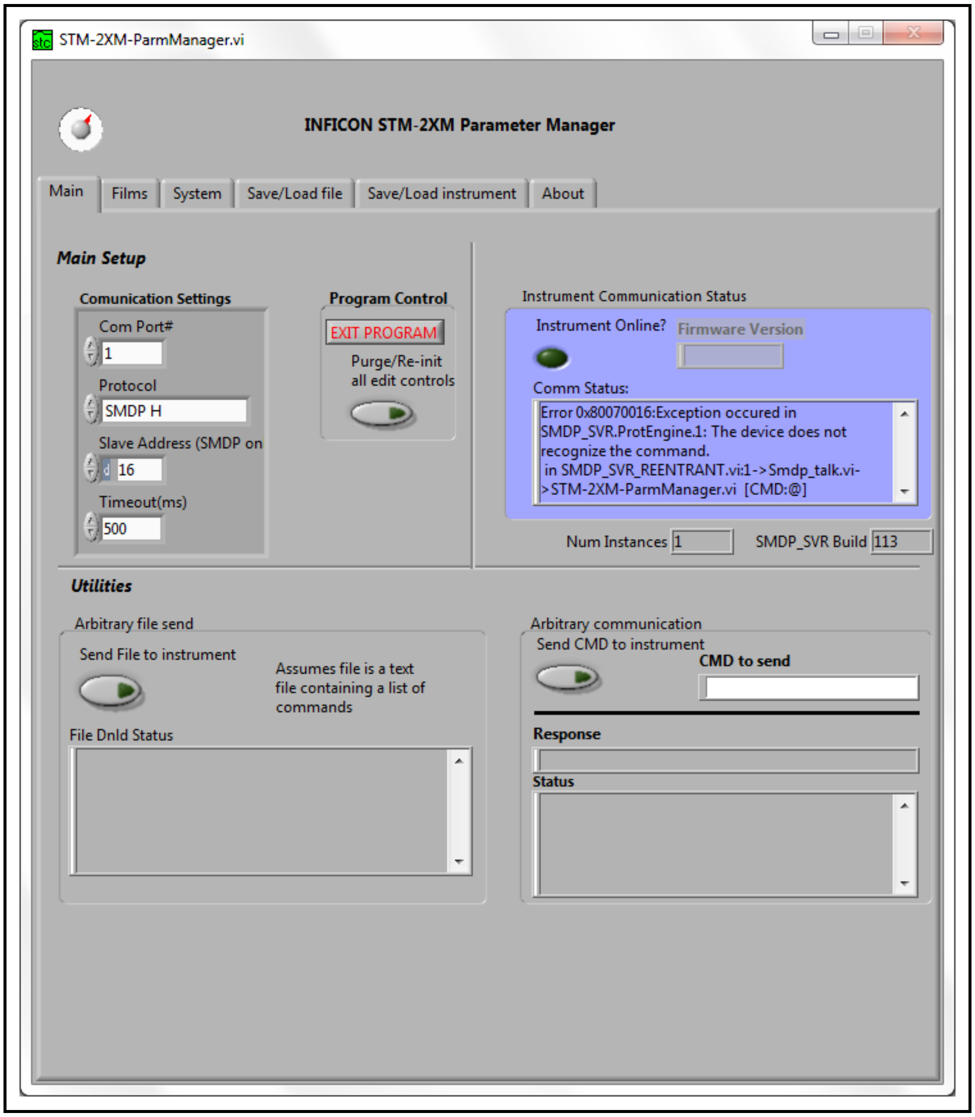
9 Click **Finish**.

4.2.3 Starting INFICON STM-2XM FilmMaker Software

4.2.3.1 Starting the Software in Windows XP or Windows 7

1. Click **Start >> All Programs >> INFICON >> INFICON STM-2XM FilmMaker**.
2. The **STM-2XM-ParmManager.vi** window will display (see Figure 4-1).

Figure 4-1 STM-2XM-ParmManager.vi initial display

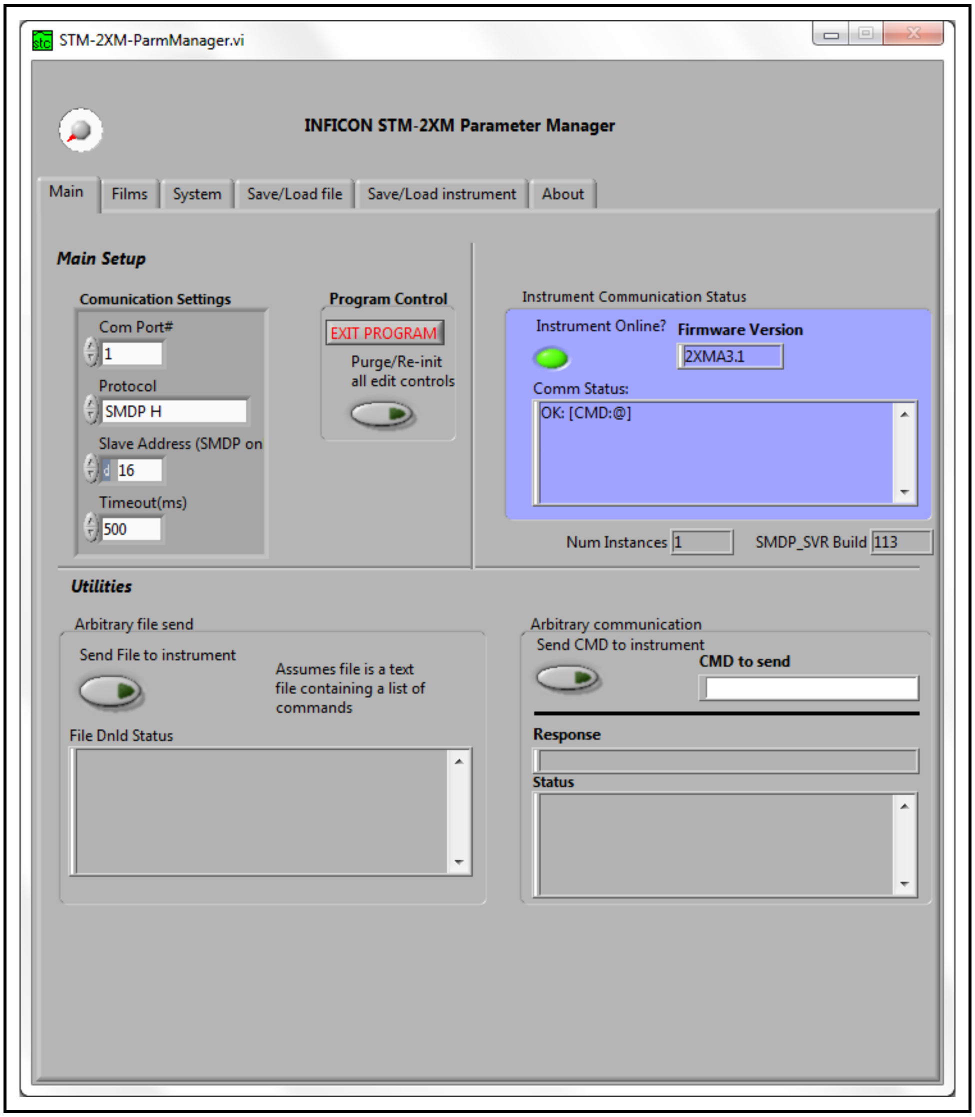


4.2.3.2 Starting the Software in Windows 8

1. In the **Start** window, click the **STM-2XM FilmMaker** icon.
2. If the icon cannot be found:
   - **2a** Click **Search >> Apps**.
   - **2b** Type **STM** in the **Search** text box.
   - **2c** Click the **INFICON STM-2XM FilmMaker** icon.

4.3 STM-2XM Parameter Manager

Figure 4-2 STM-2XM-ParmManager.vi



- **Main** tab (see section 4.3.1)
- **Films** tab (see section 4.3.2 on page 4-8)
- **System** tab (see section 4.3.3 on page 4-10)
- **Save/Load file** tab (see section 4.3.4 on page 4-17)
- **Save/Load instrument** tab (see section 4.3.5 on page 4-18)
- **About** tab (see section 4.3.6 on page 4-20)

4.3.1 Main Tab

Communication and utilities are accessed on the **Main** tab. (Refer to Figure 4-2.)

NOTE: Right-clicking on a value or parameter and then clicking **Description and Tip** will display additional information about that value or parameter.

4.3.1.1 Main Setup Pane

Communication Settings

Com Port# . . . . 1 to 255

Sets the communications port that STM-2XM is communicating through.

Protocol . . . . Sycon @ 9.6 Kbps, SMDP L (9.6 Kbps), SMDP M (38.4 Kbps), SMDP H (115.2 Kbps).

Adjustable baud rate.

NOTE: This value must match the Comm Protocol setting in the System Settings menu on STM-2XM (refer to section 3.2.1.2 on page 3-11).

Slave Address . . . . 16 to 255

SMDP address the software will use for serial communication with STM-2XM.

NOTE: This value must match the SMDP Address setting in the System Settings menu on STM-2XM (refer to section 3.2.1.2 on page 3-11).

Timeout(ms) . . . . 150 to 20000

The amount of time in microseconds that the software will wait for a response before issuing an error.

Program Control

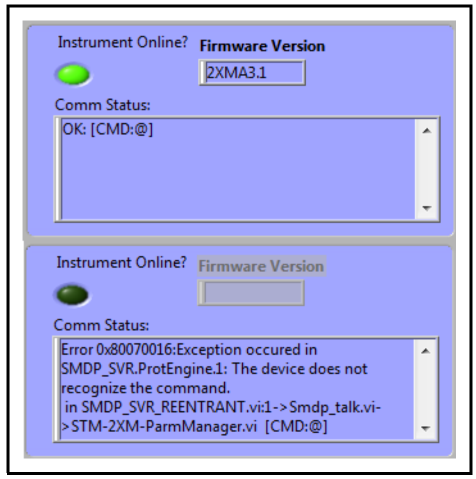
Exit Program . . . . Click to safely stop communications and exit the software program.

Purge/Re-Init all edit controls . . . . Returns all parameters edited using the software to default values.

Instrument Communication Status

Instrument Online? . . . . Indicator to display communication status. With established communication, the indicator will illuminate a light green color. Without established communication, the indicator will illuminate a dark green color (see Figure 4-3).

Figure 4-3 Instrument online indicator



Firmware Version . . . . Displays the firmware version of the connected STM-2XM.

Comm Status: . . . . Displays communications error messages. If communications have been established without error, OK: [CMD:@] will be displayed.

Num Instances . . . . Shows number of instruments using the communication server. It is possible to have multiple instances of STM-2XM Parm Manager.vi running.

SMDP_SVR Build . . . . Build or version of the communication server.

4.3.1.2 Utilities Pane

Arbitrary file send

Send File to instrument . . . . Selects a parameter file (*.2XM) to send to STM-2XM.

File DnId Status . . . . Displays status of file download to STM-2XM. Error messages and comments will be displayed after a file is selected for transmission.

Arbitrary communication

Send CMD to instrument . . . . Click to send remote command.

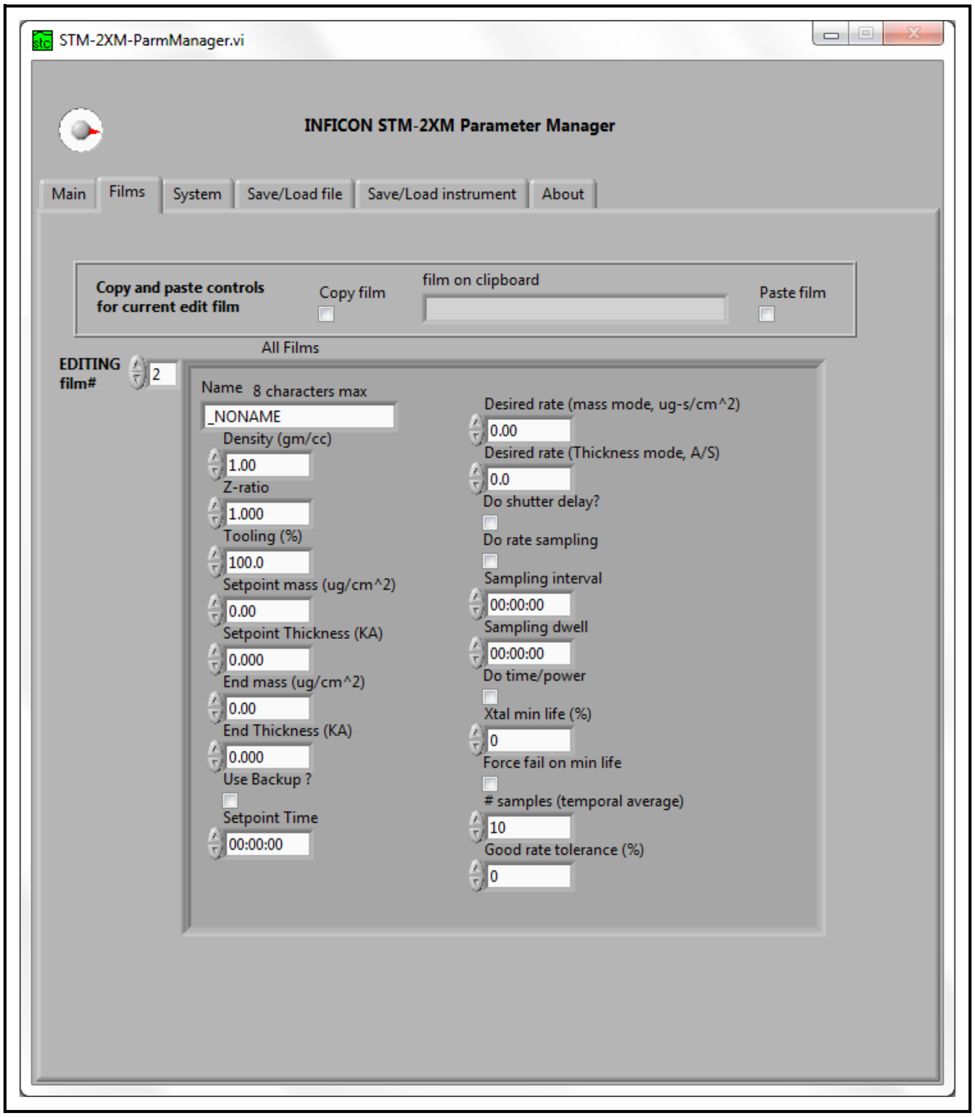
CMD to send . . . . Enter command in the **CMD to send** box. (See section 5.8, Communications Commands, on page 5-17.)

Response . . . . Receives the reply from the command sent.

Status. . . . . Displays communications error messages. If communications have been established without error, **OK: [CMD:@]** will be displayed.

4.3.2 Films Tab

Figure 4-4 Films tab



NOTE: Right-clicking on a value or parameter and then clicking **Description and Tip** will display additional information about that value or parameter.

<u>**Copy and paste controls for current edit film pane**</u>

Copy film . . . . Click to copy the current film number displayed and place it on the clipboard.

Film on clipboard . . . . Displays the film that has been copied and is in queue.

Paste film . . . . Click to paste the film parameters for the displayed film in the film on clipboard box onto the current film parameters displayed, thereby replacing the values for the current film.

All films pane

Use the spin box to increment or decrement the values for each of the parameters listed below.

EDITING film# . . . . 1 to 15

Name . . . . 8 character maximum

Density . . . . 0.40 to 99.99 g/cm^3

Z-Ratio . . . . 0.100 to 9.999

Tooling . . . . 10 to 999.9%

Setpoint mass . . . . 0.00 to 9999.99 µg/cm^2

Setpoint Thickness . . . . 0.000 to 999.999 kÅ

End mass . . . . 0.00 to 9999.99 µg/cm^2

End Thickness . . . . 0.000 to 999.999 kÅ

Use Backup . . . . Select to enable the use of the backup crystal (refer to section 3.2.1.1 on page 3-8).

Setpoint Time . . . . 00:00:00 to 9:59:59 h:mm:ss

Desired Rate . . . . 0.00 to 99.99 µg•s/cm^2

Desired Rate . . . . 0.0 to 999.9 Å/s

Do shutter delay? . . . . Select to enable shutter delay (refer to section 3.2.1.1 on page 3-8).

Do rate sampling . . . . Select to enable rate sampling (refer to section 3.2.1.1 on page 3-8).

Sampling interval . . . . 00:00:00 to 9:59:59 h:mm:ss

Sampling Dwell . . . . 00:00:00 to 9:59:59 h:mm:ss

Do time/power . . . . Select to enable time/power upon crystal fail (refer to section 3.2.1.1 on page 3-8).

Xtal min life . . . . 0 to 99%

Force fail on min life . . . . Select to enable an automatic crystal fail upon reaching the minimum crystal life input (refer to section 3.2.1.1 on page 3-8).

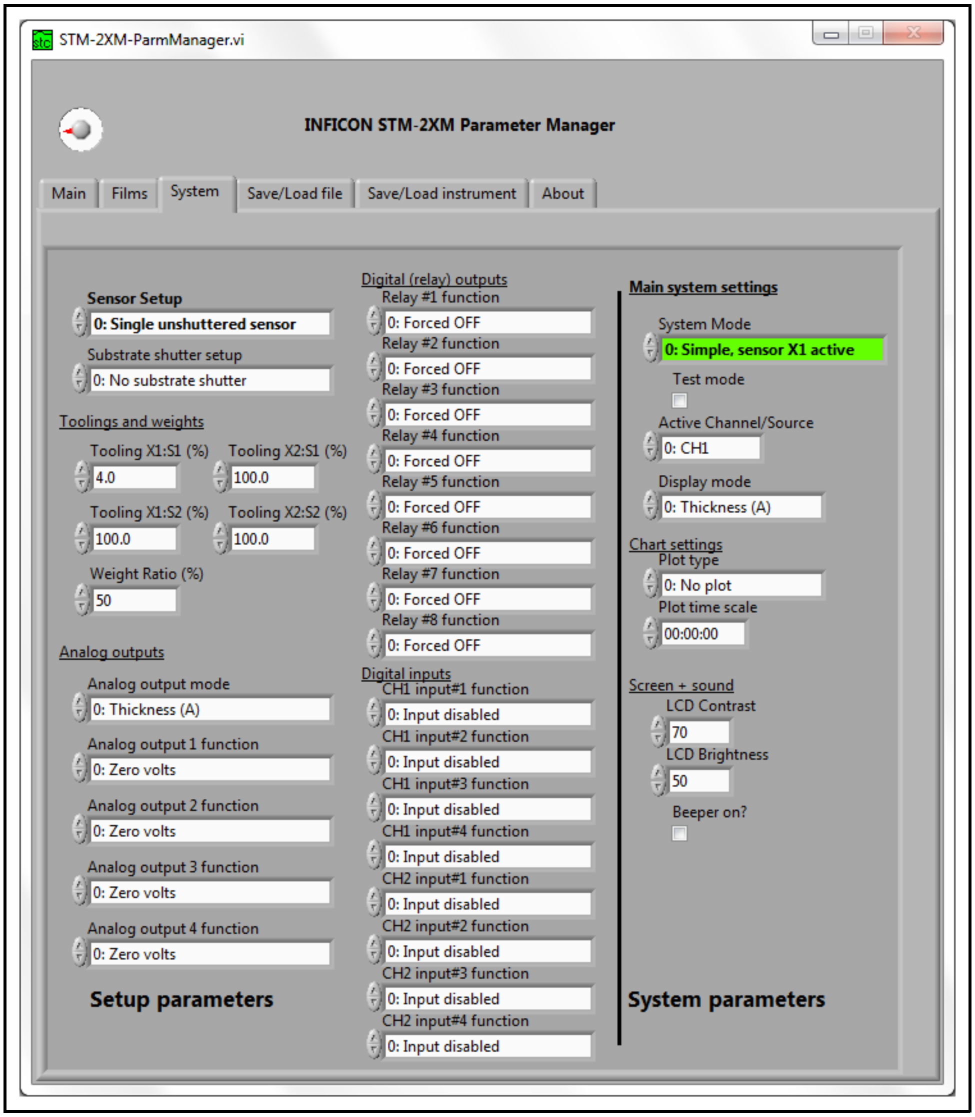
 # Samples . . . . 1 to 50

Good Rate Tolerance . . . . 0 to 50%

4.3.3 System Tab

Use the spin box to select parameter values (see Figure 4-5).

Figure 4-5 System tab



NOTE: Right-clicking on a value or parameter and then clicking **Description and Tip** will display additional information about that value or parameter.

4.3.3.1 Setup parameters Pane

Sensor setup. . . . . Main parameter that affects the choices/modes available (see Table 4-1).

Table 4-1 Sensor setup parameter

Sensor Setup	Available Modes	Rate Sampling Capable	Backup Capable
1:Single unshuttered	Simple	No	No
2:Single shuttered	Simple	Yes	No
3:Dual w/single shutter	Simple	Yes	Yes
4:Dual unshuttered	Simple, Averaging, Alloy, Independent	No	If mode is Simple
5:Dual w/dual shutters	Simple, Averaging, Alloy, Independent	Yes	If mode is Simple

Substrate shutter setup . . . . The parameter that describes the shutter assembly of the substrate(s) (see Table 4-2).

Table 4-2 Substrate shutter setup parameters

Substrate Shutter Setup	Shutter Delay Thick Hold
None	N
CH1: Substrate	Only for film on Channel 1
CH2: Substrate	Only for film on Channel 2
Shared substrate	Only allows shutter delay for one film at a time
Dual substrate	Allows dual shutter delay (alloy shutter delay)

<u>**Tooling and Weights**</u>

Tooling X1:S1 . . . . The ratio between substrate thickness using Source 1 and Sensor 1 thickness (see section 7.3, Determining Tooling, on page 7-2).

Tooling X2: S1 . . . . The ratio between substrate thickness using Source 1 and Sensor 2 thickness (see section 7.3, Determining Tooling, on page 7-2).

NOTE: For independent chambers, set this value to zero.

Tooling X1:S2 . . . . The ratio between substrate thickness using Source 2 and Sensor 1 thickness (see section 7.3, Determining Tooling, on page 7-2).

NOTE: For independent chambers, set this value to zero.

Tooling X2:S2 . . . . The ratio between substrate thickness using Source 2 and Sensor 2 thickness (see section 7.3, Determining Tooling, on page 7-2).

Weight Ratio . . . . Available only in spatial averaging mode.

This parameter describes the percentage of time the substrate is near Sensor 1. In moving substrate systems, if the substrate spends more time near one sensor than the other, this needs to be accounted for in the computations. If the substrate spends 90% of time near Sensor 1, this parameter should be programmed for 90%. If the substrate is fixed, the default value is 50%.

Analog outputs

Analog output mode . . . . 0: Thickness, 1: Mass

Analog output 1 to 4 function . . . . Determines the function of each of the analog outputs (refer to section 2.2.3 on page 2-5 for details on wiring analog outputs). (See Table 4-3.)

Table 4-3 Analog output functions

Setting	Description
0: Zero volts	Output is disabled
1: +10 V Fixed	+10 V Fixed
2: -10 V Fixed	-10 V Fixed
3: Computer controlled	Output is computer set value
4: Rate Deviation, Channel 1, 1000 Å/S	Rate Deviation, Channel 1, 1000 Å/s
5: Rate Deviation, Channel 1, 10 Å/S	Rate Deviation, Channel 1, 10 Å/s
6: Rate, Channel 1, 1000 Å/S	Rate, Channel 1, 1000 Å/s
7: Rate, Channel 1, 10 Å/S	Rate, Channel 1, 10 Å/s
8: Thickness, Channel 1, 999 Å[1]	Thickness Recorder, Channel 1, 999 Å
9: Thickness, Channel 1, 99.9 Å[1]	Thickness Recorder, Channel 1, 99.9 Å
10: Rate Deviation, Channel 2, 1000 Å/S	Rate Deviation, Channel 2, 1000 Å/s
11: Rate Deviation, Channel 2, 10 Å/S	Rate Deviation, Channel 2, 10 Å/s
12: Rate, Channel 2, 1000 Å/S	Rate, Channel 2, 1000 Å/s
13: Rate, Channel 2, 10 Å/S	Rate, Channel 2, 10 Å/s
14: Thickness, Channel 2, 999 Å[1]	Thickness Recorder, Channel 2, 999 Å
15: Thickness, Channel 2, 99.9 Å[1]	Thickness Recorder, Channel 2, 99.9 Å

[1] Sawtooth mode.

Digital (relay) outputs

Relay 1 to 8 function . . . . Determines the function of each of the digital (relay) outputs (refer to section 2.2.2 on page 2-4 for details on wiring digital outputs). (See Table 4-4.)

Table 4-4 Relay functions

Setting	Description
0: Forced OFF	Relay is inactive
1: Forced ON	Relay is always active
2: Computer controlled	Relay is controlled with remote communications
3: Front panel buttons, top	Relay is toggled using Sensor 1 OPEN/CLOSE buttons
4: Front panel buttons, bottom	Relay is toggled using Sensor 2 OPEN/CLOSE buttons
5: Channel 1 source shutter	Relay activates Channel 1 source shutter
6: Channel 2 source shutter	Relay activates Channel 2 source shutter
7: Channel 1 substrate shutter	Relay activates Channel 1 substrate shutter
8: Channel 2 substrate shutter	Relay activates Channel 2 substrate shutter
9: Sensor 1 (X1) active	Relay activates Sensor 1 shutter
10: Sensor 2 (X2) active	Relay activates Sensor 2 shutter
11: Sensor 1 (X1) failed	Relay activates when Sensor 1 fails
12: Sensor 2 (X2) failed	Relay activates when Sensor 2 fails
13: Channel 1 setpoint time	Relay activates when Channel 1 setpoint time has elapsed
14: Channel 2 setpoint time	Relay activates when Channel 2 setpoint time has elapsed
15: Channel 1 setpoint thick	Relay activates when Channel 1 setpoint thickness has been reached
16: Channel 2 setpoint thick	Relay activates when Channel 2 setpoint thickness has been reached
17: Channel 1 good rate	Relay activates when Channel 1 rate is steady and within tolerance
18: Channel 2 good rate	Relay activates when Channel 2 rate is steady and within tolerance
19: Complement of #9	Relay is Normally Closed and opens to use Sensor 1
20: Complement of #10	Relay is Normally Closed and opens to use Sensor 2

Digital inputs

CH1/CH2 input 1 to 4 function. . . . Determines the function of each of the digital (relay) outputs (refer to section 2.2.4 on page 2-6 for details on wiring remote inputs). (See Table 4-5.)

Table 4-5 Input functions

Setting	Description
0: Input disabled	Input is ignored
1: Thickness zero	Zero accumulated thickness
2: Open as if from front panel	Open source shutter and in deposit mode
3: Close as if from front panel	Closed source shutter and in monitor mode
4: Select Sensor 1/ Sensor 2 (backup mode)	Switch active crystal
5: Trigger final thickness	Source final thickness
6: Trigger final thicknesses (alloy mode)	All channels final thickness (alloy mode)
7: Sync start channels (alloy mode)	Open substrate shutter and sync start channels (alloy mode)

4.3.3.2 System parameters Pane

Main system settings

System Mode . . . . Sets STM-2XM to operate in a certain mode (refer to section 3.3 on page 3-18). (See Table 4-6.)

Table 4-6 System mode

Mode	Action	Mode	Action
0	Simple, Sensor X1 active	3	Averaging
1	Simple, Sensor X2 active	4	Alloying
2	Sensor backup	5	Independent

Test Mode . . . . Select to enable Test mode where sensor readings are simulated.

NOTE: If STM-2XM is reset, test mode is turned off automatically.

Active Channel/Source CH1, CH2

Selects where the analog and digital outputs and inputs are connected.

Display Mode . . . . Displays thickness in kiloangstroms (kÅ) or mass in micrograms per square centimeter (µg/cm^2).

Chart settings

Plot type . . . . Available in single film modes.

Displays the graph on the Runtime screen as No plot, Rate Deviation, Rate, or Thickness/Mass.

Plot time scale . . . . Sets the horizontal axis size. Defines the amount of time covered by the plot before it is overwritten.

Screen + sound

LCD Contrast . . . . 10 to 85

Adjusts the appearance of the screen.

LCD Brightness . . . . 1 to 99

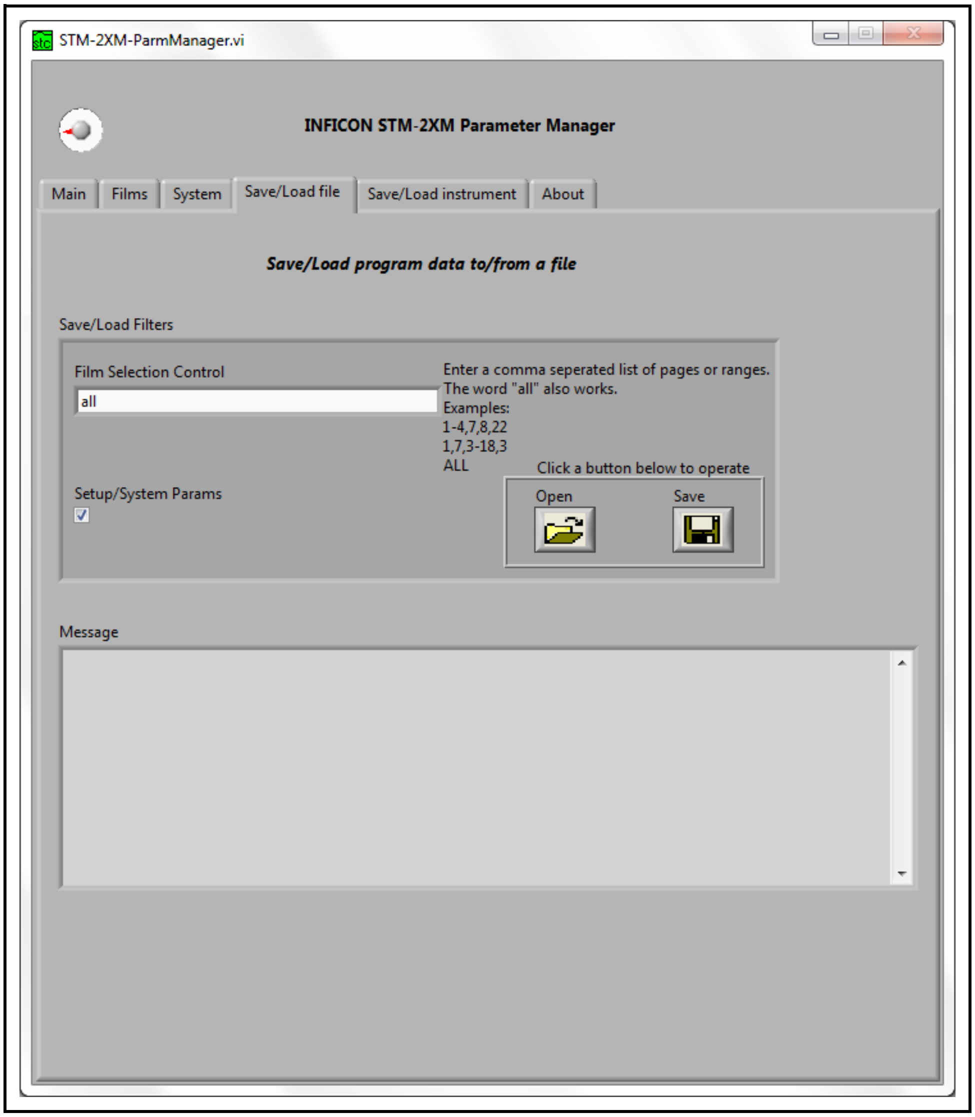
Adjusts the appearance of the screen.

Beeper on? . . . . Select to enable a sound when a front panel button is pressed.

4.3.4 Save/Load file Tab

Save a parameter file as *.2XM or load a parameter file from this tab (see Figure 4-6).

Figure 4-6 Save/Load file tab



NOTE: Right-clicking on a value or parameter and clicking **Description and Tip** will display more information about that value or parameter.

Film Selection Control . . . . A comma separated list of pages or ranges to Save/Load. Type "all" to Save/Load all pages or ranges of parameters.

Setup/System Params . . . . Select to enable to Save/Load setup and system parameters in addition to film parameters.

Open . . . . Click to browse and select the location of a file to open.

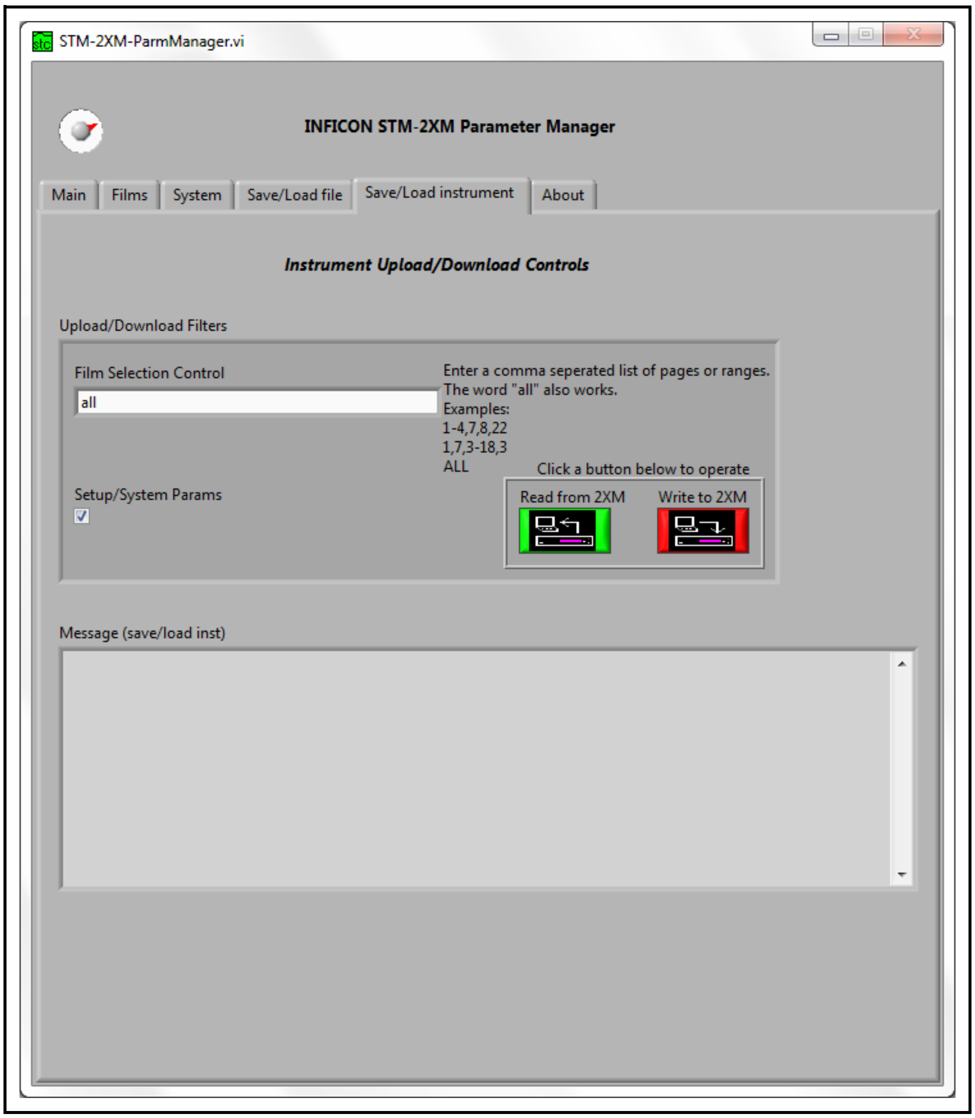
Save. . . . . Click to browse and select the location to save the current process and system configuration.

Message . . . . Displays error messages or comments regarding the saving or loading of process and system configuration files.

4.3.5 Save/Load instrument Tab

This tab is used to upload a configuration file from STM-2XM into the STM-2XM software. It will also download the configuration to STM-2XM (see Figure 4-7).

Figure 4-7 Save/Load instrument tab



NOTE: Right-clicking on a value or parameter and then clicking **Description and Tip** will display additional information about that value or parameter.

Film Selection Control . . . . A comma separated list of pages or ranges to Save/Load. Type "all" to Save/Load all pages or ranges of parameters.

Setup/System Params . . . . Select to enable to Save/Load setup and system parameters in addition to film parameters.

Read from 2XM . . . . Click to upload a configuration file from STM-2XM into the software.

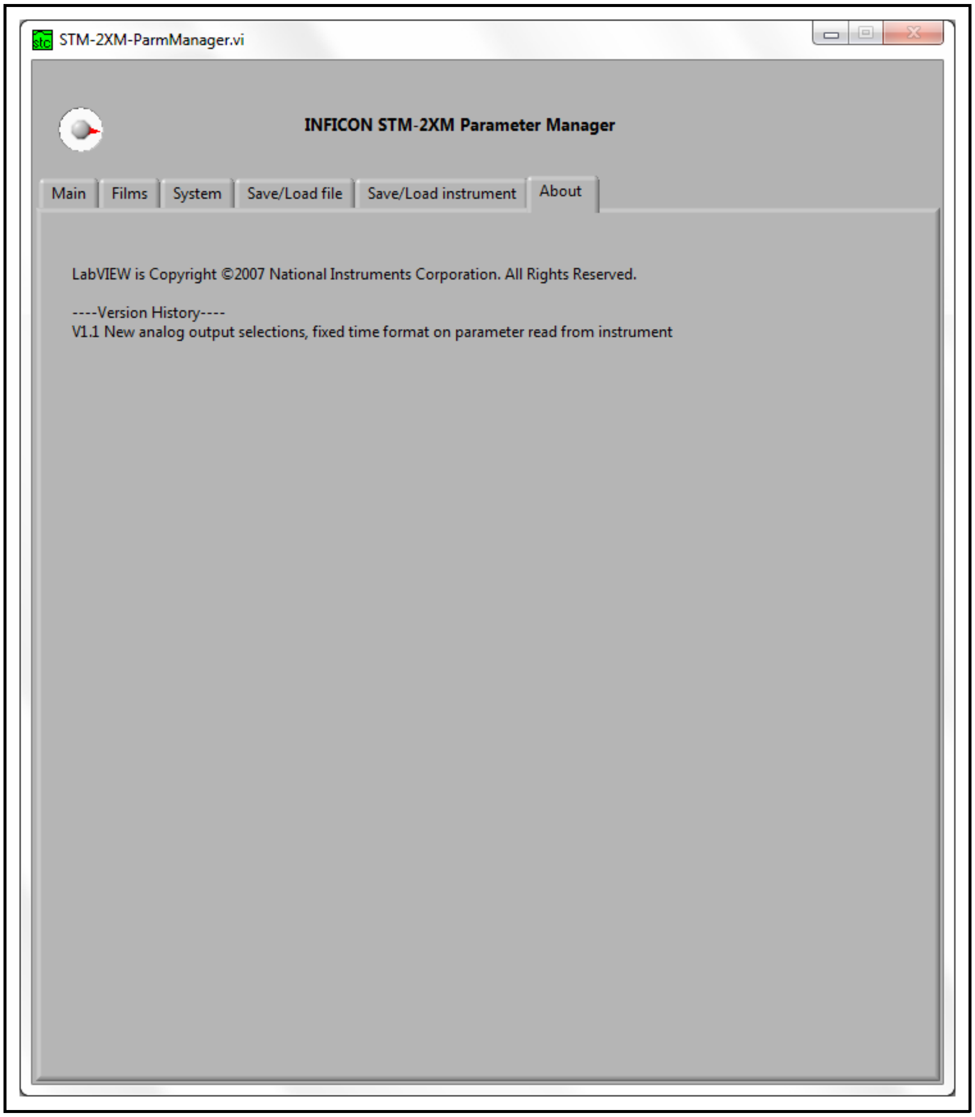
Write to 2XM . . . . Click to download the configuration parameters from the software and into STM-2XM.

Message . . . . Displays error messages or comments regarding the saving or loading of process and system configuration files.

4.3.6 About Tab

Displays copyright, version history, and software version number (see Figure 4-8).

Figure 4-8 About tab



Chapter 5 Communications

5.1 Introduction

Chapter 5 describes the Sycon Protocol and the Sycon Multi Drop Protocol (SMDP).

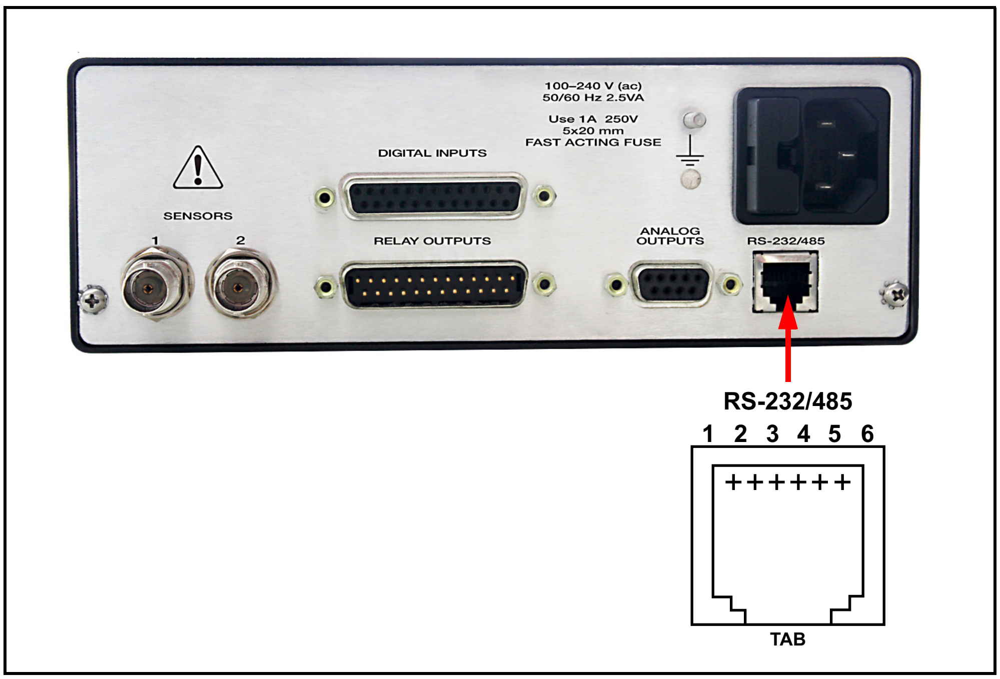
5.2 Communications Connections

STM-2XM interfaces to a computer using RS-232 through the SMDP cable provided in the ship kit, PN 783-506-000-P1.

5.2.1 RS-232/RS-485 Connector

STM-2XM uses RS-232 and RS-485 for serial communications. Both communication ports are accessed through the RS-232/485 connector. The RS-232/485 connector location and pin numbering is shown in Figure 5-1.

Figure 5-1 Rear panel



5.2.2 RS-232 Point-to-Point Mode

STM-2XM can be set to RS-232 point-to-point mode for a single host-slave connection by selecting SMDP address 16 (0x10). Point-to-point mode can be set to one of three baud rates (high-115200, medium-38400, low-9600) via the **Comm Protocol** menu accessed from the **System Settings** menu (refer to section 3.2.1.2 on page 3-11). This supports a three wire (transmit, receive, common ground) interface that can be directly connected to most RS-232 ports of a computer or controller. The protocol is standard 10 bit (1 start bit, 8 data bits, 1 stop bit) (see section 5.5 on page 5-4).

5.2.3 RS-485 TTL Differential Signaling Mode

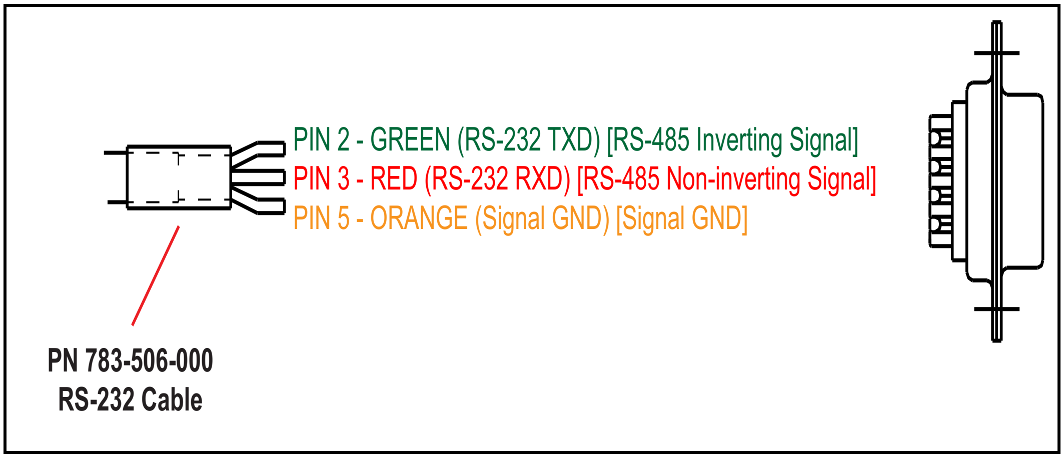
RS-485 TTL differential signaling mode is selected by SMDP address values 17 through 254. In TTL differential signaling mode, two wires are time-shared (half-duplex) between a master and 1 to N slaves. Slaves monitor the state of the A/B differential signals, looking for the master to a frame (start-data-stop-start-data-stop-etc). When a slave receives a frame that is addressed for it (address byte value 17 to 254), the slave will drive the A/B wire pair differentially with its own reply frame, which the master (and all other slaves) will see. Since the reply has an address byte embedded in it, other slaves will ignore the reply. The host will decode and verify (via checksum) the reply. If acceptable, the reply will be used by the master.

The RS-232 pin assignments for the PN 783-506-000 cable (see Figure 5-2) are Pin 2 (TXD), Pin 3 (RXD), and Pin 5 (Signal GND). The cable wiring is straight-through (not null modem).

When using the PN 783-560-000 cable for RS-485 communication, the pin assignments are Pin 2 - Green (inverting signal), Pin 3 - Red (non-inverting signal), and Pin 5 (Signal GND). The RS-485 / TIA-485 standard does not specify pin assignments, so a modification may be needed at the cable end connected to the RS-485 card. Refer to the RS-485 card operating manual to determine which pins are inverting and non-inverting.

NOTE: If the inverting and non-inverting signal connections to the RS-485 card are reversed, the RS-485 link will not communicate; however, STM-2XM and the RS-485 card will not be damaged.

Figure 5-2 PN 783-506-000 cable for RS-485



The RS-485 communications interface must be wired properly with the same baud rate used for all instruments and a unique SMDP address used for each connected instrument for communication to occur. A message will not be acknowledged, and the software will timeout if any of these conditions are not met.

5.3 Electrical

The STM-2XM SMDP interface is two-wire RS-485 providing a single master, multi-slave, half-duplex network. STM-2XM can also implement this protocol over an RS-232 interface. This allows STM-2XM to be used for RS-232 or RS-485 networks and makes an upgrade path from point-to-point.

In point-to-point RS-232 mode, the transmit and receive data lines are converted to logic levels with a standard RS-232 transceiver.

In RS-485 bus mode, a two-wire bus uses lines designated as inverting and non-inverting and carries complementary Transistor-Transistor Logic (TTL) level differential signals, time-shared (half-duplex) for messages to and from the master. When the line is idle, the non-inverting signal line is at a TTL high.

5.3.1 RS-485 Line Signal

The first bit (start bit) is a data zero value with the non-inverting signal line going to a logic low (<1 volt). The opposite differential signal (inverting RS-485) goes to a logic high (>2 volts) during the same start bit time.

NOTE: After the start bit, the eight data bits are presented in order from least significant bit (D0) through most significant bit (D7), and then follow with a stop bit (logic 1 value).

The values of the ASCII code bits as 1 or 0 are represented as normal logic (1 is high TTL, 0 is low TTL) on the non-inverting RS-485 line.

For example, the opening protocol character STX (ASCII 0x02) is transmitted on the non-inverting RS-485 wire START0-0-1-0-0-0-0-0-0-STOP1. This can be examined on an oscilloscope.

5.3.2 Bit Time

For example, a bit time is 8.68 microseconds (µs) at 115200 baud. The start and LSB zero values together would hold the line low for 2*8.68 µs or 17.36 µs. Then the D1 bit value of one would take the line high for 8.68 µs.

The remainder of the frame data bits are a zero value until the final stop bit one value returns the line to the Idle / 1 / Marking state. At the end of the master transmission, the line driver for the master enters a high-impedance state (inactive state) so that the slave can reply over the same two wires by sending back a similarly encoded frame. This master/slave (command/reply) interaction is at the heart of the protocol.

5.4 Bauds

Sycon Protocol must be 9600 baud.

All STM-2XM on the same network must have the same baud rate.

5.5 Message Format

5.5.1 Sycon Protocol

The general format for sending and receiving commands using Sycon Protocol with STM-2XM uses a start character, a length, data, and a checksum.

NOTE: Each field in angle brackets (< >) is a byte, and is not optional. Fields in regular brackets ([ ]) are optional. Ellipses (...) mean one or more of the previous.

5.5.1.1 Command Format

`<STX><DATA LENGTH><DATA>...<CKSUM>`

STX . . . . Start of text character (hexadecimal 02).

If a different character is received, it is discarded.

DATA LENGTH . . . . ASCII character from SOH (1 decimal) through P (80 decimal) and indicates the number of data characters in the message.

The data length is the count of message bytes following the data length byte plus one to designate the checksum termination. The count of message bytes can be any valid 8 bit decimal, from 0 (hexadecimal 00) through 255 (hexadecimal FF).

STM-2XM uses this number to determine where the end of the command is. If a mismatch between this number and the actual number of data characters in the message occurs, one of the following will ensue:

- If the data length number is low, STM-2XM will terminate the command prematurely. The checksum will not match. It will not respond in any way.
- If the data length number is high, STM-2XM will be waiting for more characters than actually contained in the message.

NOTE: In order to recover from either error, the host computer must have a time-out/retry capability built into the software. There is a maximum of 80 data characters allowed in any communications message, although most messages are short. The length of commands and replies depend on command specifics. This does not include any packet formatting characters.

DATA . . . . 1 to 80 characters of data (see section 5.8 on page 5-17 for data commands).

NOTE: STX characters are not allowed in the data field.

CKSUM . . . . Checksum character for the message

This is the modulo-256 checksum of data bytes only. The checksum can be any valid 8 bit decimal, from 0 (hexadecimal 00) through 255 (hexadecimal FF) depending on the data field contents. If this does not match the actual checksum of the data. STM-2XM will not respond to the command.

5.5.2 Sycon Multi-Drop Protocol (SMDP)

SMDP is a byte-packet, binary protocol. All eight bits of the data of a byte/character are used. Standard asynchronous serial conventions apply. The link must be configured for one start bit, eight data bits, and one or more stop bits. The logic polarity and bit order adopt the standard used for asynchronous serial communications (refer to section 5.3.1). A packet begins with STX (ASCII 0x02) and ends with CR (carriage return, 0x0D).

The SMDP specification provides several common, mandated command codes. STM-2XM responds to these common messages. For example, the reset command will cause STM-2XM to reboot, as though power was cycled. This will set STM-2XM into a known state. Another common command queries the product type or ID. This command (0x30) will return an ASCII integer code that identifies the product type (see section 5.5.2.1.2 on page 5-10). This allows a master computer to poll a network and locate devices by their types and ensure that the proper connection and commands are used for the appropriate product.

NOTE: Each field in angle brackets (< >) is a byte, and is not optional. Fields in regular brackets ([ ]) are optional. Ellipses (...) mean one or more of the previous.

5.5.2.1 Command Format

```
<STX><ADDR><CMD_RSP>[<DATA>...]<CKSUM1><CKSUM2><CR>
```

STX . . . . Start of text character (hexadecimal 02)

Multiple STX characters in a row are allowed. Data between STX characters is ignored. A single STX character initializes the receiver to receive a new message, purging any data collected since the last STX character or carriage return received.

ADDR . . . . One byte address field

The address (ADDR) byte identifies the SMDP address (refer to section 3.2.1.2 on page 3-11) in order to select which device the command/query is sent to.

NOTE: RS-485 communication limits the number of attached devices to 32. Each connected instrument must be assigned a unique address. The slave reply repeats the address when it replies to the master, verifying the address of the instrument receiving the command.

The range of values are 10 hexadecimal to FE hexadecimal (16 to 254 decimal).

Address FF hexadecimal is reserved. It is used as an extension to indicate another byte of address information follows for products that have an address range higher than an address of FE hexadecimal.

CMD_RSP . . . . Command/Response field

When a command is sent from master to slave, the RSPF bit is zero and the RSP field (3 bits) is zero.

When a command is received from a slave to a master, CMD bits are the same as in the message that was sent (see section 5.5.2.1.2), but the RSP2 through RSP0 field will be non-zero (indicating actual unit response status) (see section 5.5.2.1.3). The slave will set or clear the RSPF flag bit in the reply CMD_RSP frame to indicate an unacknowledged slave reset. This bit only has meaning when a command is going from slave to master. If this bit is 1, the slave has been reset since the last AckPF, acknowledge power fail, flag command was received (see Table 5-1).

Table 5-1 Command/Response

D7	D6	D5	D4	D3	D2	D1	D0
CMD3	CMD2	CMD1	CMD0	RSPF	RSP2	RSP1	RSP0

DATA . . . . Optional data

STX and carriage return characters are not allowed in the data field.

To send a data byte valued as hexadecimal 02, send the protocol escape character (hexadecimal 07) followed by zero (hexadecimal 30).

To send a data byte valued at hexadecimal 0D, send the protocol escape character (hexadecimal 07) followed by one (hexadecimal 31).

To send a data value of hexadecimal 07, send the protocol escape character followed by two (hexadecimal 32).

The protocol escape character cannot be sent as a single byte, but can only be sent as the first byte of a pair, followed by an ASCII 0, 1, or 2.

If the protocol escape character is seen but is not followed by an ASCII 0, 1, or 2, the command is invalid and is ignored.

CKSUM1,2 . . . . Checksum characters for the message

This is the mod-256 checksum of the command binary message data. The checksum does not include STX and carriage return, and it is calculated before escape character byte stuffing (see section 5.5.2.1.1).

5.5.2.1.1 Checksum

- Compute the mod 256 checksum of ADDR, CMD_RSP and DATA fields, before byte stuffing with escape characters. This is the logical content (payload) of the command.
- CKSUM1 is the upper (most significant) four bits of the checksum (read as a nibble, 0 through 15, or right justified) plus hexadecimal 30 (ASCII zero). This yields an ASCII character from zero (hexadecimal 30) to ? (hexadecimal 3f).
- CKSUM2 is the lower (least significant) four bits of the checksum plus hexadecimal 30 (ASCII zero). This yields an ASCII character from zero (hexadecimal 30) to ? (hexadecimal 3f).

NOTE: If the checksum of the command is invalid (in form or value), the packet is deemed invalid and will be ignored.

CAUTION

Invalid commands (bad checksum, too short, corrupt data, bad escape sequences) will be ignored by slaves (and masters). No response will be sent by the slave.

5.5.2.1.2 Command Packet Format

```
<STX><ADDR><CMD_RSP>[<DATA>...]<CKSUM1><CKSUM2><CR>
```

Where <CMD> is:

1	**BOOT_API**	Prefix for commands exclusively used to communicate with a sandal-loader/bootloader parser running on a target platform. Non-bootloader applications will consider this to be invalid (Err_Inv_Cmd). Bootloader parser agent will initially only respond to this command prefix, and will be unresponsive (return no reply) to any others. Once accessed through this API, bootloader parser can be commanded to open up to other CMD code values.
2	**Reserved**	Reserved for future use in protocol stack.
3	**Prod_id**	Product identifier, returned as decimal string. **NOTE:** The value for STM-2XM is 18 decimal.
4	**Version**	Request slave to return software version string.
5	**Reset**	Request slave to reset/reboot.
6	**AckPF**	Request slave to acknowledge power failure flag and clear RSPF bit.
7	**PROTV**	Request slave to return protocol stack version as decimal string.
8	**Product_Specific**	Application API prefix to precede STM-2XM commands (see section 5.8 on page 5-17).

NOTE: SMDP will respond to commands in the range of 1 through 7. Commands 2 through 7 are handled in the protocol, at the protocol layer. Applications are not to use commands 2 through 7 except to implement the protocol specification.

5.5.2.1.3 Response Packet Format

```
<STX><ADDR><CMD_RSP>[<DATA>...]<CKSUM1><CKSUM2><CR>
```

NOTE: In the CMD_RSP byte, the CMD bits are unchanged from the master, but the RSP bits are filled in according to the status of the slave.

Where <RSP> is:

1	**OK**	Command understood and executed.
2	**Err_Inv_cmd**	Illegal command (CMD code not valid).
3	**Err_syntax**	Syntax error (too many bytes in data field, not enough bytes).
4	**Err_range**	Data range error.
5	**Err_inh**	Inhibited.
6	**Err_obso**	Obsolete command. No action taken.

5.5.3 Optional Serial Command Mode

SMDP (version 3 and greater) allows for a serial number in the command to associate a command from the master with the correct response. This detects errors in serial communications ports where commands are queued and sent out of order. The protocol structure is nearly identical to section 5.5.2, Sycon Multi-Drop Protocol (SMDP), on page 5-6, except:

- A serial number byte must be placed before the checksum bytes. This must be a value greater than or equal to 0x10 (16), otherwise it could be mistaken as a framing or escape character byte (see section 5.5.3.1). This byte is summed as a part of the packet payload in computing the packet checksum value.
- The checksum character base must be hexadecimal 40 (@), instead of hexadecimal 30 (0) to inform the slave that it is receiving a packet with the extra SRLNO field postamble. This makes the last two characters of the command (the checksums) range from @ (0x40) through the letter, O (0x4f).
- For a response, the slave places the corresponding SRLNO byte into its response packet just before the two reply packet checksum characters, also 0x40 based.

In order for this serial command mode to be effective, the master should generate a new SRLNO value for each command that it sends (modulo 255, and greater than 0x10). This allows for 240 unique serial number values before repeating. The value could be an incrementing tag that rolls over from 255 to 16 with the understanding that there would never be 240 outstanding messages. Alternatively, the tag could have a unique value or range of values for each line of communication to the product at a specific address. This will allow the responses to be received by the proper line of communication.

NOTE: When an SMDP response packet is received by the master, verify the SRLNO value and use it to associate it with the source of the command/query. This will prevent out-of-sequence replies from being misinterpreted and invalid results being generated.

5.5.3.1 Optional Serial Command Format

```
<STX><ADDR><CMD_RSP>[<DATA>...]<SRLNO><ACKSM1><ACKSM2><CR>
```

SRLNO. . . . . Serial Number

Associates a command from the master with the correct response. The value must be greater than or equal to 0x10 (16) in order to not be mistaken as a framing or escape character byte.

ACKSM1, 2 . . . . Alternate 0x40 based checksum characters

This has a range of values from @ (0x40) through the letter, O (0x4f).

NOTE: Refer to section 5.5.2.1 on page 5-6 for additional information identifying the bytes in this command string.

5.5.3.2 Additional Option to Serial Command

Opcode 0x10 BOOT_API is a reserved SMDP opcode. This divides the communication response of STM-2XM into two sections, bootloader and application. A platform that is in the bootloader operational mode will only respond to BOOT_API opcode commands, and will ignore all others making the instrument invisible to standard communications interrogations.

Opcode 0x10 BOOT_API hides platforms waiting in bootloader mode from general network polls and interrogations. Special bootloader aware host code must use the BOOT_API hooks to open the platform and make it suitable for erasing and downloading new applications code, scanning for existing applications, and launching existing applications.

5.6 Communication Library

SMDP control is an ActiveX library that implements SMDP.

SMDP is built as an out-of-process server, and automatically manages multiple sessions with multiple programs. All programs that use SMDP control can share the communication link without interference or crosstalk. It is possible to have multiple programs communicating with the same instrument, transparent to the user.

Using SMDP control is a standard ActiveX control for Windows computers.

NOTE: Since all programming environments have different ways to integrate ActiveX controls, linking to the control will not be covered.

Most programming environments can use ActiveX controls (i.e., Delphi, Visual Studio (vb,vc++, etc), LabVIEW, and many others). SMDP_SVR is the name of the ActiveX control library for all programming environments.

An instance of the control should be initiated for each instrument being controlled and communicated with remotely, the parameters set accordingly, and DoTransaction called to do the communications.

SMDP control handles multiple instances on the same communications port and multiple instances for the same instrument.

5.6.1 Methods

Open . . . . (file name)

Attempts to acquire communications port and allocate resources. Open does not need to be called; if the port was not opened it will automatically be opened when the DoTransaction function is called.

DoTransaction . . . . (addr, SmdpCmd, Msg, Rsp, resetflag)

Initiates communication with STM-2XM, and waits for a reply (or timeout) before returning.

- In: addr is the SMDP address of target instrument.
- In: SmdpCmd is the SMDP command opcode enumeration constant. The value to use is based on the CMD_RSP most significant nibble value, less one. For example, a hexadecimal 60 AckPF command will pass a value of 5 as the SmdpCmd code.

NOTE: All command codes for DoTransaction SmdpCmd argument are one less than the CMD3 to CMD0 bit field used in the SMDP packet (refer to Table 5-1 on page 5-7).

- In: Msg is the message to send, may be a string or byte array.
- Out: Rsp is string response from instrument.
- Out: Boolean resetflag is true if instrument has been reset since the flag was acknowledged last.

Close() . . . . Clears resources associated with the instance. Will also close the communications port if there are no instances communicating on the port.

NOTE: In most cases it is not necessary to call this function. The programming environment will unload the control when it is finished, and the control automatically closes the resources when it is unloaded.

5.6.2 Communication Properties

ComPortNo . . . . The communications port to use for communication to STM-2XM.

Baud . . . . The baud rate. Valid baud rates are 9600, 38400, or 115200 baud.

Protocol. . . . . The protocol to use (1 - Sycon or 0 - SMDP).

NOTE: The value of 0 is used to select SMDP and the value of 1 is used to select Sycon protocol to interface to an open serial channel connection.

DoPacketStamp . . . . Set true to use SMDP-II protocol.

NOTE: This should always be true.

TimeoutMS . . . . Sets the number of milliseconds to wait for the instrument to respond before the control displays a timeout error during DoTransaction(). The valid range is 150 to 20000 milliseconds.

LastTimeTransSec . . . . The amount of time the last DoTransaction() call took to complete, in floating point (real) seconds. Typical values are in the range of 0.002 to 0.014 seconds.

NOTE: Some behaviors take longer to execute.

5.6.3 Other Properties

Numinstances. . . . . The number of instances of the control or number of users on the communication server.

Build . . . . The build number of the control (unique version identifier).

These properties are read only and return the same value across all instances.

5.7 Windows/SMDP Server Implementation

SMDP server on Windows message timeout is typically 150 milliseconds. That is, after the host sends a command, it waits 150 milliseconds for a reply. If no complete reply is returned from STM-2XM in that time, the message is considered lost. This could indicate the following:

- STM-2XM is offline
- The cable is disconnected
- The baud rate is invalid/mismatched
- There is noise corrupting the packet/checksum integrity

After 150 milliseconds have elapsed, the host can try again.

NOTE: Once a valid connection to STM-2XM is made, the command/response exchange will proceed at the fastest speed, sending a new command as soon as the prior answer has come back to the host.

If there is a loss of a packet due to noise, software error, or power loss to STM-2XM, the loss will be detected when a valid reply packet is not returned within the 150 millisecond timeout.

Retries or resending commands can continue to take place until a valid reply is returned once the 150 millisecond timeout has been reached.

5.8 Communications Commands

STM-2XM uses command prefix 0x80 to introduce command sequences. The data payload that follows 0x80 are standard ASCII character sequences. This vocabulary is documented in section 5.5.2.1, Command Format, on page 5-6.

Common commands have the same initial character sequences, and are distinguished by variable numeric arguments which further specify the intended action or target of the command/query.

Therefore, only the data payload content which distinguishes these commands are found in this section.

All responses conform to the SMDP specification (refer to section 5.5.2 on page 5-6) with the lower four bits of the returned <CMD_RSP> byte being a non-zero value in the range of 1 to 15. The upper 4 bits are the same as the host command group (CmdOpcode_xxx), 3 to 8. The lower three bits have the value 1 to 7 as defined in section 5.5.2.1.3 on page 5-11. This value indicates whether the receiver could process the query or found fault with it. If the address is not matched with a slave, the checksum of the frame fails, or the command is otherwise improper, no response is returned by the slave.

The fourth bit (D3, 8 weight) is a power fail flag bit, and the slave replies with this bit set when the platform has been reset, until such a time as the master sends one of the following:

- Acknowledge-power-fail command (CmdOpcode_ACKPF 0x60), low level SMDP message
- USRAPI_ackPfail (?) command, application specific command (0x80)

The message from the master clears the power fail flag such that the status bit, D3, of all subsequent replies is now zero. This allows the master to detect at the earliest transaction (first valid communications after reboot/reset) that the slave device has been reset and needs to be re-synchronized. This might be considered a fatal error (power supply was reset and system state harmed), a soft error which can be recovered from, or a non-issue requiring no intervention.

5.8.1 Command: ?

Command Type . . . . Acknowledge

Syntax . . . . ?

Description . . . . Clears the power fail status flag.

Command Structure . . . . USRAPI_ackPfail

5.8.2 Command: @

Command Type . . . . Query

Syntax . . . . @

Description . . . . Queries the version.

Reply Example X2MA1.3

Syntax . . . . @1

Description . . . . Display FRAM database covenant code.

Reply Example . . . . 1P6 (value dependent on firmware version)

Syntax . . . . @2

Description . . . . Reboot via watchdog.

Command Structure . . . . USRAPI_atQuery (can be followed by a 1 or 2 modifier character or entered by itself)

5.8.3 Command: C

Command Type . . . . Query

Syntax . . . . CID,inx

Description . . . . Query decimal IDHash/Index to allow ASCII string rather than binary packet. ID number is a Hash index used to identify data items (see Table 5-2). The index is typically 0.

Sent Example C5555,0

Reply Example 18

Command Structure . . . . USRAPI_RD_IEC_C

Table 5-2 Common hash values and the queried result

Number	Name	Description	Response
5555	PROD_ID	Standard product identifier	18
6857	CRC Result	16 bit CRC signature of the STM-2XM flash memory, used to verify that the proper code has been installed at the factory. The particular value for a combination of a particular version of bootloader and application image is documented in a database registry used for manufacturing support. This value is read only.	CRC checksum of the CPU flash memory, with 65536 added to it 65536 to 131071
11021	CODE_SUM	The code checksum from bootloader prefix block. This sum details the specific version of the application code that is installed into the flash memory. By comparing this value with a list of known software releases, the specific version can be determined. This value is algorithmically generated based on the actual code pattern, so it will change with any firmware change, even if the embedded version reply string was not updated. This value is read only.	
36581	PROD_BTYPE	Product build type, copied into dictionary from FRAM configuration block. This value defines the hardware platform revision and/or configuration. This value is read only.	0 Indicates that the FRAM memory has lost the information 1 to 65535
53184	PROD_SRNO	The internal product serial number assigned to the motherboard in manufacturing. This value is read only.	Returns an integer numeric value A value of 0 indicates a FRAM memory failure

5.8.4 Command: E/F

Command Type . . . . Query

Command Structure . . . . CSID_class Pid SYSTEM GROUP

Syntax . . . . En

Description . . . . Queries System Settings and Setup parameters.

Command Type . . . . Update

Syntax . . . . Fn=value

Description . . . . Updates System Settings and Setup parameters.

Parameters. (See Table 5-3.)

Table 5-3 E/F command

#	Command Structure	Comments	Values
1	CSID_SUP_SNSR	Sensor has largest effect. It should be written first to set top level.	#sensors:#shutters 0 - 1:0 - Single Open 1 - 1:1 - Single w/Shutter 2 - 2:1 - Dual 1 Shutter 3 - 2:0 - Dual Open 4 - 2:2 - Dual 2 Shutter
2	CSID_SUP_TOOLX1S1	Crystal 1 tooling versus source/substrate on Channel 1	Tooling 10.0 to 999.9% Default 100.0
3	CSID_SUP_TOOLX2S1	Crystal 2 tooling versus source/substrate on Channel 1	Tooling 10.0 to 999.9% Default 100.0
4	CSID_SUP_TOOLX1S2	Crystal 1 tooling versus source/substrate on Channel 2	Tooling 10.0 to 999.9% Default 100.0
5	CSID_SUP_TOOLX2S2	Crystal 2 tooling versus source/substrate on Channel 2	Tooling 10.0 to 999.9% Default 100.0
6	CSID_SUP_WHTRATIO	Relative weight ratio of Channel 2 to Channel 1 (averaging only) **NOTE:** Available when dual open sensors mode is selected.	Weight Ratio 0 to 100% Default 50%

Table 5-3 E/F command (continued)

#	Command Structure	Comments	Values
7	CSID_SUP_SHTR	Substrate shutter setup supshtr_class 0-4	0 - None 1 - Channel 1 2 - Channel 2 3 - Shared 4 - Dual
8	CSID_SUP_ANLGMD	Analog mode (mass/thick) sysdisp_class	0 - Thickness (Å) 1 - Mass (µgcm)
9	CSID_SUP_ALOG1	Analog function 1 anout_class value: DACINX_one_A offset access	Value 0 to 27 (see section 5.8.4.1 on page 5-25)
10	CSID_SUP_ALOG2	Analog function 2 anout_class value: DACINX_two_B offset access	Value 0 to 27 (see section 5.8.4.1 on page 5-25)
11	CSID_SUP_ALOG3	Analog function 3 anout_class value: DACINX_three_C offset access	Value 0 to 27 (see section 5.8.4.1 on page 5-25)
12	CSID_SUP_ALOG4	Analog function 4 anout_class value: DACINX_four_D offset access	Value 0 to 27 (see section 5.8.4.1 on page 5-25)
13	CSID_SUP_RLY1P1	Relay 1 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
14	CSID_SUP_RLY1P2	Relay 2 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
15	CSID_SUP_RLY1P3	Relay 3 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
16	CSID_SUP_RLY1P4	Relay 4 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
17	CSID_SUP_RLY2P1	Relay 5 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
18	CSID_SUP_RLY2P2	Relay 6 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
19	CSID_SUP_RLY2P3	Relay 7 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)
20	CSID_SUP_RLY2P4	Relay 8 function	Value 0 to 20 (see section 5.8.4.2 on page 5-27)

Table 5-3 E/F command (continued)

#	Command Structure	Comments	Values
21	CSID_SUP_INP1P1	Input function Channel 1 #1	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
22	CSID_SUP_INP1P2	Input function Channel 1 #2	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
23	CSID_SUP_INP1P3	Input function Channel 1 #3	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
24	CSID_SUP_INP1P4	Input function Channel 1 #4	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
25	CSID_SUP_INP2P1	Input function Channel 2 #1	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
26	CSID_SUP_INP2P2	Input function Channel 2 #2	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
27	CSID_SUP_INP2P3	Input function Channel 2 #3	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
28	CSID_SUP_INP2P4	Input function Channel 2 #4	Value 0 to 7 (see section 5.8.4.3 on page 5-28)
29	CSID_SYSMODE	Operational mode sysmode_class	0 - sysmode_simplex1 1 - sysmode_simplex2 2 - sysmode_backup 3 - sysmode_average 4 - sysmode_alloy 5 - sysmode_independent **NOTE:** Not all values are available. Available values are dependent on the value stored in the CSID_SUP_SNSR parameter. An invalid value returns an error. Invalid values may be made available by selecting another value for CSID_SUP_SNSR than the value currently programmed.

Table 5-3 E/F command (continued)

#	Command Structure	Comments	Values
30	CSID_SYSTESTMODE	System test mode Simulates a rate based on source shutter opening. Is cleared to False/TestOff every time a new reset/powerup.	0 - False/TestOff 1 - True/TestOn
31	CSID_SYSASRC	Active source (channel) Not meaningful in dual channel modes, such as Independent and Alloy.	0 - Channel 1 1 - Channel 2
32	CSID_SYSDISP	Display mode (thick/mass) sysdisp_class Effects numeric display and chart plot data.	0 - Thickness 1 - Mass
33	CSID_SYSPLOT	Plot type, plot_class	0 - plot_none No plot, plot disabled 1 - plot_rdev Rate Deviation, Measured - desired 2 - plot_rate Rate, measured rate in plot units 3 - plot_thick Thickness, autoscaled
34	CSID_SYSPLOTHSCL	Plot horizontal scale time type h:mm:ss	Value 0:00:00 to 9:59:59, used in intervals rounded up to nearest 5 seconds modulo For example, 0:0:0 to 0:0:5 acts like 5 seconds. 0:00:06 to 0:00:10 acts like 10 seconds.
35	CSID_SYSLCDCT	LCD contrast	Value 10 to 85 sets contrast voltage, defaults to 70
36	CSID_SYSLCDBT	LCD brightness	Value 1 to 99 sets backlight brightness in % of full, default 50

Table 5-3 E/F command (continued)

#	Command Structure	Comments	Values
37	CSID_SYSBEEP	Beeper ON/OFF	0 - False/BeepOff 1 - True/BeepOn Defaults off
38	CSID_SYSPROT	Protocol sysprot_class	0 - sysprot_SMDPH SMDP PROTOCOL @ 115,200 BAUD 1 - sysprot_SMDPM SMDP PROTOCOL @ 38,400 BAUD 2 - sysprot_SMDPL SMDP PROTOCOL @ 9600 BAUD 3 - sysprot_sycon SYCON PROTOCOL @ 9600 BAUD
39	CSID_SYSSMDPADR	SMDP Address	Value 16 to 254 16 defines RS-232 point-to-point, 17 to 254 give RS-485 multidrop network physical interface at addresses 17 to 254. **NOTE:** Not used in Sycon protocol.

5.8.4.1 Analog Output Function

anout_none 0
Zero volts

anout_pos. 1
Positive full scale

anout_neg 2
Negative full scale

anout_remote 3
Computer controlled

anout_rdev1K 4
Rate deviation, Channel 1, 1 kÅ/s or 10.00 µg full scale

anout_rdev1T 5
Rate deviation, Channel 1, 10 Å/s or 0.10 µg full scale

anout_rate1K 6
Rate, Channel 1, 1 kÅ/s or 10.00 µg full scale

anout_rate1T 7
Rate, Channel 1, 10 Å/s or 0.10 µg full scale

anout_thick1 8
Thickness or mass plot (modal), Channel 1, sawtooth mode 0 to 999 Å or 0 to 9.99 µg/cm²

anout_thick1M 9
Thickness or mass plot (modal), Channel 1 magnified, sawtooth mode 0 to 99.9 Å or 0 to 0.999 µg/cm²

anout_rdev2K 10
Rate deviation, Channel 2, 1 kÅ/s or 10.00 µg full scale

anout_rdev2T 11
Rate deviation, Channel 2, 10 Å/s or 0.10 µg full scale

anout_rate2K 12
Rate, Channel 2, 1 kÅ/s or 10.00 µg full scale

anout_rate2T 13
Rate, Channel 2, 10 Å/s or 0.10 µg full scale

anout_thick2. 14
Thickness or mass plot(modal), Channel 2, sawtooth mode 0 to 999 Å or 0 to 9.99 µg/cm²

anout_thick2M 15
Thickness or mass plot(modal), Channel 2 magnified, sawtooth mode 0 to 99.9 Å or 0 to 0.999 µg/cm²

anoutCom_rate1_5C 16
Rate, Channel 1, 500 Å/s, 5.00 µg full scale

anoutCom_rate1_2C 17
Rate, Channel 1, 200 Å/s, 2.00 µg full scale

anoutCom_rate1_1C 18
Rate, Channel 1, 100 Å/s, 1.00 µg full scale

anoutCom_rate1_5X 19
Rate, Channel 1, 50 Å/s, 0.50 µg full scale

anoutCom_rate1_2X 20
Rate, Channel 1, 20 Å/s, 0.20 µg full scale

anoutCom_rate2_5C 21
Rate, Channel 2, 500 Å/s, 5.00 µg full scale

anoutCom_rate2_2C 22
Rate, Channel 2, 200 Å/s, 2.00 µg full scale

anoutCom_rate2_1C 23
Rate, Channel 2, 100 Å/s, 1.00 µg full scale

anoutCom_rate2_5X 24
Rate, Channel 2, 50 Å/s, 0.50 µg full scale

anoutCom_rate2_2X 25
Rate, Channel 2, 20 Å/s, 0.20 µg full scale

anoutCom_rdev1_1C. 26
Rate deviation, Channel 1, 100 Å/s, 1.00 µg

anoutCom_rdev2_1C. 27
Rate deviation, Channel 2, 100 Å/s, 1.00 µg

5.8.4.2 Relay Functions

suprlyfn_none. 0
Relay always off

suprlyfn_onhard 1
Relay always on

suprlyfn_remote 2
Computer controlled

suprlyfn_fpkeys1. 3
Front panel Channel 1

suprlyfn_fpkeys2. 4
Front panel Channel 2

suprlyfn_srcshut1 5
Source shutter Channel 1

suprlyfn_srcshut2 6
Source shutter Channel 2

suprlyfn_substshut1 7
Substrate shutter Channel 1

suprlyfn_substshut2 8
Substrate shutter Channel 2

suprlyfn_XTL1shut 9
Operates sensor shutter when Sensor 1 is active

suprlyfn_XTL2shut 10
Operates sensor shutter when Sensor 2 is active

suprlyfn_xfail1 11
Operates when Sensor 1 is in state other than XtlStat_OK/XtlStat_OFF

suprlyfn_xfail2 12
Operates when Sensor 2 is in state other than XtlStat_OK/XtlStat_OFF

suprlyfn_setpt_time1 13
Channel 1 timer triggered

suprlyfn_setpt_time2 14
Channel 2 timer triggered

suprlyfn_setpt_thick1 15
Channel 1 setpoint thickness triggered

suprlyfn_setpt_thick2 16
Channel 2 setpoint thickness triggered

suprlyfn_good_rate1 17
Channel 1 rate within bounds

suprlyfn_good_rate2 18
Channel 2 rate within bounds

suprlyfn_XTL1shutNot 19
Operates sensor shutter when Sensor 1 is not active when using backup A/B shutter arrangement or when air/bellows/A/B choice is backwards

suprlyfn_XTL2shutNot 20
Operates sensor shutter when Sensor 2 is not active when using backup A/B shutter arrangement or when air/bellows/A/B choice is backwards

5.8.4.3 Input Functions

supinpfn_none 0
Ignore the input

supinpfn_zerotk 1
Zero the thickness

supinpfn_open 2
Open specific to a channel

supinpfn_close 3
Close specific to a channel

supinpfn_xtalsel 4
Select crystal as active, backup mode only

supinpfn_fnlthktrg. 5
Trigger final thick per Input channel

supinpfn_fnlthktrgAll. 6
Trigger final thick to both channels

supinpfn_alloy 7
Allow sync, channel non-specific

5.8.5 Command: G/H

Command Type . . . . Query

Command Structure . . . . GCCchannelID_class Pid CHANNEL GROUP

Syntax. . . . . G1,channel index 0/1

Description . . . . Queries active film of Channel X as index 0/1

Command Type . . . . Update

Command Structure . . . . CCHID_AFILM(1)

Syntax. . . . . H1,channel index 0/1=value

Description . . . . Updates active film

Response . . . . Active film for Channel X, value returned is 1 to 15 for Films 1 to 15. Same used to store Syntax G1,0/1 H1,0/1=1 to 15

5.8.6 Command: I/J

Command Type . . . . Query

Command Structure . . . . CFID_class Pid FILM GROUP

Syntax. . . . . IF,n

Description . . . . Queries Film parameters, where F is film number 1 to 15 and n is parameter 1 to 21

Command Type . . . . Update

Syntax. . . . . JF,n=value

Parameters. (See Table 5-4.)

Table 5-4 I/J command

#	Command Structure	Name	Comment	Default
1	CFID_FILMNAM	Name	Value string of eight characters from set {A-Z0-9_ }. Leading spaces are significant. Trailing spaces are eliminated. In film lists, names are displayed right justified, with the rightmost non-space character displayed right most. In SET ACTIVE FILM list, they are displayed left justified, with entirely empty string displayed as "- NO NAME -". Via RS-232 or Screen editor, all valid strings can be entered and displayed.	_NO NAME for all 15 films
2	CFID_FILMDENS	Density	Range 0.40 to 99.99 g/cm^3	1.00
3	CFID_FILMZRAT	Z-Ratio	Range 0.100 to 9.999	1.000
4	CFID_FILMTOOL	Tooling	Range 10.0 to 999.9%	100.0
5	CFID_FILMSETMAS	Setpoint Mass	Range 0.00 to 9999.99 µg	0.00
6	CFID_FILMSETTHK	Setpoint Thickness	Range 0.000 to 999.999 kÅ	0.000
7	CFID_FILMENDMAS	End Mass	Range 0.00 to 9999.99 µg	0.000
8	CFID_FILMENDTHK	End Thickness	Range 0.000 to 999.999 kÅ	0.000
9	CFID_FILMUBX	Use backup crystal	0 - False/No 1 - True/Yes	No
10	CFID_FILMSETPTM	Setpoint Time	Range 0:00:00 to 9:59:59 h:mm:ss	0:00:00
11	CFID_FILMRATEM	Deposit rate in µg/cm^{2}s	Range 0.00 to 99.99 µg/cm^{2}s	0.00
12	CFID_FILMRATET	Deposit rate in Å/s	Range 0.0 to 999.9 Å/s	0.0
13	CFID_FILMSDLY	Shutter delay mode	0 - False/No 1 - True/Yes	No
14	CFID_FILMSPLMOD	Rate sampling mode	0 - False/No 1 - True/Yes	No

Table 5-4 I/J command (continued)

#	Command Structure	Name	Comment	Default
15	CFID_FILMSPLIVL	Rate Sampling interval when Rate Sample On	Range 0:00:00 to 9:59:59 h:mm:ss	0:00:00
16	CFID_FILMSPLDWL	Rate Sampling dwell	Range 0:00:00 to 9:59:59 h:mm:ss	0:00:00
17	CFID_FILMTMPWR	Coast - Time/Power enable	0 - False/No 1 - True/Yes	No
18	CFID_FILMXLMIN	Crystal life minimum	Range 0 to 99%	0
19	CFID_FILMFORCEF	Force fail if crystal life < min	0 - False/No 1 - True/Yes	No
20	CFID_FILMAVGSMP	Temporal averaging # samples filter depth	Range 1 to 50	1
21	CFID_FILMGOODRATETOL	Good Rate Tolerance percent value	Range 0 to 50%	0

5.8.7 Command: K/L

Command Type . . . . Query

Syntax . . . . Kn

Description . . . . Queries the state of relays in Remote mode, where n is Relay ID 1 to 8

Command Type . . . . Update

Syntax . . . . Ln=S

Description . . . . Updates the state of relays that are in Remote mode, where n is Relay ID 1 to 8 and S is state 0 or 1 (False or True, respectively)

NOTE: If a relay is not set to Remote mode, the value set or returned has no effect on the hardware. The last value sent will be used and the hardware state of the relay associated with it will change if the relay becomes Remote after power up.

5.8.8 Command: M/N

Command Type . . . . Query

Syntax . . . . Mn

Description . . . . Queries the voltage of analog outputs set to Remote mode, where n is analog channel 1 to 4

Command Type . . . . Update

Syntax . . . . Nn=value

Description . . . . Updates the voltage of analog outputs set to Remote mode, where n is analog channel 1 to 4 and value ranges from -10000 to 10000 mV

NOTE: If an output is not set to Remote mode, the value set or returned has no effect on the hardware. The last value sent will be used and the hardware state of the analog output associated with it will change if the output becomes Remote after power up. The range of values can be expressed to mV resolution, but STM-2XM will output analog values to the nearest 10 mV.

5.8.9 Command: O

Command Type . . . . Remote

Command Structure . . . . CEVNTID_class Eid EVENT GROUP command

Syntax. . . . . On

Description . . . . Zeroes thickness, opens or closes a shutter, selects a sensor if in backup mode, and forces a final thickness. This command corresponds with the remote actions using the front panel buttons, where n is 1 to 13.

Parameters. (See Table 5-5.)

Table 5-5 O command

#	Command Structure	Description
1	CEVNTID_AckMemLoss	Ack memory loss state if present
2	CEVNTID_RCzeroch1	Zero Channel 1 thickness
3	CEVNTID_RCzeroch2	Zero Channel 2 thickness
4	CEVNTID_RCGoOpen1	Open Channel 1 shutter function
5	CEVNTID_RCGoOpen2	Open Channel 2 shutter function
6	CEVNTID_RCGoClosed1	Close Channel 1 shutter function
7	CEVNTID_RCGoClosed2	Close Channel 2 shutter function
8	CEVNTID_RCSelectXtl1	Select Sensor 1 in backup mode
9	CEVNTID_RCSelectXtl2	Select Sensor 2 in backup mode
10	CENVTID_RCFnlThkTrgr1	Force final thickness event Channel 1
11	CENVTID_RCFnlThkTrgr2	Force final thickness event Channel 2
12	CENVTID_RCFnlThkTrgrDual	Force final thickness in both channels
13	CEVNTID_RCGoAlloy	Allow sync, channel non-specific (Alloy mode)
14	CEVNTID_UIFEvnt	User interface event Reset User Display Dim down timeout Illuminate display as though a button was pressed or the spin knob was rotated

5.8.10 Command: P

Command Type . . . . Status

Command Structure . . . . QMONAD_class ItemID

Syntax . . . . Pn

Description . . . . Displays status information for STM-2XM, where n is 1 to 14.

Parameters. (See Table 5-6.)

Table 5-6 P command

#	Command Structure	Description
1	QMONAD_STRCOVEN	String return 1PN
2	QMONAD_BADNV	Readable boolean as 0/1 memloss sticky
3	QMONAD_SYST_ID	TRAP IDENT major # displays as numeric
4	QMONAD_SYST_MOD	TRAP TYPE minor # displays as numeric
5	QMONAD_CODSIG	Displays as numeric 0 to 65535 16 bit CRC
6	QMONAD_INPSTATES	Displays as numeric 0 to 255 as bit vector LSB 1 weight in input 1, MSB 128 is input 8
7	QMONAD_OUTSTATES	Displays as numeric 0 to 255 as bit vector LSB 1 weight in output 1, MSB 128 output 8
8	QMONAD_	Numeric value of AlloyState_class Value 0 to 12 (see section 5.8.10.1)
9	QMONAD_ASNSR	Numeric value of Active sensor 0/1/2 0 - Channel 1 1 - Channel 2 2 - BOTH/DUAL
10	QMONAD_INTSRLNO	Internal serial number as fetched from FRAM 0 if unknown
11	QMONAD_BUILDTYP	Build type from FRAM, harvested at power up 0 if FRAM bad

Table 5-6 P command

#	Command Structure	Description
12	QMONAD_CPLDVRSN	Numeric code 0 to 255, CPLD I.P. cpld_rev version identification field
13	QMONAD_WARNVALUE	WARNVALUE is an internal warning system code, 0 to 255 . 0 is no warning. 128 is test warning posted with test combination lock code (RLRL R2 L R2 L R2). 250 means firmware mismatched/invalid with hardware in use, or circuit failure, or both.
14	QMONAD_HW_CFG	HW_CFG 0 to 15 value based on H/W platform

5.8.10.1 Alloy State Class

AlloyState_BOGU. 0
Unset, invalid value at startup

AlloyState_INACTIVE. 1
Not alloying system mode, not a possibility

AlloyState_XTALBADA. 2
Non-depositing, only Channel 1 crystal bad

AlloyState_XTALMNLA 3
Non-depositing, Channel 1 crystal was bad, a manual override on Channel 1 only

AlloyState_XTALBADB 4
Non-depositing, only Channel 2 crystal bad

AlloyState_XTALMNLB. 5
Non-depositing, Channel 2 crystal was bad, a manual override on Channel 2 only

AlloyState_XTALBAD2 6
Non-depositing, both Channel 1 and 2 crystal bad

AlloyState_XTALMNL2. 7
Non-depositing, both Channel 1 and 2 crystals were bad, manual overrides on both

NOTE: Above have/had a bad crystal and/or did a manual override, processing cannot start up until goes to idle.

AlloyState_IDLE 8
Non-depositing no manual overrides, both crystals good at present

AlloyState_SDA 9
Shutter delay A, Channel 1 started and waiting on 2

AlloyState_SDB 10
Shutter delay B, Channel 2 started and waiting on 1

AlloyState_SD2 11
Both channels in shutter delay, waiting for synchronous exit

AlloyState_CODEP. 12
Both channels actively engaged in a codeposition until end thickness, manual shutdowns, crystal fails, or Coast to Time Power

5.8.11 Command: Q

Command Type . . . . Status

Command Structure . . . . QTWIN_class, Indx X

Syntax. . . . . Qn,X

Description . . . . Displays Diagnostic information, where n is 1 to 21 and X is an index with Channel 1 as 0 and Channel 2 as 1

Parameters. (See Table 5-7.)

Table 5-7 Q command

#	Command Structure	Comments	Values
1	QTWIN_CH_T_MASS	Channel total mass	µg
2	QTWIN_CH_T_THIK	Channel total thickness	kÅ
3	QTWIN_XRAWF1	Raw frequencies both channels	Hz
4	QTWIN_XAVGF1	Last known good averaged frequencies	Hz
5	QTWIN_XLIFE	Last known good crystal life	%
6	QTWIN_XRATEM	Last known good mass rate	µg/cm²s
7	QTWIN_XRATET	Last known good thickness rate	Å/s
8	QTWIN_XMASS	Accumulated mass	µg/cm²
9	QTWIN_XTHIK	Accumulated thickness	Å
10	QTWIN_XSTAT	Raw status (XtlStat_class)	Value 0 to 4 (see section 5.8.11.1)
11	QTWIN_XSTAT2	Raw status (XtlStat2_class)	Value 0 to 2 (see section 5.8.11.2 on page 5-39)
12	QTWIN_XACHNL	Channel that Index sensor is assigned to	0 - Channel 1 1 - Channel 2

Table 5-7 Q command (continued)

#	Command Structure	Comments	Values
13	QTWIN_SHTSRC	Source shutters	1 - True Source shutter is open 0 - False Source shutter is closed Channels not being used will return 0. This is the logical state of the process, not the actual I/O relay state.
14	QTWIN_SHTSBS	Substrate shutters	1 - True Substrate shutter is open 0 - False Substrate shutter is closed Channels not being used will return 0. This is the logical state of the process, not the actual I/O relay state.
15	QTWIN_SHTSNS	Sensor shutters	1 - True Sensor shutter is open 0 - False Sensor shutter is closed Channels not being used or coasting during rate sampling will return 0. This is the logical state of the process, not the actual I/O relay state.
16	QTWIN_CH_RATEM	Rate	$\mu g/cm^2s$
17	QTWIN_CH_RATET1	Rate	Å/s
18	QTWIN_CH_C_MASS	Current mass of current film	$\mu g/cm^2s$

Table 5-7 Q command (continued)

#	Command Structure	Comments	Values
19	QTWIN_CH_C_THIK	Current thickness of current film	kÅ
20	QTWIN_CH_STATE	Film state of FilmState_class enumeration	Value 0 to 11 (see section 5.8.11.3)
21	QTWIN_CH_TIME	Film Timer	0:00:00 to 9:59:59 h:mm:ss as timer counts up

5.8.11.1 Raw Status

XtlStat_FLTRINIT . . . . 0 ??? CRYSTAL
Frequency filter is filling

XtlStat_OK . . . . 1 OK CRYSTAL IS GOOD
Averaging filter is full, and rate is meaningful

XtlStat_LOWLIFE . . . . 2 LIFE CRYSTAL
Crystal frequency is in range, but not within bounds

XtlStat_DEAD . . . . 3 BAD CRYSTAL
Crystal frequency is out of range

XtlStat_OFF . . . . 4 OFF CRYSTAL
Crystal is not being used

5.8.11.2 Raw Status 2

XS2_normal 0
Crystal is being used normally

XS2_hold 1
Crystal is in "thick hold" mode, because substrate shutter is closed or the crystal is in use as a backup crystal

XS2_coast 2
Crystal is in coasting mode; rate and thickness values are not live (measurement based) but are incremented/simulated during time power mode

5.8.11.3 Film State

FilmState_BOGU . . . . 0 STARTUP STATE
Does not persist

FilmState_INACT . . . . 1 INACTIVE
This channel is not operational

FilmState_DEAD_TPW . . . . 2 FAIL TPW
Crystal failed/deposit estimated

FilmState_DEAD . . . . 3 X FAIL
Crystal failed

FilmState_MONITOR . . . . 4 READY
Crystal good, shutters closed

FilmState_SHUT_DLY . . . . 5 SHUT DLY
Source open/substrate closed

FilmState_COAST . . . . 6 COAST
Estimating rate/thickness deposition

FilmState_STARE. . . . . 7 DEPOSIT
Actively measuring

FilmState_PEEK. . . . . 8 DEPOSIT

FilmState_HOLD . . . . 9 HOLD

FilmState_STABILIZ. . . . . 10 STABILIZ

FilmState_MANUAL . . . . 11 MANUAL
Force shutters open, crystal failed

5.8.12 Run Screen Lock Codes and Functions

Codes are listed in run length sequences of clicks in right and then left directions. All sequences start with a right turn value after first entering the Runtime screen or pressing CANCEL/BACK while the Runtime screen is displayed to clear the sequence. There are two kinds of codes, those which require test mode on (as a protection) and those which can be performed at any time (omnipresent). Those with (T) in function description require test mode on.

Table 5-8 Run screen lock codes and functions

Name	Function	Combination
test2	(T) Just beep	R L2 R L3 R2 L R L3 R L R L R2 L2 R4 L3
ClrSys_Trap	(T) Clears system trap	R L R L R5 L2
Reboot	(T) Reboots	R4 6 3 5 2 9 7 (Hits on last 3 of 7)
BRAINDEAD	(T) Purges FRAM	R4 L4 R4 L4 R3 L3 R3 L3 R2 L2
LCDNORM	Default LCD	R L R L R3 L2 R3
SETWARN	Sets 128 warning value	R L R L R2 L R2 L R2

5.8.13 Command Examples

5.8.13.1 Query Software Version

<STX><ADDR><CMD_RSP>[<DATA>...]<CKSUM1><CKSUM2><CR>

Hexadecimal example:

<02><10><80><40><3D><30><0D>

Command Type . . . . Query

Hexadecimal 02

Description . . . . STX Frame Start Flag

Hexadecimal 10

Description . . . . Address (16 decimal)

Hexadecimal 80

Description . . . . OpCode_USRAPI value

Hexadecimal 40

Description . . . . @; USRAPI_atQuery

Hexadecimal 3D

Description . . . . Checksum 1

Hexadecimal 30

Description . . . . Checksum 2

Hexadecimal 0D

Description . . . . SMDP Packet Terminator (CR)

NOTE: The address must match the slave device (0x10 for point-to-point, or 0x11 to 0xFE for the RS-485 bus) and the command is then decoded per the 0x80 prefix.

5.8.13.2 Reboot SMDP Device

<STX><ADDR><CMD_RSP>[<DATA>...]<CKSUM1><CKSUM2><CR>

Hexadecimal example:

<02><10><50><36><30><0D>

Command Type . . . . SMDP Low Level Reboot

Hexadecimal. 02

Description . . . . STX Frame Start Flag

Hexadecimal. 10

Description . . . . Address (16 decimal)

Hexadecimal. 50

Description . . . . OpCode__RESET value

Hexadecimal. 36

Description . . . . Checksum 1

Hexadecimal. 30

Description . . . . Checksum 2

Hexadecimal. 0D

Description . . . . SMDP Packet Terminator (CR)

Chapter 6
Troubleshooting

6.1 Troubleshooting Guide

If STM-2XM does not function as expected, or appears to have diminished performance (see Table 6-1). Additional troubleshooting information can be found in the operating manuals for sensors. If the problem cannot be resolved, contact INFICON (refer to section 1.3, How To Contact INFICON, on page 1-5).

CAUTION

There are no user serviceable components within the STM-2XM case.

Refer all maintenance to qualified personnel.

Table 6-1 General troubleshooting

SYMPTOM	CAUSE	REMEDY
Rate, Thickness, and Frequency readings are unstable or incorrect.	Temperature of the crystal is unstable (an AT-cut crystal may drift as much as 10 Hz/°C).	Control the vacuum chamber temperature. Move the crystal farther away from the source (at least 25.4 cm (10 in.) from source). Check sensor water cooling for correct flow and temperature. Refer to the sensor operating manual. Clean or replace the crystal holder. Refer to the sensor operating manual. Use SPC-1157-G10 crystals designed to minimize frequency shifts due to thermal shock.
	Humidity level on the crystal is changing. Moisture being absorbed or exuded from the crystal surface.	Avoid condensation by turning off cooling water to sensor before opening the vacuum chamber to air. Flow water above the dew point of the room through the sensor when the chamber is open.
	Defective in-vacuum cable or coax cables.	Use an ohmmeter to check electrical continuity and isolation.
	Crystal seating on the crystal holder surface is scratched or contaminated.	Clean or replace crystal holder. Refer to the sensor operating manual.
	Excessive cable length between oscillator and crystal causes a self-oscillation condition.	Use no longer than a 78.1 cm (30.75 in.) in-vacuum cable. Use only the 15.2 cm (6 in.) cable between oscillator and feedthrough.

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Crystal fail	Failed or defective crystal, or no crystal in sensor.	Install a new crystal.
	Two crystals were installed or crystal is upside down.	Remove extra crystal. Reverse crystal orientation. Inspect crystal for scratches; if scratched, replace with new crystal.
	Build-up of material at crystal holder aperture is touching the crystal.	Clean or replace the crystal holder. Refer to the sensor operating manual.
	Crystal frequency is not within the Min and Max frequency settings.	Install a new crystal. Use a 6 MHz crystal.
	Excessive cable length between oscillator and crystal.	Use no longer than a 78.1 cm (30.75 in.) in-vacuum cable. Use only the 15.2 cm (6 in.) cable between oscillator and feedthrough.
	Sensor not connected, or bad electrical connection in sensor head or feedthrough, or bad cables.	Check sensor connections. Refer to the sensor operating manual. Use an ohmmeter to check electrical continuity / isolation of sensor head, feedthrough, in-vacuum cable, SMA/BNC adapter cable, and BNC cables. Refer to the sensor operating manual. Substitute a 5.5 MHz test crystal or a known good sensor for the suspect sensor.
	Bad coax cable between feedthrough and oscillator, or bad coax cable between oscillator and STM-2XM.	Use an ohmmeter to check electrical continuity / isolation. Substitute a known good coax cable.
	STM-2XM or oscillator is malfunctioning.	Substitute a known good STM-2XM (or other QCM). Substitute a known good oscillator.

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Crystal fail during deposition before “normal” life of crystal is exceeded.	Crystal is being hit by small droplets of molten material from the evaporation source (spatter or spitting).	Use a shutter to shield the sensor during source conditioning. Move the crystal farther away (at least 25.4 cm (10 in.)) from the source.
	Damaged crystal or deposited material is causing stress to crystal.	Replace the crystal. Use an Alloy crystal if appropriate for deposited material.
	Material buildup on crystal holder is partially masking the crystal surface.	Clean or replace the crystal holder. Refer to the sensor operating manual.
	Shutter is partially obstructing deposition flux or sensor is poorly positioned, causing uneven distribution of material on crystal.	Visually check crystal for an uneven coating, and if present, correct shutter or sensor positioning problem.
Crystal fail when vacuum chamber is opened to air.	Crystal was near the end of its life; opening to air causes film oxidation, which increases film stress.	Replace the crystal.
	Excessive moisture accumulation on the crystal.	Avoid condensation by turning off cooling water to sensor before opening the vacuum chamber to air, and then flow heated water above the dew point of the room through the sensor when the chamber is open.

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Rate, Thickness, and Frequency readings are noisy.	Excessive cable length between oscillator and crystal.	Use 78.1 cm (30.75 in.) in-vacuum cable (or shorter). Use 15.2 cm (6 in.) cable between oscillator and feedthrough.
	Electrical noise is being picked up by the coax cable between the oscillator and STM-2XM.	Locating the coax cable(s) at least 30.5 cm (1 ft.) away from high voltage / high power cables and other sources of electrical noise significantly reduces noise pickup.
	Inadequate system grounding.	Ground wires or straps should connect to an appropriate earth ground. Ground wires or straps should be short with large surface area to minimize impedance to ground (refer to section 2.1.2 on page 2-2).

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Thickness reading has large excursions during deposition.	Mode hopping due to damaged or heavily dampened crystal.	Replace the crystal.
	Crystal is near the end of its life.	Replace the crystal.
	Scratches or foreign particles on the crystal holder seating surface.	Clean the crystal seating surface inside the crystal holder or replace crystal holder. Refer to the sensor operating manual.
	Uneven coating onto crystal.	A straight line from center of source to center of crystal should be perpendicular to face of crystal.
	Particles on crystal.	Replace crystal. Remove source of particles.
	Intermittent cables or connections.	Use an ohmmeter to check electrical continuity / isolation of sensor head, feedthrough, in-vacuum cable, and BNC cables. Refer to the sensor operating manual.
	Inadequate cooling of crystal.	Check water flow rate and temperature for sensor cooling. Refer to the sensor operating manual.

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Thickness reading has large excursions during source warm-up or when source shutter is opened (usually causes Thickness reading to decrease) and after the termination of deposition (usually causes Thickness reading to increase).	Crystal not properly seated or dirty crystal holder.	Check crystal installation. Clean the crystal seating surface inside the crystal holder or replace crystal holder. Refer to the sensor operating manual.
	Excessive heat input to the crystal.	If heat is due to radiation from the evaporation source, move sensor farther away (at least 25.4 cm (10 in.)) from source. Use SPC-1157-G10 crystals designed to minimize frequency shifts due to thermal shock.
	Inadequate cooling of crystal.	Check water flow rate and temperature for sensor cooling. Refer to the sensor operating manual.
	Crystal is being heated by electron flux.	Use a sputtering sensor for non-magnetron sputtering.
	Crystal is being hit by small droplets of molten material from the evaporation source (spatter or spitting).	Use a shutter to shield the sensor during source conditioning. Move the crystal farther away (at least 25.4 cm (10 in.)) from the source.
	Intermittent connection occurring in sensor or feedthrough with thermal variation.	Use an ohmmeter to check electrical continuity / isolation of sensor head, feedthrough, and in-vacuum cable. Refer to the sensor operating manual.

Table 6-1 General troubleshooting (continued)

SYMPTOM	CAUSE	REMEDY
Thickness reproducibility is poor.	Erratic evaporation flux characteristics.	Move sensor to a different location. Check the evaporation source for proper operating conditions. Ensure relatively constant pool height and avoid tunneling into the melt. Use sensor averaging (refer to section 3.3.3 on page 3-20).
	Material does not adhere well to the crystal.	Check for contamination on the surface of the crystal. Evaporate an intermediate layer of appropriate material onto the crystal to improve adhesion. Use gold, silver, or alloy crystals, as appropriate.

6.2 Maintenance

Routine maintenance is not required for STM-2XM. Regular sensor maintenance procedures should be followed according to the sensor operating manual.

6.3 Spare Parts

Oscillator . . . . PN 783-500-013

BNC Cable (15.2 cm (6 in.)) . . . . PN 782-902-011

BNC Cable (3.0 m (10 ft.)) . . . . PN 782-902-012-10

BNC Cable (7.6 m (25 ft.)) . . . . PN 782-902-012-25

BNC Cable (15.2 m (50 ft.)) . . . . PN 782-902-012-50

6.4 Persistent Crystal Fail Indication

Remote oscillators have a test feature to help isolate this type of problem (see Figure 6-1). To activate the test feature, press the **Push to Test** button using a small, pointed object, such as a pencil or small screwdriver. This connects the internal test crystal to the circuit instead of the normal **Sensor** connector. If STM-2XM and the oscillator are functioning correctly, the BAD indicator will be replaced with a crystal life percentage while this button is depressed.

If crystal life is displayed while the **Push to Test** button is depressed, the problem has been isolated to be in the path between the oscillator and the sensor head. If the bad crystal indication continues while the **Push to Test** button is depressed, the problem is either the programming of the sensor selection, in the electronics of the oscillator, or the STM-2XM unit.

Figure 6-1 OSC-100A oscillator

6.5 Diagnostics Menu

STM-2XM has a diagnostics menu that is helpful in identifying problems. Some of the useful things on this menu are:

- Raw frequency of the sensor(s)
- State of the remote digital inputs
- State of the relay outputs

Also, for testing the system, the parameters for relay output allow any relay to be opened and closed to check that the system responds appropriately.

Chapter 7
Calibration Procedures

7.1 Importance of Density, Tooling and Z-Ratio

The quartz crystal microbalance is capable of precisely measuring the mass added to the face of the oscillating quartz crystal sensor. STM-2XM recognizes the density of this added material to allow conversion of the mass information into thickness. In some instances, where highest accuracy is required, it is necessary to make a density calibration (see section 7.2).

Because the flow of material from a deposition is not uniform, it is necessary to account for the different amount of material flow onto the sensor, compared to the substrates. This is accounted for by the Tooling parameter. Tooling can be experimentally established by following the guidelines in section 7.3 on page 7-2.

If the Z-Ratio is not known, it could be estimated from the procedures, outlined in section 7.4 on page 7-3.

7.2 Determining Density

NOTE: The bulk density values retrieved from Appendix A are sufficiently accurate for most applications.

To determine density value:

1. Place a substrate (with proper masking for film thickness measurement) adjacent to the sensor, to ensure the same thickness will be accumulated on the crystal and substrate.
2. Set Density to the bulk value of the Film material or to an approximate value.
3. Set Z-Ratio to 1.000 and Tooling to 100%.
4. Place a new crystal in the sensor and make a short deposition (1000 to 5000 Å).
5. After deposition, remove the test substrate and measure the Film thickness with either a multiple beam interferometer or a stylus-type profilometer.

6 Determine the new Density value with equation [1]:

$$\text{Density}(g/cm^3) = D_1\left(\frac{T_x}{T_m}\right) \quad [1]$$

where:

D_1 = Initial Density setting

T_x = Thickness reading on STM-2XM

T_m = Measured thickness

7 A quick check of the calculated Density may be made. If the thickness displayed by STM-2XM has not been zeroed between the test deposition, enter the calculated Density. Program STM-2XM with the new Density value and observe whether the displayed thickness is equal to the measured thickness.

NOTE: Due to variations in source distribution and other system factors, it is recommended that a minimum of three separate evaporations be made, to obtain an average value for Density.

NOTE: Slight adjustment of Density may be necessary, in order to achieve $T_x = T_m$.

7.3 Determining Tooling

1 Place a test substrate in the substrate holder of the system.

2 Make a short deposition and determine actual thickness.

3 Calculate Tooling from the relationship shown in equation [2]:

$$\text{Tooling}(\%) = TF_i\left(\frac{T_m}{T_x}\right) \quad [2]$$

where

T_m = Actual thickness at substrate holder

T_x = Thickness reading in STM-2XM

TF_i = Initial tooling factor

4 Round percent tooling to the nearest 0.1%.

5 When entering this new value for Tooling into the program, if calculations are done properly, T_m will equal T_x.

NOTE: To account for variations in source distribution and other system factors, obtain an average value for Tooling, using a minimum of three separate evaporations.

7.4 Laboratory Determination of Z-Ratio

A list of Z-Ratio values for materials commonly used are available in Appendix A. For other materials, Z-Ratio can be calculated from the following formulas:

$$Z = \left(\frac{d_q \mu_q}{d_f \mu_f}\right)^{\frac{1}{2}} \qquad [3]$$

$$Z = 9.378 \times 10^5 (d_f \mu_f)^{-\frac{1}{2}} \qquad [4]$$

where:

d_f = Density (g/cm^3) of deposited film

μ_f = Shear modulus (dynes/cm^2) of deposited film

d_q = Density of quartz (crystal) (2.649 g/cm^3)

μ_q = Shear modulus of quartz (crystal) (3.32 x 10^{11} dynes/cm^2)

NOTE: The densities and shear moduli of many materials can be found in a number of handbooks.

Laboratory results indicate that Z-Ratio of materials in thin-film form are very close to the bulk values; however, for high stress producing materials, Z-Ratio values of thin films are slightly smaller than those of the bulk materials. For applications that require more precise calibration, the following direct method is suggested:

1. Establish the correct density value as described in section 7.2 on page 7-1.
2. Install a new crystal and record its starting Frequency, F_{co}.
   The starting Frequency will be displayed on the **Status/Diagnostics** menu.
3. Make a deposition on a test substrate such that the percent Crystal Life display will read approximately 50%, or near the end of crystal life for the particular material, whichever is smaller.
4. Stop the deposition and record the ending crystal Frequency F_c.
5. Remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.

6 Using the Density value from step 1 and the recorded values for F_{co} and F_c, adjust the Z-Ratio value in thickness equation [5] to bring the calculated thickness value into agreement with the actual thickness.

- If the calculated value of thickness is greater than the actual thickness, increase the Z-Ratio value.
- If the calculated value of thickness is less than the actual thickness, decrease the Z-Ratio value.

$$T_f = \frac{Z_q \times 10^4}{2\pi z p}\left\{\left(\frac{1}{F_{co}}\right)ATan\left(zTan\left(\frac{\pi F_{co}}{F_q}\right)\right) - \left(\frac{1}{F_c}\right)ATan\left(zTan\left(\frac{\pi F_c}{F_q}\right)\right)\right\} \quad [5]$$

where:

T_f = Thickness of deposited film (kÅ)

F_{co} = Starting frequency of the sensor crystal (Hz)

F_c = Final frequency of the sensor crystal (Hz)

F_q = Nominal blank frequency = 6045000 (Hz)

z = Z-Ratio of deposited film material

Z_q = Specific acoustic impedance of quartz = 8765000 (kg/(m^2*s))

p = Density of deposited film (g/cm^3)

For multiple layer deposition (for example, two layers), the Z-Ratio used for the second layer is determined by the relative thickness of the two layers. For most applications, the following three rules will provide reasonable accuracies:

- If the thickness of layer 1 is large compared to layer 2, use material 1 Z-Ratio for both layers.
- If the thickness of layer 1 is thin compared to layer 2, use material 2 Z-Ratio for both layers.
- If the thickness of both layers is similar, use a value for Z-Ratio which is the weighted average of the two Z-Ratio values for deposition of layer 2 and subsequent layers.

Chapter 8
Measurement and Theory

8.1 Basics

The Quartz Crystal deposition Monitor (QCM) utilizes the piezoelectric sensitivity of a quartz monitor crystal to added mass. The QCM uses this mass sensitivity to control the deposition rate and final thickness of a vacuum deposition.

When a voltage is applied across the faces of a properly shaped piezoelectric crystal, the crystal is distorted and changes shape in proportion to the applied voltage. At certain discrete frequencies of applied voltage, a condition of sharp electro-mechanical resonance is encountered.

When mass is added to the face of a resonating quartz crystal, the frequency of these resonances are reduced. This change in frequency is very repeatable and is precisely understood for specific oscillating modes of quartz. This heuristically easy-to-understand phenomenon is the basis of an indispensable measurement and process control tool that can easily detect the addition of less than an atomic layer of an adhered foreign material.

In the late 1950's, it was noted by Sauerbrey[1,2] and Lostis[3] that the change in frequency, DF = F_q-F_c, of a quartz crystal with coated (or composite) and uncoated frequencies, F_c and F_q respectively, is related to the change in mass from the added material, M_f , as follows:

$$\frac{M_f}{M_q} = \frac{(\Delta F)}{F_q} \qquad [1]$$

where M_q is the mass of the uncoated quartz crystal. Simple substitutions led to the equation that was used with the first "frequency measurement" instruments:

$$T_f = \frac{K(\Delta F)}{d_f} \qquad [2]$$

where the film thickness, T_f, is proportional (through K) to the frequency change, DF, and inversely proportional to the density of the film, d_f. The constant, K = $N_{at}d_q/F_q^2$; where d_q (= 2.649 g/cm^3) is the density of single crystal quartz and N_{at} (=166100 Hz cm) is the frequency constant of AT cut quartz.

1.G. Z. Sauerbrey, Phys. Verhand .8, 193 (1957)
2.G. Z. Sauerbrey, Z. Phys. 155,206 (1959)
3.P. Lostis, Rev. Opt. 38,1 (1959)

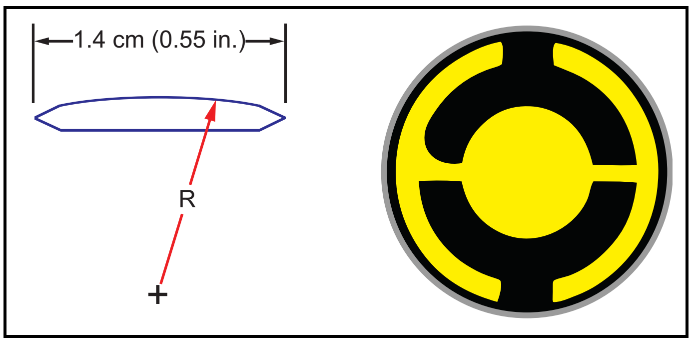
A crystal with a starting frequency of 6.0 MHz will display a reduction of its frequency by 2.27 Hz when 1 angstrom of Aluminum (density of 2.77 g/cm^3) is added to its surface. In this manner, the thickness of a rigid adlayer is inferred from the precise measurement of the frequency shift of the crystal.

The quantitative knowledge of this effect provides a means of determining how much material is being deposited on a substrate in a vacuum system, a measurement that was not convenient or practical prior to this understanding.

8.1.1 Monitor Crystals

No matter how sophisticated the electronics surrounding it, the essential device of the deposition monitor is the quartz crystal. The quartz crystal shown in Figure 8-1 has a frequency response spectrum that is schematically shown in Figure 8-2. The ordinate represents the magnitude of response, or current flow of the crystal, at the specified frequency.

Figure 8-1 Quartz resonator



The lowest frequency response is primarily a “thickness shear” mode that is called the **fundamental**. The characteristic movement of the thickness shear mode is for displacement to take place parallel to the major monitor crystal faces. In other words, the faces are displacement antinodes as shown in Figure 8-3 on page 8-4.

The responses located slightly higher in frequency are called **anharmonics**; they are a combination of the thickness shear and thickness twist modes. The response at about three times the frequency of the fundamental is called the **third quasiharmonic**. There are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

The monitor crystal design depicted in Figure 8-1 is the result of several significant improvements from the square crystals, with fully electroded plane parallel faces, that were first used.

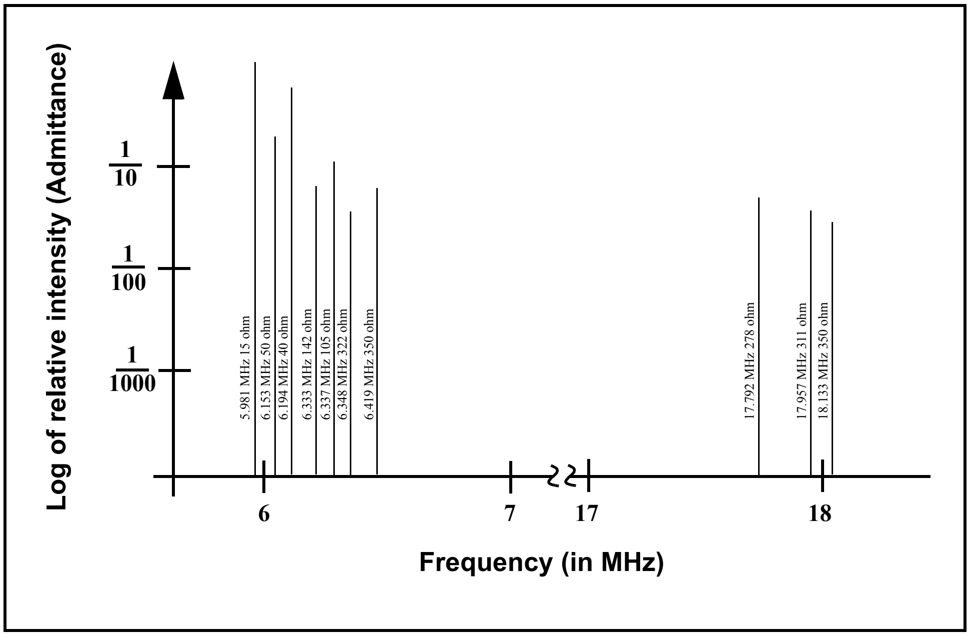
The first improvement implemented the use of circular crystals. The resulting increase in symmetry greatly reduced the number of allowed vibrational modes.

The second set of improvements was to contour one face of the crystal and to reduce the size of the exciting electrode. These improvements have the effect of trapping the acoustic energy.

Reducing the electrode diameter limits the excitation to the central area. Contouring dissipates the energy of the traveling acoustic wave before it reaches the edge of the crystal. Energy is not reflected back to the center where it can interfere with other newly launched waves, essentially making a small crystal appear to behave as though it is infinite in extent.

With the vibrations in the crystal restricted to the center, it is practical to clamp the outer edges of the crystal to a holder, and not produce any undesirable effects. Contouring also reduces the intensity of response of the generally unwanted anharmonic modes; hence, the potential for an oscillator to sustain an unwanted oscillation is substantially reduced.

Figure 8-2 Frequency response spectrum

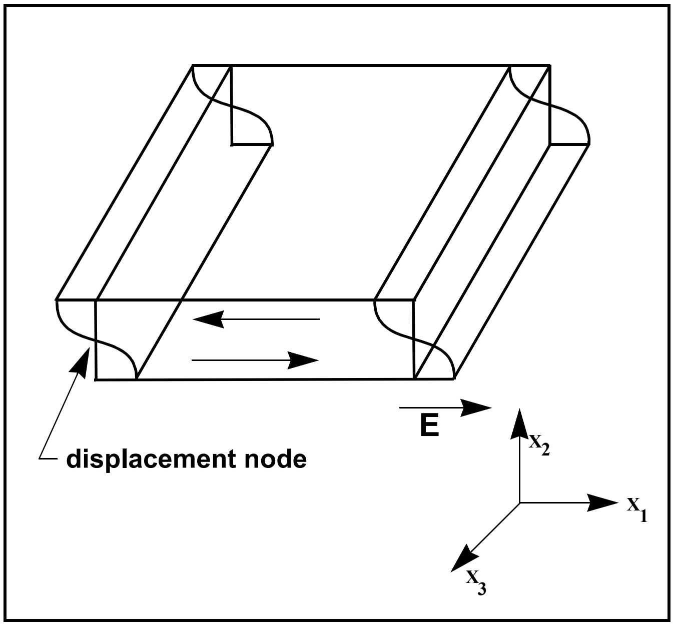


The use of an adhesion layer has improved the electrode-to-quartz bonding, reducing “rate spikes” caused by micro-tears between the electrode and the quartz, as film stress rises. These micro-tears leave portions of the deposited film unattached, and therefore unable to participate in the oscillation. These free portions are no longer detected, which prevents the consequential wrong thickness from being inferred.

The “AT” resonator is usually chosen for deposition monitoring, because at room temperature it can be made to exhibit a very small frequency change, due to temperature changes.

Since there is currently no way to separate the frequency change caused by added mass (which is negative), or even the frequency changes caused by temperature gradients across the crystal or film induced stresses, it is essential to minimize these temperature-induced changes. It is only in this way that small changes in mass can be measured accurately.

Figure 8-3 Thickness shear displacement



8.1.2 Period Measurement Technique

Although instruments using equation [2] were very useful, it was soon noted that they had a limited range of accuracy, typically holding accuracy for DF less than 0.02 F_q. In 1961, it was recognized by Behrndt[4] that:

$$\frac{M_f}{M_q} = \frac{(T_c - T_q)}{T_q} = \frac{(\Delta F)}{F_c} \qquad [3]$$

where T_c and T_q are the periods of oscillation of the crystal with film (composite) and the bare crystal, respectively.

The period measurement technique was the outgrowth of two factors:

- the digital implementation of time measurement, and
- the recognition of the mathematically rigorous formulation of the proportionality between the thickness of the crystal, l_q, and the period of oscillation, $T_q = 1/F_q$.

4.K. H. Behrndt, J. Vac. Sci. Technol. 8, 622 (1961)

Electronically, the period measurement technique uses a second crystal oscillator, or reference oscillator, not affected by the deposition, which is usually much higher in frequency than the monitor crystal. This reference oscillator is used to generate small precision time intervals, which are used to determine the oscillation period of the monitor crystal. This is done by using two pulse accumulators:

- The first is used to accumulate a fixed number of cycles, m, of the monitor crystal.
- The second is turned on at the same time and accumulates cycles from the reference oscillator until m counts are accumulated in the first.

Since the frequency of the reference is stable and known, the time to accumulate the m counts is known to an accuracy equal to $\pm 2/F_r$ where F_r is the reference frequency of the oscillator.

The period of the monitor crystal is $(n/F_r)/m$, where n is the number of counts in the second accumulator. The precision of the measurement is determined by the speed of the reference clock and the length of the gate time (set by the size of m). Increasing one or both of these leads to improved measurement precision.

Having a high frequency reference oscillator is important for rapid measurements (which require short gating times), low deposition rates, and low density materials. All of these require high time precision to resolve the small, mass-induced frequency shifts between measurements.

When the change of frequency of the monitor crystal between measurements is small, that is, on the same order of size as the measurement precision, it is not possible to establish quality rate control. The uncertainty of the measurement injects more noise into the control loop, which can be counteracted only by longer time constants. Long time constants cause the correction of rate errors to be very slow, resulting in relatively long term deviations from the desired rate.

These deviations may not be important for some simple films, but can cause unacceptable errors in the production of critical films such as optical filters or very thin-layered superlattices grown at low rates.

In many cases, the desired properties of these films can be lost if the layer-to-layer reproducibility exceeds one, or two, percent. Ultimately, the practical stability and frequency of the reference oscillator limits the precision of measurement for conventional instrumentation.

8.1.3 Z-match Technique

After learning of fundamental work by Miller and Bolef [5], which rigorously treated the resonating quartz and deposited film system as a one-dimensional, continuous acoustic resonator, Lu and Lewis[6] developed the simplifying Z-match™ equation in 1972. Advances in electronics taking place at the same time, namely the micro-processor, made it practical to solve the Z-match equation in “real-time.”

Most deposition process controllers/monitors sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown in equation [4]:

$$T_f = \left(\frac{N_{at} d_q}{\pi d_f F_c Z}\right) \arctan\left(Z \tan\left[\frac{\pi(F_q - F_c)}{F_q}\right]\right) \quad [4]$$

where $Z=(d_q u_q/d_f u_f)^{1/2}$ is the acoustic impedance ratio and u_q and u_f are the shear moduli of the quartz and film, respectively.

Finally, there was a fundamental understanding of the frequency-to-thickness conversion that could yield theoretically correct results in a time frame that was practical for process control.

To achieve this new level of accuracy requires only that the user enter an additional material parameter, Z, for the film being deposited. This equation has been tested for a number of materials, and has been found to be valid for frequency shifts equivalent to $F_f = 0.4F_q$.

Keep in mind that equation [2] was valid to only $0.02F_q$ and equation [3] was valid only to $\sim 0.05F_q$.

5.J. G. Miller and D. I. Bolef, J. Appl. Phys. 39, 5815, 4589 (1968)
6.C. Lu and O. Lewis, J Appl. Phys. 43, 4385 (1972)

Appendix A
Material Table

A.1 Introduction

The following Table A-1 represents the density and Z-Ratio for various materials. The list is alphabetical by chemical formula.

CAUTION

Some of these materials are toxic. Please consult the material safety data sheet and safety instructions before use.

An * is used to indicate that a Z-ratio has not been established for a certain material. A value of 1.000 is defaulted in these situations.

Table A-1 Material table

Formula	Density	Z-Ratio	Material Name
Ag	10.500	0.529	silver
AgBr	6.470	1.180	silver bromide
AgCl	5.560	1.320	silver chloride
Al	2.700	1.080	aluminum
Al_2O_3	3.970	0.336	aluminum oxide
Al_4C_3	2.360	*1.000	aluminum carbide
AlF_3	3.070	*1.000	aluminum fluoride
AlN	3.260	*1.000	aluminum nitride
AlSb	4.360	0.743	aluminum antimonide
As	5.730	0.966	arsenic
As_2Se_3	4.750	*1.000	arsenic selenide
Au	19.300	0.381	gold
B	2.370	0.389	boron
B_20_3	1.820	*1.000	boron oxide
B_4C	2.370	*1.000	boron carbide
BN	1.860	*1.000	boron nitride
Ba	3.500	2.100	barium
BaF_2	4.886	0.793	barium fluoride

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
BaN_2O_6	3.244	1.261	barium nitrate
BaO	5.720	*1.000	barium oxide
$BaTiO_3$	5.999	0.464	barium titanate (tetr)
$BaTiO_3$	6.035	0.412	barium titanate (cubic)
Be	1.850	0.543	beryllium
BeF_2	1.990	*1.000	beryllium fluoride
BeO	3.010	*1.000	beryllium oxide
Bi	9.800	0.790	bismuth
Bi_2O_3	8.900	*1.000	bismuth oxide
Bi_2S_3	7.390	*1.000	bismuth trisulfide
Bi_2Se_3	6.820	*1.000	bismuth selenide
Bi_2Te_3	7.700	*1.000	bismuth telluride
BiF_3	5.320	*1.000	bismuth fluoride
C	2.250	3.260	carbon (graphite)
C	3.520	0.220	carbon (diamond)
C_8H_8	1.100	*1.000	parlyene (union carbide)
Ca	1.550	2.620	calcium
CaF_2	3.180	0.775	calcium fluoride
CaO	3.350	*1.000	calcium oxide
$CaO\text{-}SiO_2$	2.900	*1.000	calcium silicate (3)
$CaSO_4$	2.962	0.955	calcium sulfate
$CaTiO_3$	4.100	*1.000	calcium titanate
$CaWO_4$	6.060	*1.000	calcium tungstate
Cd	8.640	0.682	cadmium
CdF_2	6.640	*1.000	cadmium fluoride
CdO	8.150	*1.000	cadmium oxide
CdS	4.830	1.020	cadmium sulfide
CdSe	5.810	*1.000	cadmium selenide
CdTe	6.200	0.980	cadmium telluride
Ce	6.780	*1.000	cerium
CeF_3	6.160	*1.000	cerium (III) fluoride
CeO_2	7.130	*1.000	cerium (IV) dioxide
Co	8.900	0.343	cobalt

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
CoO	6.440	0.412	cobalt oxide
Cr	7.200	0.305	chromium
Cr_2O_3	5.210	*1.000	chromium (III) oxide
Cr_3C_2	6.680	*1.000	chromium carbide
CrB	6.170	*1.000	chromium boride
Cs	1.870	*1.000	cesium
Cs_2SO_4	4.243	1.212	cesium sulfate
CsBr	4.456	1.410	cesium bromide
CsCl	3.988	1.399	cesium chloride
CsI	4.516	1.542	cesium iodide
Cu	8.930	0.437	copper
Cu_2O	6.000	*1.000	copper oxide
Cu_2S	5.600	0.690	copper (I) sulfide (alpha)
Cu_2S	5.800	0.670	copper (I) sulfide (beta)
CuS	4.600	0.820	copper (II) sulfide
Dy	8.550	0.600	dysprosium
DY_2O_3	7.810	*1.000	dysprosium oxide
Er	9.050	0.740	erbium
Er_2O_3	8.640	*1.000	erbium oxide
Eu	5.260	*1.000	europium
EuF_2	6.500	*1.000	europium fluoride
Fe	7.860	0.349	iron
Fe_2O_3	5.240	*1.000	iron oxide
FeO	5.700	*1.000	iron oxide
FeS	4.840	*1.000	iron sulfide
Ga	5.930	0.593	gallium
Ga_2O_3	5.880	*1.000	gallium oxide (B)
GaAs	5.310	1.590	gallium arsenide
GaN	6.100	*1.000	gallium nitride
GaP	4.100	*1.000	gallium phosphide
GaSb	5.600	*1.000	gallium antimonide
Gd	7.890	0.670	gadolinium
Gd_2O_3	7.410	*1.000	gadolinium oxide

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Ge	5.350	0.516	germanium
Ge_3N_2	5.200	*1.000	germanium nitride
GeO_2	6.240	*1.000	germanium oxide
GeTe	6.200	*1.000	germanium telluride
Hf	13.090	0.360	hafnium
HfB_2	10.500	*1.000	hafnium boride
HfC	12.200	*1.000	hafnium carbide
HfN	13.800	*1.000	hafnium nitride
HfO_2	9.680	*1.000	hafnium oxide
$HfSi_2$	7.200	*1.000	hafnium silicide
Hg	13.460	0.740	mercury
Ho	8.800	0.580	holmium
Ho_2O_3	8.410	*1.000	holmium oxide
In	7.300	0.841	indium
In_2O_3	7.180	*1.000	indium sesquioxide
In_2Se_3	5.700	*1.000	indium selenide
In_2Te_3	5.800	*1.000	indium telluride
InAs	5.700	*1.000	indium arsenide
InP	4.800	*1.000	indium phosphide
InSb	5.760	0.769	indium antimonide
Ir	22.400	0.129	iridium
K	0.860	10.189	potassium
KBr	2.750	1.893	potassium bromide
KCl	1.980	2.050	potassium chloride
KF	2.480	*1.000	potassium fluoride
KI	3.128	2.077	potassium iodide
La	6.170	0.920	lanthanum
La_2O_3	6.510	*1.000	lanthanum oxide
LaB_6	2.610	*1.000	lanthanum boride
LaF_3	5.940	*1.000	lanthanum fluoride
Li	0.530	5.900	lithium
LiBr	3.470	1.230	lithium bromide
LiF	2.638	0.778	lithium fluoride

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
$LiNbO_3$	4.700	0.463	lithium niobate
Lu	9.840	*1.000	lutetium
Mg	1.740	1.610	magnesium
$MgAl_2O_4$	3.600	*1.000	magnesium aluminate
$MgAl_2O_6$	8.000	*1.000	spinel
MgF_2	3.180	0.637	magnesium fluoride
MgO	3.580	0.411	magnesium oxide
Mn	7.200	0.377	manganese
MnO	5.390	0.467	manganese oxide
MnS	3.990	0.940	manganese (II) sulfide
Mo	10.200	0.257	molybdenum
Mo_2C	9.180	*1.000	molybdenum carbide
MoB_2	7.120	*1.000	molybdenum boride
MoO_3	4.700	*1.000	molybdenum trioxide
MoS_2	4.800	*1.000	molybdenum disulfide
Na	0.970	4.800	sodium
Na_3AlF_6	2.900	*1.000	cryolite
$Na_5Al_3F_{14}$	2.900	*1.000	chiolite
NaBr	3.200	*1.000	sodium bromide
NaCl	2.170	1.570	sodium chloride
$NaClO_3$	2.164	1.565	sodium chlorate
NaF	2.558	1.645	sodium fluoride
$NaNO_3$	2.270	1.194	sodium nitrate
Nb	8.578	0.492	niobium (columbium)
Nb_2O_3	7.500	*1.000	niobium trioxide
Nb_2O_5	4.470	*1.000	niobium (V) oxide
NbB_2	6.970	*1.000	niobium boride
NbC	7.820	*1.000	niobium carbide
NbN	8.400	*1.000	niobium nitride
Nd	7.000	*1.000	neodymium
Nd_2O_3	7.240	*1.000	neodymium oxide
NdF_3	6.506	*1.000	neodymium fluoride
Ni	8.910	0.331	nickel

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
NiCr	8.500	*1.000	nichrome
NiCrFe	8.500	*1.000	Inconel
NiFe	8.700	*1.000	permalloy
NiFeMo	8.900	*1.000	supermalloy
NiO	7.450	*1.000	nickel oxide
P_3N_5	2.510	*1.000	phosphorus nitride
Pb	11.300	1.130	lead
$PbCl_2$	5.850	*1.000	lead chloride
PbF_2	8.240	0.661	lead fluoride
PbO	9.530	*1.000	lead oxide
PbS	7.500	0.566	lead sulfide
PbSe	8.100	*1.000	lead selenide
$PbSnO_3$	8.100	*1.000	lead stannate
PbTe	8.160	0.651	lead telluride
Pd	12.038	0.357	palladium
PdO	8.310	*1.000	palladium oxide
Po	9.400	*1.000	polonium
Pr	6.780	*1.000	praseodymium
Pr_2O_3	6.880	*1.000	praseodymium oxide
Pt	21.400	0.245	platinum
PtO_2	10.200	*1.000	platinum oxide
Ra	5.000	*1.000	radium
Rb	1.530	2.540	rubidium
RbI	3.550	*1.000	rubidium iodide
Re	21.040	0.150	rhenium
Rh	12.410	0.210	rhodium
Ru	12.362	0.182	ruthenium
S_8	2.070	2.290	sulfur
Sb	6.620	0.768	antimony
Sb_2O_3	5.200	*1.000	antimony trioxide
Sb_2S_3	4.640	*1.000	antimony trisulfide
Sc	3.000	0.910	scandium
Sc_2O_3	3.860	*1.000	scandium oxide

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Se	4.810	0.864	selenium
Si	2.320	0.712	silicon
Si_3N_4	3.440	*1.000	silicon nitride
SiC	3.220	*1.000	silicon carbide
SiO	2.130	0.870	silicon (II) oxide
SiO_2	2.648	1.000	silicon dioxide
Sm	7.540	0.890	samarium
Sm_2O_3	7.430	*1.000	samarium oxide
Sn	7.300	0.724	tin
SnO_2	6.950	*1.000	tin oxide
SnS	5.080	*1.000	tin sulfide
SnSe	6.180	*1.000	tin selenide
SnTe	6.440	*1.000	tin telluride
Sr	2.600	*1.000	strontium
SrF_2	4.277	0.727	strontium fluoride
SrO	4.990	0.517	strontium oxide
Ta	16.600	0.262	tantalum
Ta_2O_5	8.200	0.300	tantalum (V) oxide
TaB_2	11.150	*1.000	tantalum boride
TaC	13.900	*1.000	tantalum carbide
TaN	16.300	*1.000	tantalum nitride
Tb	8.270	0.660	terbium
Tc	11.500	*1.000	technetium
Te	6.250	0.900	tellurium
TeO_2	5.990	0.862	tellurium oxide
Th	11.694	0.484	thorium
ThF_4	6.320	*1.000	thorium (IV) fluoride
ThO_2	9.860	0.284	thorium dioxide
$ThOF_2$	9.100	*1.000	thorium oxyfluoride
Ti	4.500	0.628	titanium
Ti_20_3	4.600	*1.000	titanium sesquioxide
TiB_2	4.500	*1.000	titanium boride
TiC	4.930	*1.000	titanium carbide

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
TiN	5.430	*1.000	titanium nitride
TiO	4.900	*1.000	titanium oxide
TiO_2	4.260	0.400	titanium (IV) oxide
TI	11.850	1.550	thallium
TIBr	7.560	*1.000	thallium bromide
TICI	7.000	*1.000	thallium chloride
TII	7.090	*1.000	thallium iodide (B)
U	19.050	0.238	uranium
U_3O_8	8.300	*1.000	tri uranium octoxide
U_4O_9	10.969	0.348	uranium oxide
UO_2	10.970	0.286	uranium dioxide
V	5.960	0.530	vanadium
V_2O_5	3.360	*1.000	vanadium pentoxide
VB_2	5.100	*1.000	vanadium boride
VC	5.770	*1.000	vanadium carbide
VN	6.130	*1.000	vanadium nitride
VO_2	4.340	*1.000	vanadium dioxide
W	19.300	0.163	tungsten
WB_2	10.770	*1.000	tungsten boride
WC	15.600	0.151	tungsten carbide
WO_3	7.160	*1.000	tungsten trioxide
WS_2	7.500	*1.000	tungsten disulfide
WSi_2	9.400	*1.000	tungsten silicide
Y	4.340	0.835	yttrium
Y_20_3	5.010	*1.000	yttrium oxide
Yb	6.980	1.130	ytterbium
Yb_2O_3	9.170	*1.000	ytterbium oxide
Zn	7.040	0.514	zinc
Zn_3Sb_2	6.300	*1.000	zinc antimonide
ZnF_2	4.950	*1.000	zinc fluoride
ZnO	5.610	0.556	zinc oxide
ZnS	4.090	0.775	zinc sulfide
ZnSe	5.260	0.722	zinc selenide

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
ZnTe	6.340	0.770	zinc telluride
Zr	6.490	0.600	zirconium
ZrB_2	6.080	*1.000	zirconium boride
ZrC	6.730	0.264	zirconium carbide
ZrN	7.090	*1.000	zirconium nitride
ZrO_2	5.600	*1.000	zirconium oxide

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