INFICON

O P E R A T I N G   M A N U A L

XTC/C XTC/2
Thin Film Deposition Controller

IPN 074-183M

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DECLARATION OF CONFORMITY

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

INFICON Inc.
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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:	XTC/2 and XTC/C Deposition Controllers, including the Oscillator Package and Crystal Sensor as properly installed.
Applicable Directives:	73/23/EEC as amended by 93/68/EEC 89/336/EEC as amended by 93/68/EEC
Applicable Standards:	EN 61010-1 : 1993, Fixed Equipment EN 55011, Group 1, Class A : 1991 EN 50082-2 : 1995
CE Implementation Date:	January 3, 1995 Revised to include EMC Directive: January 2, 1997
Authorized Representative:	Gary W. Lewis Vice President - Quality Assurance INFICON Inc.

ANY QUESTIONS RELATIVE TO THIS DECLARATION OR TO THE SAFETY OF INFICON'S PRODUCTS SHOULD BE DIRECTED, IN WRITING, TO THE QUALITY ASSURANCE DEPARTMENT AT THE ABOVE ADDRESS.

04/15/97

Warranty

WARRANTY AND LIABILITY - LIMITATION: Seller warrants the products manufactured by it, or by an affiliated company and sold by it, and described on the reverse hereof, to be, for the period of warranty coverage specified below, free from defects of materials or workmanship under normal proper use and service. The period of warranty coverage is specified for the respective products in the respective Seller instruction manuals for those products but shall in no event exceed one (1) year from the date of shipment thereof by Seller. Seller's liability under this warranty is limited to such of the above products or parts thereof as are returned, transportation prepaid, to Seller's plant, not later than thirty (30) days after the expiration of the period of warranty coverage in respect thereof and are found by Seller's examination to have failed to function properly because of defective workmanship or materials and not because of improper installation or misuse and is limited to, at Seller's election, either (a) repairing and returning the product or part thereof, or (b) furnishing a replacement product or part thereof, transportation prepaid by Seller in either case. In the event Buyer discovers or learns that a product does not conform to warranty, Buyer shall immediately notify Seller in writing of such non-conformity, specifying in reasonable detail the nature of such non-conformity. If Seller is not provided with such written notification, Seller shall not be liable for any further damages which could have been avoided if Seller had been provided with immediate written notification.

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No warranty is made by Seller of any Seller product which has been installed, used or operated contrary to Seller's written instruction manual or which has been subjected to misuse, negligence or accident or has been repaired or altered by anyone other than Seller or which has been used in a manner or for a purpose for which the Seller product was not designed nor against any defects due to plans or instructions supplied to Seller by or for Buyer.

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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Chapter 1
Introduction

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1.0 Introduction and Specifications

1.1 Instrument Safety

1.1.1 Notes, Cautions, 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 instrument efficiency when followed.

CAUTION: *Failure to heed these messages could result in damage to the instrument.*

WARNING!!

THE MOST IMPORTANT MESSAGES. FAILURE TO HEED COULD RESULT IN PERSONAL INJURY AND/OR SERIOUS DAMAGE TO THE INSTRUMENT.

WARNING!!

THIS SYMBOL IS INTENDED TO ALERT THE USER TO THE PRESENCE OF IMPORTANT OPERATION AND MAINTENANCE (SERVICE) INSTRUCTIONS IN THE LITERATURE ACCOMPANYING THE INSTRUMENT.

1.1.2 General Safety Information

WARNING!!

THERE ARE NO USER SERVICEABLE COMPONENTS WITHIN THE INSTRUMENT CASE.

POTENTIALLY LETHAL VOLTAGES ARE PRESENT WHEN THE LINE CORD, SYSTEM I/O OR AUX I/O ARE CONNECTED.

REFER ALL MAINTENANCE TO QUALIFIED PERSONNEL.

__CAUTION:__ This instrument 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.

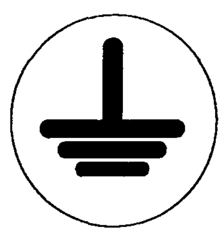
1.1.3 Earth Ground

This instrument is connected to earth via 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 conductor.

WARNING!!

NEVER INTERRUPT THE PROTECTIVE EARTH CIRCUIT.

ANY INTERRUPTION OF THE PROTECTIVE EARTH CONNECTION INSIDE OR OUTSIDE THE INSTRUMENT, OR DISCONNECTION OF THE PROTECTIVE EARTH TERMINAL IS LIKELY TO MAKE THE INSTRUMENT DANGEROUS.



THIS SYMBOL INDICATES WHERE THE PROTECTIVE EARTH GROUND IS CONNECTED INSIDE THE INSTRUMENT. NEVER UNSCREW OR LOOSEN THIS CONNECTION.

1.1.4 Main Power Connection

WARNING!!

THIS INSTRUMENT HAS A LINE VOLTAGE PRESENT ON THE PRIMARY CIRCUITS WHENEVER IT IS PLUGGED INTO A MAIN POWER SOURCE.

NEVER REMOVE THE COVERS FROM THE INSTRUMENT DURING NORMAL OPERATION.

THERE IS NO OPERATOR SERVICEABLE ITEM WITHIN THIS INSTRUMENT.

REMOVAL OF THE TOP OR BOTTOM COVERS MUST BE DONE ONLY BY A TECHNICALLY QUALIFIED PERSON.

IN ORDER TO COMPLY WITH ACCEPTED SAFETY STANDARDS, THIS INSTRUMENT MUST BE INSTALLED INTO A RACK SYSTEM WHICH CONTAINS A MAINS SWITCH. THIS SWITCH MUST BREAK BOTH SIDES OF THE LINE WHEN IT IS OPEN AND IT MUST NOT DISCONNECT THE SAFETY GROUND.

1.2 Introduction to the Instrument

The XTC/2 and XTC/C are quartz crystal transducer type deposition process controllers with three layer capability. They are readily connected to interact with and control the other instruments associated with a vacuum coating plant of moderate complexity. These instruments incorporate the patented (US #5,117,192—May 27, 1992) ModeLock™ measurement system. This innovative system provides process security, measurement speed and precision at a level that no active oscillator based instrument can provide.

The bright Liquid Crystal Display of the XTC/2 is easily read and keeps the operator continuously informed with pertinent deposition data including rate, thickness, phase, rate deviation and elapsed time. Special messages such as Stop, Crystal Fail or Time-Power are clearly presented to reduce operator uncertainty and eliminate the possibility of costly mistakes.

The XTC/C is a variant of the XTC/2 that has a limited front panel. Instead of an LCD display, it has 8 LED type status indicators that indicate process status and instrument functional status. It is primarily designed for use in vacuum coating plants that have a computer based central controller. The original equipment manufacturer (OEM) will design a custom user input-output system through his system controller. Once programmed and started, the XTC/C will essentially run as independent of the central controller as is desired. The deposition layer can complete without further intervention, freeing the central controller for other tasks. Status and data may be queried as frequently as is desired, however.

Interaction with the coating system for both units is multifaceted. All units come with RS232 and support data rates to 9600 baud. The SECSII protocol is supported. The optional computer interface is IEEE-488. The instrument is configured to sequentially control two separate deposition sources with 15 bit resolution using either PID or integrating type controller algorithms. Twelve relays are used to manipulate various external devices such as source and sensor shutters, heaters or valves. Lower power outputs are used to control the position of multi-hearth crucibles. There are eight input lines to provide the ability to sense and react to discrete external signals.

There are numerous special control functions for accommodating the needs of the deposition process. Full predeposit processing is provided, including shutter delay which allows the establishment of the desired rate prior to opening the substrate shutter. A Rate Ramp allows the deposition rate to be changed during the deposit phase. The RateWatcher feature allows the deposition stream to be periodically sampled, extending the life of the crystal.

These instruments are fully compatible with the complete family of Inficon transducers, including Dual and CrystalSix™.

1.3 Specifications

At the time of this manual's writing, the specifications for performance are as published below. INFICON continuously improves its products, affecting the instrument's performance.

1.3.1 Specifications XTC/2 and XTC/C

MEASUREMENT	
Crystal Range & Precision	6.0 to 5.0 MHz +/- .05 Hz (per 250 msec sample)
Thickness & Rate Resolution*	.0617Å (per 250 msec sample)
Thickness accuracy	0.5%
Measurement frequency	4 Hz
SOURCE CONTROLS	
Source-Control Voltage	0 to +/- 10 v
Number of Sources	2
Resolution	15 bits over full range (10 v)
Update Rate	4 Hz max.
Function	Rate / Thickness / Rate Deviation
Maximum Load	2 KOhm (100 Ohm internal impedance)
INPUT/OUTPUT	
Inputs	9 TTL inputs
Outputs a) relay	12 SPST 2.5-amp relays rated @ 120 v (100 VA)
b) crucible select	8 open collector (5 volt DC max sink, 5 TTL loads)
Scan/Change Rate	4 Hz
RECORDER OUTPUT	
Voltage	0 to +10 v
Resolution	13 bits over full range (one reserved for sign)
Update Rate	4 Hz
Function	Rate / Thickness / Mass
Maximum Load	2.0 KOhm (100 Ohm internal impedance)
DISPLAY**	
Type	4x multiplexed custom LCD with backlight***
Thickness Resolution	1 Å
Rate Resolution	.1 Å for 1 to 99.9 Å/sec 1 Å for 100 to 999 Å/sec
Update Rate	1 Hz
PROCESS RECIPE STORAGE	
Film Programs	9, 30 variables per program
Process layers	3

HARDWARE INTERFACE	
Sensors --Single	2
--Dual	1
--CrystalSix	2
Sources	2 BNC female
Crucible Locations	8, 1 of 8 and BCD encoded
I/O --Standard (inputs/outputs)	8/12
--Optional	None
Communications --Standard	RS232C
--Optional	IEEE
Chart Recorder	1 BNC female
OPERATION	
Power Requirements	100VAC +10/-5%, 115VAC ±10%, 230VAC ±10%, 50/60 Hz ±5%, 40 VA
Operating Temperature	0° to 50°C (32° to 122° F)
Size	3.5" H x 8" W x 12" D (8.9cm x 20.3cm x 30.5cm)
Weight	6 lb. (2.7 kg)

*Material density = 1.0; Z-ratio = 1.0; crystal frequency = 6 MHz. Å/S/M = Angstroms/second/measurement.

**Applies to XTC/2 only; the XTC/C provides LED annunciators.

***If desired, backlight automatically dims during prolonged period of inactivity, automatically brightening when activity begins.

1.3.2 Transducer Specifications (Optional)

	Max. Bakeout Temperature*	Size (Max. Envelope)	Water Tube & Coax Length	Body & Holder	IPN
CrystalSix Sensor	130°C	3.5" dia. x 2.0" high (8.9cm dia. x 5.1cm high)	30" (76cm)	304 SS (plate, holders, & material shield)**	750-446-G1
Standard Sensor	130°C	1.063" x 1.33" x .69" high (2.7cm dia. x 3.4cm x 1.75cm high)	30" (76cm)	304 SS	750-211-G1
Standard Sensor with Shutter	130°C	1.06" x 2.24" x .69" high (2.7cm dia. x 5.7cm x 1.75cm high)	30" (76cm)	304 SS	750-211-G2
Sputtering Sensor	105°C	1.36" dia. x .47" high (3.45cm dia. x 1.18cm high)	30" (76cm)	Au-plated BeCu	007-031
Compact Sensor	130°C	1.11" x 1.06" x 1.06" high (2.8cm x 2.7cm x 2.7cm high)	30" (76cm)	304 SS	750-213-G1
Compact Sensor with Shutter	130°C	2.08" x 1.62" x 1.83" high (5.3cm x 4.1cm x 4.6cm high)	30" (76cm)	304 SS	750-213-G2
UHV Bakeable Sensor	450°C	1.35" x 1.38" x .94" high (3.4cm x 3.5cm x 2.4cm high)	12" (30.5cm) 20" (50.8cm) 30" (76.2cm)	304 SS	007-219 007-220 007-221
UHV Bakeable Sensor with Shutter	400°C	1.46" x 1.37" x 1.21" high (3.7cm x 3.5cm x 3.1cm high)	12" (30.5cm) 20" (50.8cm) 30" (76.2cm)	304 SS	750-012-G1 750-012-G2 750-012-G3
Dual Sensor	130°C	1.45" x 3.45" x 1.70" high (3.7cm x 8.8cm x 4.3cm high)	30" (76cm)	304 SS	750-212-G2
Shutter Assembly	400°C	two models available	N/A	300-series SS	750-210-G1 750-005-G1 (Sputtering)

*For Bake only; waterflow is required for actual deposition monitoring. These temperatures are conservative maximum device temperatures, limited by the properties of Teflon (PTFE) at higher temperatures. In usage, the water cooling allows operation in environments that are significantly elevated, without deleterious affects.

**Aluminum body for heat transfer.

1.3.3 XIU (Crystal Interface Unit) Specifications

The XTC/2 Series instruments use a new type of "passive intelligent" oscillator. It is available with cable lengths of 15, 30, 50, and 100 feet as IPN 757-305-G15, G30, G50, or G100, respectively. Conventional, active style oscillators do not work with these instruments. In-vacuum cable lengths to a maximum of 2 meters are supported with this new technology.

1.4 Guide to the Use of the Manual

This manual is configured to be used by both experienced and inexperienced deposition process engineers. For those with significant experience, especially on Inficon controllers, nearly all pertinent information is contained in the section called **"QUICK USE GUIDE"**. Other sections contain the details that supplement the information in the quick use section.

Every user should read the complete manual. It is strongly suggested that the user or installer follow the following plan to gain the most information in the shorted period of time.

1) Register the instrument to receive updates and important information from the factory.

2) Read the section **"NOTES / CAUTIONS / WARNINGS"** to understand the safety related issues.

3) Read the **"QUICK USE GUIDE"** section to become familiar with the instrument's needs and capabilities. Use the other sections of the manual to supplement areas where you do not feel you have an adequate understanding of the material. Throughout the **"QUICK USE GUIDE"** there will be frequent references to the manual sections that provide more detailed information. The final sections of the **"QUICK USE GUIDE"** build the understanding of the full use of the instrument in a logical progression, as suggested in Section 2.3.

XTC/C USERS AND INSTALLERS NOTE:

The XTC/C can do anything that an XTC/2 can do, but it must be controlled through the computer interface. In order to install and use this instrument effectively, all aspects of XTC/2 operation must be understood. Because of this additional burden, it is probably not cost effective for an end-user of a single unit to purchase and install the XTC/C version.

WARNING!!

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POTENTIALLY LETHAL VOLTAGES ARE PRESENT WHEN THE LINE CORD, SYSTEM I/O OR AUX I/O ARE CONNECTED.

REFER ALL MAINTENANCE TO QUALIFIED PERSONNEL.

Related Manuals

Transducers are covered under separate manuals.

IPN	Transducer Type
074-154	Bakeable
074-155	CrystalSix
074-156	Single/Dual/Compact
074-157	Sputtering

Chapter 2
Quick Use Guide

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2.0 Quick Use Guide

2.1 Unpacking, Initial Inspection and Inventory

2.1.1 Unpacking and Inspection Procedures

1. If you haven't removed the instrument from its shipping containers, do so now.

2. Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice signs of obvious rough handling on the outside of the cartons. *Report any damage to the carrier and to INFICON, immediately.*

3. DO NOT discard any packing materials until you have taken inventory and have verified proper instrument operation to your satisfaction. See Section 2.2 for voltage selection and Section 3.6 for test mode operation.

2.1.2 Inventory

Make sure you have received all of the necessary equipment by checking the contents of the shipping containers with the parts list below. INFICON ships these products on a feature-option basis. Check your order for the part number before comparing to the lists below.

2.1.2.1 XTC/2 System Configuration

XTC/2 — ☐☐☐☐

BASIC CONFIGURATION	IPN #	CODE#
115V 50/60 Hz	757-500-G1	1
230V 50/60 Hz	757-500-G2	2
Computer Communications Module		
None	757-211-G1	1
IEEE-488 Parallel	760-142-G1	2
Remote Module		
None		0
Hand Controller	755-262-G1	1
Rack Mounting		
None		0
1 Unit Mounting Kit	757-212-G1	1
2 Unit Mounting Kit	757-212-G2	2

2.1.2.2 XTC/C System Configuration

XTC/C — ☐☐☐☐

BASIC CONFIGURATION	IPN #	CODE#
115V 50/60 Hz	759-500-G1	1
230V 50/60 Hz	759-500-G2	2
Computer Communications Module		
None	757-211-G1	1
IEEE-488 Parallel	760-142-G1	2
Remote Module		
None		0
Hand Controller	755-262-G1	1
Rack Mounting		
None		0
1 Unit Mounting Kit	757-212-G1	1
2 Unit Mounting Kit	757-212-G2	2

2.1.2.3 Ship Kit - XTC/2 XTC/C

Both instruments are shipped with the following accessories. To find which accessories were shipped with your unit look for the "X" which represents the voltage of your particular instrument and follow that column.

Item	Qty G2 (230V)	Qty G1 (115V)	IPN Number	Part # and/or Description
01	-	X	757-203-G1	Ship Kit - XTC/2 & XTC/C 115V
02	X	-	757-203-G2	Ship Kit - XTC/2 & XTC/C 230V
03	-	1	068-002	17250 Power Cord, North America
04	1	-	068-151	86511000 European Power Cord
05	1	1	051-485	Conn 9 Pin Male D/Sub Sod. Cup
06	1	1	051-620	Cable Clamp 11.3015
07	2	2	051-483	Conn 25 Pin Female D/Sub Sod. Cup
08	2	2	051-619	Cable Clamp
09	-	1	062-011	3/8 Amp Fuse S.B.
10	1	-	062-053	3/16 Amp Fuse S.B.
11	4	4	070-811	8014 Bumpon Feet

In addition, you have already found a copy of this manual, IPN 074-183.

2.2 Voltage Selection

Voltage selection is required only between low (nominal 100-120V) and high (nominal 200-240V) ranges. There is no distinction between 50 and 60 Hz supplies. See Section 1.3.1 for specific power requirements.

CAUTION: *Verify that the correct fuse is in place by pulling the fuse extractor and visually inspecting the fuse for the proper rating. Use of an improperly sized fuse may create a safety hazard.*

- *for 100-120 Volt operation use a 3/8 amp slow blow type*
- *for 200-240 Volt operation use a 3/16 amp slow blow type*

NOTE: These instruments are designed to operate at voltages 10% lower or higher than the specified ranges.

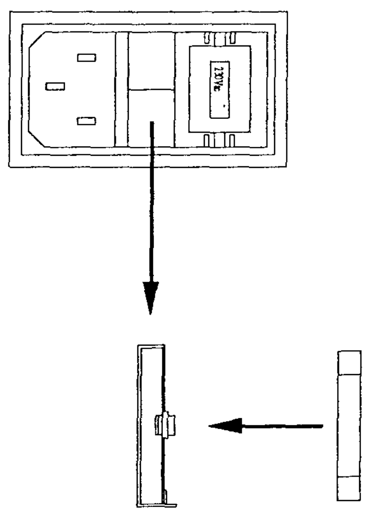


Figure 2.1 Fuse

CAUTION: *Visually verify that the voltage selector barrel has been oriented to the proper position.*

- *for 100-120 Volt operation the label should read 115V*
- *for 200-240 Volt operation the label should read 230V*

If the voltage selector barrel needs to be changed, it is required that the power cord and fuse holder be removed. Reorient the selector to the correct (115/230V) position, replace the fuse and push it firmly into place. Install the proper size fuse for the voltage selected.

2.3 Installation Guide and Schematic

Many experienced deposition monitor users will be able to fully install and the use the instrument by studying the Installation Schematic, Figure 2.2 on the next page, and the State Sequence Diagrams, Figures 4.1, 4.2 and 4.3.

A more systematic approach would be to start by reviewing the two figures and then following the procedure below.

1. Completely review Section 1.1 on safety.
2. Check for correct line voltage, Section 2.2
3. Verify basic unit operation by exercising it in the Test Mode, Section 3.6.
4. Review the system interface capability as outlined in Section 2.6. Be especially attentive of the special features available on the configuration switches, Section 2.6.2.
5. Wire the necessary connectors following the installation procedures in Sections 3.1, 3.2 and 3.3.
6. Review the front panel controls and display description per Section 2.4 for the XTC/2 or Section 2.5 for the XTC/C.
7. Program the desired film parameter values per Section 4.1 and 4.2.
8. Verify the operation of the just programmed film utilizing the Test Mode.
9. Attach the XIU (757-305-G15, G30 or G100) to an existing transducer or install a new transducer following the guidelines of Section 3.5 and Figure 3.3.
10. Exit the Test Mode and deposit when ready.

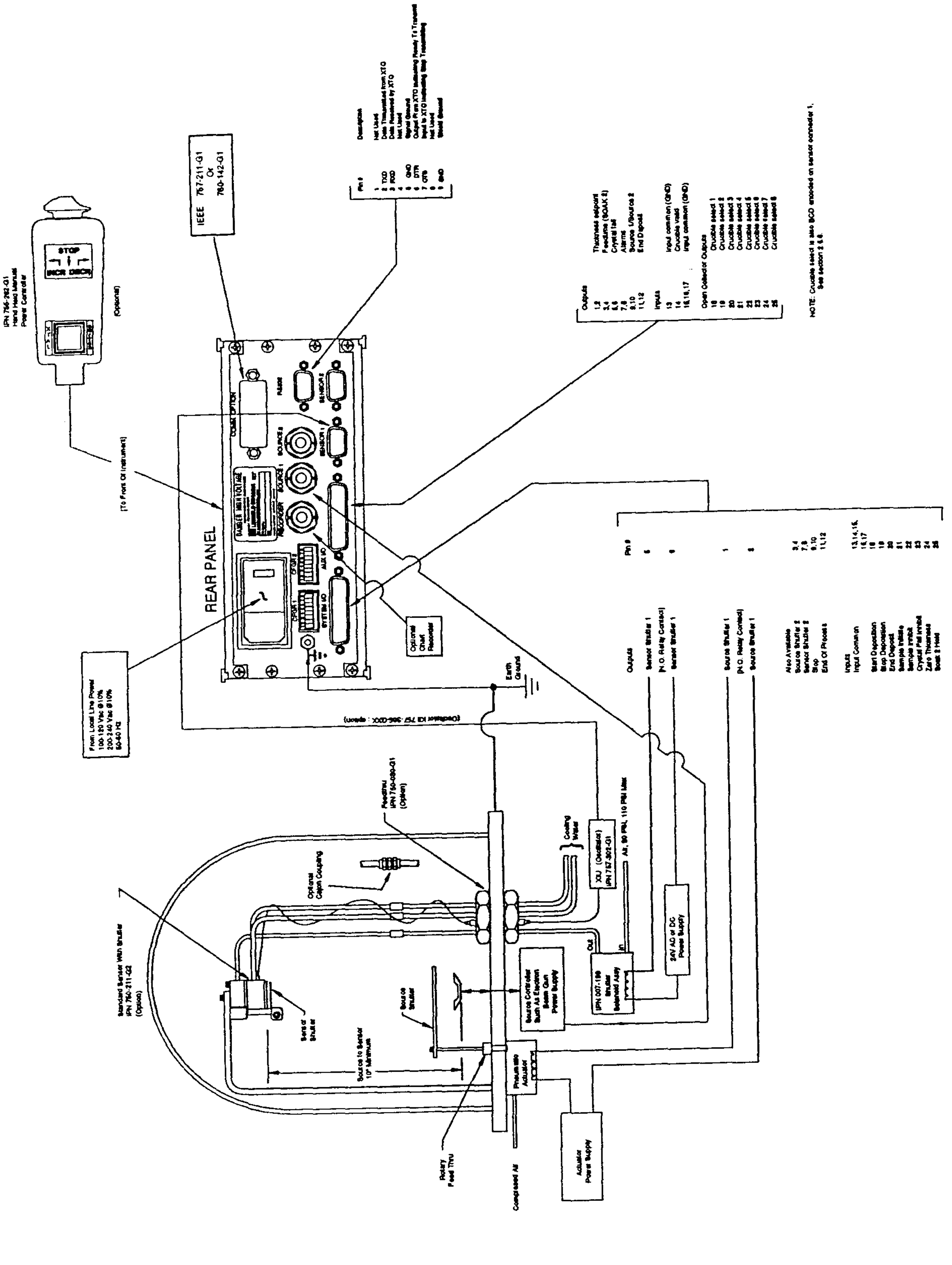


Figure 2.2 Installation Guide Schematic

2.4 XTC/2 Front Panel Description

The description of the XTC/2 front panel is divided into two sections, the display area and the front control panel.

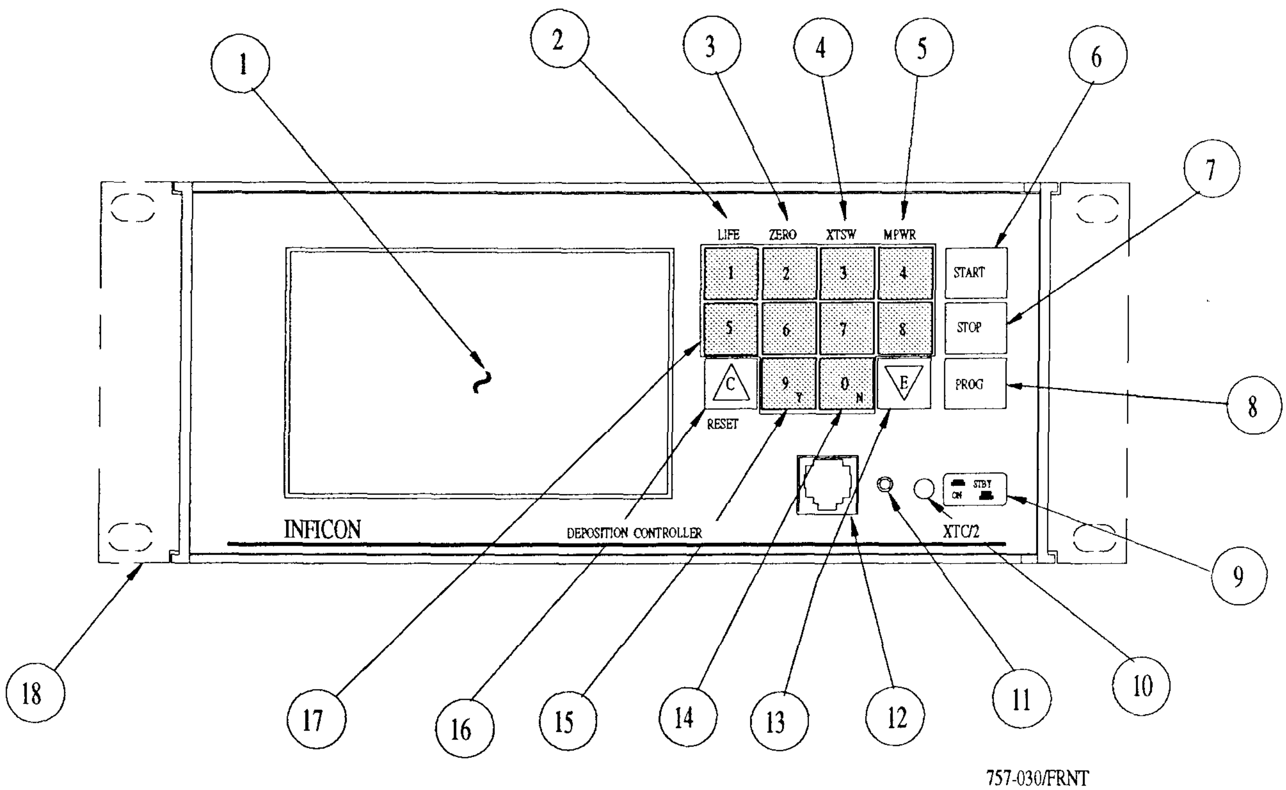


Figure 2.3 Front Panel XTC/2

2.4.1 XTC/2 Front Control Panel Description

1— **LCD DISPLAY**	Highly visible display of current information. See Section 2.4.2 for details.
2— **LIFE**	Pressing the 1 key momentarily switches the display to percent of crystal life used, software version, crystal frequency, and S and Q values, when the display is in the operate mode.
3— **ZERO**	Pressing the 2 key zeros the displayed thickness when the display is in the operate mode.

4—**XTSW**	CrystalSwitch. Pressing the 3 key advances the CrystalSix to the next available crystal or changes the active crystal of the dual head when the display is in the operate mode. (See Section 4.15.1)
5—**MPWR**	Manual. Pressing the 4 key places the unit in manual power control or rate control mode when the display is in the operate mode.
6—**START**	Initiates action. (Starts State Sequencing, see Fig. 4.1)
7—**STOP**	Halts State Sequencing, see Fig. 4.1.
8—**PROG**	Program. Toggles the display between the program and operate modes.
9—**ON/STBY**	Switches secondary power of the instrument between **ON** and **STANDBY**.
10—○	Green LED indicates that the unit is connected to an active line power source and the **ON/STBY** switch is set to ON.
11—●	Access to adjust LCD contrast, see Section 6.1.
12—▢	Connection for optional manual power and crystal switch hand controller (IPN 755-262-G1).
13—▽E	Enter and cursor down. Two function switch used when the display is in the program mode. All numeric and "Y" "N" parameter entries need to be followed by a ▽E. Also used to manually decrease source power when in **MPWR** and the display is in the operate mode.
14—**0/N**	Zero or no. Two function switch used when the display is in the program mode. Also, places unit in communications set up mode if held down during power up, see Section 3.7.5.
15—**9/Y**	Nine or yes. Two function switch used when display is in program mode.
16—△C/**RESET**	Clear and cursor up. Two function switch that is also used to "reset" the instrument to the beginning of a process from a STOP state. Also used to increase source power when in **MPWR** and the display is in the operate mode.
17—**DIGITS (0-9)**	Decimal based key pad for data entry. If the nine key is held down during power-up, all of the LCD segments will remain lit until the key is released, see Figure 2.4.
18—	Optional mounting kit, (IPN 757-212-G1) for mounting one unit in full rack or (757-212-G2) for mounting two units side by side in full rack.

2.4.2 XTC/2 DISPLAY DESCRIPTION

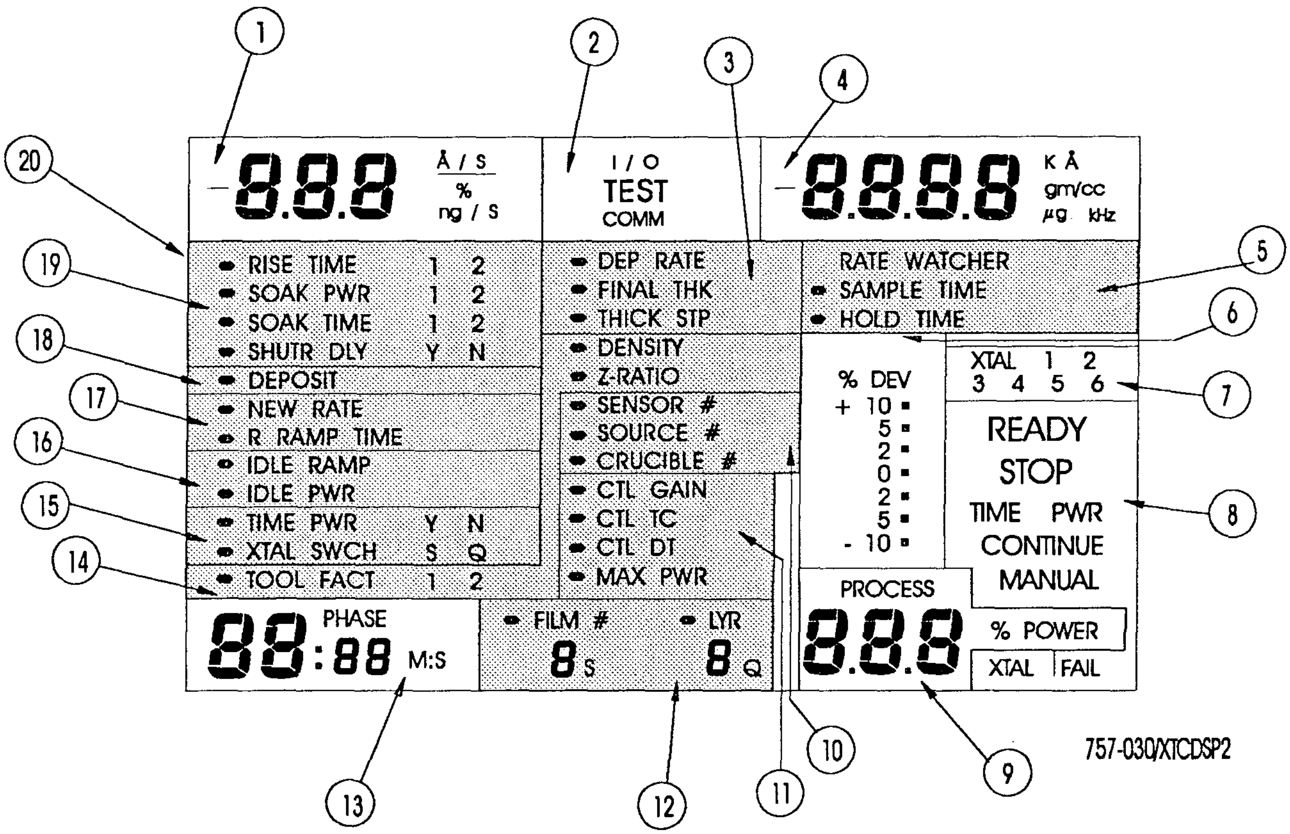


Figure 2.4 XTC/2 Display

1— **RATE DISPLAY GROUP**

Indicates the deposition or etching rate in Å/sec or the version level of the installed firmware when the **LIFE** key is pressed and display is in the Operate mode. When the display is in the Program mode, it is used to display and enter the values of parameters requiring three significant digits.

2— **COMMUNICATIONS & TEST GROUP**

A message area that:

a. Indicates that the **I/O** has been put into external communication control through the **R**-15 through **R**-18 commands.

b. The instrument is in **TEST** mode, see Section 3.6.

c. The instument is sending or receiving an external computer **COMM**unication command.

3— **DEPOSITION (ETCH) RATE and THICKNESS SUBGROUP**

Indicators and annunciators for parameter entry of starting **DEP**osition **RATE**, film's **FINAL** **TH**ic**K**ness and an intermediate **TH**ic**K**ness **S**et**P**oin**T**.

4— **THICKNESS and FREQUENCY GROUP**

Indicates the deposited (etched) thickness or the active crystal's frequency in KHz when the **LIFE** key is pressed when the display is in the operate mode. When the display is in the Program mode it is used to display and enter the values of parameters that require four significant digits.

5— **RATEWATCHER SUBGROUP**

Indicator annunciator and cursor array for the definition of the RateWatcher parameters when the display is in the Program mode. Used as an indicator of the **SAMPLE** and **HOLD** deposition substates when the display is in the Operate mode.

6— **RATE DEVIATION GROUP**

A graphic annunciator that displays the current deviation of the deposition rate from the value of the active film's **DEP RATE** parameter. this annunciator structure is updated each 250ms measurement when the display is in the Operate mode. A 0% deviation is indicated when the computed value is less than +/-2%. The plus or minus 10% values are indicated when the computed value is more than +/-10%, respectively.

7— **ACTIVE CRYSTAL INDICATION GROUP**

A graphic annunciator that provides information concerning the presently active crystal or the availability of backup crystals. Its meaning is somewhat altered by the instrument's configuration regarding the cyrstal switch type, see Section 2.6.2.

a. If the instrument is configured for "Single Heads"; the annunciator will indicate which sensor is active.

b. If the instrument is configured for "Dual Sensor Head"; the annunciator will display the number representing the active crystal's "sensor number." Whenever the instrument is operating with the secondary (backup) crystal the number of the backup crystal will be flashing as an indication of the lack of a subsequent backup crystal.

c. If the instrument is configured for one or two CrystalSix, the annunciator will display the numbers of all crystals of the active sensor's output that are "good." The "active" crystal's number will flash. The absence of all numbers may also indicate that the switcher is not operating.

8— **STATUS MESSAGE GROUP**

A group of annunciators that provide information concerning the state of the instrument.

a. READY — when lit the instrument will accept a start command to begin state processing of the active layer.

b. STOP — when lit indicates that the instrument is in the STOP state, refer to Sections 4.3 and 4.4.

c. TIME PWR — when lit indicates that the instrument is in the Time-Power state. See Section 4.11.

d. CONTINUE — when lit the instrument will again execute state processing of the active layer, allowing for any previously accumulated material, when the START key is pressed. Pressing the RESET key prior to the START key resets the process to layer 1; see Section 4.4.

e. MANUAL — when lit the instrument is in the manual power control mode and the source's power level is modified by either the optional hand controller or the front panel ▽E △C keys (XTC/2 only).

f. XTAL FAIL — this indicator lights when the active crystal has failed. In the case of instruments configured for dual or CrystalSix operation it indicates that no further crystals are available.

9— **POWER and PROCESS GROUP**

Indicates the relative source power when the display is in the Operate mode and displays the % xtal life when the LIFE key is pressed. When the display is in the Program mode, these three digits are used for the entry of some 3 digit film parameter values. It is also used to define the instrument's sequencing of multi-layers, see Section 2.9.

10— SENSOR and SOURCE SUBGROUP

The anunciators and cursors for the definition of a film's:

a. SENSOR # — designates the active or primary (for dual head) sensor as 1 or 2.

b. SOURCE # — designates the film's active source control output as 1 or 2.

c. CRUCIBLE # — designates the active film's crucible pocket as 1-8, corresponding to crucible select outputs 1-8. A value of 0 disables this parameter and associated outputs; see Section 2.6.5.

11— CONTROL PARAMETER SUBGROUP

The annunciators and cursors for entering the values used in a film's Rate Control algorithm; see Section 4.5.

12— CRYSTAL and PROCESS SUBGROUP

When the display is in the Program mode:

a. the **XTAL SWCH** parameter's values are entered for **S** & **Q** as labeled.

b. the "FILM #" parameter value defines the particular film's (1-9) values being programmed/displayed.

c. The "LYR #" defines the process layer to be assigned a film. This parameter works with the power and process display group.

When the display is in the Operate mode:

a. "FILM #" parameter value defines the film being executed and the "LAYER #" parameter value defines the layer being executed.

13— TIMER GROUP

When the display is in the Operate mode, serves as the elapsed time indicator and unit annunciator. Also displays **S** & **Q** values when the **LIFE** key is pressed. The values in the **S** accumulator replace the time display while the **LIFE** key is pressed. When the key is released the value of the **Q** accumulator is shown for about 1 second. Used for entering and displaying the value of time-based parameters when the display is in the Program mode.

14— CALIBRATION SUBGROUP

Annunciators and cursors used when the display is in the Program mode. Allows conversion of the crystal's frequency shift to material thickness; see Sections 5.1 - 5.4.

15— CRYSTAL FAIL SUBGROUP

Annunciators and cursors used when the display is in the program mode to determine tolerated levels of crystal performance and subsequent instrument actions.

a. TIME PWR Y-N —defines the action taken when a crystal fails; see Section 4.11.

b. XTAL SWCH S-Q — a two parameter data field used with the digits in the crystal and process subgroup. These are used to set the level of soft crystal failures tolerated; see Section 4.6.

16— POST DEPOSIT SUBGROUP

Annunciators and cursors used to define the source's post deposition power levels; see Section 4.9.3.

17— RATE RAMP SUBGROUP

Annunciators and cursors used to define a change in deposition rate during the deposit state; see Section 4.7.

18— DEPOSIT STATE INDICATOR

Annunciator used to indicate that the instrument is executing the deposit state of the active film; see Section 4.1.

19— PRE DEPOSIT SUBGROUP

Annunciators and cursors used to define the predeposition source conditioning when the display is in the Program mode.

a. RISE TIME 1-2 — defines the length of the rise 1 (2) state.

b. SOAK PWR 1-2 — defines the power level(s) of the soak 1 (2) state.

c. SOAK TIME 1-2 — defines the length of the soak 1 (2) state.

These parameters, together, define a two step source power profile with linear changes in power between levels as shown graphically in Figure 2.5.

d. SHUTR DLY Y-N — executes (Y) or skips (N) the shutter delay phase; see Section 4.13.

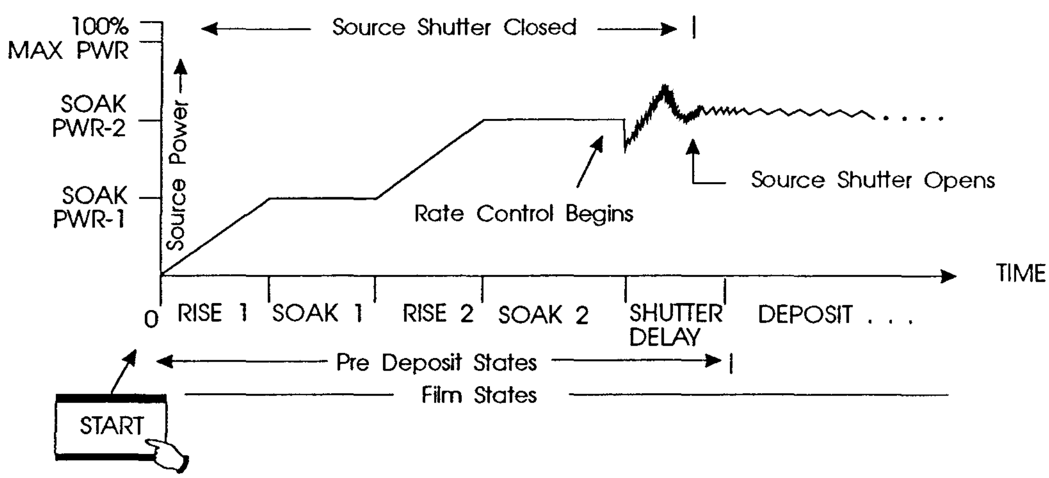


Figure 2.5 Source Power Level Profile

20— PROGRAMMING and PHASE INDICATOR GROUP

Annunciators and cursors for navigating, displaying and changing a film's individual parameter values when the display is in the Program mode.

The annunciators are also used to indicate the current state of the film being executed when the display is in the Operate mode.

2.5 XTC/C Front Panel Description

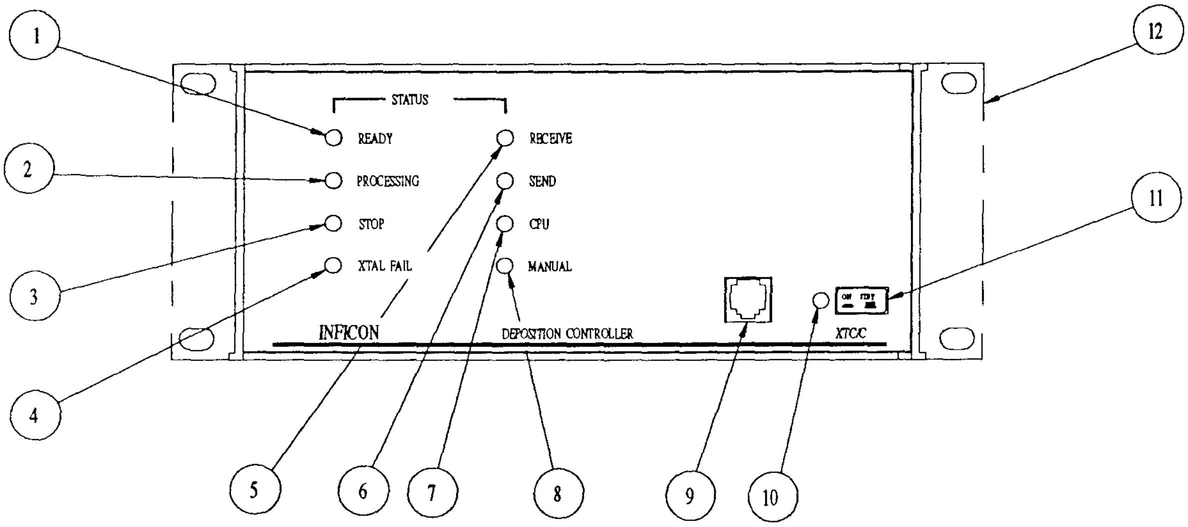


Figure 2.6 Front Panel XTC/C

1— **READY**	When the associated LED is lit the instrument is in the READY TO START state
2— **PROCESSING**	When the associated LED is lit the instrument is state executing a layer. See Figure 4.1.
3— **STOP**	When the associated LED is lit the instrument is in the STOP state.
4— **XTAL FAIL**	When the associated LED is lit the measurement crystal has failed. In the case of units configured for dual or CrystalSix operation it indicates that there are no further crystals available.
5— **RECEIVE**	When the associated LED is lit the instrument is receiving information from the connected computer controller.
6— **SEND**	When the associated LED is lit the instrument is sending information to the connected computer controller.
7— **CPU**	When the associated LED is lit the instrument's computer is not operating normally.

8— **MANUAL** — When the associated LED is lit the instrument is capable of responding to power changes as directed by the optional manual power controller.

9— — Connection for optional manual power and crystal switch hand controller (IPN 755-262-G1).

10— — Green LED indicates that the unit is connected to an active line power source and the ON/STBY switch is set to ON.

11—**ON/STBY** — Switches secondary power of the instrument between **ON** and **STANDBY**.

12— — Optional mounting kit for mounting one instrument in full rack (IPN 757-212-G1) or for mounting two units side by side in full rack (IPN 757-212-G2).

2.6 Rear Panel Description

The rear panel provides the interface for all external connections to the instrument, as shown below in Figure 2-7.

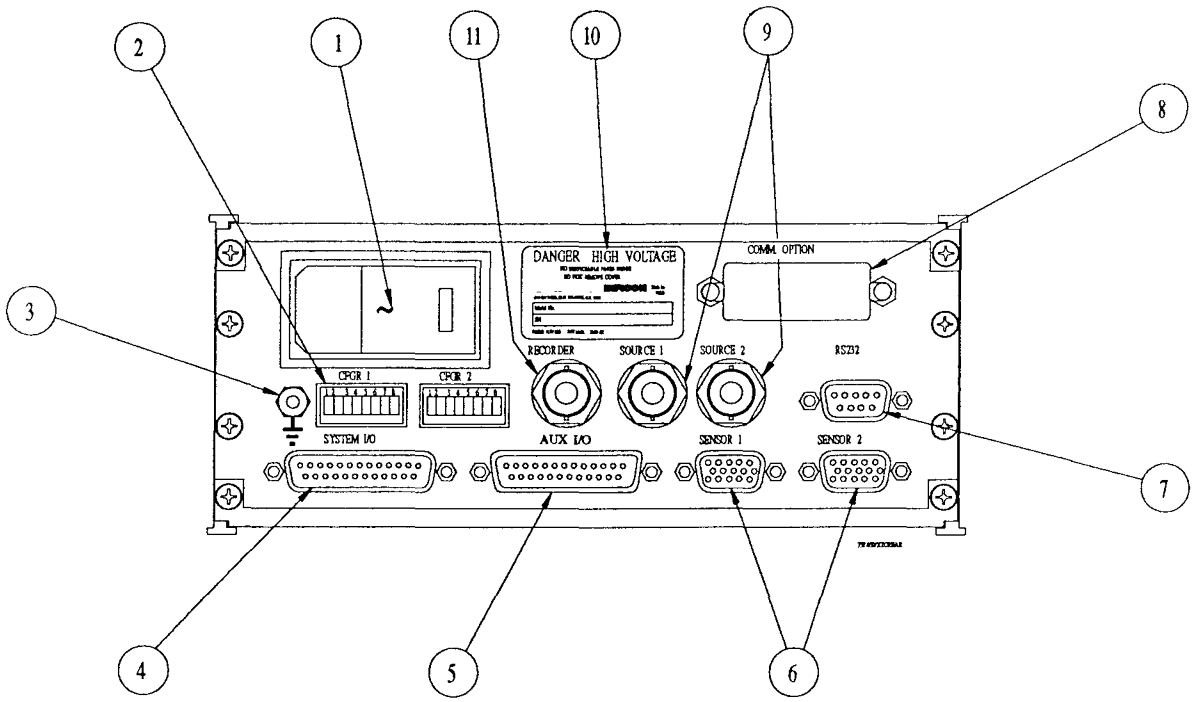
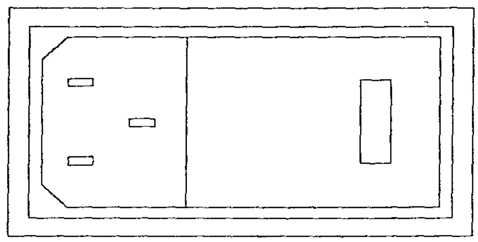


Figure 2.7 Rear Panel

2.6.1 Power Module

Allows selection of optional voltages, contains the instrument fuse and provides modular connection to line power. See Section 2.2.



757-030/XTCPWR

Figure 2.8 Power Module

2.6.2 Configuration Switches 1 & 2

Two eight position DIP switches used to customize the instrument as follows.

Switch # 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

757-030/XTCFGR

Figure 2.9 Configuration Switch

CAUTION: *The configuration switches are only read on instrument power up. If an option is changed the instrument must be switched to standby and then powered up.*

Table 2.1 Configuration Switch Settings

	XTC/2		XTC/C	
SWITCH 1	Test Mode	(0=off, 1=on)	Communications Address	(2^4)
SWITCH 2	Parameter Lock	(0=off, 1=on)	Communications Address	(2^3)
SWITCH 3	Control Mode	(0=deposit, 1=etch)	Communications Address	(2^2)
SWITCH 4	Stop On Alarms	(0=no, 1=yes)	Communications Address	(2^1)
SWITCH 5	Stop on Max Power	(0=no, 1=yes)	Communications Address	(2^0)

NOTE: XTC/C Switches 1-5 are only used for the optional IEEE488 (IPN 760-142-G1 or 757-122-G1). [Addresses 0 to 30 are allowed.]

	XTC/2	XTC/C
SWITCH 6	Recorder Type MSB	Communications Protocol 0=Inficon, 1=SECS
SWITCH 7	Recorder Type	Baud Rate MSB
SWITCH 8	Recorder Type LSB	Baud Rate LSB

NOTE: for the XTC/2:

000 designates Rate, 100 Å/s full scale (unfiltered)
001 designates Rate, 1000 Å/s full scale (unfiltered)
010 designates Thickness, 100 Å full scale
011 designates Thickness, 1000 Å full scale
100 designates Power %
101 designates Rate Deviation (±50 Å/s)
110 designates Rate 100 Å/s full scale - smoothed
111 designates Rate 1000 Å/s full scale - smoothed

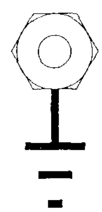
NOTE: for the XTC/C:

00 is 9600 baud
01 is 4800 baud
10 is 2400 baud
11 is 1200 baud

	XTC/2	XTC/C
SWITCH 9	Beep On/Off (0=on, 1=off)	Checksum (0=no, 1=yes)
SWITCH 10	Backlight Dim (0=no, 1=yes)	Unused
SWITCH 11	Start Layer without backup crystal (0=no, 1=yes)	Start layer without backup crystal (0=no, 1=yes)
	NOTE: See Section 4.16 for description	
SWITCH 12	Input Option 0=standard 1=film select	Unused
SWITCH 13	Relay Option 0=on Relay 7 = End of Film Relay 10 = In Process 1=off Relay 7 = Thickness Setpoint Relay 10 = Alarms	0=on Relay 7 = End of Film Relay 10 = In Process 1=off Relay 7 = Thickness Setpoint Relay 10 = Alarms
SWITCH 14	Crystal Switch Type MSB	Crystal Switch Type MSB
SWITCH 15	Crystal Switch Type LSB	Crystal Switch Type LSB
	NOTE: 00 designates single head(s) 01 designates one dual head 10 designates one CrystalSix, on Sensor 1 11 designates two CrystalSixs	
SWITCH 16	Source Control Voltage polarity 0=neg, 1=pos	Source Control Voltage polarity 0=neg, 1=pos

2.6.3 Grounding Stud

Recommended point for connecting the system ground strap. For specific recommendations see "electrical grounding and shielding requirements" as it is covered in this manual's **Installation** section.



757-030/XTCGND

Figure 2.10 Grounding Stud

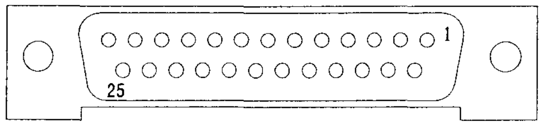
2.6.4 System I/O

A 25-pin male "D" type connector for interface connection. (See Figure 2.11 — 25-Pin Type "D" Male Connector and Section 3.7 for details.)

	Pin #	Function
<u>Relay #</u>	<u>Outputs</u>	
1	1,2	Source Shutter 1
2	3,4	Source Shutter 2
3	5,6	Sensor Shutter 1*
4	7,8	Sensor Shutter 2*
5	9,10	STOP
6	11,12	End of Process
	*Also used for crystal switch, see Section 4.15.1	
<u>Input #</u>	<u>Inputs</u>	
	13,14,15,16,17	INPUT Common (GND)
1	18	START deposition
2	19	STOP deposition
3	20	END deposit
4	21	Sample initiate
5	22	Sample inhibit
6	23	Crystal fail inhibit
7	24	ZERO thickness
8	25	Soak 2 HOLD

2.6.5 AUX I/O

A 25-pin male "D" type connector for interface connection, see Figure 2.11 and Section 3.7.



757-030/XTCI-O

Figure 2.11 25-Pin Type "D" Male Connector

	Pin #	Function
<u>Relay #</u>	<u>Outputs</u> (Relays)	
7	1,2	Thickness setpoint/End of Film*
8	3,4	Feedtime (SOAK 2)
9	5,6	Crystal fail
10	7,8	Alarms/In Process*
11	9,10	Source 1/Source 2 toggle (closed when source 2 is active)
12	11,12	End Deposit
<u>Input #</u>	<u>Inputs</u>	
	13	Input common (GND)
9	14	Crucible valid
	15,16,17	Input common (GND)
TTL <u>Output #</u>	<u>Outputs</u> (Open Collector 1 of 8 encoding)**	
1	18	Crucible select 1
2	19	Crucible select 2
3	20	Crucible select 3
4	21	Crucible select 4
5	22	Crucible select 5
6	23	Crucible select 6
7	24	Crucible select 7
8	25	Crucible select 8

***NOTE:** See description of configuration switch 13, Section 2.6.2.

****NOTE:** The crucible select outputs are available BCD encoded on the Sensor 1 connector, see Section 2.6.6.

2.6.6 Sensor 1, Sensor 2

High density 15-pin female "D" type. Input connectors for intelligent oscillators 1, 2 (IPN 757-302 G1). These oscillators are normally supplied with 15 foot (4.5 meter) cables as IPN 757-305-G15. These are specifiable as 30 foot and 100 foot by changing the group (G-xx) designation to 30 or 100, respectively. The crucible select outputs are open collector BCD encoded only on Sensor 1.

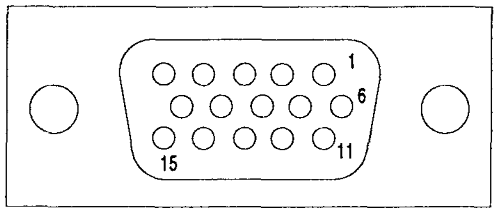


Figure 2.12 15-Pin Type "D" Female Connector

Pin #	Description	
11	Crucible Select (LSB)	BCD encoding
12	Crucible Select	
13	Crucible Select (MSB)	
14	Ground	
15	Ground	

CAUTION: *Only connect to pins 11-15, inclusive. Ignoring this warning will effect crystal and instrument performance.*

Be sure to follow the best wiring and grounding practice possible see Section 3.2.3.

2.6.7 RS232

A 9-pin female “D” type connector which enables the instrument to be controlled by a host computer.

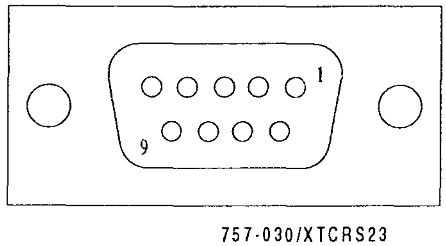


Figure 2.13 9-Pin Type “D” Female Connector

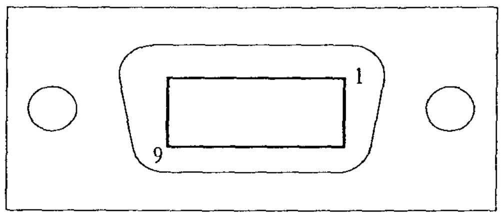
Pin #	Description	DB9*	DB25**
1	Not used	1	-
2 TXD	Data transmitted from XTC	2	3
3 RXD	Data received by XTC	3	2
4	Not used	4	-
5 GND	Signal ground	5	7
6 DTR	Output from XTC indicating ready to transmit	6	6
7 CTS	Input to XTC indicating stop transmitting	7	4
8	Not used	8	-
9 GND	Shield ground	9	-

*Host **IBM compatible computer connector

2.6.8 Communication Option

Location of optional computer interface.

IEEE488

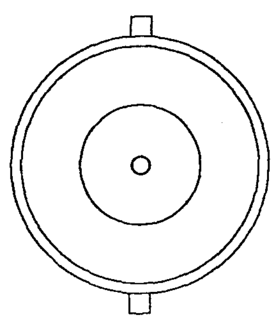


757-030/XTCXTCOPT

Figure 2.14 IEEE488 Option

2.6.9 Source 1,2

BNC type female connectors that supply control voltage to the designated evaporation source power supplies. The output voltage is selected as either plus or minus with respect to the shield by a *Configuration Switch*. See Section 2.6.2.



757-030/XTCBNC

Figure 2.15 BNC Connector

2.6.10 Manufacturer's Identification and Serial Number Plate

This plate is installed at final assembly to identify the instrument's model and serial numbers.

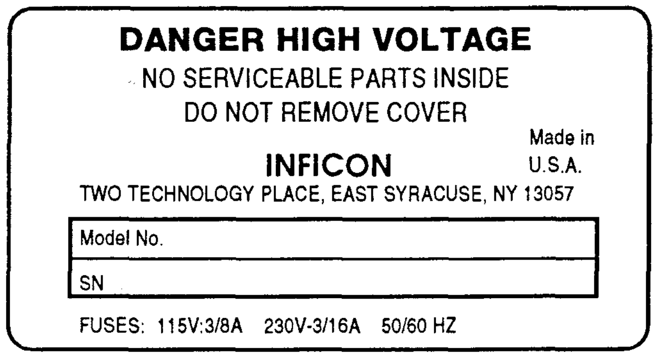
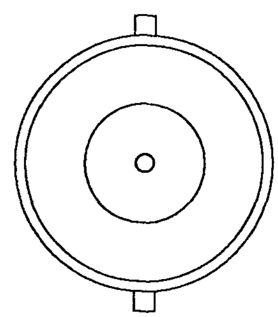


Figure 2.16 Serial Number Plate

2.6.11 Recorder

A BNC type female connector that supplies analog voltage proportional to rate, thickness, power or rate deviation. The function is determined by *configuration switches*. See Section 2.6.2. See the Remote Command description in Section 3.7.6 for how to choose this function via the remote communications when using an XTC/C.



757-030/XTCBNC

Figure 2.17 BNC Connector

2.7 Operation as a Deposition Monitor

Although this instrument is designed as a multi-layer process controller, it is also easily used as a rate and thickness deposition monitor. In addition, it is easily used for many other types of mass measurement applications.

The following discussion is divided into four segments. The first is for applications that do not require a source shutter. The second relates to those that use a source shutter. The third section is a simple application of the instrument for manual rate sampling. The fourth segment is directed towards those applications that are nontraditional; including biological, electroplating, etching and the measurement of liquid samples.

2.7.1 Monitoring- Systems Without a Source Shutter

To operate the instrument as a film rate/thickness monitor only the following three parameters need to be programmed. Press the **PROG** key to place the display in the program mode and enter the appropriate values for:

DENSITY Depends on the material to be measured, see Table of Densities and Z-ratios, Section 5.7.

Z-RATIO Depends on the material to be measured, see Table of Densities and Z-ratios, Section 5.7.

TOOLING 1,2 Corrects for the geometrical differences between the sensor and the substrate, see the section on "determining tooling" in **Calibration and Measurement**. **TOOLING 2** is used for the backup sensor when a dual head is used.

Properly mount and attach the appropriate transducer (see "guideline for the installation of and connection to sensors" in **Installation**).

Set the rear panel configuration switches for the appropriate transducer type; see Section 2.6.2.

Press the **PROG** key to change the display between the program and operate modes.

A **STOP** is cleared by pressing the **START** or **RESET** switch. **RESET** starts the process over (i.e., at the beginning of Layer 1).

Pressing the **ZERO** key at any time sets the displayed thickness to 000.0 KÅ.

The Rate display group will indicate the evaporation rate and the Thickness display group will increment accordingly. The front panel controls work normally.

2.7.2 Monitoring- Systems with a Source Shutter

In addition to measuring rate and thickness, these instruments can be used to terminate the deposition at the proper thickness. Implementation requires that the deposition system have a source (or substrate) shutter capable of automatic operation. The source shutter controller must be wired through the **SYSTEM I/O** connector on the rear panel of the instrument. The following parameters (in addition to those required in the section above) must also be programmed.

DEP RATE Program to 0.1 Å/sec.

NOTE: Programming the **DEP RATE** to 0.0 Å/sec skips the Deposit state.

FINAL THK Program to the desired film thickness.

In addition set all of the pre and post deposition parameters to zero (see **Programming and Operation Details**)

The operator manually increases the source power (using the source power supply's control) to the nominal operating level. Once the user is satisfied, the deposition begins when the **START** switch is pressed. This action zeros the accumulated thickness display and opens the source shutter. The operator must then adjust the source power manually to achieve the desired rate. The shutter will close automatically when the final thickness set point is achieved.

2.7.3 Rate Sampling

It is possible to use these instruments to periodically sample the rate in a deposition system. A shuttered transducer must be used, see "sensor selection guide" in the **Installation** portion of this manual.

NOTE: It will be useful to refer to the separate **Inficon Crystal Sensor Manual** (see list below) for transducer and actuator control valve installation.

IPN	Type
074-154	Bakeable
074-155	CrystalSix
074-156	Standard, Compact and Dual
074-157	Sputtering

1. Electrically connect the pneumatic shutter actuator control valve (IPN 007-199) to the sensor shutter pins of the **SYSTEM I/O** connector.

   CAUTION: Verify proper electrical connection, do not confuse the source shutter relay with the sensor shutter relay.

2. Program the **DEP RATE** parameter to 0.1 Å/sec.

   NOTE: Programming the **DEP RATE** to 0.0 Å/sec skips the Deposit state.

3. Program the **FINAL THK** parameter to a value which allows approximately 20 seconds of material accumulation onto the sensor head. For example, if the nominal rate is 20 Å/sec, set the final thickness to 20 sec x 20 Å/sec = 400Å. If the sample time is too short there could be errors induced by temperature transients across the monitor crystal.

   A sample is initiated by pressing **START** (from the **READY** mode). This zeros the displayed thickness and opens the sensor shutter. The operator may view the deposition rate display (allowing it to stabilize) and then comparing it to the desired rate. If a time longer than the programmed sample time is required to adjust the actual deposition rate the operator can press the **MPWR** key. Once the adjustments are completed, again pressing the **MPWR** key closes the shutter.

2.7.4 Nontraditional Applications

In addition to their normal application as a deposition monitor/controller, quartz crystal microbalances have significant utility as generalized mass sensors. This particular instrument family is capable of measuring mass increases or decreases on the face of the monitor crystal to an accuracy of +/- 0.617 nanograms/cm^2 (density = 1.00, z = 1.00). As always, it is imperative that the mass be well adhered to the face of the crystal or improper readings will be taken. It is especially important to recognize this requirement for measurements of liquids or other non-rigid materials. Inficon's 6MHz crystal holders have an open area of ~0.535 cm^2. For the highest accuracy possible, it is suggested that the individual crystal holder be measured with a traveling microscope to determine the exact opening area.

2.7.4.1 Etching

The instrument may be configured to display the thickness or mass removed from the face of a crystal. It is imperative that the material be removed uniformly over the active area of the crystal or improper readings will be taken. This inaccuracy occurs because of radial mass sensitivity differences across the face of the monitor crystal.

The etch mode is established by setting a configuration switch (see Section 2.6.2) on the back of the instrument.

The unit is operated normally, with the **ZERO** or **START** keys used to zero the displayed thickness. The **FINAL THK** parameter may be programmed to terminate the process.

2.7.4.2 Immersion in Liquids

Measurement of mass change in liquids is a relatively new field, consequently application information is limited. The energy loss from the vibrating crystal into the liquid environment is high, limiting the accuracy of the measurement in some cases. The ModeLock oscillator again provides superior performance, allowing operation in liquids of higher viscosity than an active oscillator system would provide. The presence of bubbles on the face of the crystal as it is immersed will drastically change the noted frequency shift and alter the sensitivity of the technique from immersion to immersion.

NOTE: It is not recommended to use standard Inficon sensors in Liquids without modification.

2.7.4.3 Biological

The measurement of biological specimens is subject to many of the same problems as covered in the measurement of liquids.

2.7.4.4 Measurement of Liquids

The measurement of the mass of a liquid on the face of a crystal is a technique that is subject to very large errors. The two primary problems with liquids are that they are not infinitely rigid structures and do not necessarily form in uniform layers. Because liquids do not oscillate as a rigid solid, not all of the mass participates in the resonance. Consequently, not all of the liquid is detected. In some ways, the crystal is more appropriately called a viscosity sensor. The second problem is that liquids tend to form spheres on the face of the crystal after only very modest accumulations of a few monolayers. This aggravates the problem caused by non-infinite rigidity. Another aspect of the problem is that the liquid spheres form at random locations across the crystal. Because monitor crystals have differential radial mass sensitivity an uncontrollable measurement problem exists. Spheres formed at the center of the crystal contribute more than spheres formed near the edge of the sensor's aperture.

2.8 Operation as a One Layer Controller

This instrument is designed to provide automatic deposition rate control with thickness termination as well as pre and post deposition source conditioning. Fully automatic operation requires that the instrument be interfaced with the deposition source power supply controller and the source shutter. In addition, the instrument interfaces to many other deposition system components through the **SYSTEM I/O** and **AUX I/O** connectors.

To operate the instrument as a single layer controller it is necessary to program the film sequence parameters. A film sequence begins with a **START** command and ends when the same film reaches the "IDLE" state.

> **NOTE:** A **START** command may be provided by pressing the **START** or by activating the **START** input on the system I/O connector.

All instrumental action that occurs between these events is determined by the values programmed into the appropriate film specific parameters. Programming the instrument is easily accomplished once you have made the determination to monitor or control the process, chosen the type of material to deposit and its required rate and thickness and have become familiar with the instrument programming procedure. If you are familiar with the terminology of depositions, it is only required that the desired values of each parameter be entered for the designated **FILM #**.

A film is composed of many possible states, with a state being defined as one process event. These states sequence in order and are defined and diagramed in this manual in the section **Programming and Operation Details**. The values used in the various parameters tell the instrument how to specifically execute the deposition process, see Section 4.2 for a description of which parameters affect a given process state. Figure 2.18 is a generalized overview of the normal processing of a film and its source control.

For example, if the first layer of the process is 1000Å of copper it would be convenient to dedicate film 1's parameters to describing this particular layer of the process.

These instruments allow up to nine individual film programs to be defined, stored and recalled. When the display is in the program mode the particular **FILM #** being modified is always visible (except when the **S** and **Q** parameters are being programmed). The **FILM #** may be changed by moving the cursor to that parameter and changing its value. When the display is in the operate mode the film executing or about to execute is displayed as **FILM #**.

A **START** command will begin processing that film if it is not already processing another film or in the **STOP** state. **START** commands are ignored if a film is already processing.

Skipping a State Overview

It is not necessary to use all possible film states when a film is programmed. Unwanted states will be executed in 250 ms if the film parameters which are used to define the state are set to zero. The **IDLE** state of a film, however, will always be executed. When the desired **DEP RATE** is programmed to zero, the entire **DEPOSIT** state will be skipped (including any rate ramps). If no parameters have been programmed, the film will immediately sequence to the **IDLE** state when the **START** key is pressed.

Idle State Processing Overview

When a film program finishes in the **IDLE** state at a programmed **IDLE PWR** level other than zero, a subsequent **START** command will initiate any film program utilizing the same source output at the **RISE TIME 2** state, skipping all previous states, even if they were programmed. If **RISE TIME 2** is not present in the film , the instrument will sequence to the next viable state - **SHUTR DLY**, **DEPOSIT**, **IDLE RAMP** or **IDLE** (in the stated order).

Manual Power Overview

The **MANUAL** state may be entered whenever the instrument is not in the **STOP** or **IDLE** state by pressing the **MPWR** switch. The shutter will always open and the **FINAL THK** event will be ignored. When the **MANUAL** control state is ended, the unit will sequence to the **DEPOSIT** state, provided that the **FINAL THK** limit has not been exceeded. Any thickness accumulated while the unit has been in the **MANUAL** state will be retained and added to when the **DEPOSIT** state is entered.

When the instrument is in the MANUAL state the control voltage output (% Power on the display) may be increased or decreased either through the Handheld Power Controller (optional) or the △ or ▽ keys on the front panel. The rate of change of source power is linearly ramped from 0.4% per second to 4% per second over 4 seconds and then held at a constant 4% per second. This feature is designed to allow fine adjustment of the control voltage when needed, while also allowing rapid control voltage adjustment if desired.

Time Power State Overview

The time-power state will only be entered while the instrument is in the **DEPOSIT** or **RATE RAMP** state and the film program has been set to complete on time-power in the event of a failed crystal. If a crystal fail is detected during the pre-deposit states the instrument will not sequence further, causing an instrument **STOP** even if the complete on **TIME-PWR (Y)** option is selected .

Once in the TIME-POWER state, the source power will remain at the 5 seconds average power value of the source control output computed 2.5 seconds prior to the failure. (These times are appropriately modified for PID control.) Thickness is accumulated at the programmed **DEP RATE** value. The time-power state will terminate when the **FINAL THK** value has been exceeded. Any post-deposit states will be executed exactly as if a normal deposition had occurred. The **TIME-PWR** annunciator will remain on the display. When the post-deposit states are complete, the instrument will enter the **STOP** state. A **RATE RAMP** cannot be executed in TIME-POWER and that state is consequently skipped.

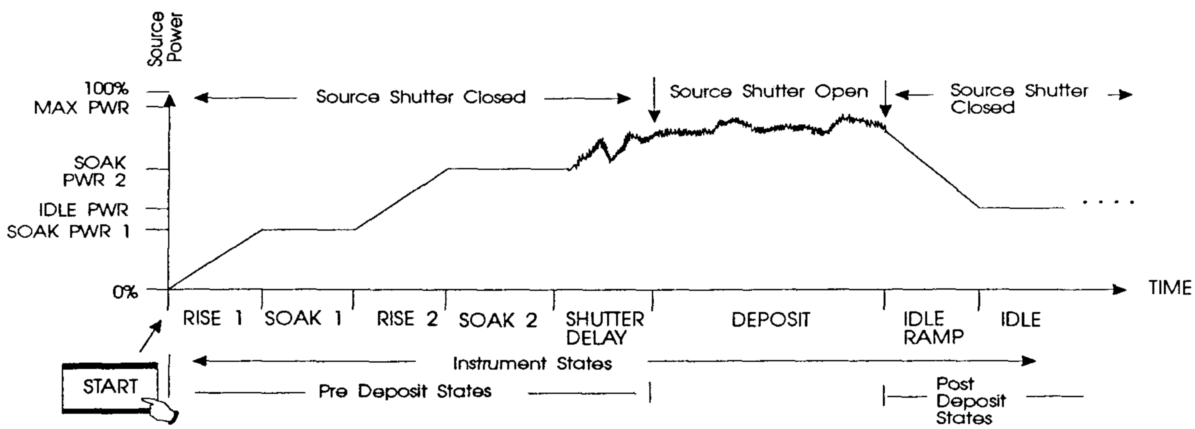


Figure 2.18 State Processing for a Film

Controlling the Source Overview

Stable rate control during the **DEPOSIT** state requires the proper setting of the following control loop algorithm adjusting parameters: **CTL GAIN**, **CTL TC**, and **CTL DT**. By properly adjusting these parameters it is possible to control sources of nearly any physical characteristic by employing either a **PID** or integrating algorithm. The proper adjustment technique and a detailed algorithm description is covered in the section on "tuning the control loop," in Section 4.5, **Programming and Operations Details**.

2.9 Operation as a Multi-Layer Controller

This instrument can be programmed to execute a series of up to three of the stored films in a repetitive sequence. This sequence of films is called a **PROCESS**. A separate **START** command is necessary to initiate each layer of a process. This command may be initiated from the front panel switch, through the rear panel I/O or through the computer interfaces.

Defining a Process Overview

A process is programmed by moving the cursor to the **LYR** parameter when the display is in the program mode. The **LYR** parameter value is visible any time the display is in the operating mode. When the **LYR** parameter is selected; the segmented digit immediately to the right begins to flash. Entering a digit between one and nine will designate the **FILM** associated with that number to be the film first executed in the **PROCESS**. Upon entry, the selected digit will become static and the second segmented digit will blink. Entering a second (or even the same) number will establish the second layer of the **PROCESS**. Now the third digit will flash, entering a third number will complete the process sequence.

A **PROCESS** sequence may be altered any time the keyboard is unlocked or through the various computer interfaces.

NOTE: If a zero is entered for the second or third layer, that layer(s) will be skipped. The first layer must be a non-zero value.

INFICON

Chapter 3
Installation

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3.0 Installation

3.1 Installing the Instrument - Details

A general schematic of instrument installation is given in Section 2.3, use it for reference. *The importance of grounding the instrument cannot be over emphasized for both safety and performance needs.*

3.1.1 Control Unit Installation

Review the specific suggestions and warnings concerning safety and installation that are presented in Section 1.

It is generally advisable to centrally locate the controller, minimizing the length of external cabling. The cable from the instrument to the XIU is fifteen feet. Longer cables are specifiable as 30 or 100 ft. (max.), see Section 2.6.6 for ordering details.

The control unit is designed to be rack mounted. It may be also used on a table; four self-adhesive rubber feet are included in the ship kit for this purpose.

3.2 Electrical Grounding and Shielding Requirements

Careful consideration of simple electrical guidelines during installation will avoid many problems caused by electrical noise.

To maintain the required shielding and internal grounding as well as insuring safe and proper operation, the instrument must be operated with all enclosure covers and option panels in place. These must be fully secured with the screws and fasteners provided.

3.2.1 Verifying/ Establishing Earth Ground

If local facilities engineering cannot provide a low impedance earth ground close to the instrument, the following procedure is recommended.

Where soil conditions allow, drive two ten foot copper clad steel rods into the ground six feet apart. Pour a copper sulfate or other salt solution around the rods to improve the soil's conduction. A near zero resistance measurement between the two rods indicates that a desirable earth ground has been established. In severe cases it may take several soakings of solution over several days to reach this condition.

> **NOTE:** Keep connections to this grounding network as short as possible. Most noise transients contain significant power at high frequencies. A long path adds to the ground circuit's inductance and thereby increases its impedance at these frequencies.

3.2.2 Connections to Earth Ground

The ground connection on the instrument is a threaded stud with a hex nut. It is convenient to connect a ring terminal to the ground strap, thus allowing a good connection with easy removal and installation. See figure 3-1 for the suggested grounding scheme. In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030 thick X 1" wide) is more suitable because of its lower RF impedance.

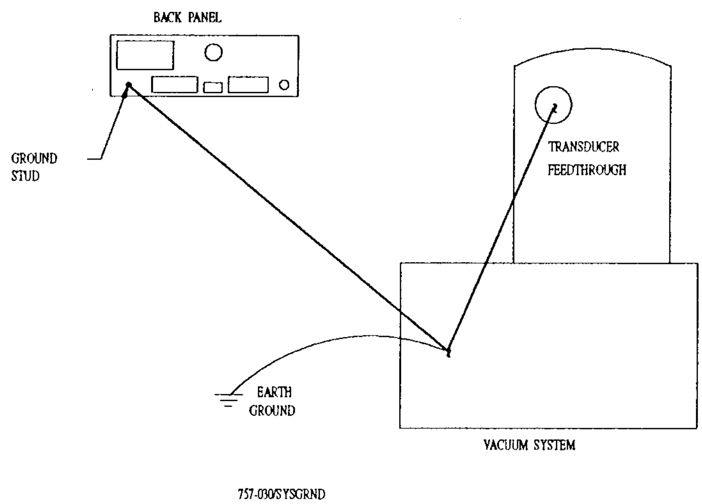


Figure 3.1 System Grounding Diagram

WARNING!!

AN EXTERNAL GROUND CONNECTION IS REQUIRED TO ENSURE PROPER OPERATION, ESPECIALLY IN ELECTRICALLY NOISY ENVIRONMENTS.

When used with RF powered sputtering systems, the grounding scheme may have to be modified to optimize the specific situation. An informative article on the subject of "Grounding and RFI Prevention" was published by H.D. Alcaide, in "Solid State Technology", p 117 (April, 1982).

3.2.3 Minimizing Noise Pickup from External Cabling

When an instrument is fully integrated into a deposition system, there are many wire connections; each a potential path for noise to be conducted to the inside. The likelihood of these wires causing a problem can be greatly diminished by using the following guidelines:

- Use shielded coax cable or twisted pairs for all connections.
- Minimize cable lengths by centralizing the controller.

- Avoid routing cables near areas that have the potential to generate high levels of electrical interference. For example, large power supplies, such as those used for electron beam guns or sputtering sources, can be a source of large and rapidly changing electro-magnetic fields. Placing cables as little as one foot (30 cm) from these problem areas can be a very significant improvement.
- Be sure that a good ground system and straps are in place as recommended above.
- Ensure that all instrument covers and option panels are in place and tightly secured with the provided fasteners.

3.3 Connection to Rear Panel

The long term performance of this instrumentation is dependent on the quality of the installation. A first rate installation includes the proper assembly of the user/OEM installed cabling. The assembly instructions for the connectors used on this instrumentation are shown in the following sections.

3.3.1 The BNC Connectors

Because complete BNC cables are so common, there are no mating connectors supplied in the ship kit for the source and recorder outputs. It is recommended that completed BNC type cables be purchased locally, even if one end is cut off for connection to the external apparatus.

3.3.2 The "D" - Shell Connectors

The "D" shell connectors use solder cup contacts that will accept solid or stranded wire with a maximum individual wire size of 20 AWG. Multiple stranded wire jumpers may equal 18 AWG, or two 22 AWG wires may be employed. The recommended wire strip length is ¼" (6.4mm).

The duplex tin/lead solder cup readily accepts tinned leads and will securely strain-relieve wires when properly soldered.

The American National Standards Institute *Standards For Soldering Electronic Interconnections* (ANSI/IPC-S-815A) is recommended for establishing soldering quality guidelines.

The soldering procedure is as follows:

1. Obtain a connector and wire(s) of the type and size required for your application.
2. Ensure that surfaces to be soldered are clean and free of any contaminants that may inhibit solderability.
3. Strip wire(s) to recommended strip length (¼"). Tin the leads if required.
4. Obtain resin flux, 40/60 alloy solder, and a low-wattage soldering iron.

> **NOTE:** It is common to use heat shrink tubing over solder joints to insulate the exposed solder connection at the cup. If using heat shrink tubing, ensure that the tubing sections are cut to proper length and placed on the wire(s) prior to soldering. After wires are terminated, slide tubing over solder connections and shrink with an appropriate heat source.

5. Coat the stripped portion of the wire(s) with the flux and insert into the solder cup of the contact until the conductor is bottomed in the cavity.

6. Heat the solder cup with the soldering iron and allow the solder to flow into the cup until the cavity is filled but not over filled.

7. Continue soldering wires until all terminations are complete.

8. Clean the soldered connections with a suitable alcohol/water rinse to remove flux and solder residue.

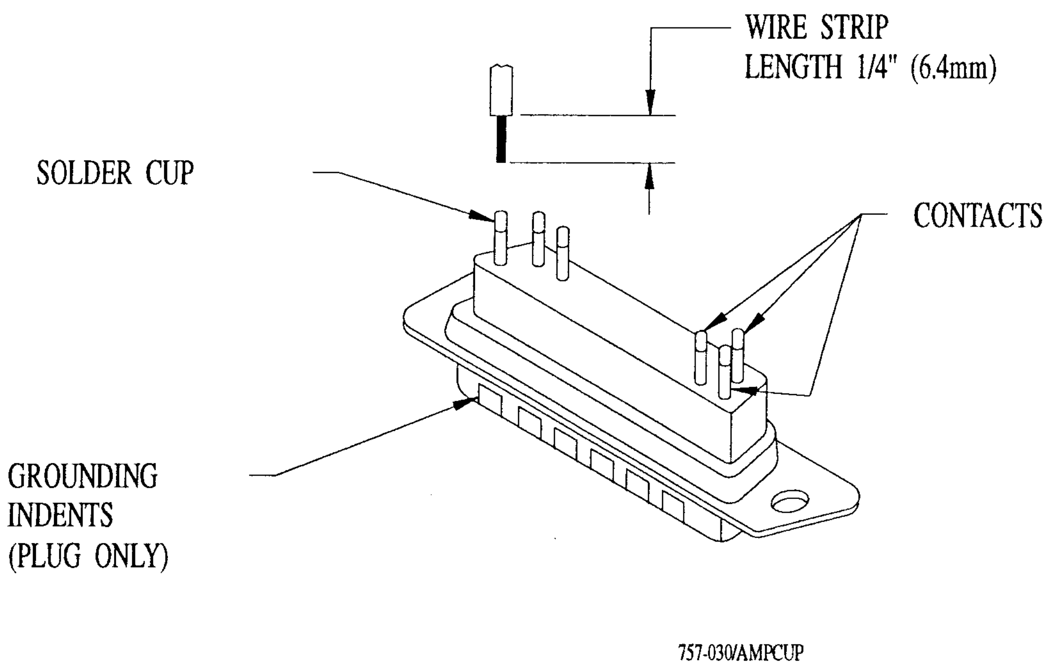


Figure 3.2 Solder Cup Connector

3.4 Sensor Selection Guide

The choice of sensor type must be dictated by the process, the deposition material and the physical characteristics of the process chamber. General guidelines for each sensor type produced by Inficon are outlined in the Sensor Selection table below. For specific recommendations, consult your Inficon representative.

Table 3.1 Sensor Selection Table

		FEATURES			
Name	**IPN**	**Temp °C***	**Crystal Exchange**	**Utility Connector**	**Comments**
Standard	750-211-G1	130°	Front	Side	
Standard w/Shutter	750-211-G2	130°	Front	Side	
Compact	750-213-G1	130°	Front	Rear	For tight spaces.
Compact w/Shutter	750-213-G2	130°	Front	Rear	For tight spaces.
Dual	750-212-G2	130°	Front	Side	Two crystals for crystal switch. Includes shutter.
Sputtering	007-031	130°	Rear	Side	For RF and diode sputtering. (Optional shutter available.)
Bakeable:					
12"	007-219	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout.
20"	007-220				
30"	007-221				
Bakeable w/Shutter:					
12"	750-012-G1	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout.
20"	750-012-G2				
30"	750-012-G3				
CrystalSix	750-446-G1	130°	Front	Side	6 crystals for process security.

*These temperatures are conservative maximum device temperatures, limited by the properties of Teflon at higher temperatures. In usage, the water cooling allows operation in environments that are significantly elevated, without deleterious effects.

NOTE: Do not allow water tubes to freeze. This may happen if the tubes pass through a cryogenic shroud and the water flow is interrupted.

NOTE: For best operation, limit the maximum input water temperature to less than 30°C.

NOTE: In high temperature environments more heat may transfer to the water through the water tubes than through the actual transducer. In extreme cases it may be advantageous to use a radiation shield over the water tubes.

3.5 Guidelines for Transducer Installation

CAUTION: *The performance of this instrument depends on the careful installation of the chosen transducer. Improper installation will cause problems with deposition repeatability, crystal life and rate stability.*

3.5.1 Sensor Installation

Figure 3.3 shows a typical installation of an Inficon water cooled crystal sensor in the vacuum process chamber. Use the illustration and the following guidelines to install your sensors for optimum performance and convenience.

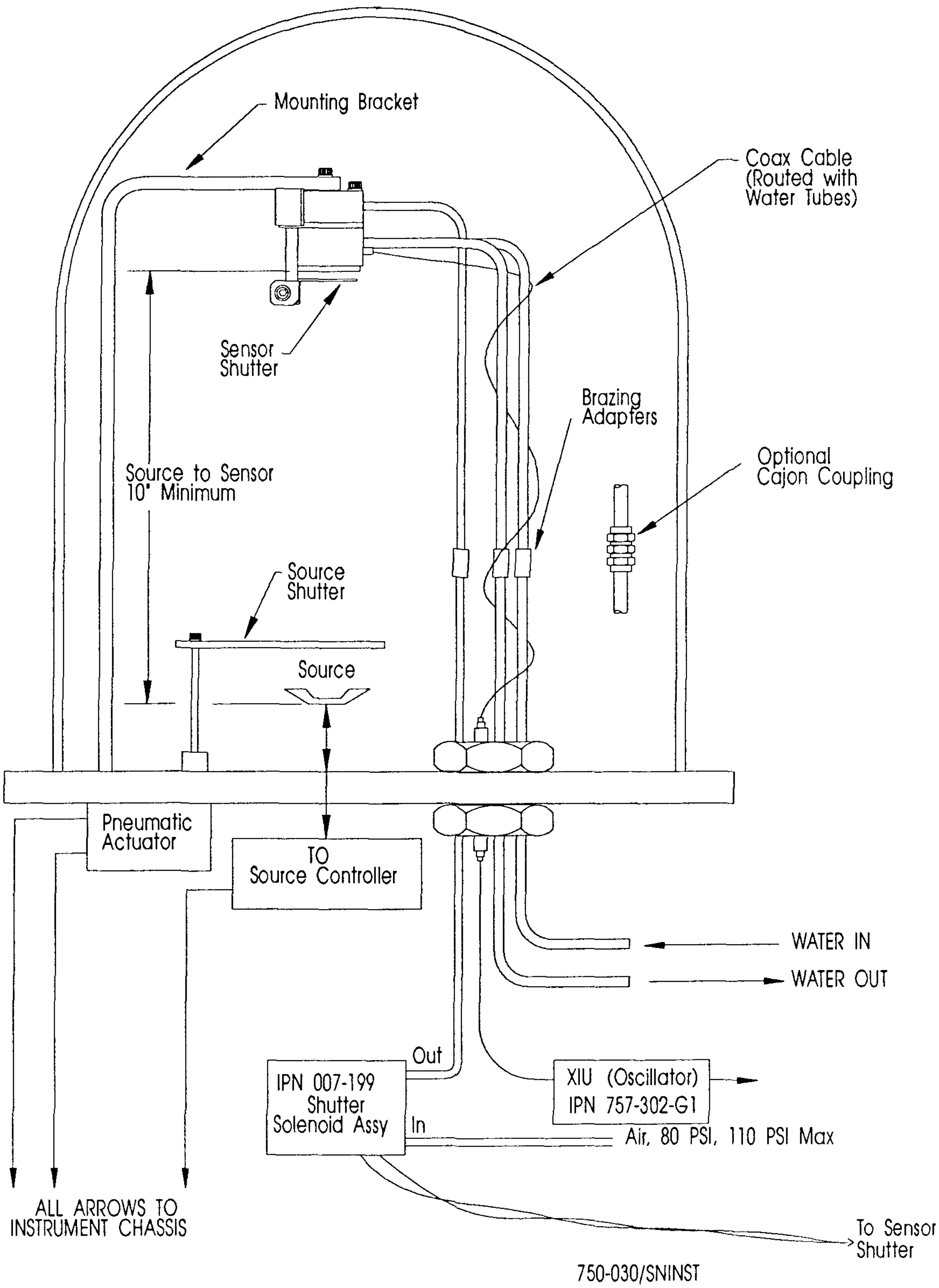


Figure 3.3 Typical Installation

Generally, install the sensor as far as possible from the evaporation source (a minimum of 10" or 25.4 cm) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 3.4 shows proper and improper methods of installing sensors.

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

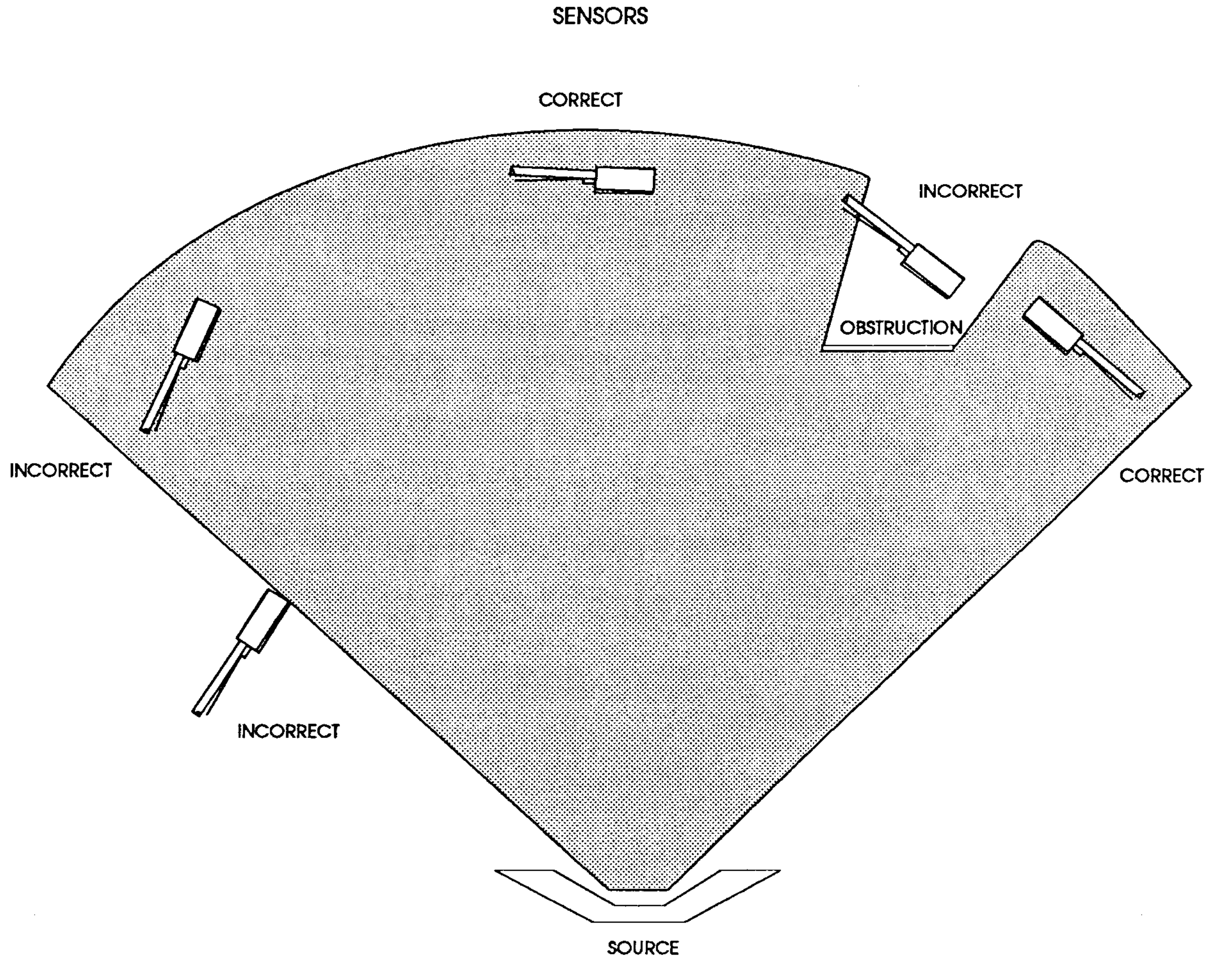


Figure 3.4 Sensor Installation Guidelines

3.5.2 CrystalSix

Installing the CrystalSix transducer requires that the CrystalSwitch configuration switches be set appropriately; see Section 2.6.2. Follow the guidelines in the CrystalSix Manual (IPN 074-155) and Figure 3.5. If the unit is configured for one CrystalSix, it must be connected to Sensor 1.

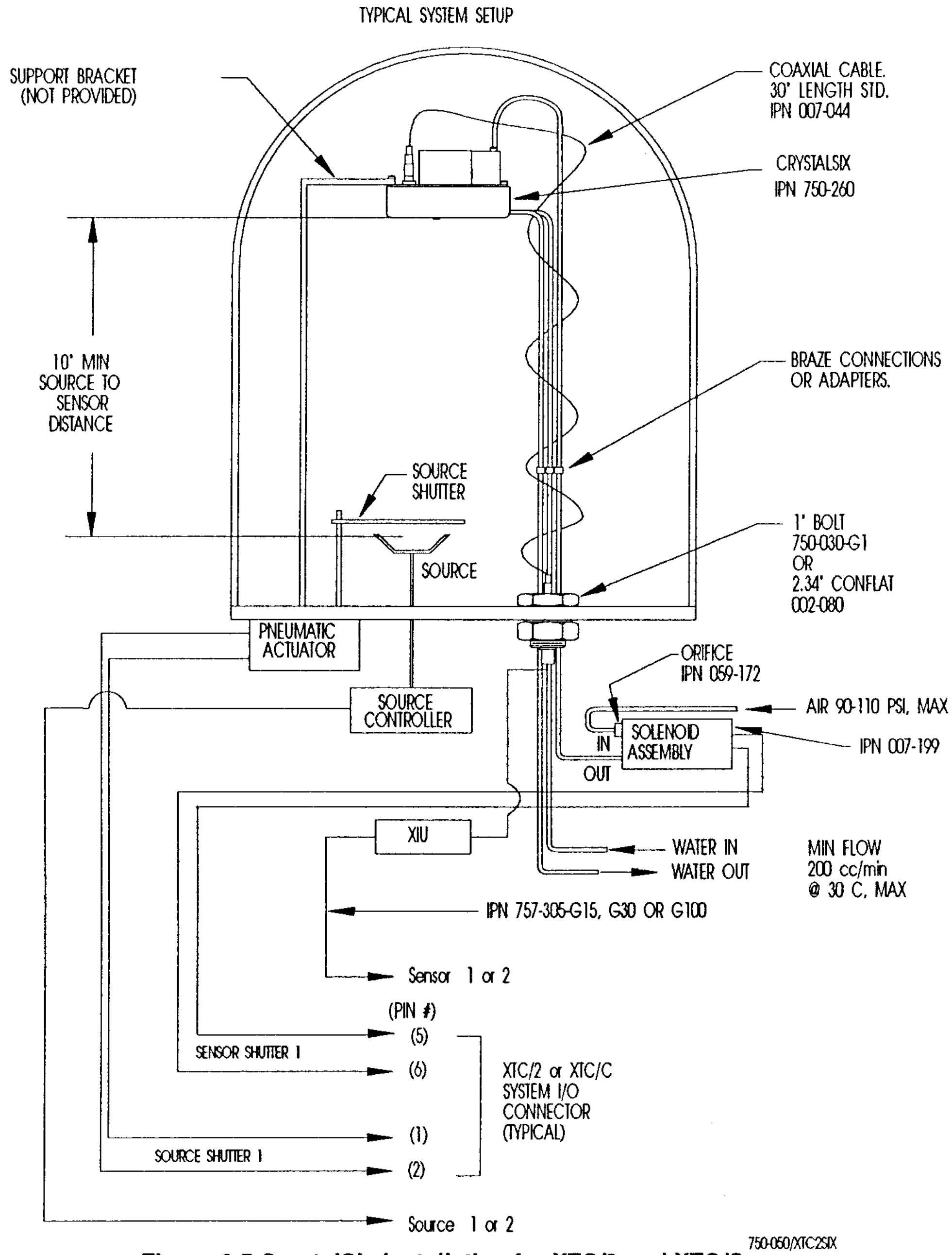


Figure 3.5 CrystalSix Installation for XTC/2 and XTC/C

3.5.3 Check List for Transducer Installation

- Mount the sensor to something rigid and fixed in the chamber. Do not rely on the water tubes to provide support.
- Plan the installation to insure that there are no obstructions blocking the path between the Sensor and the Source. Be certain to consider rotating or moving fixtures.
- Install sensors so their central axis (an imaginary line drawn normal to the center of the crystal's face) is aimed directly at the virtual source being monitored.
- Be sure there is easy access for the exchange of crystals.
- For systems employing simultaneous source evaporation (co-dep), try to locate the sensors so the evaporant from each source is only flowing to one sensor. This is not generally possible to do without special shielding or optional "material directors" for the transducers.
- The use of water cooling is always recommended, even at very low heat loads and low rates.
- If penetrating a cryogenic shroud, be sure that the cooling water is kept flowing or drained between uses. Failure to do so could cause the water to freeze and the water tubing to rupture.
- Avoid running cold water tubes where condensation can drip into the feedthroughs. This condensate can effectively short the crystal drive voltage, causing premature crystal failure.

3.6 Use of the Test Mode (XTC/2 Only)

This instrument contains a software controlled test mode which simulates actual operation. The purpose of the Test Mode is to verify basic operation and for demonstrating typical operation to the technician.

The Rate displayed during Test Mode operation is determined as follows:

$$\text{Displayed Rate} = \frac{40}{\textbf{Density}\ (\text{gm/cc})} \times \frac{\textbf{Tooling}\ (\%)}{100\%}\ \text{Å/sec}$$

All relays and inputs operate normally during Test Mode operation.

3.6.1 Operational Test

The power switch should be in the **STBY** position before the instrument is connected to line power.

Perform the self test as follows:

1. Verify that no system cables other than the power cord are connected to the unit. Relays may be verified with an ohm meter or custom test box.

2. Set configuration switch 1 to the "ON" position.

3. Press the **ON/STBY** switch, the green power LED should light. If **Err** is displayed on the LCD refer to "**Error Messages**," Section 6.2.

4. The following LCD displays will appear:

   TEST
   READY
   XX:XX PHASE MIN:SEC
   XX% POWER
   XTAL FAIL

5. Press the **PROG** key. The program display will appear and the cursor will be located beside **RISE TIME.**

6. Refer to the list of parameters in Table 3.2 and enter the data as they are given.

Table 3.2 Operational Test Parameters

RISE TIME 1	00:20	min:sec
SOAK PWR 1	20	%
SOAK TIME 1	00:10	min:sec
RISE TIME 2	00:15	min:sec
SOAK PWR 2	35	%
SOAK TIME 2	00:10	min:sec
SHUTR DLY	N	Y:N
NEW RATE	00.0	Å/sec
R RAMP TIME	00:0	min:sec
IDLE RAMP	00:00	min:sec
IDLE PWR	02	%
TIME PWR	N	Y:N
XTAL SWCH S	0	
XTAL SWCH Q	0	
TOOL FACT 1	110	%
TOOL FACT 2	100	%
DEP RATE	16.2	Å/sec
FINAL THK	2.000	kÅ
THICK SPT	0.000	kÅ
DENSITY	02.73	gm/cc
Z-RATIO	1.000	
SENSOR #	1	
SOURCE #	1	
CRUCIBLE #	0	
CTL GAIN	10	Å/sec / %
CTL TC	5	sec
CTL DT	0.1	sec
MAX PWR	50	%
SAMPLE	5	%
HOLD TIME	00:00	min:sec

8. When the correct sequence of numerals appear in the flashing display, press the E key to enter and store the data.

9. Press the **PROG** key to exit the program display.

10. Press **START** to begin the programmed sequence.

11. **RISE TIME 1** will be displayed, the min:sec counter begins to decrement from 00:20, while **POWER** increases to 20%. At time 00:00 the state message changes to **SOAK TIME 1** while the counter begins to decrement from 00:10. Upon reaching time 00:00, the state message again changes to **RISE TIME 2**.

12. **RISE TIME 2** begins to decrement from time 00:15 while **POWER** increases to 35%. Upon reaching time 00:00, the state message changes to **SOAK TIME 2** and the time again begins to decrement from time 00:10. At time 00:00 the state message changes to **DEPOSIT**.

13. Once in **DEPOSIT**, the time begins to increment and the deposition rate will be 16.1 Å/s. The **THICK SPT** annunciator is displayed and power is at 36%. Upon reaching the **FINAL THK** parameter of 2.000kÅ, deposition stops with an elapsed time of 02:03. The clock immediately begins counting up from 00:00. The **FINAL THK** annunciator is displayed.

14. The instrument is now in **IDLE PWR** and will remain in this mode until **START** is pressed.

15. When **START** is pressed, the process will repeat steps 12 through 14.

    NOTE: If **IDLE PWR** is reprogrammed to 0, the process will begin at **RISE TIME 1**.

16. After successful completion of the above steps, power down the instrument to leave the **TEST** mode by turning configuration switch 1 "OFF" and then placing the unit first in **STBY** and then "ON" to read the new configuration.

3.7 Input and Output Details

3.7.1 Relays

The relays and circuits used are safety rated 120 Vac, 100 VA with a maximum current of 2.5 amps. Their function is as follows:

Table 3.3 System I/O Connector

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
1	1,2	**Source Shutter 1**	During Deposit and Manual states when Source 1 is designated.	Balance
2	3,4	**Source Shutter 2**	During Deposit and Manual states when Source 2 is designated	Balance
3 4	5,6 7,8	**Sensor Shutter 1** **Sensor Shutter 2**	During the following states when the designated sensor is active: • RateWatcher Sample • Deposit • Manual • CrystalSwitch to dual head backup • Pulses during CrystalSix transitions • Shutter delay	Balance
5	9,10	**Stop**	When a stop condition is generated, see 4.3.2, 4.3.1 and 2.6.2	When stop condition is cleared
6	11,12	**End of Process**	When last layer of the process reaches **IDLE** state	At the start of next process

Table 3.4 AUX I/O Connector

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
7	1,2	**Thickness Set Point** or **End of Film**	**THK SPT** exceeded for two consecutive measurements When layer reaches the idle state	Entry of IDLE state On a RESET or START of the next layer
8	3,4	**Feedtime (Soak 2)**	During Soak 2	Balance
9	5,6	**Crystal Fail**	When all crystals have been consumed	When crystal fail has been cleared
10	7,8	**Alarms** or **In Process**	When alarm conditions have been triggered; see 4.3.1. When a process is started	When alarm condition ceases When in the STOP, READY, or IDLE states
11	9,10	**Source 1/Source 2**	At start of a layer utilizing Source 1 (toggle)	At start of layer utilizing Source 2
12	11,12	**END Deposit**	When **FINAL THK** is exceeded for two consecutive measurements	Entry of READY state

Table 3.5 Open Collector Outputs* (one of eight encoding)

TTL Output #			High	Low
1	18	**Crucible Select 1**	If the active layer's designated crucible is 1, or 0.	Balance
2	19	**Crucible Select 2**	If the active layer's designated crucible is 2	Balance
3	20	**Crucible Select 3**	If the active layer's designated crucible is 3	Balance
4	21	**Crucible Select 4**	If the active layer's designated crucible is 4	Balance
5	22	**Crucible Select 5**	If the active layer's designated crucible is 5	Balance
6	23	**Crucible Select 6**	If the active layer's designated crucible is 6	Balance
7	24	**Crucible Select 7**	If the active layer's designated crucible is 7	Balance
8	25	**Crucible Select 8**	If the active layer's designated crucible is 8	Balance

*The crucible select outputs are open collector type, 5 volt maximum with a capability of driving 5 TTL loads (10 mA)

Function may be overwritten by Remote Communications Commands **R15 - **R**18, see Section 3.8.5.

3.7.2 Inputs

Inputs are activated by pulling the specific input's terminal to ground (<0.8V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 ma (1 low power TTL load). These ports are read every 250 ms; signals must be present during a read cycle.

Table 3.6 System I/O Connector

Input #	Pin #	Function	Description
	13,14,15,16,17	Input Common (GND)	Used as reference for activating any of the inputs
1	18	**START** deposition	Detection of a falling edge duplicates front panel START
2	19	**STOP** deposition	Detection of a falling edge induces a STOP
3	20	**END** deposit	Detection of a falling edge terminates the Deposit state just as if the FINAL THK were achieved.
Configuration switch #12 set for "Standard" Input Option:			
4	21	**SAMPLE INITIATE**	Detection of a falling edge initiates a RateWatcher sample if the film is programmed for this feature.
5	22	**SAMPLE INHIBIT**	Application of a ground reference voltage maintains the RateWatcher in the Hold condition.
6	23	**CRYSTAL FAIL INHIBIT**	Application of a ground reference voltage prohibits the closure of the Crystal Fail Relay and the associated Stop.
7	24	**ZERO** thickness	Detection of a falling edge duplicates the front panel ZERO.
8	25	**SOAK 2 HOLD**	Application of a ground reference voltage extends the SOAK 2 state until the signal/closure is removed.
Configuration switch #12 set for "Film Select" Input Option:			
4	21	**RESET**	
5	22	**Select Film MSB**	
6	23	**Select Film**	
7	24	**Select Film**	
8	25	**Select Film LSB**	

pin22	pin23	pin24	pin25	Film #
0	0	0	X(don't care	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	X	1	X	1

Table 3.7 AUX I/O Connector

Input #	Pin #	Function	Description
	13	Input Common (GND)	Used as a reference for activating any of the inputs.
9	14	**CRUCIBLE VALID**	Application of a ground reference voltage from the crucible rotation mechanism is used to signal that the proper crucible has indexed into position and state sequencing may proceed.
	15,16,17	Input Common (GND)	Used as a reference for activating any of the inputs.

3.7.3 Chart Recorder

The chart recorder output has 12 bit resolution with one additional bit of sign information over the range of -10 to +10 volts. It can supply up to 5 milliamps and has an internal resistance of 100 ohms. The output is proportional to rate, thickness or rate deviation depending on the setting of the XTC/2's configuration switches; see Section 2.6.2. The XTC/C's default recorder function is 0-100 Å/sec rate and is changed by sending the **R** 38 command, see Section 3.7.6. It is normal for ripple to appear on these outputs to a maximum of 5 mV at ~84 Hz. This output is updated every 250 milliseconds.

3.7.4 Source Outputs

The source outputs will drive +/- 10.00 volts into a 400 ohm load. The output is proportional (15 bits) to the required source power. It is normal for ripple to appear on these outputs to a maximum of 50mV at ~84 Hz. The polarity is set with a configuration switch; see Section 2.6.2. This output is updated every 250 milliseconds.

3.8 Computer Communications

This instrument supports a number of standard and optional computer communications protocol formats. RS232 is standard, operating in either checksum or non-checksum as well as SECS II formats. It may also be configured to automatically output process data (data logging) upon reaching **FINAL THK**. Additionally, an IEEE communications option may be installed.

3.8.1 Communications Setup

To set up the remote communication interface, when powering up the XTC/2, hold down the 0 key. The following set of parameters can be entered using the digits, enter, and clear keys.

tyPE (0 = Inficon Checksum, 1 = Inficon no checksum, 2 = SECS, 3 = Datalog)

(If SECS is chosen for tyPE the next 5 parameters are accessed):

d Id (Device ID 0-32767)

t1 (Timer 1 per SECS definition) (0-10.0 seconds)

t2 (Timer 2 per SECS definition) (0.2-25.0 seconds in 0.2 increments)

rtrY (Retry limit per SECS definition) (0-31)

dUPL (Duplicate block per SECS definition)

baUd (0=1200, 1=2400, 2=4800, 3=9600)

IEEE (IEEE address, 0-30) - requires optional hardware

When this list is complete, the READY message is flashed and the choice will be given to either repeat the list or continue with normal operation. Pressing ENTER will continue with normal operation. Pressing CLEAR will repeat the list.

NOTE: Do not turn the unit off while in the Communications Program Mode, otherwise the new parameter values will not be saved properly.

To set up the communication interface for the XTC/C, see the configuration switch setup (2.6.2) and review the communication command Section 3.8.5. The cables used between the XTC and the host computer must be wired as depicted in the cable diagram in Section 2.6.7.

3.8.1.1 IEEE Settings for a National Instruments IEEE-GPIB Board

When establishing IEEE communications the following settings are found to work using a National Instruments IEEE-GPIB board. These values are set using the IBCONF.EXE file provided by National Instruments.

Board Characteristics

National Instruments	Board Characteristics	IBM AT, PS/2-25/30
Board: GPIB0		SELECT (use right/left arrow keys):
Primary GPIB Address ◄►	0	0 to 30
Secondary GPIB Address...........	NONE	
Timeout setting....................	T300ms	
EOS byte..........................	0AH	
Terminate Read on EOS............	yes	
Set EOI with EOS on Write..........	yes	
Type of compare on EOS	7-bit	
Set EOI w/last byte of Write	yes	
System Controller	yes	
Repeat addressing.................	no	
Disable Auto Serial Polling	yes	
High-speed timing.................	no	
Interrupt setting	7	
Base I/O Address..................	2C0H	
DMA channel (Arbitration)...........	5	
F1: Help F2: Explain Field		F6: Reset Value F9: Return to Map

Device Characteristics

National Instruments	Device Characteristics	IBM AT, PS/2-25/30
Device: XTC2	Access: GPIB0	SELECT (use right/left arrow keys):
Primary GPIB Address ◄►	3	0 to 30
Secondary GPIB Address...........	NONE	
Timeout setting....................	T300ms	
EOS byte..........................	0AH	
Terminate Read on EOS............	yes	
Set EOI with EOS on Write..........	yes	
Type of compare on EOS	7-bit	
Set EOI w/last byte of Write	no	
F1: Help F2: Explain Field		F6: Reset Value F9: Return to Map

3.8.2 Basic Command Structure

The following commands are available via the computer communications:

E	Echo. Returns the sent message.
H	Hello. Returns the model and software version number.
Q	Query. Interrogates the programmable parameters and returns the value of parameter requested.
U	Update. Replaces the particular parameter with the value sent.
S	Status. Sends back pertinent information based on the specific request made.
R	Remote. Perform an action based on the specific command given. Many of these mimic front panel keystrokes.

The send and receive protocol formats are described below and use the following abbreviations:

STX	Start of transmission character
00,NN	The size of the command is 2 bytes long with 00 representing the high order Byte and NN representing the low order byte.
ACK	Command acknowledged character
NAK	Command not acknowledged character
LF	Line Feed (EOT byte for IEEE)
CS	Checksum
CR	Carriage Return

CHECKSUM FORMAT MESSAGE PROTOCOL

To XTC:	STX 00 NN message_string CS	
From XTC:	STX 00 NN ACK message_string CS	(if success)
	- or -	
	STX 00 NN NAK error_code CS	(if failure)

NONCHECKSUM FORMAT MESSAGE PROTOCOL

To XTC:	message_string ACK	
From XTC:	message_string ACK	(if success)
	- or -	
	error_code NAK	(if failure)

IEEE488 FORMAT MESSAGE PROTOCOL

To XTC:	message_string LF	
From XTC:	message_string LF	(if success)
	- or -	
	error_code LF	(if failure)

SECS FORMAT MESSAGE PROTOCOL

To XTC:	NN SECS_10_BYTE_HEADER message CS CS
From XTC:	NN SECS_10_BYTE_HEADER ACK message CS CS (if success)
	- or -
	NN SECS_10_BYTE_HEADER NAK error_code CS CS (if not)

The following Error Codes are used:

A - Illegal command
B - Illegal Value
C - Illegal ID
D - Illegal command format
E - No data to retrieve
F - Cannot change value now
G - Bad checksum

3.8.3 Service Requests and Message Available

In the IEEE mode there are a number of events which will trigger service requests, a request by the instrument to transmit information to the host. The instrument does this by triggering the **RQS** bit of the Status Byte. A host initiated serial poll then identifies the requesting device by the presence of a 1 in the **RQS** (2^6) bit of the status byte. The particular service request generator event is encoded in bits 2^0 - 2^3 inclusive, as shown below:

	RQS		MAV				
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
not used		not used		Service request generation encoding			

Table 3.8 Service Request Encoding

Generator Event	Code	Value
Final Thickness	0001	1
Instrument in **STOP** State	0010	2
End of a Layer	0011	3
STBY/ON sequence	0100	4
End of a Process	0101	5
Crystal Fail	0110	6
250ms **DATA READY**. Available only after **R**23 is issued, see Section 3.7.6. This is automatically cleared on crystal failure.	0111	7

It takes the instrument various lengths of time to formulate a correct response to queries for information. To avoid unnecessarily repeated bus traffic, it is suggested that the host monitor the MAV (message available) status bit to determine when a response for information is fully assembled and ready to transmit. See Section 3.8.8 for a sample program utilizing these features.

3.8.4 Datalogging

The DATALOG data output represents the information concerning the latest "shutter open" to "shutter close" sequence.

Automatic data logging is enabled by choosing DATALOG for the communications type, see Section 3.8.1. If DATALOG is chosen, the RS232 port is configured to output the DATALOG information only and cannot receive commands from a host computer. The IEEE option, if installed, will continue to work in the normal fashion.

The data is a series of ASCII strings, each separated by a "carriage return and line feed", in the order below:

1) Layer # (1-3)
2) Film # (1-9)
3) Rate = _ _ _._Å/s
4) Thickness = _ _ _ _._ _ _ _ kÅ [Last good thickness, if crystal failed]
5) Deposit Time = _ _:_ _ Min:Sec.
6) Average Power = _ _._%
7) Begin Frequency = _ _ _ _ _ _ _ _._ Hz
8) End Frequency = _ _ _ _ _ _ _ _._ Hz [negative of last good frequency if crystal fail]
9) Crystal Life = _ _%
10) End on Time Power or Normal Completion

> **NOTE:** In addition— if the Layer is the first one of a process, a preface "Begin Process" followed by 2 blank lines is output. If the layer is the last one of the process, a post script "End Process", preceded by 2 blank lines is output.

Automatic datalogging is available only on the XTC/2; however, the datalog information string is available via the **S19** command for both the XTC/2 and XTC/C.

3.8.5 Computer Command Details

ECHO COMMAND

Echoes the message, i.e., returns the sent message.

The format is: **E** message string

HELLO COMMAND

The HELLO command will return the string "XTC/2 VERSION x.xx" where x.xx is the software revision code.

The format is: **H**

QUERY COMMAND

The Query command returns information concerning current instrument parameter values.

The format of the query command is:
Q pp **F** - Query parameter pp of film **F** or **Q** pp **L** for layer parameters. A space is used as a delimiter between **Q** and pp as well as pp and **F**, where **F** (or **L**), is a digit between 1 and 9, **L** is a digit between 0 and 3, inclusive, and represents the interrogated film or layer number.

NOTE: If pp is set to 99, output all parameters in the order specified below; each parameter is separated by a space. This command allows a rapid block transfer of data which is convenient for downloading films.

Table 3.9 Parameter Definition Table (for Query and Update Commands)

PP	XTC/2 Parameter	Range
0	Rise Time 1	0 - 9959 or 00:00 - 99:59
1	Soak Power 1	0.0 - 100.0
2	Soak Time 1	(See 0)
3	Rise Time 2	(See 0)
4	Soak Power 2	(See 1)
5	Soak Time 2	(See 0)
6	Shutter Delay	1 or 0 or 'Y' or 'y' or 'N' or 'n'
7	New Rate	0.0 - 999.9
8	Rate Ramp Time	(See 0)
9	Idle Ramp	(See 0)
10	Idle Power	0.0 - 100.0
11	Time Power	(See 6)
12	Xtal Switch S	0 - 9
13	Xtal Switch Q	0 - 9
14	Tool Factor 1	10 - 500.0
15	Tool Factor 2	(See 14)
16	Deposition Rate	0 - 999.9
17	Final Thickness	0.0 - 999.000
18	Thickness Spt	(See 17)
19	Density	0.5 - 99.99
20	Z-Ratio	.1 - 9.999
21	Sensor	1 - 2
22	Source	1 - 2
23	Crucible	0 - 8
24	Control Gain	0.01- 99.99
25	Control TC	0.1 - 100
26	Control DT	0.1 - 100
27	Max Power	0.0 - 100.0
28	Sample	0 - 99
29	Hold Time	(See 0)
30-39	** NOT USED **	
40	Layer	1-3[1], 0-9[2]
99	All	See note on page 3-25

[1]May be 0 for Q command; if 0, will return values for layers 1 - 3.

[2]0 not allowed for layer 1.

UPDATE COMMAND

The Update command replaces the current parameter value with the DATA Sent.

To update film parameters the format of the update command is:

U pp **F** vvv - Parameter pp of film **F**, value vvv.

Update parameter pp of film **F**, with value vvv, a space is used as a delimiter between the pp and **F** values as well as the **F** and vvv values, where **F** is a digit between 1 and 9. See table 3.9 for a numbered list of parameters and their limits.

NOTE: If pp is set to 99, the data is a list of all parameters in the order specified. This command allows a rapid block transfer of data which is convenient for downloading films. Each parameter value must be separated by a space.

To update layers the format of the update command is:

U 40 **L** v
Where 40 designates a layer is to be updated. The value **L** indicates which layer to update. The value of **L** can be 1, 2, or 3, and v designates the film number to insert into layer **L**.

For example, the update command

U 40 **1** 4

will enter film number 4 into layer 1.

STATUS COMMAND

Sends back information based on specific request made.

The format of the status command is:

S xx Return the status (value) of xx

where:

S Is the literal S

xx One or two digit code per list below:

S0 Process information. All the information from **S1** to **S10**, separated by spaces.

S1 Rate (Å/s) currently read. x.x to xxx.x Å/s

S2 Power (%) currently output. x.x to xxx.x %

S3 Thickness (KÅ) currently accumulated. x.xxxx kÅ to xxxx.xxxx kÅ

S4 Phase currently in process. x

S4 Response Codes

0	Ready phase
1	Source switch phase
2	Rise 1 phase
3	Soak 1 phase
4	Rise 2 phase
5	Soak 2 phase
6	Shutter delay phase
7	Deposit phase
8	Rate ramp phase
9	Manual phase
10	Time power phase
11	Idle ramp phase
12	Idle phase

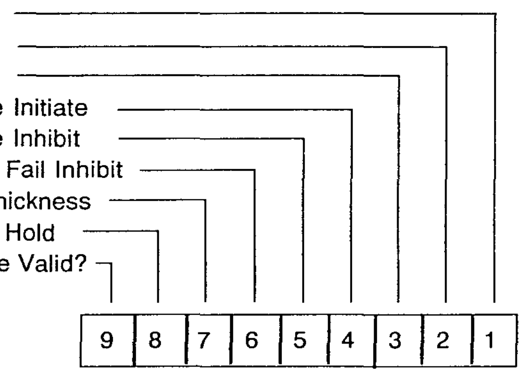
S5	Phase time (mm:ss).	xx:xx
S6	Active layer.	x
S7	Active film	x
S8	Active crystal.	x
S9	Crystal life (%).	x % to xx %
S10	Power source number.	x

S11 Output status - returns a string of 16 ASCII bytes, 1 per output. Each byte has an ASCII value of 0 or 1, corresponding to the output status.

Position	Outputs	
1	Source Shutter 1	1=open, 0=closed
2	Source Shutter 2	1=open, 0=closed
3	Sensor Shutter 1	1=open, 0=closed
4	Sensor Shutter 2	1=open, 0=closed
5	Stop	1=stop, 0=not stop
6	End of Process	1=end of process 0=not end of process
7	Thickness Setpoint	1=Thk Setpoint
8	Feedtime (Soak 2)	1=soak 2 phase
9	Crystal Fail	1=Xtal Fail
10	Alarms	1=Alarm Cond.
11	Source 1/Source 2 (toggle)	1=Source 2 0=Source 1
12	End Deposit	1=closed
13	Crucible Select (LSB)	binary value encoding
14	Crucible Select	binary value encoding
15	Crucible Select (MSB)	binary value encoding
16	Unused	

S12 Input status - returns 9 ASCII bytes, 1 per input. Each byte has an ASCII value of 0 or 1, corresponding to the input's status.

Input #	Function
1	Start
2	Stop
3	End
4	Sample Initiate
5	Sample Inhibit
6	Crystal Fail Inhibit
7	Zero Thickness
8	Soak 2 Hold
9	Crucible Valid?



0=grounded (active)

S13 Raw frequency - Frequency of crystal being read. xxxxxxx.x Hz [negative of last good frequency if failed]

S14 Xtal Fail - Returns ASCII 1 if currently failed crystal, 0 if not.

S15 Max Power - Returns ASCII 1 if currently outputting maximum power, 0 if not.

S16 Crystal switching - Returns ASCII 1 if currently crystal switching, 0 if not.

S17 End of process - Returns ASCII 1 if process has ended, 0 if not.

S18 STOP - Returns ASCII 1 if process is in STOP.

S19 DATALOG - Returns the datalog string see Section 3.8.4 for details. Data is separated by spaces instead of CR/LF. ***

***The last byte returned identifies the End on Time Power or Normal Completion information as a 1 or 0 respectively. Also, when using the **S19** command the "Begin Process" and "End Process" messages are not returned.

S20 Present Configuration Switch Settings - returns 16 ASCII bytes with a value of 0 or 1, corresponding to the position of configuration switches 1-16; byte 1 corresponds to switch 1.

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

1=switch on

Also see **S**22 below.

NOTE: Switch settings do not take effect until a power STBY/Power On sequence takes place.

S21 Error Flag - If more than one error code exists, the response string will return them all, each separated by a single space.

S21 Response Codes

0	Error 0
2	Power Fail or **STBY/ON** sequence
9	Error 9
10	No Errors

S22 Instrument configuration readout - the position of the configuration switches at the last **STBY/ON** sequence. Also see **S** 20 above and Section 2.6.2.

REMOTE COMMAND The format of the remote command is:

R xx vvv

where

R Is the literal **R**

xx Is the remote code per list below.

vvv Is the associated value needed for some remote commands.

R0	Start. Equivalent to pressing the **START** key.
R1	Stop. Equivalent to pressing the **STOP** key.
R2	Reset. Equivalent to pressing the **RESET** key.
R3	Remote Lock On. Prohibits any parameter from being entered via the front panel.
R4	Remote Lock Off. Clears remote lock condition.
R5	Crystal fail inhibit on. Simulates remote input.
R6	Crystal fail inhibit off. Simulates release of remote input.
R7	Soak hold 2 on. Simulates remote input.
R8	Soak hold 2 off. Equivalent release of remote input.
R9	Manual on. Equivalent to front panel **MPWR** keystroke.
R10	Manual off. Equivalent to front panel **MPWR** keystroke.
R11	Set power level vv. Sets the active source's power to vv%.
R12	Zero thickness. Simulates remote input or front panel **ZERO** keystroke.
R13	Final thickness trigger. Simulates remote input.
R14	CrystalSwitch. Equivalent to front panel **XTSW** keystroke.
R15	Enter communication i/o mode - See **R16** (Only applies when in communication i/o mode.)
R16	Exit communication i/o mode - See **R15** (Only applies when in communication i/o mode.)
R17	Set (close) relay xx (xx = 1-12)
R18	Clear (open) relay xx (xx = 1-12)
R19	Turn backlight ON
R20	Turn backlight OFF
R21	Trigger beeper

R22 Clear Error Flag

R23 Set 250ms DATA Ready Service request (IEEE only).

R24 Clear 250ms DATA Ready Service request (IEEE only).

R25 Set upper frequency limit to 6.027 MHz.

NOTE: A crystal fail automatically clears the 250ms service request.

The following additional commands are available on the XTC/C only:

R30 Test ON

R31 Test OFF

R32 Control Mode Deposit

R33 Control Mode Etch

R34 Stop on Alarms

R35 No Stop on Alarms

R36 Stop on Max Power

R37 No stop on Max Power

R38 x Recorder Type x (0 = Rate 0 to 100 Å/s, 1 = Rate 0 to 1000 Å/s, 2 = Thickness 0 to 100 Å, 3 = Thickness 0 to 1000 Å, 4 = Power, 5 = Rate Deviation, 6 = Rate 0 to 100 Å/s smoothed, 7 = Rate 0 to 1000 Å/s smoothed)

R39 Set SECS Timer 1 (0.1 - 10.0)

R40 Set SECS Timer 2 (0.2 - 25.0)

R41 Set SECS Max Retries (0-31)

R42 Set SECS Duplicate Block to Yes

R43 Set SECS Duplicate Block to No

3.8.6 Examples of RS232 Programs

```
10 '----XTC/2 RS232 COMMUNICATIONS PROGRAM WITHOUT CHECKSUM----
20 '
30 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTC/2
        AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC 2.32.
40 '
50 OPEN "COM1:9600,N,8,1,CS,DS" AS #1                  :'--OPEN COMM PORT 1
60 NAK$ = CHR$(21): ACK$ = CHR$(6)                     :'--DEFINE ASCII CODES
70 '
80 INPUT "ENTER COMMAND"; CMD$                         :'--ENTER COMMAND TO XTC/2
90 GOSUB 130                                           :'--GOTO TRANSMIT COMMAND
                                                            SUBROUTINE.
100 PRINT RESPONSE$                                    :'--PRINT XTC/2 RESPONSE
110 GOTO 80                                            :'--LOOP BACK FOR ANOTHER
                                                           COMMAND.
120 '
130 '----TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE----
140 '
150 '----SEND COMMAND MESSAGE STREAM TO THE XTC/2----
160 PRINT #1, CMD$ + ACK$;
170 '
180 '----RECEIVE RESPONSE MESSAAGE FROM THE XTC/2----
190 RESPONSE$ = ""                                     :'--NULL THE RESPONSE
200 TOUT = 3: GOSUB 260                                :'  STRING AND SET TIMER.
210 IF I$ = ACK$ THEN RETURN                           :'--IF THE END OF RESPONSE
220 IF I$ = NAK$ THEN RETURN                           :'  CHARACTER IS RECEIVED
                                                           GOTO PRINT RESPONSE.
230 RESPONSE$ = RESPONSE$ + I$                         :'--BUILD RESPONSE STRING
240 GOTO 200                                           :'  CHARACTER BY CHARACTER.
250 '
260 '----READ SERIALLY EACH CHARACTER FROM THE INSTRUMENT INTO VARIABLE I$----
270 ON TIMER (TOUT) GOSUB 300: TIMER ON
280 IF LOC(1) < 1 THEN 280 ELSE TIMER OFF: I$ = INPUT$(1,#1)
290 RETURN
300 TIMER OFF                                          :'--INDICATE IF A CHARACTER
310 RESPONSE$ = "RECEIVE TIMEOUT"                      :'  IS NOT RECEIVED WITHIN
320 I$ = NAK$: RETURN 290                              :'  3 SECS.
```

```
10 '--XTC/2 RS232 COMMUNICATIONS PROGRAM WITH CHECKSUM USING THE INFICON FORMAT--
20 '
30 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS  TO THE XTC/2
    AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC 2.32.
40 '
50 OPEN "COM1:9600,N,8,1,cs,ds" AS #1               :'--OPEN COMM PORT 1
60 STX$ = CHR$(2) : NAK$ = CHR$(21) : ACK$ = CHR$(6)        :'--DEFINE ASCII CODES
70 '
80 INPUT "ENTER COMMAND"; CMD$                      :'--ENTER COMMAND TO XTC/2
90 GOSUB 170                                        :'--GOTO TRANSMIT COMMAND SUBROUTINE
100 IF RESPONSE$ = "RECEIVE TIMEOUT" THEN 140
110 L = LEN(RESPONSE$): L = L-1                     :'--STRIP OFF THE ACK OR
120 RESPONSE$ = RIGHT$(RESPONSE$,L)                 :' NAK CHARACTER FROM THE
130 '                                               :' RESPONSE STRING.
140 PRINT RESPONSE$                                 :'--PRINT XTC/2 RESPONSE
150 GOTO 80                                         :'--LOOP BACK FOR ANOTHER COMMAND.
160 '
170 '----TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE----
180 '
190 '--BUILD COMMAND MESSAGE STREAM AND SEND TO THE XTC/2--
200 SIZEM$ = CHR$(LEN(CMD$) / 256)                  :'--CALCULATE THE 2 BYTE
210 SIZEL$ = CHR$(LEN(CMD$) MOD 256)                :' SIZE OF THE COMMAND.
220 '
230 CHECKSUM = 0                                    :'--INITIALIZE CHECKSUM TO
240 FOR X = 1 TO LEN(CMD$)                          :' ZERO AND CALCULATE A
250 CHECKSUM = CHECKSUM + ASC(MID$(CMD$,X,1))       :' CHECKSUM ON THE COMMAND
260 NEXT X                                          :' STRING.
270 CHECKSUM$ = CHR$(CHECKSUM AND 255)              :'--USE LOW ORDER BYTE AS CHECKSUM.
280 '
290 PRINT #1, STX$ + SIZEM$ + SIZEL$ + CMD$ + CHECKSUM$
300 '
310 '----RECEIVE RESPONSE MESSAGE FROM THE XTC/2----
320 TOUT = 3: GOSUB 510                             :'--SET TIMER AND WAIT FOR
330 IF I$ <> STX$ THEN 290                          :' START OF TRANSMISSION CHARACTER.
340 TOUT = 3: GOSUB 510                             :'--RECIEVE HIGH ORDER BYTE
350 SIZE = 256 * ASC(I$)                            :' OF TWO BYTE RESPONSE SIZE.
360 TOUT = 3: GOSUB 510                             :'--RECIEVE LOW ORDER BYTE
370 SIZE = SIZE + ASC(I$)                           :' OF TWO BYTE RESPONSE      SIZE.
380 CHECKSUM = 0                                    :'--SET CHECKSUM TO ZERO
390 RESPONSE$ = ""                                  :' AND NULL THE RESPONSE
400 FOR I = 1 TO SIZE                               :' STRING.BUILD THE
410 TOUT = 3: GOSUB 510                             :' RESPONSE STRING AND
420 RESPONSE$ = RESPONSE$ + I$                      :' CALCULATE THE CHECKSUM
430 CHECKSUM = CHECKSUM + ASC(I$)                   :' CHARACTER BY CHARACTER.
440 NEXT I
450 TOUT = 3: GOSUB 510                             :'--RECIEVE THE CHECKSUM
460 N = ASC(I$)                                     :'  CHARACTER AND COMPARE
470 Z = (CHECKSUM AND 255)                          :' IT TO THE LOW ORDER
480 IF N <> Z THEN PRINT "RESPONSE CHECKSUM ERROR"  :' BYTE OF THE CALCULATED
490 RETURN                                          :' CHECKSUM.
500 '
510 '----READ SERIALLY EACH CHARACTER FROM THE INSTRUMENT INTO VARIABLE I$----
520 ON TIMER (TOUT) GOSUB 550: TIMER ON
530 IF LOC(1) < 1 THEN 530 ELSE TIMER OFF: I$ = INPUT$(1,#1)
540 RETURN
550 TIMER OFF                                       :'--INDICATE IF A CHARACTER
560 RESPONSE$ ="RECEIVE TIMEOUT": RETURN 570        :' IS NOT RECEIVED WITHIN
570 RETURN 490                                      :' 3 SECS.
```

3.8.7 Example of SEMI II Program

```
10 'XTC/2 RS232 COMMUNICATIONS PROGRAM USING THE SECS FORMAT
20 '——THIS PROGRAM IS DESIGNED TO TRANSMIT——
30 '———INDIVIDUAL COMMANDS TO THE XTC/2———
40 CLS
50 '
60 '
70 OPEN "COM1:2400,N,8,1,CS,DS" FOR RANDOM AS #1
80 EOT$ = CHR$(4): ENQ$ = CHR$(5): ACK$ = CHR$(6): NAK$ = CHR$(21)
90 TOUT = 3
100 C = 0:CHECKSUM = 0: CHEKSUMM$ = CHR$(0): CHEKSUML$ = CHR$(0)
110 INPUT "ENTER COMMAND"; CMD$
120 CMDLEN = LEN(CMD$):              ' CALUCULATE THE COMMAND LENGTH
130 '
140 '—ADD THE TWO BYTE PREAMBLE TO THE COMMAND—
150 PRE$ = CHR$(65) + CHR$(CMDLEN)
160 CMD$ = PRE$ + CMD$
170 CMDLEN = CMDLEN + 2
180 '
190 '—BUILD LENGTH BYTE, HEADER, TEXT, AND CHECKSUM BLOCK——
200 '
210 '–BUILD HEADER—
220 DID = 257:                     ' DEVICE ID
230 'RBIT = 0,                       :' MESSAGE DIRECTION IS FROM HOST TO DEVICE
240 '
250 '—DETERMINE THE STREAM AND FUNCTION CODES—
260 '
270 STREAM$ = CHR$(64):              ' USER DEFINED STREAM CODE
280 FUNCTION$ = CHR$(65):            ' USER DEFINED FUNCTION CODE
290 '
300 '
310 WBIT$ = CHR$(128):               'RESPONSE FROM XTC/2 REQUIRED
320 STREAM$ = CHR$(ASC(WBIT$) + ASC(STREAM$))
330 '
340 '—ENTER THE BLOCK BYTES—
350 '
360 BYTE5$ = CHR$(128):              ' LAST BLOCK IN THE SERIES
370 BYTE6$ = CHR$(1):                ' ONLY BLOCK IN THE SERIES
380 '
390 '—ENTER THE SYSTEM BYTES—
400 '
410 BYTE7$ = CHR$(0): BYTE8$ = CHR$(0): BYTE9$ = CHR$(0): BYTE10$ = CHR$(1)
420 '
430 '——CALCULATE THE LENGTH BYTE——
440 LTHBYT = CMDLEN + 10: LTHBYT$ = CHR$(LTHBYT)
450 '
460 '——CALCULATE THE CHECKSUM——
470 FOR X = 1 TO CMDLEN
```

```
480 CHECKSUM = CHECKSUM + ASC(MID$(CMD$, X, 1))
490 NEXT X
500 BYTE1$ = CHR$(DID / 256)
510 BYTE2$ = CHR$(DID MOD 256)
520 CHECKSUM = ASC(BYTE1$) + ASC(BYTE2$) + ASC(STREAM$) + ASC(FUNCTION$) + ASC(BYTE5$) + ASC(BYTE6$)
          + ASC(BYTE7$) + ASC(BYTE8$) + ASC(BYTE9$) + ASC(BYTE10$) + CHECKSUM
530 CHEKSUMM$ = CHR$(FIX(CHECKSUM / 256))
540 CHEKSUML$ = CHR$(CHECKSUM MOD 256)
550 '——HOST BID FOR LINE / DEVICE BID FOR LINE——
560 '
570 PRINT #1, ENQ$;
580 I$ = "": RESPONSE$ = ""
590 C = C + 1
600 ON TIMER(TOUT) GOSUB 1000: TIMER ON
610 IF LOC(1) < 1 THEN 610 ELSE TIMER OFF: I$ = INPUT$(1, #1)
620 IF C = 3 THEN 660
630 IF I$ = ACK$ THEN GOTO 580
640 IF I$ = NAK$ THEN RESPONSE$ = "COMMAND NOT ACKNOWLEDGED": GOTO 1010
650 IF I$ = EOT$ THEN 690 ELSE REPOSNSE$ = "DEVICE NOT ACKNOWLEDGED": GOTO 1010
660 IF I$ = ENQ$ THEN 790 ELSE RESPONSE$ = "DEVICE DID NOT BID FOR LINE": GOTO 1010
670 '
680 '
690 '——SEND COMMAND TO XTC/2——
700 '
710 '
720 HEADER$ = BYTE1$ + BYTE2$ + STREAM$ + FUNCTION$ + BYTE5$ + BYTE6$ + BYTE7$ + BYTE8$ + BYTE9$ + BYTE10$
730  PRINT #1, LTHBYT$; HEADER$; CMD$; CHEKSUMM$; CHEKSUML$;
740  GOTO 580
750 '
760 '
770 '——WAIT FOR DATA FROM XTC/2——
780 '
790 '——FIND SIZE OF RESPONSE——
800 '
810 PRINT #1, EOT$;
820 I$ = ""
830 ON TIMER(TOUT) GOSUB 1000: TIMER ON
840 IF LOC(1) < 1 THEN 840 ELSE TIMER OFF: I$ = INPUT$(1, #1)
850 S = ASC(I$): L = S - 13
860 S = S + 2
870 '
880 '——RECEIVE RESPONSE TO COMMAND——
890 '
900 I$ = "": RESPONSE$ = ""
910 FOR R = 1 TO S
920 ON TIMER(TOUT) GOSUB 1000: TIMER ON
930 IF LOC(1) < 1 THEN 930 ELSE TIMER OFF: I$ = INPUT$(1, #1)
940 RESPONSE$ = RESPONSE$ + I$
950 NEXT R
960 PRINT #1, ACK$;
970 RESPONSE$ = MID$(RESPONSE$, 13, L)
980 '
990 GOTO 1010
1000 TIMER OFF: RESPONSE$ = "RECEIVE TIMEOUT"
1010 PRINT RESPONSE$
1020 '
1030 GOTO 90
```

3.8.8 Example of IEEE488 Program

```
10 '----------------------XTC/2 GPIB COMMUNICATIONS PROGRAM--------------------
20 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTC/2
     AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC2.32.
30 '
40 '----THE NEXT 5 LINES DEFINE THE IEEE DRIVERS USED AND ARE SPECIFIC TO THE
     PARTICULAR IEEE BOARD IN YOUR COMPUTER AND THE LANGUAGE USED--------
50 '
60 CLEAR ,55000! : IBINIT1 = 55000! : IBINIT2 = IBINIT1 + 3
70BLOAD "bib.m",IBINIT1
80 CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,IBPPC,IBBNA,IBONL,IBRSC,
  IBSRE,IBRSV,IBPAD,IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,IBWRTF)
90 CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,
  IBSTOP,IBRPP,IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,IBWRTIA,IBSTA%,IBERR%,IBCNT%)
100 '
110 GPIB$="GPIB0" :CALL IBFIND(GPIB$,GPIB%) '--OPEN BOARD FOR COMM
120 CALL IBSIC(GPIB%)                       '--SEND INTERFACE CLEAR
130 XTC2$="XTC2" : CALL IBFIND(XTC2$,XTC2%) '--OPEN DEVICE 0
140 V% = &HA                                '--SET THE END OF STRING
150 CALL IBEOS(GPIB%,V%)                    ' BYTE TO LINE FEED
160 V%=1 : CALL IBEOT(XTC2%,V%)             '--ASSERT EOI ON WRITE
170 V%=12 : CALL IBTMO(XTC2%,V%)            '--SET THREE SEC TIMEOUT
180 INPUT "ENTER COMMAND";COMMAND$          '--ENTER COMMAND TO XTC/2
190 CALL IBCLR(XTC2%)                       '--CLEAR THE XTC/2 COMM
200 GOSUB 240                               '--GOTO TRANSMIT COMMAND
                                              SUBROUTINE.
210 PRINT I$                                '--PRINT XTC/2 RESPONSE
220 GOTO 180                                '--LOOP BACK FOR ANOTHER COMMAND.
230 '
240 '----TRANSMIT COMMAND & RECEIVE RESPONSE SUBROUTINE----
250 '
260 '----SEND COMMAND MESSAGE STREAM TO THE XTC/2----
270 COMMAND$ = COMMAND$ + CHR$(&HA)
280 CALL IBWRT(XTC2%,COMMAND$)
290 '
300 '----RECEIVE RESPONSE MESSAGE FROM THE XTC/2----
310 '
320 I$=SPACE$(40) : CALL IBRD(XTC2%,I$)
330 IF (IBSTA% AND &H4000) THEN 340 ELSE 350'--INDICATE IF A RESPONSE
340 PRINT "RECEIVE TIMEOUT": GOTO 180       ' IS NOT RECEIVED WITHIN
350 RETURN                                  ' 3 SECS.
```

To implement serial polling of the Message Available (MAV) bit the following lines may be added to the IEEE488 program listed above.

```
285 CALL IBRSP (XTC2%,SPR%)
287 B = SPR% / 16: B = INT(B)
289 IF B = 1 THEN 290 ELSE 285
```

After sending a command to the XTC/2 the Status Byte is polled. The response to the command is retrieved only after the MAV bit is set (2^4 = 16).

To implement serial polling of the Request for Service bit you need only test for the RQS bit to be set.

For example:

```
(serial poll)     CALL IBRSP (XTC2%,SPR%)
                  B = SPR% / 64 : B = INT(B)
                  IF B = 1 THEN (continue prog) ELSE (serial poll)
```

If the RQS bit is set, the program may then be made to read the first 4 bits of the Status Byte (2^0 through 2^3) to determine what event generated the service request. Once this is determined the appropriate action may be taken.

3.9 Co-Deposition (Two Unit Interconnection)

It is possible to control two (or more) sources simultaneously by interconnecting multiple XTC units. This is most easily accomplished by interconnecting the inputs and outputs of the units as shown in Figure 3.6.

Two user installed components are suggested. An "External Start" switch is used to synchronize the initiation of the two units' films by simultaneously applying a signal to the **START** input on the System I/O. The relay inverter is used to ensure that both units enter the **DEPOSIT** state simultaneously.

When using the suggested configuration:

- A **STOP** condition in either unit stops the other unit. Pushing the **STOP** key on either instrument stops both instruments.
- The unit that first reaches **FINAL THK** triggers the End Deposit input of the other unit.
- The unit designated "slave" must be programmed to reach the end of the **SOAK 2** state before the "master" to avoid a delay upon the termination of the Soak Hold.
- The operator must ensure that both units are in the **READY** state before pressing the External Start Switch.
- If a **STOP** is encountered and a rework layer is not desired (see Section 4.4), a **RESET** command must be individually given to each unit.
- If there is material cross sensitivity (if an instrument's transducer receives material from more than one source) the **TOOLING** or **FINAL THK** parameter(s) must be adjusted to account for this condition.
- It may be necessary to adjust the Z-Ratio to account for the mixing of materials on the sensors. This is especially important if composition over extended runs is critical.

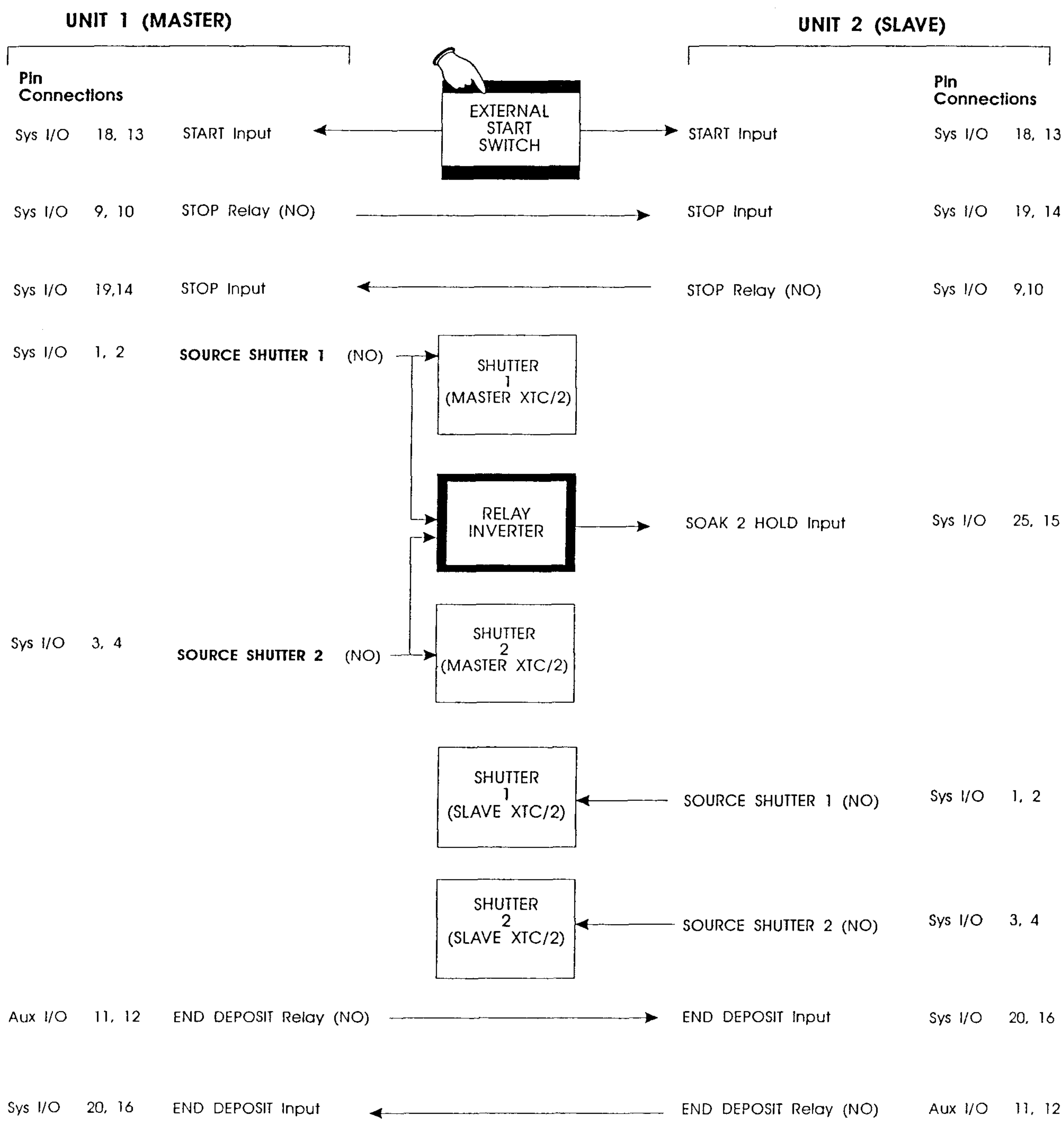


Figure 3.6 Interconnecting Two XTC/2 Units for Co-Deposition

INFICON

Chapter 4
Programming & Operation

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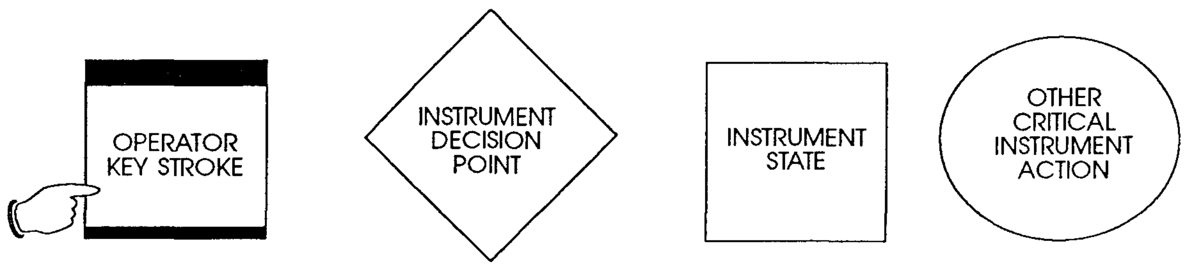
4.0 Programming System Operation Details

4.1 State and Measurement System Sequencing

The following pages give an overview of the instrument's operational flow. There are only three basic execution loops; two of which are essentially independent: 1) the Display Loop; and 2) the Measurement and Control Processing Loop. The third loop, State Processing, is, however, the most visible to the operator as it directs the instrument's interaction with the coating system. Because of the time critical nature of the Measurement and Control Loop it may be thought of as the essence of the instrument with the state sequencing and display functions nested within its operation. The following symbols are used in these flow charts:



NOTE: The flow diagrams presented, while generally accurate, are not complete from the standpoint of containing enough information to cover all possible eventualities. They are presented as a means of quick overview of the instrument's operations.

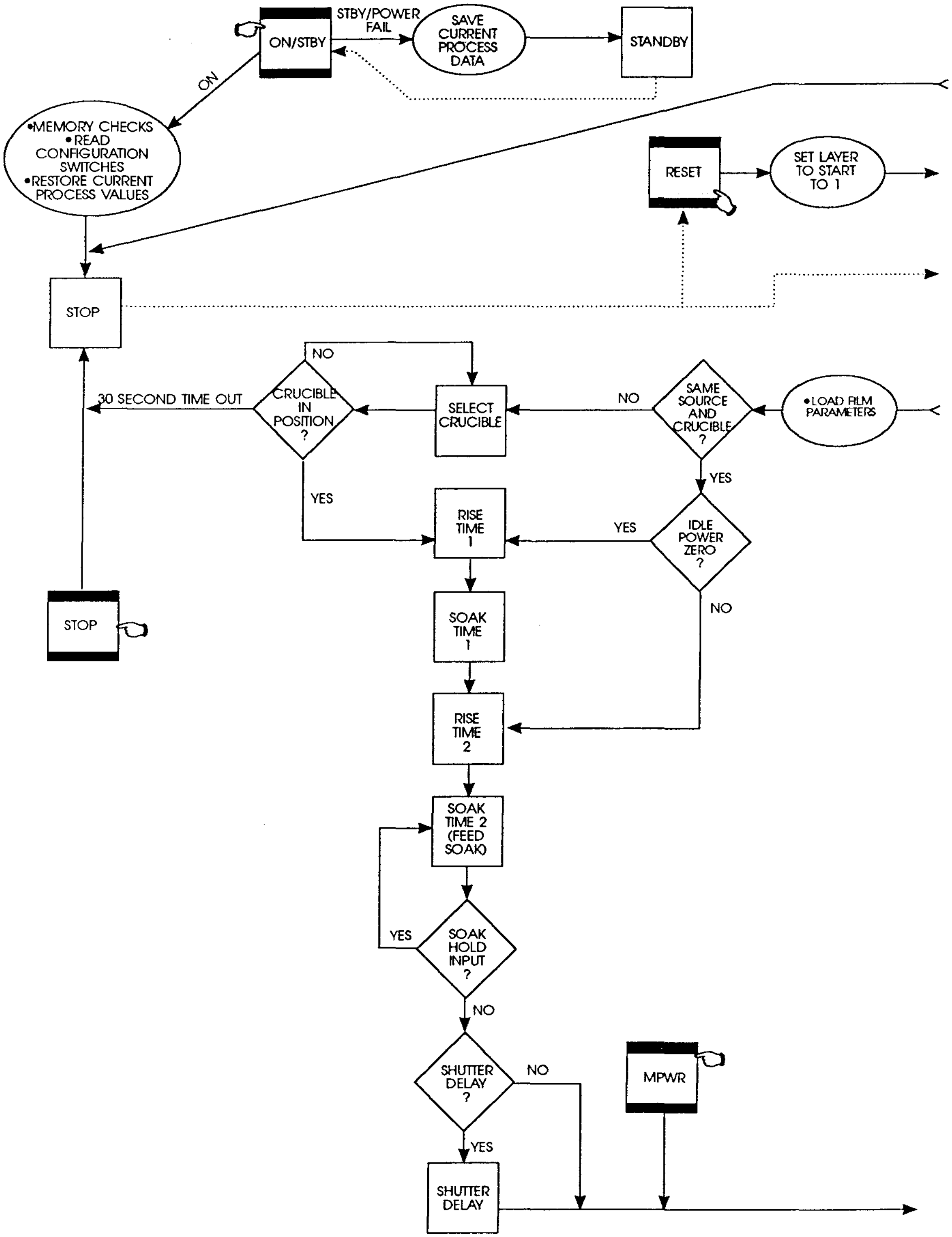


Figure 4.1 State Diagram for a Film

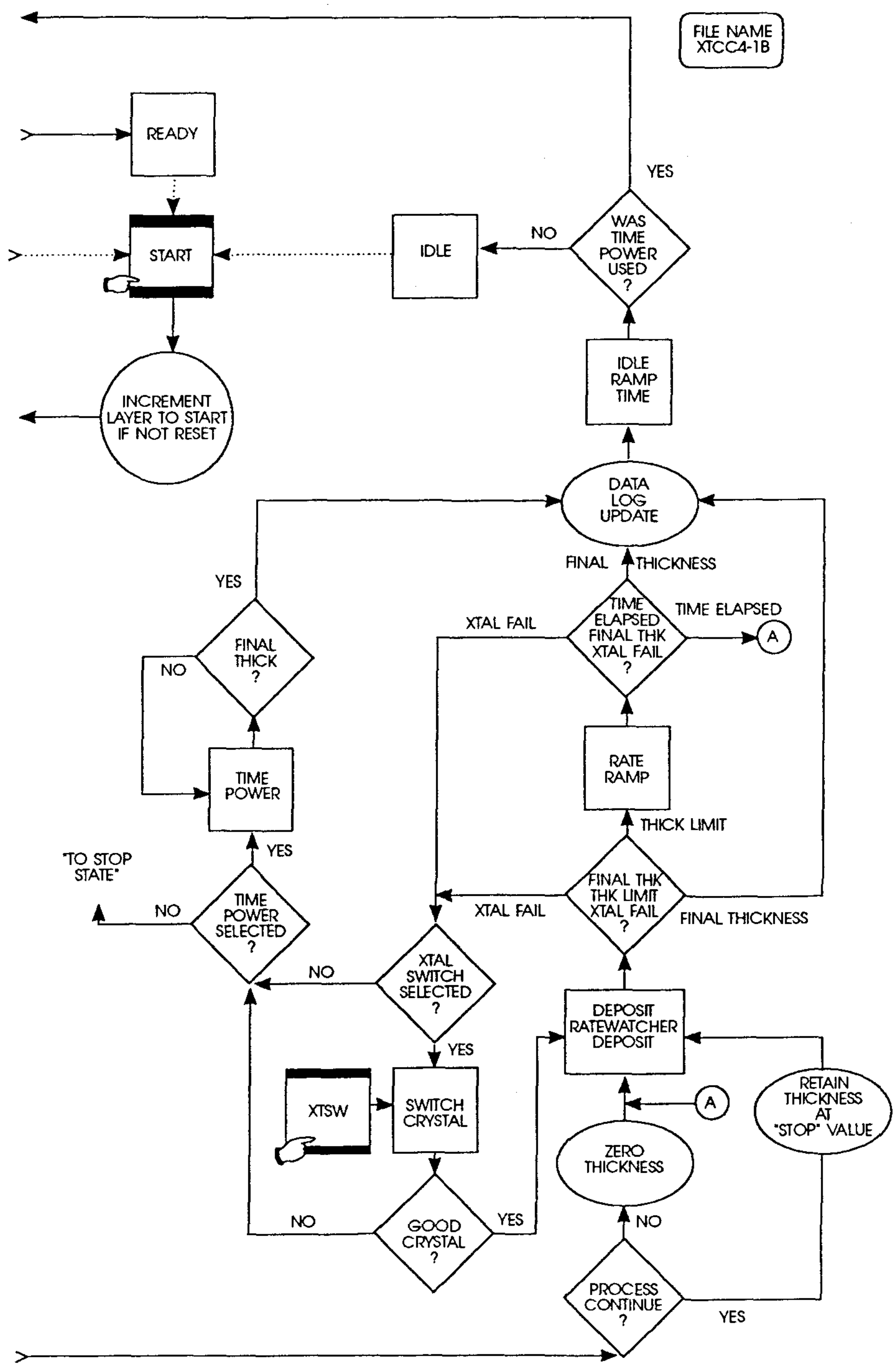


Figure 4.1a State Diagram for a Film (continued)

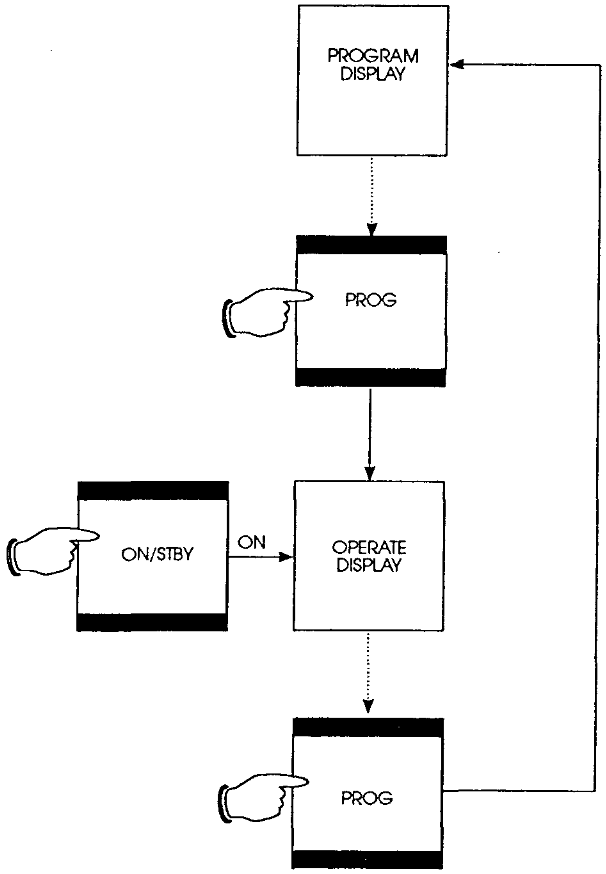


Figure 4.2 Display Loop

The Measurement and Control Loop is characterized by its time-critical nature. No matter what else is happening, the instrument will measure the crystal's frequency and update the Control Loop voltage and all other outputs every 250 milliseconds.

Cable compensation processing is used to match the crystal, transducer, feedthrough and in-vacuum cables to the drive circuit.

Sweep processing frequency scans the system for the fundamental resonance of the crystal. Once this resonance is found normal frequency tracking is implemented.

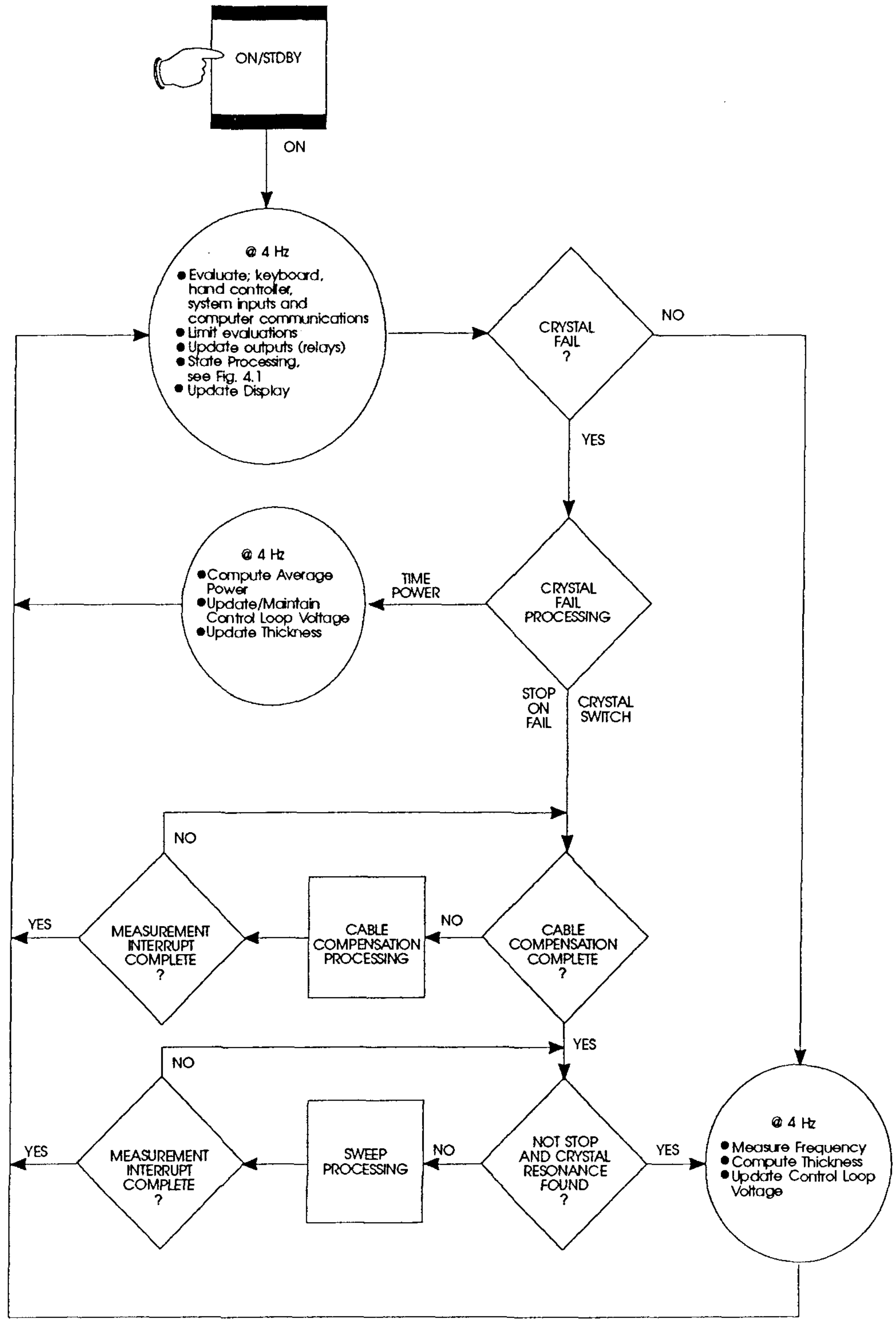


Figure 4.3 Measurement and Control Processing Loop

4.2 State Descriptions and Parameter Limits

Operating the XTC as a film thickness/rate controller requires programing the film sequence parameters. A film sequence begins with a **START** command and ends when the film in process reaches the idle state. Any process control that occurs between these events is determined by the values programmed in the possible parameters. A film sequence consists of many possible states, with a state being defined as one process event. These states are described below; also, see Figure 4.1. The parameters that affect each state are listed in brackets at the end of the state description.

Table 4.1 State Descriptions

STATE	CONDITION	RELAY CONTACT STATUS		
	NOTE: *1 through 7 are Pre-Deposit States.*	**Source Shutter**	**Sensor Shutter**	**Feed**
1. **READY**	Will accept a START command.	Open	Open	Open
2. **SELECT CRUCIBLE/ SWITCH CRYSTAL**	Instrument advances to next state when "crucible in position" input is low. If **IDLE PWR** of previous layer is not equal to zero, power is set to zero before crucible position changes. If a sensor other than the one last used is selected, then the switch to that sensor will occur. [Crucible #, Sensor #, Source #]	Open	Open	Open
3. **RISE TIME 1**	Source rising to Soak Power 1 level. [Rise Time 1]	Open	Open	Open
4. **SOAK TIME 1**	Source maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1]	Open	Open	Open
5. **RISE TIME 2** (feed ramp)	Source rising to Soak Power 2 level. [Rise Time 2]	Open	Open	Open
6. **SOAK TIME 2** (feed soak)	Source maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2]	Open	Open	Closed
7. **SOAK HOLD**	Source maintained at Soak Power 2 level. [Soak Hold Input]	Open	Open	Open

STATE	CONDITION	RELAY CONTACT STATUS		
	NOTE: 8 through 14 are Deposit states.	Source Shutter	Sensor Shutter	Feed
8. **SHUTTER DELAY**	Rate control. Advances to Deposit State once the Source is in Rate Control within 5% [Shutr Dly Y]	Open	Closed	Open
9. **DEPOSIT**	Rate control. [Dep Rate, Final Thk, Ctl Gain, Ctl Tc, Ctl Dt]	Closed	Closed	Open
10. **RATE RAMP TIME**	Rate control, desired rate changing. [Thick Spt, New Rate, R.Ramp Time]	Closed	Closed	Open
11. **RATEWATCHER** (SAMPLE)	Rate control. [Sample %]	Closed	Closed	Open
12. **RATEWATCHER** (HOLD)	Constant power, based on last sample's average power. [Hold Time]	Closed	Open	Open
13. **MANUAL**	Source power controlled by hand held controller.	Closed	Closed	Open
14. **TIME-POWER**	Crystal failed; source maintained at average control power prior to crystal failure. [Time Pwr Y]	Closed	Closed	Open
	NOTE: 15 through 16 are Post-Deposit states.			
15. **IDLE RAMP**	Source changing to Idle Power. [Idle Ramp]	Open	Open	Open
16a. **IDLE POWER** (=0%)	Source maintained at zero power; will accept a **START** command. [Idle Pwr]	Open	Open	Open
16b. **IDLE POWER** (>0%)	Source resting at Idle Power; will accept a **START** command.	Open	Open	Open

NOTE: The **STOP** state — instrument will accept a **START** provided a Crystal Fail has not occurred. Refer also to Section 4.16.

The following variable parameters and their limits are listed below. If a value outside the stated limits is attempted, the message **ERR 1** is displayed.

TABLE 4.2 Limits for Film Parameters

PARAMETER	LIMITS	UNITS
RISE TIME 1, 2	00:00 - 99:59	MIN:SEC
SOAK PWR 1, 2	0.0 - 100	%
SOAK TIME 1, 2	00:00 - 99:59	MIN:SEC
SHUTR DLY	Yes or No	——
NEW RATE	0.000 - 999.9	KÅ
R RAMP TIME	00:00 - 99:59	MIN:SEC
IDLE RAMP	00:00 - 99:59	MIN:SEC
IDLE PWR	0.0 - 100	%
TIME PWR	Yes or No	——
XTAL SWCH S, Q	0 - 9	Whole Numbers
TOOL FACT 1,2	10.0 - 500	%
DEP RATE	0.000 - 999.9	Å/SEC
FINAL THK	0.000 - 999.9	KÅ
THK SPT	0.000 - 999.9	KÅ
DENSITY	0.500 - 99.99	GM/CC
Z-RATIO	0.100 - 9.999	——
SENSOR #	1 or 2	——
SOURCE #	1 or 2	——
CRUCIBLE #	0 - 8	Whole Numbers
CTL GAIN	00.01 - 100.0	(Å/SEC)/%
CTL TC	0.1 - 100	SEC
CTL DT	0.1 - 100	SEC
MAXPWR	0.0 - 100	%
SAMPLE	0 - 99	%
HOLD TIME	00:00 - 99:59	MIN:SEC

4.3 Alarms and Stops

There are a number of unusual instrument situations that may require operator attention. These situations are detected and then treated as **ALARMS** or if very serious, **STOPS**.

Both alarms and stops are indicated by a separate relay closure. An alarm condition is not fatal, the instrument will continue the layer or process to normal termination. A **STOP** is fatal, immediately halting the process. If desired, the user may set the **STOP ON ALARM** configuration switch (see Section 2.6.2) to configure the instrument to treat an **ALARM** the same as **STOP**; i.e., halting processing upon detection of the abnormal condition.

4.3.1 Alarms

The following conditions are considered **ALARMS** by the instrument and close the **ALARM RELAY**.

- Crucible hearth selection is not validated by the **CRUCIBLE VALID** input within 30 seconds.
- Rate control not established during the first 60 seconds of **SHUTTER DELAY** (or 20X **CTL TC** if **PID** loop is used).
- Rate has been out of control in **DEPOSIT** for 60 seconds (or 20X **CTL TC** if **PID** loop is used).
- The source power has constantly exceeded the **MAX PWR** parameter for 5 seconds. This is also indicated by the MAX POWER annunciator blinking.

4.3.2 Stops

The following actions or conditions produce a **STOP** state. This condition is indicated by the **STOP** annunciator on the XTC/2 or the **STOP LED** on the XTC/C and the closure of the **STOP** relay.

- Pressing the front panel switch on the XTC/2
- Activating the **STOP** external input
- A **CRYSTAL FAIL** detected during any pre-deposit phase (when crystal switching is not available).
- A **CRYSTAL FAIL** detected during the **DEPOSIT** state if the **TIME PWR** parameter is set to **N** (when crystal switching is not available).

- Following the **POST-DEPOSIT** states of a layer that completed the **DEPOSIT** state in **TIME PWR**.
- Any of the **ALARM** conditions listed in Section 4.3.1 if the **STOP ON ALARM** or **STOP ON MAX PWR** configuration switch is activated.

4.4 Recovering From "STOPS"

These instruments have the ability to complete a process (recover) from a **STOP** without manually reprogramming any film or process parameters. Recovery from a **STOP** (generated by an operator or any machine induced condition) requires only that the **START** command be given (be sure that the **CONTINUE** annunciator is visible on the display). The film in process at the time of the **STOP** will again be executed from the beginning, but the displayed thickness will not be "zeroed" upon reentry of the **DEPOSIT** state. Instead, the thickness that was accumulated at the time of the generation of the **STOP** will be used. Thickness will accumulate in the normal fashion from that point. All processing will occur in the normal fashion from the reentry of the deposit state, forward. In this manner a "repair" layer may be added to the previous run to bring the film to the specified thickness.

If it is not desired to recover, the process may be reset to the beginning of layer one by issuing a **RESET** command prior to a **START** command. The **CONTINUE** annunciator will not be visible on the operating display after the **RESET** command is given. This procedure may be used if the layer in question cannot be successfully repaired by adding a second layer of the same material to achieve final thickness specification.

NOTE: A **RESET** command may be given by pressing the front panel reset key when the display is in the operate mode, or through the remote communications.

4.5 Tuning the Control Loop

The function of the control loop parameters is to match the instrument's reaction to an error (between the measured deposition rate and the desired rate) to the time related characteristics of the deposition source and its power supply. There are three adjustable parameters; **CTL GAIN**, **CTL TC** and **CTL DT** used to accomplish this. It is convenient to think of sources as falling into two categories "fast" or "slow". Fast sources use an integrating type controller while slow sources are better controlled with a PID type. A more extensive discussion of control loops is presented in Section 5.6. The tuning parameters are affected by source level, rate, sweep range or beam density, tooling and source condition.

NOTE: The use of a chart recorder, especially when beginning a new application is highly recommended. Set the recorder output to "rate" and use it to monitor the response to small changes in the **DEP RATE**.

NOTE: If you do not know if the source is fast or slow, it is straight forward to measure the delay with the chart recorder. Using manual power control, establish rate and allow it to become steady. When the chart recorder pen crosses some convenient reference point, increase the source power a few percent (~5% if possible). Allow the source to again stabilize. Graph the delay time, as is shown in Figure 5.7, to determine if the source is "fast" or "slow". Run the recorder at a chart speed sufficiently fast to accurately measure time. Delay times greater than 1 second characterize the source as "slow".

4.5.1 Tuning a Fast Source

A fast source, for the purpose of this discussion, is a deposition source that has not more than a one second delay (lag) between the control voltage change (into the source's power supply) and the measurement system's ability to sense that change has taken place. In general, fast sources are: all electron beam types (unless a hearth liner is used), some very small filament sources and sputtering sources.

If the source response has been characterized as "FAST" (as suggested in the NOTES in Section 4.5); it is easy to set the INTEGRATING TYPE control parameters as follows:

CTL DT - since this is a fast source, set this parameter to 0.1 and leave it there.

CTL TC - set this parameter to 0.1 and leave it there.

CTL GAIN - approximate the process gain by dividing the increase in deposition rate (Å/sec) by the increase in source power (%). Set this parameter to this computed value. Optimize this value by changing the value in use. Remember that increasing the value of this parameter reduces the controller change for a given error in the deposition RATE.

NOTE: If satisfactory control cannot be established using only **CTL GAIN** the source is probably not a "fast" source.

The response of a system with too little controller gain (its **CTL GAIN** value is too large) is characterized as over damped as shown in Figure 4.4. Decrease the **CTL GAIN** value until the system oscillates as is shown by the under damped curve. Proper control is established by an intermediate value that approximates the critically damped curve.

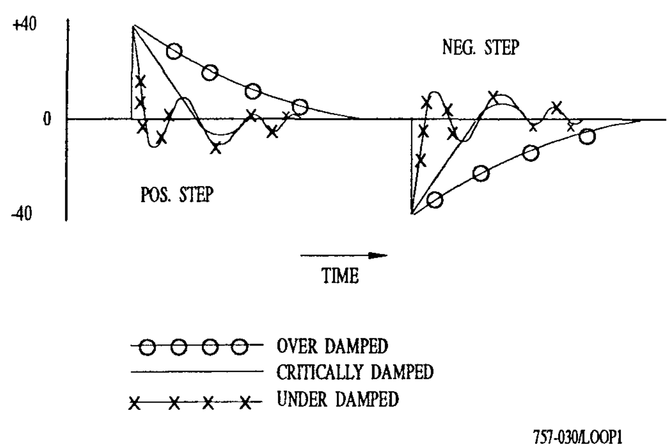


Figure 4.4 Examples of Damped Curves

4.5.2 Tuning a Slow Source

A slow source, for the purpose of this discussion, is a deposition source that has more than a one second delay (lag) between the control voltage change (into the source's power supply) and the measurement system's ability to sense that change has taken place. Most thermal sources are slow sources. (A typical fast source is an electron beam heated type that does not use a hearth liner.)

If the source response has been characterized as "SLOW" (as suggested in the NOTES in Section 4.5); review Section 5.6 and then set the PID control parameters as follows:

CTL GAIN	= K_p, enter this value into the parameter
CTL TC	= T_1, enter this value into the parameter
CTL DT	= L, enter this value into the parameter

As illustrated in Figure 5.7, the control dead time, L, is the time delay between a change in the source's power setting and a noticeable change in deposition rate. The control time constant, T_1 is ($T_{0.632}$ - L) where $T_{0.632}$ is the time between a change in the source's power setting and the time to achieve 63.2% of the new equilibrium rate.

K_p is then the ratio of the change in rate over the change in source power setting.

$$K_p = \frac{\text{(change in output)}}{\text{(change in control signal)}} = \frac{\Delta \text{ Å/sec}}{\Delta \text{ \% Pwr}}$$

These values may be adjusted slightly in use to optimize the tuning. The tuning may change because of process variations. Usually **CTL TC** and **CTL DT** do not need to be changed.

> **NOTE:** Remember that increasing the value of **CTL GAIN** reduces the controller change for a given rate error.

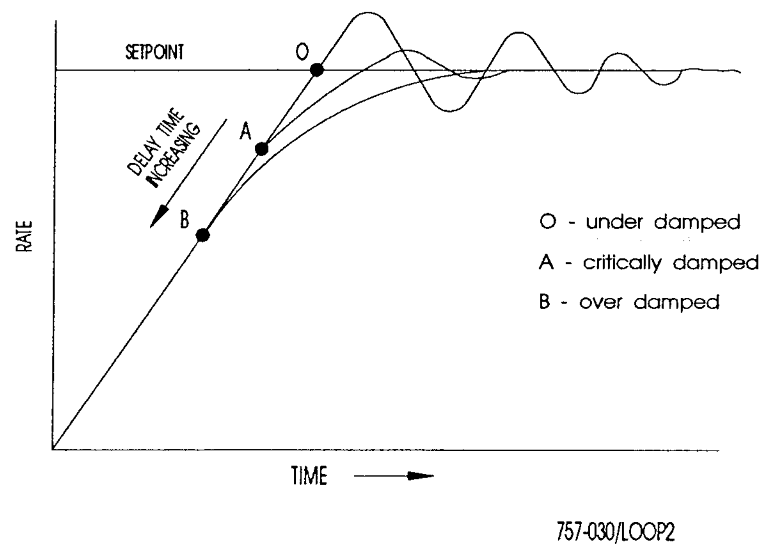


Figure 4.5 Examples of Delay Settings

4.5.3 Setting Maximum Power

The MAX PWR parameter is generally used to ensure that no significant damage can take place when a deposition source under rate control experiences an unusual event. By placing a limit on the most power allowed to be applied to the source, serious damage might be avoided if, for example, material is depleted. Without this protection Rate Control would keep adding power until the full 100% were applied. This is frequently catastrophic! It is normal to set this parameter at a value that is 2-5% more than the normal power required during deposition. Exceeding maximum power can result in a STOP or Alarm condition; see Section 4.3.

4.6 Setting S&Q Parameters (Soft Crystal Failures)

At some point during deposition the crystal may become unstable or erratic yet continue to oscillate within the instrument's acceptable frequency range of 6.0 MHz to 5.0 MHz. The resulting rate control will be poor and thickness measurements may be inaccurate. By programming non-zero values for **S** and/or **Q**, various improvements in process control can be achieved. The instrument can be made to automatically switch to a different crystal and continue the deposition normally, complete the run in the **TIME-POWER** mode or even terminate the process whenever the programmed threshold of instability is exceeded. As the **Q** and **S** factors are programmed to larger values the level of instability tolerated prior to switching is lowered.

4.6.1 Q-Factor (Quality)

The Q-Factor is a measure of the quality of the rate control of the active process. When the Q-Factor is activated the instrument senses the amount of rate deviation from the desired programmed rate. Setting **Q** between 1 and 9 activates an algorithm which sets threshold limits on allowed rate deviation. If the rate deviation relative to the programmed rate is greater than the programmed threshold limit, the **Q** counter is incremented. If the rate deviation is less than the programmed threshold, the **Q** counter is decremented. **Q** is not allowed to have negative values. If the **Q** counter exceeds a value of 50, the instrument will then automatically crystal switch, complete the process on **TIME-POWER** or **STOP** the process. The quality limits (or band of allowed rate deviation) are shown in Table 4.3. This deviation is computed on each individual reading of the crystal during the deposit phase, i.e., every 250 ms.

TABLE 4.3

QUALITY LIMITS

Q-Factor	Threshold of Rate Deviation (%)
0	Disabled
1	30.0
2	25.0
3	20.0
4	15.0
5	12.5
6	10.0
7	7.5
8	5.0
9	2.5

Example: If the Programmed rate is: 45 Å/s and the actual rate is: 40 Å/s, then the Deviation (%) = $\frac{45-40}{45} \times 100\% = 11.1\%$

4.6.2 S-Factor (Stability)

Normally, as material is deposited on a crystal its operating frequency decreases. It is from this change in frequency (over the measurement time period) that the instrument derives its thickness measurement and rate control functions.

There are times when the crystal may become unstable and will experience a positive frequency shift over the measurement time period. The S-Factor can then be used as a measure of the crystal's instability.

When the S-Factor is activated, and a positive frequency shift occurs, the magnitude of the positive shift is accumulated in the S-register. A limit is placed on the total cumulative positive frequency shift by programming the S-Factor between 1 and 9. When the limit is exceeded the instrument will fail the crystal and effect a CrystalSwitch, Complete on Time Power, or STOP, depending on the instrument configuration.

Maximum accumulations for selected S-Factors are listed in Table 4.4. To prevent random noise from accumulating in the S-register a minimum positive frequency shift of 25 Hz is required.

Table 4.4

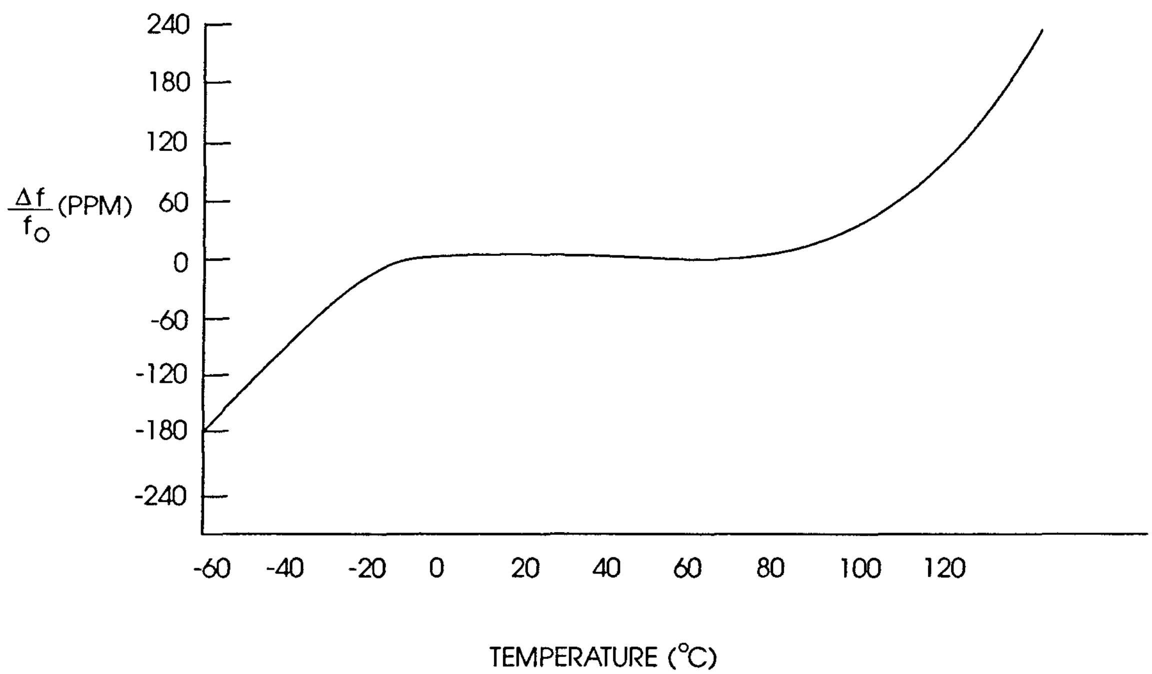
MAXIMUM ACCUMULATIONS FOR SELECTED S-FACTORS

S-Factor	Pos. Frequency Accumulation
0	Disabled
1	5000 (max single shift 1250)
2	1000
3	500
4	400
5	200
6	200 (max single shift 100)
7	100
8	100
9	25

There are many reasons for a crystal to exhibit a positive frequency shift. For example, when a crystal is near the end of its life it is prone to instabilities that may result in a temporary increase in crystal frequency. Also positive frequency shifts may occur due to film stress relieving or a film tearing off a crystal.

Additionally, temperature effects may cause positive frequency excursions. A crystal subjected to temperatures over 100°C is more sensitive to small changes in temperature inducing frequency changes. When heat is applied inside a chamber and/or when the shutter is opened (exposing the crystal to the hot source), the crystal frequency will shift higher until thermal equilibrium is obtained. When the active process ends and/or the shutter closes, the crystal frequency will shift in a negative direction due to cooling.

Figure 4.6 shows temperature versus frequency relationship for an AT cut crystal.



Frequency Change vs. Temperature for an AT crystal cut at 35°20'
Figure 4.6

4.6.3 Determining Q and S Values

The **Q** and **S** Factors are used to ensure that the evaporation process is always under the best possible rate control a crystal can provide. The process engineer can program values between 0 and 9 for these parameters. Thus, when the primary crystal reaches a point where its behavior is objectionable it will be disabled and the proper switch/time-power/stop decision made. The tolerance of instabilities becomes increasingly smaller as **Q** and **S** increase towards 9. They are independent parameters and may be treated one at a time.

If the crystal fails and no backups are available, the **TIME PWR** parameter determines whether the process should stop (N) or complete on time-power (Y), [or crystal switch if a dual or CrystalSix crystal sensor head is employed].

Q and **S** can be observed when the display is in the operate mode and the **LIFE** key is depressed. The value in the **S** accumulator replaces the **TIME** display. When the life key is released, the **Q** value replaces the **S** value in the **TIME** display for about 1 second.

With a new crystal, the value in the **Q** accumulator will usually be one or zero if the **Q** parameter is programmed properly. As a crystal deteriorates, larger values will appear as the **Q** accumulator builds up or counts down. The switch point occurs when the **Q** accumulator equals 50. The designated count of 50 requires that the rate deviation instability be sustained for several seconds. This is so the algorithm does not trip out for short-lived events. The **Q** accumulator does not retain its values, but rather, builds up when the rate deviation exceeds its set tolerance and counts down to zero when the rate deviation is within its programmed tolerance band.

The **S** accumulator shows the total magnitude of only the positive frequency shifts (in Hz) from the moment the start button is pushed until that film is completed and the next film layer is started. When the **S** value exceeds the set point, the crystal is disabled. Unlike the **Q** accumulator, the **S** values are retained and added to the accumulator whenever the positive frequency shift is greater than 25 Hz. Table 4.4 shows the accumulated frequency shift required to trigger the switch.

One problem is E-B gun arcing. If the **S** value constantly increments during arcs it usually indicates poor grounding and the **S** factor should be disabled until this problem is corrected.

Improved rate and thickness information results from programming non-zero values for **Q** and **S**. The trade off is between improved process control and lower crystal utilization. By observing the behavior on the operating display a determination can be made, after several runs, whether or not the programmed values provide a desirable compromise.

Inficon's laboratory experiments have shown the following values to be useful and they can serve as general guidelines.

SOURCE	MATERIAL	S-FACTOR	Q-FACTOR
2" E-B gun w/liner	Cu	7	7
2" E-B gun	Cu	5	7
1-1/8" E-B gun	Al	4	4
1-1/8" E-B gun	Ni	4	3
Integral W-Al_2O_3	Cu	6	7

If the process/crystal behavior is unknown and you want to employ the **Q** and **S** factors, start with **S** = **Q** = 5 and watch their behavior on the display by pressing the **LIFE** switch. Monitor and fine tune these parameters until the desired level of rate control is ensured.

Often during process setup, the initial settings of the **Q** factor may soft fail the crystal sensor. This can be caused by process delays in getting the system under control (i.e., slow response sources or SOAK2 power levels poorly set). The crystal sensor's state of soft failure can be cleared or reset by changing or re-entering the value of the **Q** or **S** factor parameter.

For example, if the **Q** factor parameter has a value of 5 and the rate control varies by more than ±12.5% this causes the **Q** counter to increment. When it reaches the value of 50 the crystal is "Soft Failed" due to the crystal quality algorithm. This "**Q**" failed crystal can be cleared by re-entering the parameter value 5 for the **Q** factor parameter or by changing it to another value.

4.7 Rate Ramps

Each film program includes a rate change parameter. It may be used to generate a precise linear variation in the evaporation rate. "Rate Ramps" execute during the deposit state of the film. They are initiated when the **THICK SPT** parameter of the film program is reached. If the rate ramp state terminates before the film reaches **FINAL THK**, the instrument will return to the deposit phase.

The slope of a rate ramp is determined by the following equation: delta rate per sec = (**NEW RATE - DEP RATE**) divided by **RAMP TIME**. If a ramp parameter is changed during the ramp, a new slope will be calculated, taking into consideration the time the ramp has already been in process.

4.7.1 Rate Ramp to Zero Rate

It is sometimes desirable to ramp to zero rate for alloy phasing purposes, completing the film processing as if a final thickness had been achieved. Rate ramps, however, are ordinarily deleted by entering zero for the **NEW RATE.** Therefore, in order to implement this type of film termination, program the **NEW RATE** value of the rate ramp to 0.1 Å/sec. When this rate value is achieved, the film program will proceed as if a **FINAL THK** limit had been reached.

While a rate ramp is being processed, the **DEP RATE** parameter's internal value is continuously updated to match the slope of the Rate Ramp.

> **NOTE:** If the **TIME-POWER** state is entered, a rate ramp will not be executed; with the film completing at the programmed **FINAL THK.**

4.8 Use of the Hand Controller (Option)

A hand held controller is provided as an option. The controller serves as a wired remote to manually control power, switch crystals and produce a **STOP**.

The controller is attached to the instrument with a coiled cord and attaches with a modular plug to the front panel of the instrument. The **POWER/STOP** switch located at the top of the controller is asymmetrical to increase awareness of the direction of power increment and decrement.

Power is affected (only when in Manual mode) by moving the **POWER/STOP** switch laterally. A **STOP** is produced by plunging the **POWER/STOP** switch down.

When in **READY**, a crystal switch is activated by depressing the red button on the body of the controller. This action alternates the active crystal of a dual head configuration or advances the active crystal of a CrystalSix to the next crystal position. This may be done any time the instrument is not in **STOP**.

> **NOTE:** Upon leaving the **MANUAL POWER** state the instrument enters the **DEPOSIT** state. The deposition will terminate if the **FINAL THK** parameter value has been exceeded.

The ship kit includes a convenience hook for the controller that can be attached to the instrument or other accessible location.

4.9 Setting the Soak and Idle Power Levels

These instruments provide 0 to +/- 10 Volts source power control from the **SOURCE #** connectors on the rear panel. The voltage output is proportional to the percent power display with 50% power outputting 5 volts. The control voltage polarity is set by the appropriate configuration switch, see Section 2.6.2.

NOTE: The maximum voltage output is limited by the value of the **MAX PWR** parameter of each film.

4.9.1 Setting Soak Power 1 Parameters

SOAK PWR 1 is typically set at a level that produces a source temperature just below significant evaporation. This is easily translated into a power percentage (**SOAK PWR 1**) with the help of the hand held controller or the △C/▽E keys when in manual power mode. Slowly bring the power level to a level where melting is just beginning and then note the power percentage value on the LCD display. Use this value for the **SOAK PWR 1** setting. This power level may also be used in fast coaters for a non-zero Idle Power. Set the associated Rise Time and Soak Time to insure that the melting does not cause violent turbulence but does not waste excessive time.

4.9.2 Setting Soak Power 2 Parameters

SOAK PWR 2 is typically set at a level that is just below the power that is used for maintaining the selected evaporation rate. This is determined by manually bringing the power level up to the desired rate and then entering automatic rate control. Allow the source to stabilize, then note the average power on the display. Use this value or one slightly lower for the **SOAK PWR 2** value. Set the associated rise and soak times long enough to insure that the melting does not cause violent spattering, but short enough that expensive materials are not wasted.

4.9.3 Setting Idle Power Parameters

After a deposit has completed, it may be necessary to slowly reduce the source's power to zero or to some non-zero value. The **IDLE RAMP** parameter defines the time spent in linearly tapering the power from the value at the end of deposit to the **IDLE PWR** value.

4.10 Implementing RateWatcher

It is easy to set up to automatically sample the deposition rate periodically and then maintain the proper source power level necessary to keep the Auto Control Rate at the set point for extended periods of time. With inherently stable deposition sources; such as the planar magnetron, an occasional check of the rate (with the associated automatic recomputation of the necessary power level) is all that is needed.

This "sample and hold" type of control can supersede the fully active type of rate control that normally limits the utility of the crystal monitor for in-line or load locked systems.

The RateWatcher feature requires a two parameter entry.

First, the Process Engineer must decide on the **SAMPLE** percent. This parameter sets the accuracy that must be maintained over the 5 second interval.

NOTE: The minimum accuracy range settings are internally limited to 0.5Å/sec difference between the setpoint and the just sampled rate. This avoids unnecessary power changes.

Second, the **HOLD TIME** must be programmed. This is the length of time between the completion of the last sample period (or the achievement of rate control) and the initiation of the next sample period. The process engineer may set the interval up to a maximum of 99:59 for automatic operation. If longer intervals or periodic samples are needed **SAMPLE INITIATE** and **SAMPLE INHIBIT** inputs are available on the **SYSTEM I/O** connector. During **HOLD** periods, thickness is accumulated at the Auto Control Rate (**DEP RATE**) and power is held at the internally computed Time-Power value. During **SAMPLE** periods, the power will not be changed unless two consecutive samples fall out of the specified accuracy range (1-99%).

Entering a **HOLD TIME** of 00:00 disables the RateWatcher feature.

NOTE: The RateWatcher function is disabled if the sensor type is configured for a Dual or CrystalSix sensor head. Refer to Section 4.15.1.

4.11 Crystal Fail

Whenever the ModeLock measurement system is unable to effectively identify and drive a monitor crystal, a special set of sweep and find instructions are executed. This sequence takes up to five seconds as it is repeated a number of times. This sequence of events is depicted in the "Measurement and Control Processing Loop" flow chart, Figure 4.3.

If the measurement system is unable to recover, the message XTAL FAIL is displayed. The action next taken by the instrument is dependent on the value of the **TIME-POWER** parameter as described in Section 4.12.

Sometimes a monitor crystal will spontaneously recover if its temperature is reduced or sufficient time passes and the stress induced by the coating is naturally relieved. Even with the XTAL FAIL message displayed the measurement system will continue to attempt to find the fundamental resonant mode's frequency. This message will disappear when the crystal recovers or is replaced.

Additional information on crystal failures is presented in Section 6.3.2. The ModeLock oscillator is more fully explained in Sections 5.5.5 and 5.5.6.

4.12 Completing on TIME-POWER

When used as a controller this instrument has the ability to complete a deposition normally if a crystal fails during the deposit phase. Depending on the setting of the **TIME-PWR** parameter, the unit will either complete on **TIME-POWER (Y)**, or **STOP (N)** on crystal fail. When set up to complete on **TIME-POWER** and a crystal fail is encountered the instrument will establish an average power—based on the values output to the source prior to the crystal failure. This average power is used while thickness is accumulated at the **DEP RATE**. The deposition will terminate normally. The thickness accuracy will depend on the duration of the **TIME-POWER** phase. A shorter duration of **TIME-POWER** will increase the Final Thickness accuracy; longer durations will decrease accuracy. This feature has no utility when used in a monitor only situation.

4.13 Crystal Fail Inhibit

In many coating plants the crystal fail output relay closure is given major importance and causes the entire system to shut down. This can cause problems when the crystal is changed as part of the normal reloading procedure. This potential conflict is resolved by utilizing the crystal fail inhibit input; see Section 2.6.4. When this input is activated the crystal fail relay will not close on crystal fail.

The crystal fail inhibit input is ignored if the instrument is in the Deposit state.

The front panel messages and instrument operation still work normally. The operator may now change the crystal and verify that it is operating without inducing a major process interruption.

The crystal fail inhibit input may be switched manually or automatically by using the **END DEPOSIT** relay; see Section 2.6.5.

4.14 Shutter Delay

SHUTR DLY is used to establish rate control before exposing the substrates to the evaporant. The sensing crystal must be exposed to the deposition source during the Shutter Delay state for this to be accomplished. Shutter delay is accessed by programming the **SHUTR DLY** parameter to **Y** (yes). The control loop attempts to establish rate control at the end of the pre-deposition film states. However, the source shutter opening is delayed for a period of time to insure stable rate control. When rate control has been established (within 5% of the **DEP RATE** value), the shutter opens, the accumulated thickness is zeroed, and the substrates are immediately exposed to an evaporant that is under tight rate control. With proper adjustment of the control loop parameters, the delay time can be kept to a minimum. If the instrument is unable to establish rate control in 60 seconds (or 20x **CTL TC** if the PID Loop is used), the alarm relay on the **AUX I/O** will close. Also the instrument may be set up to automatically **STOP** on this alarm condition if the appropriate configuration switch is turned on; see Section 2.6.2.

4.15 Crystal Switch Details

A crystal switch will automatically occur when:

1. The instrument is configured for a dual head, a layer is running on the primary sensor, and the primary crystal fails.

2. The instrument is configured for a CrystalSix, a layer is running, and there is at least one good crystal left in the carousel when the active crystal fails.

3. The instrument is configured for a dual head or single heads, a START is executed and the designated primary sensor is different than the last sensor run. This switch will take place before entering a RISE 1 or RISE 2 state.

   NOTE: When using a dual head, a layer cannot START if the primary crystal for that layer is failed, unless the "start layer without backup crystal" configuration switch is activated; see Sections 2.6.2 and 4.16.

4. A soft crystal failure is generated; see Section 4.6.

A crystal switch will **NOT** automatically occur:

1. In STOP, READY or IDLE.

2. When the designated primary sensor is already failed at the START of a layer. A STOP will occur unless the "proceed without backup" configuration switch is chosen; see Section 4.16.

3. When the secondary crystal of a dual head fails. (A TIME-POWER or STOP will occur.)

A crystal switch can be manually executed via the front panel, handheld controller, or remote communications any time the system is configured for dual or CrystalSix.

NOTE: The primary sensor # of a dual head is the sensor programmed in the film's parameters. The secondary sensor is the other sensor. On the XTC/2 Display, the active crystal's number is lit. If the primary crystal has failed, the active crystal's number (backup) flashes to indicate that there is no backup.

CrystalSix crystals are all read on power up to determine how many good crystals are present. On power up, when configured for a CrystalSix sensor, the XTC/2 display will be blank except for the CrystalSwitch and STOP annunciators. Once the initialization is complete the XTC/2 will automatically go to the Operate Display. On the XTC/2 Display, the annunciators of the good crystals are lit, with the active crystal's number flashing. The XTC/2 will identify a CrystalSix switcher fail by turning off all the crystal annunciators. A CrystalSix switcher fail will occur if the CrystalSix carousel fails to rotate properly.

NOTE: The crystal fail annunciator is lit when no more good crystals remain for both the XTC/2 and the XTC/C.

4.15.1 Sensor Shutter / CrystalSwitch Output

The function of the Sensor Shutter outputs depend on the Configuration switch settings on the back of the unit. (See Table 2.1 for a list of configuration switch setting definitions.) If a single head sensor type is chosen the Sensor Shutter relay contacts are set to be Normally Open. The Sensor Shutter relay contacts close (opening the shutter) when entering the Deposit state, Shutter Delay state, or during the Sample period of the RateWatcher function.

If a Dual sensor type is chosen, the Sensor Shutter relay now functions as a CrystalSwitch relay. The contacts are set to be Normally Open. The Sensor Shutter relay contacts close upon initiating a CrystalSwitch. This actuates the shutter mechanism, toggling the shutter, exposing Sensor 2's crystal and covering Sensor 1's crystal. A second CrystalSwitch function will open the contacts, toggling the shutter, exposing Sensor 1's crystal and covering Sensor 2's crystal. Due to the change in function of the relay output from that of Sensor Shutter to one of CrystalSwitch, RateWatcher is disabled when the unit is configured for a Dual sensor.

NOTE: When configured for a dual sensor, sensor 1's shutter relay is used for the CrystalSwitch function. Sensor 2's shutter relay is disabled.

If a CrystalSix sensor type is chosen the Sensor Shutter relay functions as a CrystalSwitch relay. The operation of the relay contacts is different than when the sensor is a Dual head. In this case the relay contacts are pulsed closed for one second, opened for one second, closed for one second, then opened. When connected properly, the first one second closure will advance the CrystalSix carousel into an intermediate position between two crystals. Opening the closure for one second allows the ratchet mechanism to relax whereupon the second contact closure advances the next crystal into the proper position. The intermediate position between two crystals is important in automatically verifying the proper operation of the CrystalSix sensor head. Due to the change in function of the relay output from that of Sensor Shutter to one of CrystalSwitch, RateWatcher is disabled when the unit is configured for a CrystalSix sensor.

4.16 Start Layer Without Backup Crystal Configuration

These instruments allow the option of automatically continuing a Process with the "backup" sensor. In normal operation if the sensor fails during the Process, the Process is automatically stopped and the crystal must be replaced in order to continue. With Configuration Switch 11 on, the user is allowed to continue the Process with the second, "backup", sensor. All CrystalSwitching or Complete on Time Power functions work normally. The following examples further elucidate various situations.

For example if using two single sensors and a crystal fails during the Layer, the Layer will Complete on Time Power or **STOP**, XTAL FAIL, whichever is programmed. If Configuration Switch 11 is on, the "backup" crystal is good, and **START** is pressed, either the Layer will be continued, or the next Layer is started.

If using a Dual Head and a crystal fails while the Layer is in Deposit, the instrument will "crystal switch" to the secondary crystal of the Dual Head and complete the Layer. Then, with Configuration Switch 11 on, pressing **START** will begin the next Layer in the Process using the "backup" crystal, even though that Layer's primary crystal is failed. When using a CrystalSix sensor, all 6 crystals must fail prior to using the "backup" crystal.

If using two single sensors or a dual sensor, whenever the "backup" crystal is in use the XTAL # annunciator will flash. When using a CrystalSix, the annunciator for the crystal currently in use will flash as always.

Additionally, if the instrument switches to the "backup" crystal during the Process it will continue using the "backup" crystal until the Process is **RESET**, even if the primary crystal is replaced. This may be circumvented by manually crystal switching to the primary crystal once the failed crystal is replaced.

4.17 Crystal Life and Starting Frequency

Crystal life is displayed as a percentage of the monitor crystal's frequency shift relative to the 1 MHz frequency shift allowed by the instrument. This quantity is useful as an indicator of when to change the monitor crystal to safeguard against crystal failures during deposition. It is normal to change a crystal after a specific amount of crystal life (% change) is consumed.

It is not always possible to use a monitor crystal to 100% of crystal life. Useful crystal life is highly dependent on the type of material being deposited and the resulting influence of this material on the quartz monitor crystal. For well behaved materials, such as copper, at about 100% crystal life the inherent quality, Q, of the monitor crystal degrades to a point where it is difficult to maintain a sharp resonance and therefore the ability to measure the monitor crystal's frequency deteriorates.

When depositing dielectric or optical materials, the life of a gold, aluminum or silver quartz monitor crystal is much shorter; as much as 10 to 20%. This is due to thermal and intrinsic stresses at the quartz-dielectric film interface, which are usually exacerbated by the poor mechanical strength of the film. For these materials, the inherent quality of the quartz has very little to do with the monitor crystal's failure.

It is normal for a brand new quartz monitor crystal to display a crystal life anywhere from 0 to 5% due to process variations in producing the crystal. Naturally, this invites the question: "Is a brand new crystal indicating 5% life spent inferior to a crystal indicating 1% life spent?"

If a new crystal indicates 5% life spent, it means that either the quartz blank is slightly thicker than normal (more mechanical robustness), or the gold electrode is slightly thicker than normal (better thermal and electrical properties), or both. In either case, its useful life with regard to material deposition should not be adversely affected. To verify this assertion, laboratory testing was performed on crystals which covered the crystal life range in question. Results indicate that a brand new crystal which indicates 3 to 5% life spent is just as good, if not better than a crystal indicating 0 to 2% life spent.

As a consequence, it is important to consider the change in crystal life (Δ%), not just the absolute crystal life (%) indicated.

Chapter 5
Calibration & Measurement

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5.0 Calibration and Measurement

5.1 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. The instrument's knowledge of the density of this added material (specified by the film's density parameter), allows conversion of the mass information into thickness. In some instances, where highest accuracy is required, it is necessary to make a density calibration as outlined in Section 5.2.

Because the flow of material from a deposition source is not uniform everywhere, it is necessary to account for the different amount of material flow onto the sensor compared to the substrates. This factor is accounted for by the film's tooling parameter. The tooling factor can be experimentally established by following the guidelines in Section 5.3

Z-ratio is a parameter that corrects the frequency change to thickness transfer function for the effects of acoustic impedance mismatch between the crystal and the coated material.

5.2 Determining Density

NOTE: The bulk density values retrieved from the **Table of Densities and Z-Ratios** are sufficiently accurate for most applications.

Follow the steps below to determine density value:

1. Place a substrate (with proper masking for film thickness measurement) adjacent to the sensor, so that the same thickness will be accumulated on the crystal and this 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 (1000-5000 Å), using the manual control.
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 the following equation:

$$\text{Density (gm/cm}^3\text{)} = D_1 \frac{T_x}{T_M}$$

where

D_1 = Initial density setting

T_x = Thickness reading on display

T_M = Measured thickness

7. A quick check of the calculated density may be made by programming the instrument with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that the instrument has not been zeroed between the test deposition and entering the calculated density.

NOTE: Slight adjustment of density may be necessary in order to achieve $T_x = T_M$.

5.3 Determining Tooling

1. Place a test substrate in the system's substrate holder.

2. Make a short deposition and determine actual thickness.

3. Calculate tooling from the relationship:

$$\text{Tooling (\%)} = TF_I \times \frac{T_M}{T_x}$$

where

T_M	=	Actual thickness at substrate holder
T_x	=	Thickness reading on the display
TF_I	=	Initial tooling factor

4. Round off percent tooling to the nearest 0.1%.

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

NOTE: It is recommended that a minimum of three separate runs be made when calibrating tooling. Variations in source distribution and other system factors will contribute to slight thickness variations from run to run. An average value tooling factor should be used for final calibrations.

5.4 Laboratory Determination of Z-ratio

A list of Z-values for materials commonly used is available in the **Table of Densities and Z-ratios**, Section 5.7. For other materials, Z can be calculated from the following formula:

$$Z = (d_q \mu_q / d_f \mu_f)^{1/2}$$

$$= 9.378 \times 10^5 (d_f \mu_f)^{-1/2}$$

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 gm/cm^3)

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

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

Laboratory results indicate that Z-values of materials in thin-film form are very close to the bulk values. However, for high stress producing materials, Z-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. Using the calibrated density and 100% tooling, make a deposition 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.

2. Place a new substrate next to the sensor and make a second, short deposition (1000-5000Å).

3. Determine the actual thickness on the substrate (as suggested in density calibration).

4. Adjust the Z-ratio value in the instrument to bring the thickness reading into agreement with actual thickness.

For multiple layer deposition (for example, two layers), the Z-value 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's Z-value for both layers.

If the thickness of layer 1 is thin compared to layer 2, use material 2's Z-value 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 values for deposition of layer 2 and subsequent layers.

5.5 Measurement Theory

5.5.1 Basics

The Quartz Crystal deposition Monitor, or 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 piezo electric crystal, the crystal is distorted and changes shape in proportion to the applied voltage. At certain discrete frequencies of applied voltage a condition of very sharp electro-mechanical resonance is encountered. When mass is added to the face of a resonating quartz crystal, the frequency of these resonances is reduced. This change in frequency is very repeatable and is presently precisely understood for specific oscillating modes of quartz. This heuristically easy to understand phenomena 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, DELTA F = 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:

$$\frac{M_f}{M_q} = \frac{(\text{DELTA F})}{F_q} \qquad \text{Eqn. 1}$$

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

$$T_f = \frac{K(\text{DELTA F})}{d_f} \qquad \text{Eqn. 2}$$

where thickness, T_f, is proportional (through K) to the frequency change, DELTA F, 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 gm/cm^3) is the density of single crystal quartz and N_{at} (=166100 Hz cm) is the frequency constant of AT cut quartz. 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 gm/cm^3) is added to its surface. In this manner the thickness of a rigid adlayer is inferred from the precise measurement of the crystal's frequency shift. 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.

5.5.2 Monitor Crystals

No matter how sophisticated the surrounding electronics, the essential device of the deposition monitor is the quartz crystal. The quartz resonator shown in Figure 5.1 has a frequency response spectrum that is schematically shown in Figure 5.2. The ordinate represents the magnitude of response, or current flows of the crystal, at the specific frequency.

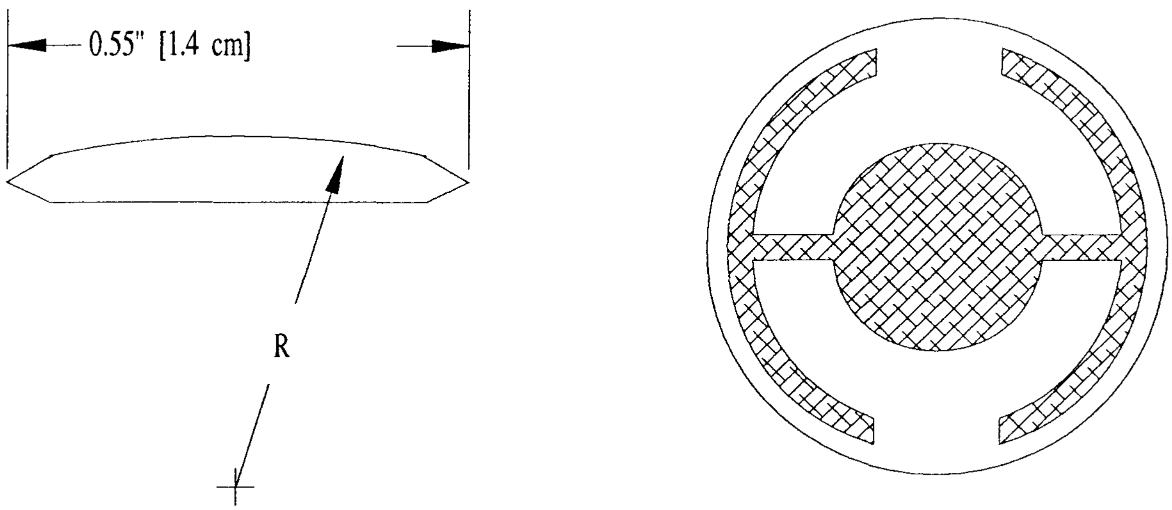


Figure 5.1 Quartz Resonator

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 5-3. The responses located slightly higher in frequency are called anharmonics, they are a combination of 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 5.1 is the result of several significant improvements from the square crystals with fully electroded plane parallel faces that were first used. The first improvement was to use circular crystals. The increased 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. A contoured crystal traps the energy of the traveling acoustic wave through what is essentially total internal reflection before it reaches the edge. Energy is reflected back to the center where it can constructively interfere with other newly launched waves, essentially making a small crystal appear to behave as though it is infinite in extent. With the crystal's vibrations 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 and hence the potential for an oscillator to sustain an unwanted oscillation is substantially reduced. 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 tears leave portions of the deposited film unattached, and therefore unable to participate in the oscillation. These free portions are no longer detected and the wrong thickness is consequently inferred.

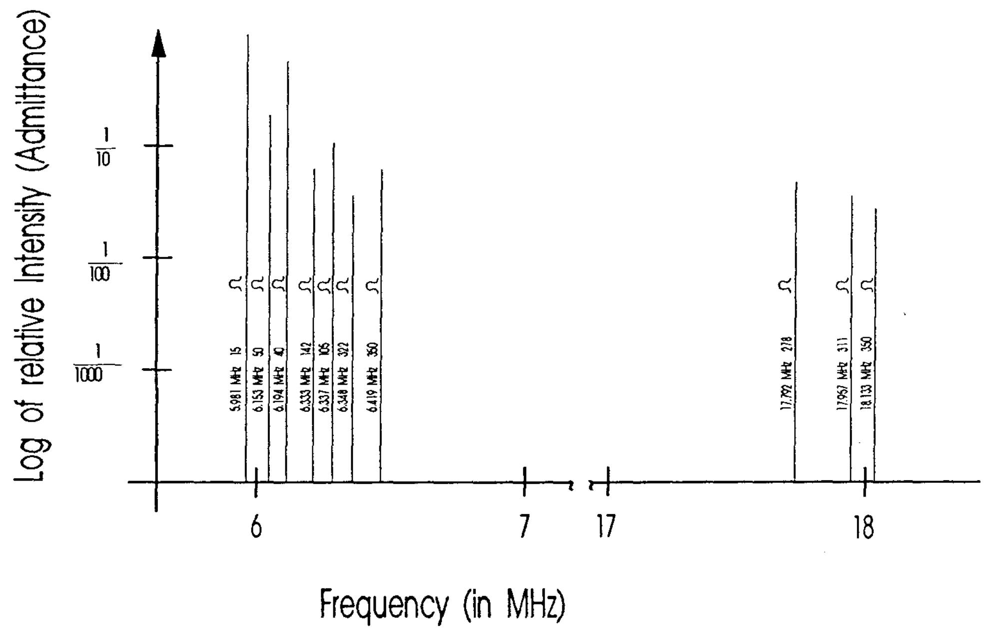


Figure 5.2 Frequency Response Spectrum

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 presently no way to separate the frequency change caused by added mass (which is negative) from the frequency changes caused by a change in temperature (which may be positive or 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.

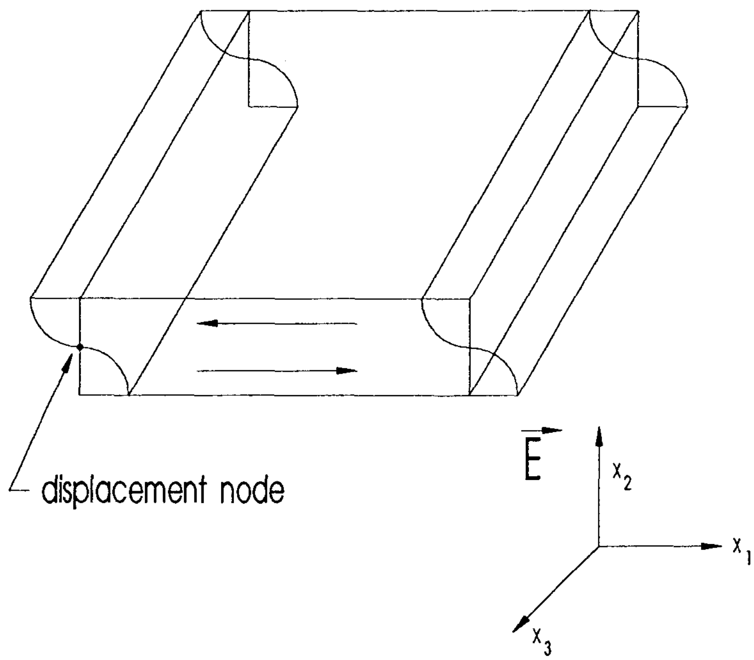


Figure 5.3 Thickness Shear Displacement

5.5.3 Period Measurement Technique

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

$$\frac{M_f}{M_q} = \frac{(T_c - T_q)}{T_q} = \frac{\text{DELTA F}}{F_c} \qquad \text{Eqn. 3}$$

where T_c and T_q are the periods of oscillation of the crystal with film and the bare crystal respectively. The period measurement technique was the outgrowth of the digital implementation of time measurement and ultimately the recognition of the mathematically rigorous formulation of the proportionality between the crystal's thickness, lq, and the period of oscillation, $T_q = 1/F_q$. Electronically the period measurement technique utilizes a second crystal oscillator, or reference oscillator, not effected by the deposition and 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 gated (turned) on at the same time and accumulates cycles from the reference oscillator until m counts is 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 oscillator's frequency. The monitor crystal's period 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 (which is 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 a monitor crystal's frequency 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 only be counteracted 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 more than one or two percent. Ultimately, the practical stability and frequency of the reference oscillator limits the precision of measurement for conventional instrumentation.

5.5.4 Z-Match[1] 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 concurrently taking place at that time, namely the micro-processor, made it practical to solve the Z-Match equation in "real-time". Most deposition process controllers sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown below.

$$T_f = \left(\frac{N_{at}\, d_q}{Pi\, d_f\, F_c\, Z}\right) \arctan\left(Z \tan\left[\frac{Pi(F_q - F_c)}{F_q}\right]\right) \qquad \text{Eqn. 4}$$

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 and found to hold for a number of materials; exhibiting validity to frequency shifts equivalent to $F_f=0.4F_q$. Keep in mind that equation 2 only was valid to $0.02F_q$ and equation 3 was valid only to $\sim 0.05\ F_q$.

[1]Z-Match™ is a trademark of INFICON.

5.5.5 Active Oscillator

All of the instrumentation developed to date has relied on the use of an active oscillator circuit, generally the type schematically shown in Figure 5.4. This circuit actively keeps the crystal in resonance, so that any type of period or frequency measurement may be made. In this type of circuit, oscillation is sustained as long as there is sufficient gain provided by the amplifiers to offset losses in the crystal and circuit and the crystal can provide the required phase shift.

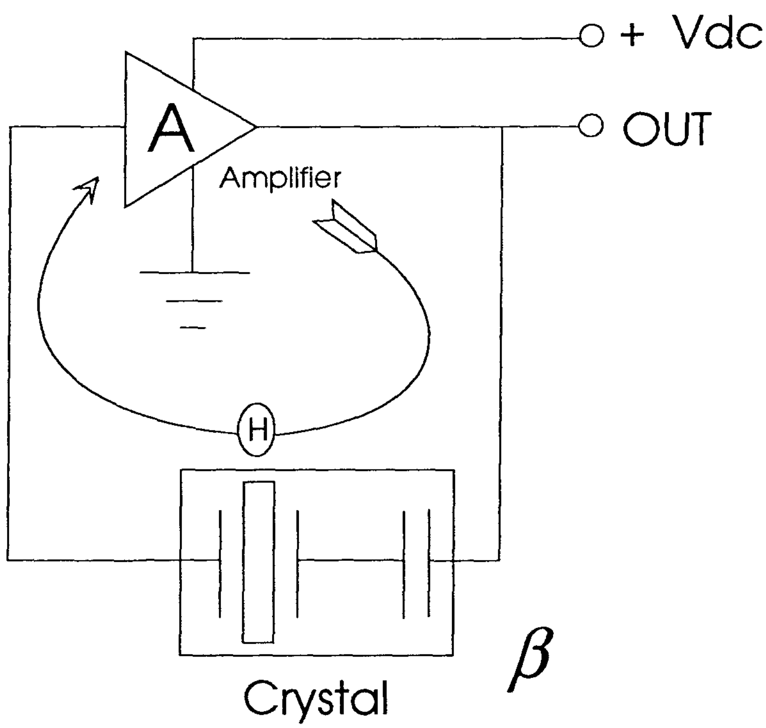


Figure 5.4 Active Oscillator Circuit

The basic crystal oscillator's stability is derived from the rapid change of phase for a small change in the crystal's frequency near the series resonance point, as shown in Figure 5.5.

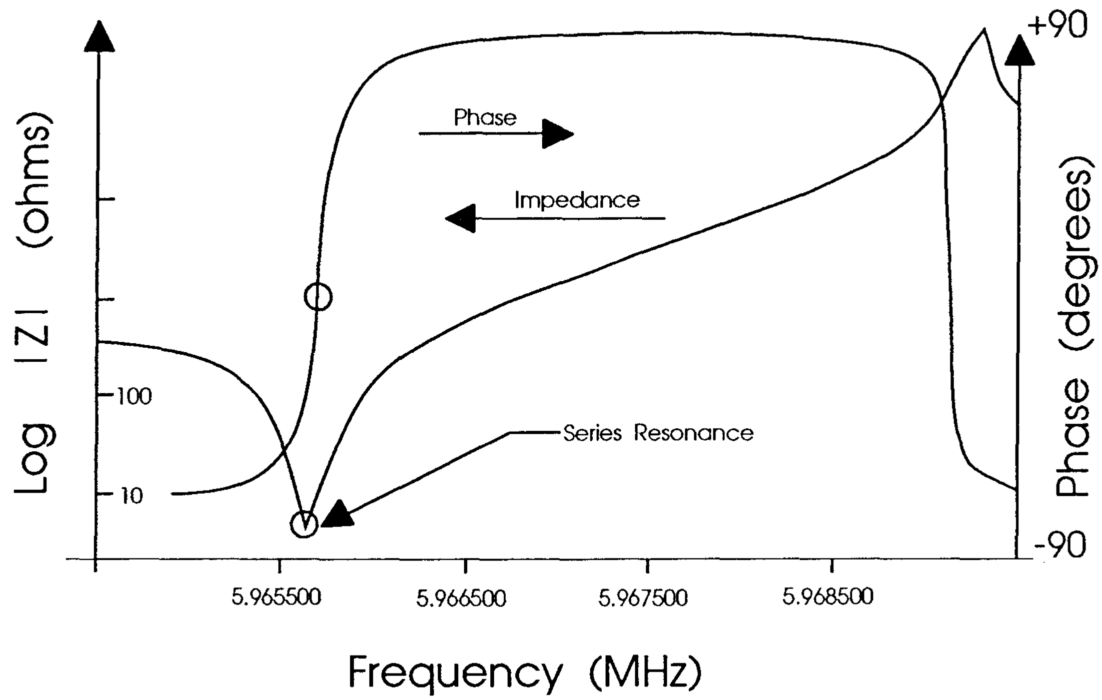


Figure 5.5 New Crystal's Phase and Gain Near Series Resonance

The oscillator circuit is normally designed so that the crystal is required to produce a phase shift, θ, of 0 degrees that allows it to operate at the series resonance point. Long and short term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain the phase shift required for oscillation. Frequency stability is provided by the quartz crystal even though there are long term changes in electrical component values caused by temperature or aging or short term noise induced phase jitter. As mass is added to a crystal, its electrical characteristics change.

Figure 5.6 is the same plot as Figure 5.5 with the response of a heavily loaded crystal overlaid. The crystal has lost the steep slope displayed in Figure 5.5. Because the phase slope is less steep, any noise in the oscillator circuit translates into a greater frequency shift than that which would be produced with a new crystal. In the extreme, the basic phase/frequency shape is not preserved, the crystal is not able to provide a full 90 degrees of phase shift.

The impedance, Z, is also noted to rise to an extremely high value. When this happens it is often more favorable for the oscillator to resonate at one of the anharmonic frequencies. This condition is sometimes short lived, with the oscillator switching between the fundamental and anharmonic modes, or it may continue to oscillate at the anharmonic. This condition is known as mode hopping and in addition to annoying rate noise can also lead to false termination of the film because of the apparent frequency change. It is important to note that the controller will frequently continue to operate under these conditions; in fact there is no way to tell that this has happened except that the film's thickness is suddenly apparently thinner by an amount equivalent to the frequency difference between the fundamental and the anharmonic that is sustaining the oscillation.

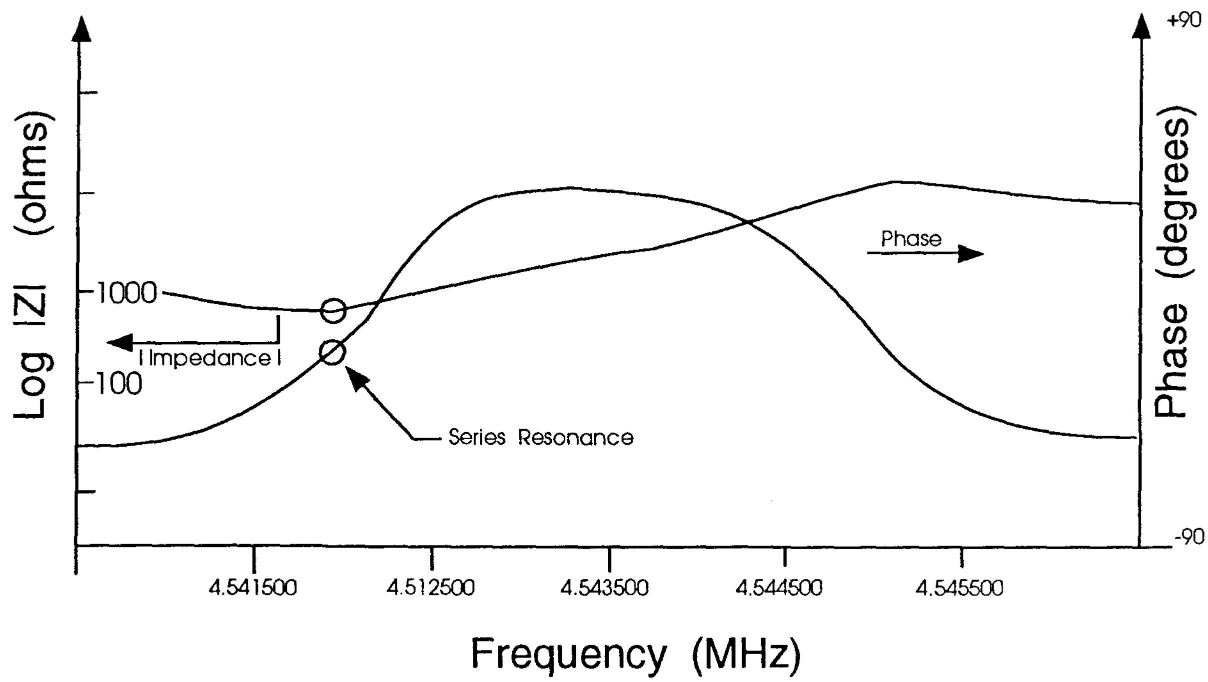


Figure 5.6 Heavily Loaded Crystal's Phase and Gain Near Series Resonance

5.5.6 ModeLock™ Oscillator

INFICON has created a new technology[7] that eliminates the active oscillator and its limitations. This new system constantly tests the crystal's response to an applied frequency in order to not only determine the resonant frequency but to also verify that the crystal is oscillating in the desired mode. This new system is essentially immune to mode hopping and the resulting inaccuracies. It is fast and accurate, determining the crystal's frequency to less than 0.05 Hz at a rate of 4 times per second. Because of the system's ability to identify and then measure particular crystal modes it is now possible to offer new features that take advantage of the additional informational content of these modes.

This new "intelligent" measurement system uses the phase/frequency properties of the quartz crystal to determine the resonant frequency. It operates by applying a synthesized sine wave of specific frequency to the crystal and measuring the phase difference between the applied signal's voltage and the current passing through the crystal. At series resonance, this phase difference is exactly 0 degrees; that is, the crystal behaves like a pure resistance. By separating the applied voltage and the current returned from the crystal and monitoring the output of a phase comparator it is possible to establish if the applied frequency is higher or lower than the crystal's resonance point. At frequencies well below the fundamental, the crystal's impedance is capacitive and at frequencies slightly higher than resonance it is inductive in nature. This information is useful if the resonance frequency of a crystal is unknown. A quick sweep of frequencies can be undertaken until the output of the phase comparator changes, marking the resonance event.

For AT crystals we know that the lowest frequency event encountered is the fundamental. The events slightly higher in frequency are anharmonics. This information is useful not only for initialization, but also for the rare case that the instrument loses track of the fundamental. Once the frequency spectrum of the crystal is determined the instrument's task is to follow the changing resonance frequency and to periodically provide a measurement of the frequency for subsequent conversion to thickness.

The use of the "intelligent" measurement system has a series of very apparent advantages when compared to the previous generation of active oscillators; namely, immunity from mode hopping, speed of measurement, precision of measurement, and the ability to measure heavily loaded (damped) crystals.

5.6 Control Loop Theory

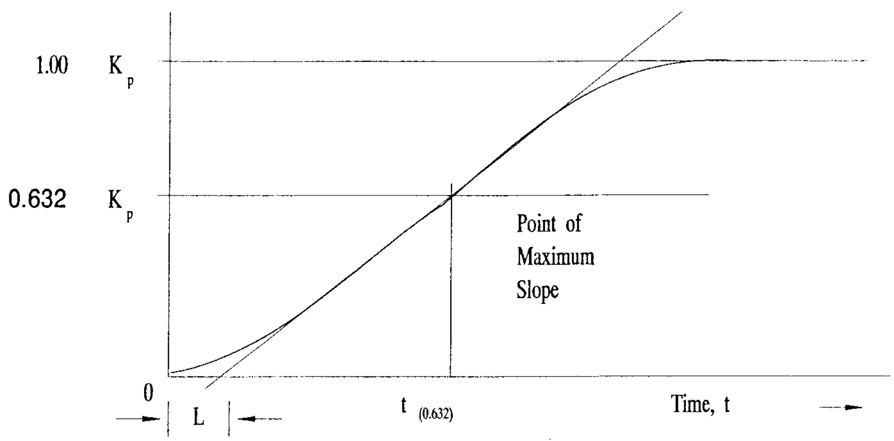
The instrumental advances in measurement speed, precision and reliability would not be complete without a means of translating this improved information into improved process control. For a deposition process, this means keeping the deposition rate as close as possible to the desired rate. The purpose of a control loop is to take the information flow from the measurement system and to make power corrections that are appropriate to the characteristics of the particular evaporation source. When properly operating, the control system translates small errors in the controlled parameter, or rate, into the appropriate corrections in the manipulated parameter, power. The controller's ability to quickly and accurately measure and then react appropriately to the small changes keeps the process from deviating very far from the set point.

The most commonly chosen controller model for converting error into action, is called PID. In the PID, P stands for proportional, I stands for integral and D stands for derivative action. Certain aspects of this model will be examined in detail a little further on.

Knowledge of the responses of the evaporation source can be found by repetitively observing the system response to a disturbance under a particular set of controller settings. After observing the response, improved controller parameters are estimated and then tried again until satisfactory control is obtained. Control, when it is finally optimized, essentially matches the parameters of the controller model to the characteristics of the evaporation source.

In general, it is not possible to characterize all processes exactly; some approximation must be applied. The most common is to assume that the dynamic characteristics of the process can be represented by a first-order lag plus a dead time. The Laplace transform for this model (conversion to the s domain) is approximated as:

$$\frac{\text{Output}}{\text{Input}} = \frac{K_p \exp(-L / s)}{T1s + 1} \qquad \text{Eqn. 5}$$



$T1 = t_{(0.632)} - L$

K_p = (CHANGE IN OUTPUT)/CHANGE IN CONTROL SIGNAL)

Figure 5.7 Response of Process To An Open Loop Step Change At t=0 (Control Signal Is Increased)

Three parameters are determined from the process reaction curve. They are the steady state process gain, K_p, the dead time, L, and the time constant, T1. Several methods have been proposed to extract the required parameters from the system response as graphed in Figure 5.7. These are a one point fit at 63.2% of the transition (one time constant), a two point exponential fit, or a weighted least square exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be customized.

A controller model that has been used extensively is the PID type which is shown in Laplace form in equation 6 below.

$$M(s) = K_c *(1 + \frac{s}{T_i} + T_d * s) * E(s) \qquad \text{Eqn. 6}$$

Where

$M(s)$ = manipulated variable or power

K_c = controller gain (the proportional term)

T_i = integral time

T_d = derivative time

$E(s)$ = process error

Figure 5.8 below represents the controller algorithm and a process with first order lag and dead time. The process block implicitly includes the dynamics of the measuring devices and the final control elements, in our case the evaporator power supply. R(s) represents the rate setpoint. The feedback mechanism is the error generated by the difference between the measured deposition rate, C(s), and the rate set point, R(s).

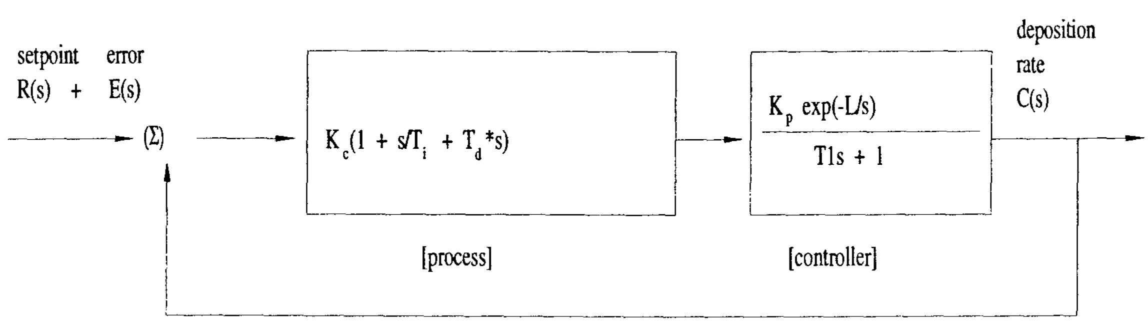


Figure 5.8 PID Controller Block Diagram

The key to using any control system is to choose the proper values of K_c, T_d and T_i. Optimum control is a somewhat subjective quantity as noted by the presence of several mathematical definitions as shown below.

The integral of the squared error (ISE) is a commonly proposed criterion of performance for control systems. It can be described as:

$$ISE = \int e^2(t)dt \qquad \text{Eqn. 7}$$

Where error = e = setpoint - measured rate. The ISE measure is relatively insensitive to small errors, but large errors contribute heavily to the value of the integral. Consequently, using ISE as a criterion of performance will result in responses with small overshoots but long settling times, since small errors occurring late in time contribute little to the integral.

The integral of the absolute value of the error (IAE) has also been frequently proposed as a criterion of performance:

$$IAE = \int | e(t) | dt \qquad \text{Eqn. 8}$$

This criterion is more sensitive to small errors, but less sensitive to large errors, than ISE.

Alternately, Graham and Lathrop[8] introduced the integral of time multiplied by the absolute error (ITAE) as a criterion of performance:

$$ITAE = \int t | e(t) | dt \qquad \text{Eqn. 9}$$

ITAE is insensitive to the initial and somewhat unavoidable errors, but it will weight heavily errors occurring late in time. Optimum responses defined by ITAE will consequently show short total response times and larger overshoots than with either of the other criteria. It has been found that this criteria is generally most useful for deposition process control.

Since the process response characteristics depend on the position of the system (i.e. deposition rate for this discussion), the process response is best measured at the desired operating point of the system. This measured process information (i.e. process gain, K_p, time constant, T1, and dead time, L) is used to generate the best fitting PID control loop parameters for the specific system.

The most satisfactory performance criterion for deposition controllers is the ITAE. There will be overshoot, but the response time is quick, and the settling time is short. For all of the above integral performance criteria, controller tuning relations have been developed to minimize the associated errors. Using manually entered or experimentally determined process response coefficients, ideal PID controller coefficients can be readily calculated for the ITAE criteria as shown below.

$$K_c = (1.36/K_p)(L/T1)^{-0.947} \qquad \text{EQN. 10}$$

$$T_i = (1.19\,T1)(L/T1)^{0.738} \qquad \text{EQN. 11}$$

$$T_d = (0.381T1)(L/T1)^{0.995} \qquad \text{EQN. 12}$$

For slow systems, in order to avoid controller windup (windup: the rapid increase in control signal before the system has the chance to respond to the changed signal), the time period between manipulated variable (control voltage) changes is lengthened. This allows the system to respond to the previous controller setting change, consequently, aggressive controller settings can be used. A secondary advantage is that immunity to process noise is increased since the data used for control is now comprised of multiple readings instead of a single rate measurement, taking advantage of the mass integrating nature of the quartz crystal.

With process systems that respond quickly (short time constant) and with little to no measurable dead time, the PID controller often has difficulty with the deposition process noise (beam sweep, fast thermal shorts of melt to crucible, etc.). In these situations a control algorithm used successfully is an integral/reset type of controller. This type of controller will always integrate the error, driving the system towards zero error. This technique works well when there is little or no dead time. If this technique is used on a process with measurable lag or dead time, then the control loop will tend to be oscillatory due to the control loop over compensating the control signal before the system has a chance to respond.

REFERENCES

1] G. Z. Sauerbrey, Phys. Verhandl .8, 193 (1957)

2] G. Z. Sauerbrey, Z. Phys. 155,206 (1959)

3] P. Lostis, Rev. Opt. 38,1 (1959)

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

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)

7] U. S. Patent No. 5,117,192 (May 26, 1992), International Patents Pending

8] Graham, D., and Lanthrop, R.C., "The Synthesis of Optimum Transient Response: Criteria and Standard Forms, Transactions IEEE, vol. 72 pt. II, November 1953.

5.7 Table of Densities and Z-ratios

The following information is provided on a best effort basis. An * is used to indicate that a Z-ratio has not been established for a certain material. Use Z=1.000 or an experimentally determined value for these materials. We would appreciate any information you may have to supplement this chapter; send it to INFICON, Attention Thin Film Product Manager.

WARNING!!

SOME OF THESE MATERIALS ARE TOXIC. PLEASE CONSULT THE MATERIAL SAFETY DATA SHEET AND SAFETY INSTRUCTIONS BEFORE USE.

Formula	Density	Z-ratio	Material Name
Ag	10.500	0.529	Silver
AgBr	6.470	1.180	Silver Bromide
AgCl	5.560	1.320	Silver Chloride
Al	2.700	1.080	Aluminum
Al_2O_3	3.970	0.336	Aluminum Oxide
Al_4C_3	2.360	*1.000	Aluminum Carbide
AlF_3	3.070	*1.000	Aluminum Fluoride
AlN	3.260	*1.000	Aluminum Nitride
AlSb	4.360	0.743	Aluminum Antimonide
As	5.730	0.966	Arsenic
As_2Se_3	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B_2O_3	1.820	*1.000	Boron Oxide
B_4C	2.370	*1.000	Boron Carbide
Ba	3.500	2.100	Barium
BaF_2	4.886	0.793	Barium Fluoride
BaN_2O_6	3.244	1.261	Barium Nitrate
BaO	5.720	*1.000	Barium Oxide
$BaTiO_3$	5.999	0.464	Barium Titanate (Tetr)
$BaTiO_3$	6.035	0.412	Barium Titanate (Cubic)
Be	1.850	0.543	Beryllium
BeF_2	1.990	*1.000	Beryllium Fluoride
BeO	3.010	*1.000	Beryllium Oxide
Bi	9.800	0.790	Bismuth
Bi_2O_3	8.900	*1.000	Bismuth Oxide
Bi_2S_3	7.390	*1.000	Bismuth Trisulphide
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
BN	1.860	*1.000	Boron Nitride
C	2.250	3.260	Carbon (Graphite)
C	3.520	0.220	Carbon (Diamond)

Formula	Density	Z-ratio	Material Name
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
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 Sulphide
Ga	5.930	0.593	Gallium
Ga_2O_3	5.880	*1.000	Gallium Oxide (B)
GaAs	5.310	1.590	Gallium Arsenide

Formula	Density	Z-ratio	Material Name
GaN	6.100	*1.000	Gallium Nitride
GaP	4.100	*1.000	Gallium Phosphide
GaSb	5.600	*1.000	Gallium Antimonide
Gd	7.890	0.670	Gadolinium
Gd_2O_3	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium
Ge_3N_2	5.200	*1.000	Germanium Nitride
GeO_2	6.240	*1.000	Germanium Oxide
GeTe	6.200	*1.000	Germanium Telluride
Hf	13.090	0.360	Hafnium
HfB_2	10.500	*1.000	Hafnium Boride
HfC	12.200	*1.000	Hafnium Carbide
HfN	13.800	*1.000	Hafnium Nitride
HfO_2	9.680	*1.000	Hafnium Oxide
$HfSi_2$	7.200	*1.000	Hafnium Silicide
Hg	13.460	0.740	Mercury
Ho	8.800	0.580	Holminum
Ho_2O_3	8.410	*1.000	Holminum Oxide
In	7.300	0.841	Indium
In_2O_3	7.180	*1.000	Indium Sesquioxide
In_2Se_3	5.700	*1.000	Indium Selenide
In_2Te_3	5.800	*1.000	Indium Telluride
InAs	5.700	*1.000	Indium Arsenide
InP	4.800	*1.000	Indium Phosphide
InSb	5.760	0.769	Indium Antimonide
Ir	22.400	0.129	Iridium
K	0.860	10.189	Potassium
KBr	2.750	1.893	Potassium Bromide
KCl	1.980	2.050	Potassium Chloride
KF	2.480	*1.000	Potassium Fluoride
KI	3.128	2.077	Potassium Iodide
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
LaN_5	8.77	0.36	Lanthanum Nickel
Li	0.530	5.900	Lithium
LiBr	3.470	1.230	Lithium Bromide
LiF	2.638	0.778	Lithium Fluoride
$LiNbO_3$	4.700	0.463	Lithium Niobate
Lu	9.840	*1.000	Lutetium
Mg	1.740	1.610	Magnesium
$MgAl_2O_4$	3.600	*1.000	Magnesium Aluminate
MgF_2	3.180	0.637	Magnesium Fluoride
MgO	3.580	0.411	Magnesium Oxide
$MgO_3Al_2O_3$	8.000	*1.000	Spinel

Formula	Density	Z-ratio	Material Name
Mn	7.200	0.377	Manganese
MnO	5.390	0.467	Manganese Oxide
MnS	3.990	0.940	Manganese (II) Sulfide
Mo	10.200	0.257	Molybdenum
Mo_2C	9.180	*1.000	Molybdenum Carbide
MoB_2	7.120	*1.000	Molybdenum Boride
MoO_3	4.700	*1.000	Molybdenum Trioxdide
MoS_2	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na_3AlF_6	2.900	*1.000	Cryolite
$Na_5Al_3F_{14}$	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	0.949	Sodium Fluoride
$NaNO_3$	2.270	1.194	Sodium Nitrate
Nb	8.578	0.492	Niobium (Columbium)
$Nb2O_3$	7.500	*1.000	Niobium Trioxide
$Nb2O_5$	4.470	*1.000	Niobium (V) Oxide
NbB_2	6.970	*1.000	Niobium Boride
NbC	7.820	*1.000	Niobium Carbide
NbN	8.400	*1.000	Niobium Nitride
Nd	7.000	*1.000	Neodynium
$Nd2O_3$	7.240	*1.000	Neodynium Oxide
NdF_3	6.506	*1.000	Neodynium Fluoride
Ni	8.910	0.331	Nickel
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
Pb_2TiO_3	7.50	1.16	Lead Titanate
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

Formula	Density	Z-ratio	Material Name
PtO_2	10.200	*1.000	Platinum Oxide
Ra	5.000	*1.000	Radium
Rb	1.530	2.540	Rubidium
RbI	3.550	*1.000	Rubidium Iodide
Re	21.040	0.150	Rhenium
Rh	12.410	0.210	Rhodium
Ru	12.362	0.182	Ruthenium
S_8	2.070	2.290	Sulphur
Sb	6.620	0.768	Antimony
Sb_2O_3	5.200	*1.000	Antimony Trioxide
Sb_2S_3	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandium
Sc_2O_3	3.860	*1.000	Scandium Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si_3N_4	3.440	*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 Fluroide
$SrTiO_3$	5.123	0.31	Strontium Titanate
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta_2O_5	8.200	0.300	Tantalum (V) Oxide
TaB_2	11.150	*1.000	Tantalum Boride
TaC	13.900	*1.000	Tantalum Carbide
TaN	16.300	*1.000	Tantalum Nitride
Tb	8.270	0.660	Terbium
Tc	11.500	*1.000	Technetium
Te	6.250	0.900	Tellurium
TeO_2	5.990	0.862	Tellurium Oxide
Th	11.694	0.484	Thorium
ThF_4	6.320	*1.000	Thorium (IV) Fluoride
ThO_2	9.860	0.284	Thorium Dioxide
$ThOF_2$	9.100	*1.000	Thorium Oxyfluoride
Ti	4.500	0.628	Titanium
Ti_2O_3	4.600	*1.000	Titanium Sesquioxide
TiB_2	4.500	*1.000	Titanium Boride

Formula	Density	Z-ratio	Material Name
TiC	4.930	*1.000	Titanium Carbide
TiN	5.430	*1.000	Titanium Nitride
TiO	4.900	*1.000	Titanium Oxide
TiO_2	4.260	0.400	Titanium (IV) Oxide
Tl	11.850	1.550	Thallium
TlBr	7.560	*1.000	Thallium Bromide
TlCl	7.000	*1.000	Thallium Chloride
TlI	7.090	*1.000	Thallium Iodide (B)
U	19.050	0.238	Uranium
U_4O_9	10.969	0.348	Uranium Oxide
UO_2	10.970	0.286	Uranium Dioxide
U_3O_8	8.300	*1.000	Tri Uranium Octoxide
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
WC	15.600	0.151	Tungsten Carbide
WB_2	10.770	*1.000	Tungsten Boride
WO_3	7.160	*1.000	Tungsten Trioxide
WS_2	7.500	*1.000	Tungsten Disulphide
WSi_2	9.400	*1.000	Tungsten Silicide
Y	4.340	0.835	Yttrium
Y_2O_3	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb_2O_3	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn_3Sb_2	6.300	*1.000	Zinc Antimonide
ZnF_2	4.950	*1.000	Zinc Fluoride
ZnO	5.610	0.556	Zinc Oxide
ZnS	4.090	0.775	Zinc Sulfide
ZnSe	5.260	0.722	Zinc Selenide
ZnTe	6.340	0.770	Zinc Telluride
Zr	6.490	0.600	Zirconium
ZrB_2	6.080	*1.000	Zirconium Boride
ZrC	6.730	0.264	Zirconium Carbide
ZrN	7.090	*1.000	Zirconium Nitride
ZrO_2	5.600	*1.000	Zirconium Oxide

[1]Z-match is a trademark of Leybold Inficon.

INFICON

Chapter 6
Adjustments and Problems

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6.0 Adjustments and Problems

The only user serviceable adjustment is the LCD contrast (see below). There are no user serviceable components inside the instrument enclosures.

WARNING!!

THERE ARE POTENTIALLY LETHAL VOLTAGES INSIDE THIS INSTRUMENT'S ENCLOSURES. THE SOURCE OF THESE VOLTAGES IS FROM THE LINE POWER AND ALSO FROM THE SYSTEM AND AUX I/O CONNECTIONS.

6.1 LCD Contrast Adjustment (XTC/2 only)

The LCD contrast is optimized for "above the display" viewing angles and adjusted at the factory. It may be better optimized on site for use in positions that place the instrument in extreme viewing angles.

To adjust for best possible contrast in the installed position use a potentiometer adjustment tool or small common screwdriver carefully inserted through the front panel (see Section 2.4 Item 11) and turn clockwise or counter clockwise to obtain the best possible display contrast for your viewing angle.

6.2 Error Messages

The following error codes are generated and displayed by the XTC/2.

6.2.1 Powerup Errors

- ERR 0 Film parameters lost on power up. This may be cleared by pressing any key. All film and layer parameters will have to be re-entered.
- ERR 9 Process data lost on power up. This is cleared by pressing any key. Automatic process recovery will not be possible.

NOTE: Upon detection of power failure, all current layer and process data is normally saved for process recovery use on subsequent deposition system recovery.

6.2.2 Parameter Update Errors

- ERR 1 Parameter out of range; the value attempted to be entered was outside of the instrument's acceptable range. This is cleared with the C key. See Table 4.2 for parameter ranges.
- LOC Parameter entry (or alteration) attempted while the PARAMETER LOCK configuration switch is set or the parameters are locked out through remote communications. LOC is also displayed when attempting to update certain parameters (sensor, source, layer) during an active process.

6.2.3 Other Errors

- Err 7 Processor out of time error. It is not expected that this error will be seen by a user.

6.3 Troubleshooting Guide

If the instrument fails to work, or appears to have diminished performance, the following Symptom/Cause chart may be helpful.

WARNING!!

THERE ARE NO USER SERVICEABLE COMPONENTS WITHIN THE INSTRUMENT CASE.

POTENTIALLY LETHAL VOLTAGES ARE PRESENT WHEN THE LINE CORD, SYSTEM I/O OR AUX I/O ARE CONNECTED.

REFER ALL MAINTENANCE TO QUALIFIED PERSONNEL.

CAUTION: *This instrument contains delicate circuitry which is susceptible to transients. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.*

6.3.1 Major Instrument Components, Assemblies and Mating Connectors

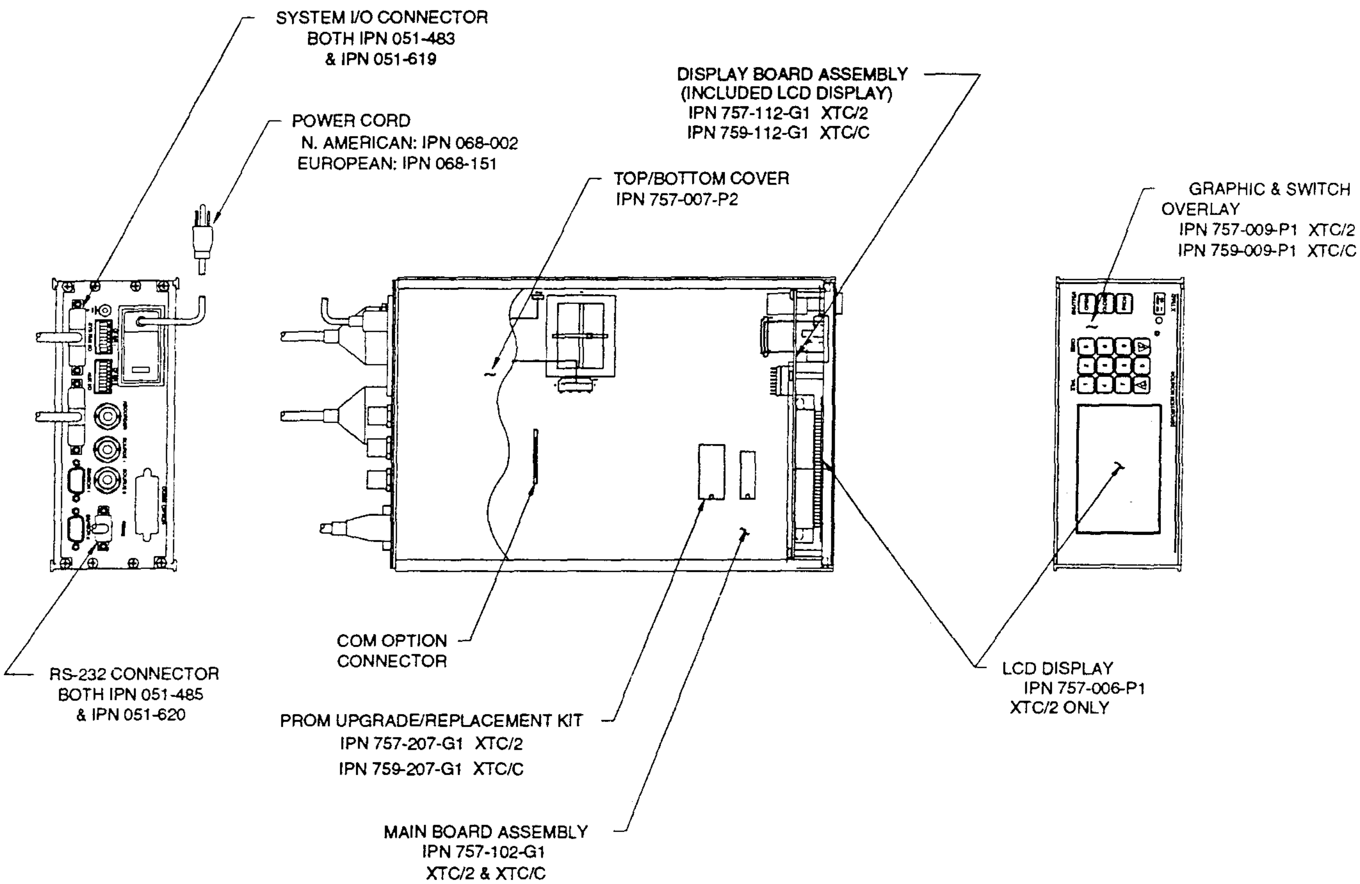

Figure 6.1 Components, Assemblies and mating Connectors

6.3.2 Troubleshooting the Instrument

SYMPTOM	CAUSE	REMEDY
1. power on LED not lighted	a. blown fuse/circuit breaker tripped	a. have qualified personnel replace fuse/reset circuit breaker
	b. electrical cord unplugged from wall or back of instrument	b. re-connect power cord
	c. incorrect line voltage	c. have qualified personnel verify line voltage, verify the instrument is configured for the correct voltage
2. unit "locks" up	a. cover or back panels not attached to the instrument	a. ensure all covers and panels are in place and securely fastened
	b. high electrical noise environment	b. re-route cables to reduce noise pickup (1 ft away from high power conducting lines makes a sizable reduction in the amount of noise entering the instrument), keep all ground wires short with large surface area to minimize ground impedance
	c. poor grounds or poor grounding practice	c. verify proper earth ground, use appropriate ground strap, eliminate ground loops by establishing the correct system grounding, verify proper instrument grounding
3. instrument does not retain parameters on power down (loss of parameters on power up)	a. faulty static RAM	a. SRAM battery has a normal life expectancy of ten years, contact Inficon service department
	b. power supply problem	b. contact Inficon service department
4. some keys on front panel function while others do not	a. faulty keypad or faulty keypad ribbon cable	a. contact Inficon service department

SYMPTOM	CAUSE	REMEDY
5. all keys on the front panel fail to function	a. instrument is "locked" up	a. turn power to OFF or to STBY, then to ON, see item 2 above
6. control voltage output does not function properly	a. DAC board damaged from applying voltage to the control voltage output	a. ensure cable connection to the DAC board does not have a potential across the contacts, contact Inficon service department
	b. reversed polarity of control voltage relative to that accepted by the source power supply	b. verify source output polarity of DAC and the required input polarity of the source power supply, refer to the instruction manual to reconfigure the instrument if necessary
	c. improper control cable fabrication	c. check for correct cable wiring in the appropriate section of the manual
7. CRT or LCD display dull or blank	a. brightness/contrast adjustment required	a. refer to manual for location of adjustment potentiometer, adjust as desired
	b. LCD or CRT/power supply problem	b. contact Inficon service department
8. poor rate control	a. control loop parameters improperly selected	a. refer to the instruction manual section on tuning control loop parameters
	b. electron beam sweep frequency "beating" with the instrument's measurement frequency	b. adjust the sweep frequency so it it not a multiple of the instrument's measurement frequency
9 crystal fail always on	a. XIU/oscillator not connected	a. verify proper sensor/oscillator connections
	b. XIU/oscillator malfunctioning	b. if available, insert a known working XIU/oscillator in place of suspect one; if XIU/oscillator is confirmed bad, contact Inficon service department

SYMPTOM	CAUSE	REMEDY
	c. defective cable from feedthrough to XIU/oscillator or from instrument to XIU/oscillator	c. use an ohm meter or DVM to check electrical continuity or isolation as appropriate
	d. poor electrical contact in the transducer, feedthroughs, or in-vacuum cable	d. use an ohm meter or DVM to check electrical continuity or isolation as appropriate
	e. failed crystal/no crystal	e. replace crystal/insert crystal
	f. two crystals placed into the crystal holder	f. remove one of the crystals

6.3.3 Troubleshooting Transducers/Sensors

NOTE: The most useful tool for diagnosing sensor head problems is the DVM (Digital Volt Meter). Disconnect the short oscillator cable from the feedthrough and measure the resistance from the center pin to ground. If the reading is less than 1-2 megaohms, the source of the leakage should be found and corrected. Likewise, with the vacuum system open check for center conductor continuity, a reading of more than 1 ohm from the feedthrough to the transducer contact indicates a problem. Cleaning contacts or replacing the in-vacuum cable may be required.

NOTE: A more detailed troubleshooting guide is shipped with the sensor. Refer to that manual for more detailed information in some cases.

SYMPTOM	CAUSE	REMEDY
1. large jumps of thickness reading during deposition	a. mode hopping due to defective crystal	a. replace crystal, use ModeLock™ measurement system
	b. stress causes film to peel from crystal surface	b. replace crystal or use high performance buffered crystal; consult factory
	c. particulate or "spatter" from molten source striking crystal	c. thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	d. scratches or foreign particles on the crystal holder seating surface (improper crystal seating)	d. clean and polish the crystal seating surface on the crystal holder
	e. small pieces of material fell on crystal (for crystal facing up sputtering situation)	e. check the crystal surface and blow it off with clean air
	f. small pieces of magnetic material being attracted by the sensor magnet and contacting the crystal (sputtering sensor head)	f. check the sensor cover's aperture and remove any foreign material that may be restricting full crystal coverage

SYMPTOM	CAUSE	REMEDY
2. crystal ceases to oscillate during deposition before it reaches its "normal" life	a. crystal struck by particulate or "spatter" from molten source	a. thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	b. material on crystal holder partially masking crystal cover aperture	b. clean crystal holder
	c. existence of electrical short or open condition	c. using an ohm meter or DVM, check for electrical continuity in the sensor cable, connector, contact springs, connecting wire inside sensor, and feedthroughs..
	d. check for thermally induced electrical short or open condition	d. see "c" above

NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition.

SYMPTOM	CAUSE	REMEDY
3. crystal does not oscillate or oscillates intermittently (both in vacuum and in air)	a. intermittent or poor electrical contact (contacts oxidized)	a. use an ohm meter or DVM to check electrical continuity, clean contacts
	b. leaf springs have lost retentivity (ceramic retainer, center insulator)	b. rebend leafs to approx. 45°
	c. RF interference from sputtering power supply	c. verify earth ground, use ground strap adequate for RF ground, change location of instrument and oscillator cabling away from RF power lines, connect instrument to a different power line
	d. cables/oscillator not connected, or connected to wrong sensor input	d. verify proper connections, and inputs relative to programmed sensor parameter

SYMPTOM	CAUSE	REMEDY
4. crystal oscillates in vacuum but stops oscillation after open to air	a. crystal was near the end of its life; opening to air causes film oxidation which increases film stress	a. replace crystal
	b. excessive moisture accumulates on the crystal	b. turn off cooling water to sensor prior to venting, flow warm water through sensor while chamber is open
5. thermal instability: large changes in thickness reading during source warm-up (usually causes thickness reading to decrease) and after the termination of deposition (usually causes thickness reading to increase)	a. inadequate cooling water/ cooling water temperature too high	a. check cooling water flow rate, be certain that cooling water temperature is less than 30°C; refer to appropriate sensor manual
	b. excessive heat input to the crystal	b. if heat is due to radiation from the evaporation source, move sensor further away from source and use sputtering crystals for better thermal stability; install radiation shield
	c. crystal not seated properly in holder	c. clean or polish the crystal seating surface on the crystal holder
	d. crystal heating caused by high energy electron flux (often found in RF sputtering)	d. use a sputtering sensor head
	e. poor thermal transfer from water line to body (CrystalSix sensor)	e. use a new water tube whenever the clamping assembly has been removed from the body; if a new water tube is not available, use a single layer of aluminum foil between the cooling tube and sensor body, if your process allows
	f. poor thermal transfer (Bakeable)	f. use Al or Au foil washer between crystal holder and sensor body

SYMPTOM	CAUSE	REMEDY
6. poor thickness reproducibility	a. variable source flux distribution	a. move sensor to a more central location to reliably sample evaporant, ensure constant relative pool height of melt, avoid tunneling into the melt
	b. sweep, dither, or position where the electron beam strikes the melt has been changed since the last deposition	b. maintain consistent source distribution by maintaining consistent sweep frequencies, sweep amplitude and electron beam position settings
	c. material does not adhere to the crystal	c. make certain the crystal surface is clean; avoid touching crystal with fingers, make use of an intermediate adhesion layer
	d. cyclic change in rate	d. make certain source's sweep frequency is not "beating" with the measurement frequency [nearly the same frequency or a near multiple of the measurement (4 Hz)]
7. large drift in thickness (greater than 200 Å for a density of 5.00 g/cc) after termination of sputtering	a. crystal heating due to poor thermal contact	a. clean or polish the crystal seating surface on the crystal holder
	b. external magnetic field interfering with the sensor's magnetic field (sputtering sensor)	b. rotate sensor magnet to proper orientation with external magnetic field, refer to the sputtering sensor manual IPN 074-157
	c. sensor magnet cracked or demagnetized (sputtering sensor)	c. check sensor magnetic field strength, the maximum field at the center of the aperture should be 700 gauss or greater

SYMPTOM	CAUSE	REMEDY
8. CrystalSix, crystal switch problem (does not advance or not centered in aperture)	a. loss of pneumatic supply, or pressure is insufficient for proper operation	a. ensure air supply is regulated at 80-90 psi
	b. operation has been impaired as a result of material accumulation on cover	b. clean material accumulation as needed, refer to CrystalSix manual IPN 074-155 for maintenance
	c. improper alignment	c. realign as per instructions in CrystalSix manual IPN 074-155
	d. 0.0225" diameter orifice not installed on the supply side of solenoid valve assembly	d. install orifice as shown in the CrystalSix manual IPN 074-155

6.3.4 Troubleshooting Computer Communications

SYMPTOM	CAUSE	REMEDY
1. communications cannot be established between the host computer and the instrument	a. improper cable connection	a. verify for correct cable wiring as described in the manual
	b. BAUD rate in host computer not the same as the instrument	b. verify BAUD rate in the host's applications program, verify BAUD rate in the instrument
	c. incompatible protocols being used	c. verify that the instrument protocol: RS232, SECS, GPIB, DATALOG, CHECKSUM, matches host
	d. incorrect device address (GPIB or SECS protocol)	d. verify device address in host's applications program, (or in IBCONF file for National Instrs. GPIB) and verify instrument address
2. error code returned	a. A = illegal command	a. the command sent was not valid; verify command syntax as shown in the instrument's manual (placement of spaces within the command string are important)
	b. B = illegal value	b. the parameter's value sent is outside the range for the given parameter, verify parameter's range
	c. C = illegal ID	c. the command sent was for a parameter which doesn't exist; verify the correct parameter number
	d. D = illegal command format	d. the command sent is not valid; verify command syntax as shown in the instrument's manual (placement of spaces within the command string are important)
	e. E = no data to retrieve	e. some parameters may not be in use, depending on the value of other parameters

SYMPTOM	CAUSE	REMEDY
	f. F = cannot change value now	f. the command sent is for a parameter that cannot be changed while the instrument is executing a Process; place the instrument in the READY state in order to change the value
	g. G = bad checksum	g. checksum value does not match the value sent by the host's application program, may be caused by noise on the RS232 cable or the checksum is not calculated properly by the applications program
	h. O = data overrun	h. I/O port unable to keep up with data transfer rate; lower BAUD rate, increase speed of host's applications program by; using a compiled version of the program, stream lining program execution, a faster CPU

6.4 Replacing the Crystal

The procedure for replacing the crystal is basically the same with all transducers, except the CrystalSix.

CAUTIONS: *Always use clean nylon lab gloves and plastic tweezers for handling the crystal (to avoid contamination which may lead to poor adhesion of the film to the electrode).*

Do not rotate the ceramic retainer assembly after it is seated (as this will scratch the crystal electrode and cause poor contact).

Do not use excessive force when handling the ceramic retainer assembly since breakage may occur.

NOTES: Certain materials, especially dielectrics, may not adhere strongly to the crystal surface and may cause erratic readings.

Thick deposits of some materials, such as SiO, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, change the crystals.

6.4.1 Standard and Compact

Follow the procedure below to replace the crystal in the Standard and Compact sensor:

1. Gripping the crystal holder with your fingers, pull it straight out of the sensor body.
2. Gently pry the crystal retainer from the holder (or use crystal snatcher; see Figure 6.5).
3. Turn the retainer over and the crystal will drop out.
4. Install a new crystal, with the patterned electrode face up.
5. Push the retainer back into the holder and replace the holder in the sensor body.

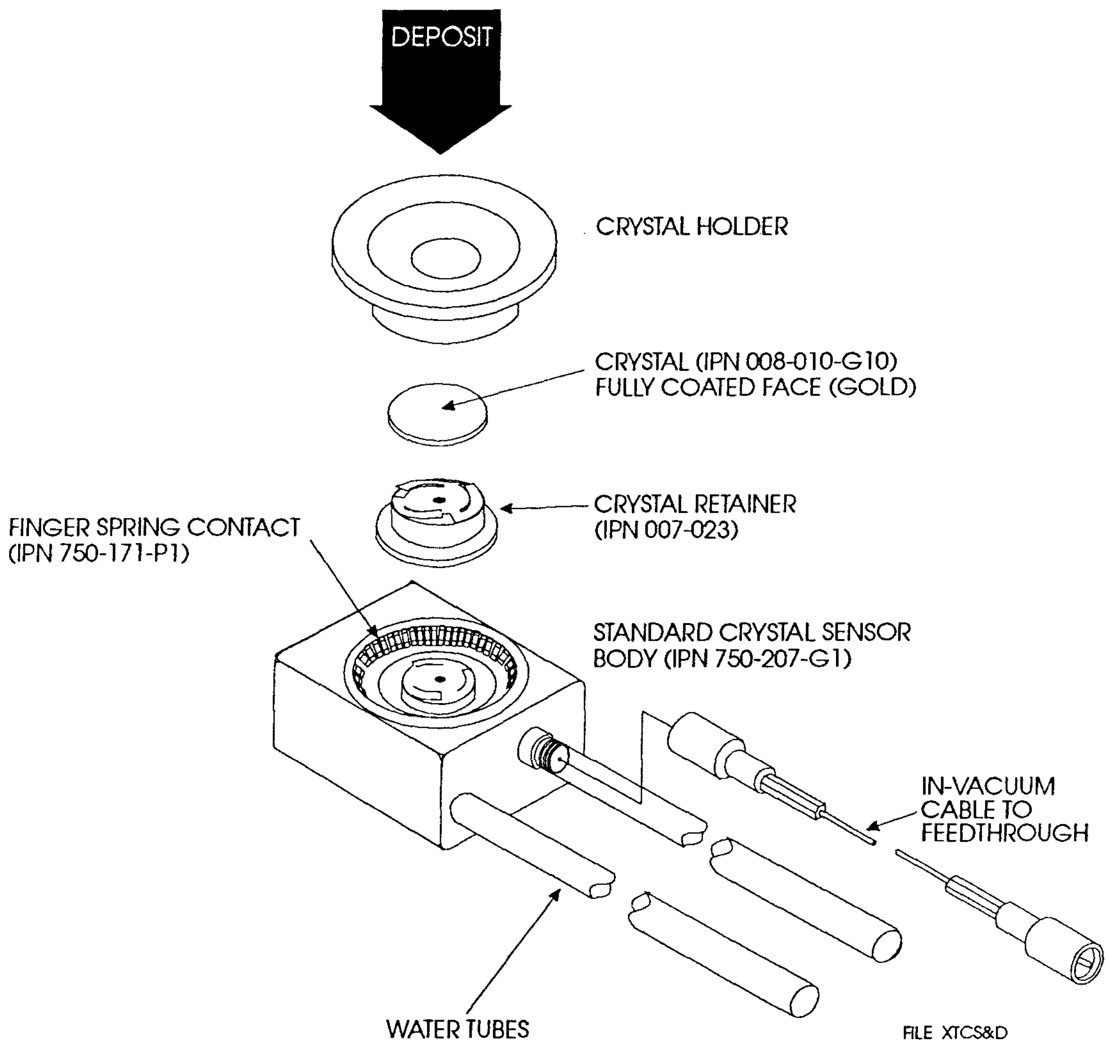

Figure 6.2 Standard Crystal Sensor (Exploded)

6.4.2 Shuttered and Dual Sensors

There is no difference in the crystal changing procedure between shuttered and non-shuttered Standard and Compact sensors, since the shutter pivots away from the crystal opening when the shutter is in the relaxed state.

6.4.3 Bakeable Sensor

For the Bakeable sensor, the procedure is the same as the regular crystal except that you must first unlock the cam assembly by flipping it up. Once the crystal has been replaced, place a flat edge of the holder flush with the cam mechanism and lock it in place with the cam (Figure 6.3).

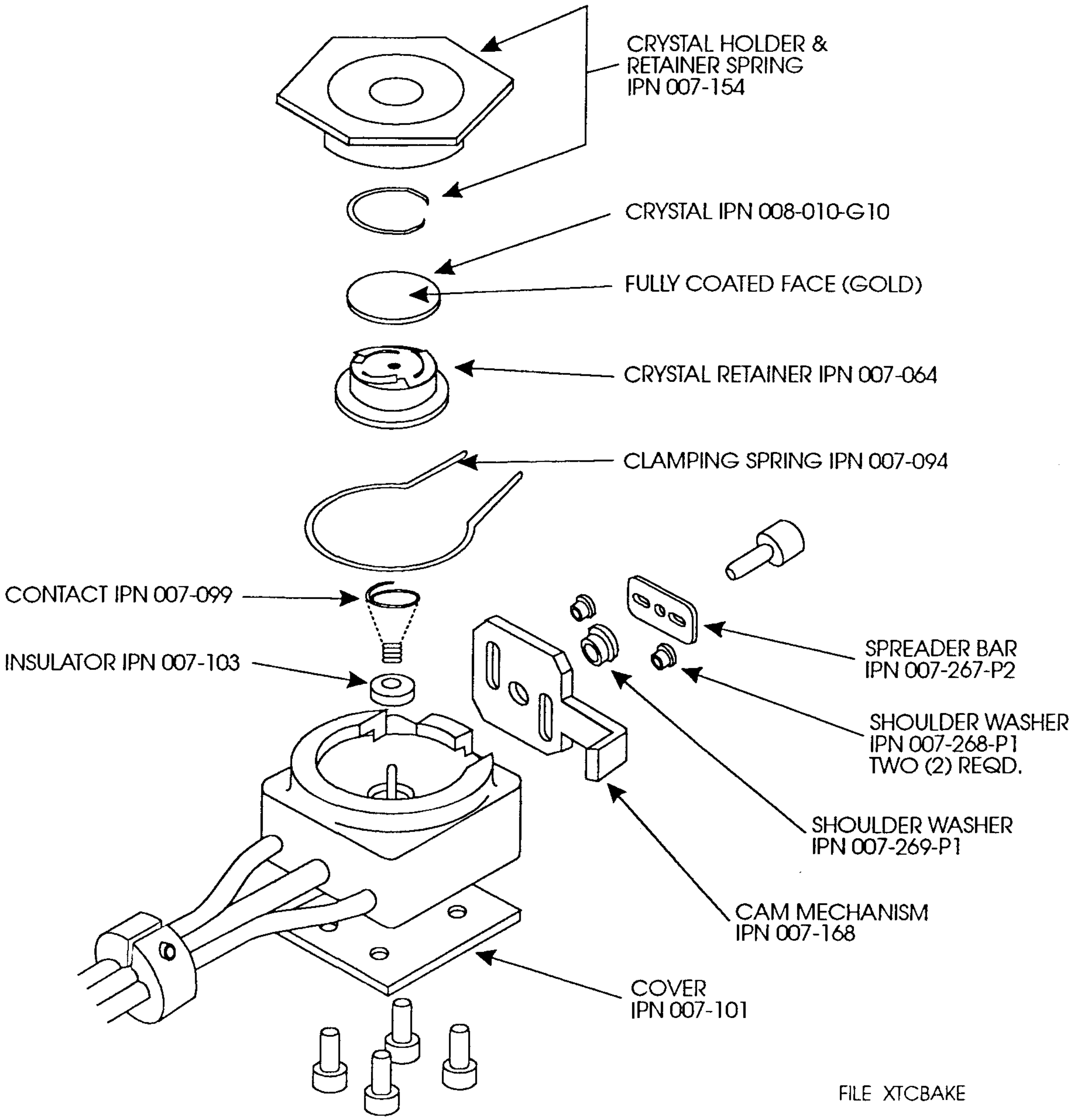

Figure 6.3 Bakeable Crystal Sensor (Exploded)

6.4.4 Sputtering Sensor

Observe the general precautions (Section 6.4) for replacing crystals and follow the instructions below to replace the crystal in a sputtering sensor.

1. Grip the body assembly with your fingers and pull it straight out to separate it from the water-cooled front part. (You may have to disconnect the sensor cable in order to separate the parts.) See Figure 6.4.
2. Pull the crystal holder straight out from the front of the sensor.
3. Remove the ceramic retainer from the crystal holder by pulling it straight out with the crystal snatcher (Section 6.4.5 - Using the Crystal Snatcher).
4. Turn the crystal holder over so that the crystal drops out.
5. Install a new crystal into the crystal holder with the patterned electrode facing the back and contacting the leaf springs on the ceramic retainer. (Use only special crystals for sputtering, IPN 008-009-G10.)
6. Put the ceramic retainer back into the crystal holder and put the holder into the front cover of the sensor.
7. Align the position of the back part so that the connector matches with the notch on the front of the sensor. Snap the two parts together. Reconnect the sensor cable if it has been disconnected.

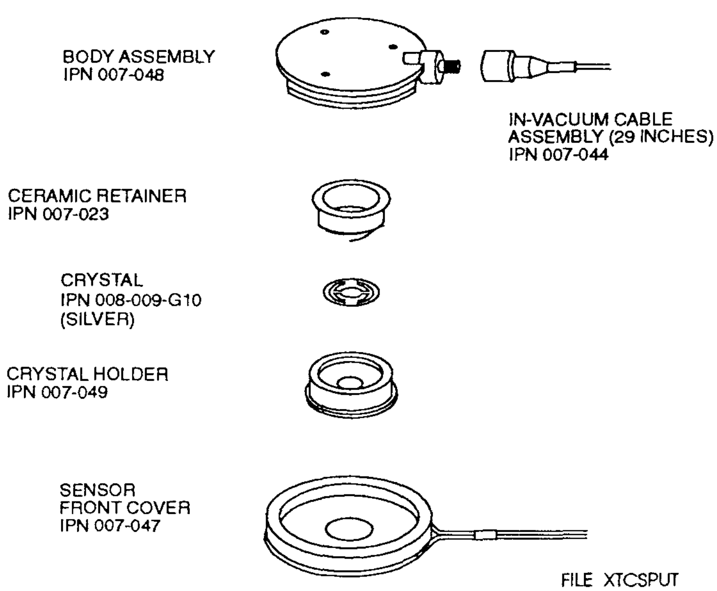

Figure 6.4 Sputtering Crystal Sensor (Exploded)

6.4.5 Crystal Snatcher

To use the crystal snatcher supplied with the sensor follow the instructions below:

1. Insert crystal snatcher into ceramic retainer (1) and apply a small amount of pressure. This locks the retainer to the snatcher and allows the retainer to be pulled straight out (2).
2. Re-insert the retainer into the holder after the crystal has been changed.
3. Release the crystal snatcher with a slight side-to-side motion.

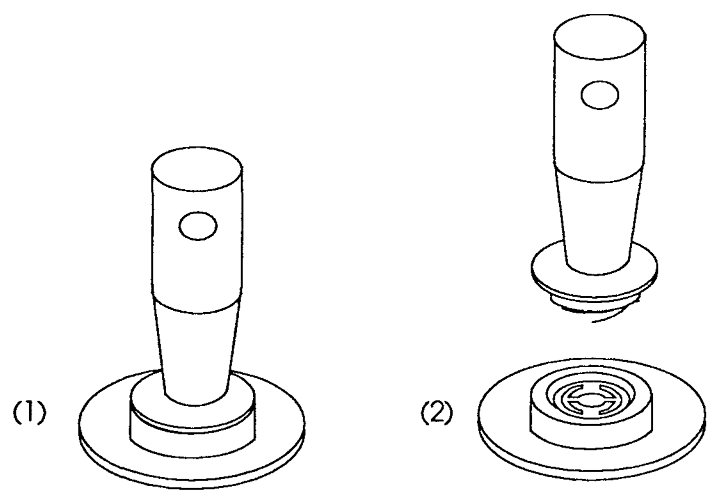

Figure 6.5 Use of Crystal Snatcher

6.4.6 CrystalSix

See the manual (IPN 074-155) for specific instructions for this device.