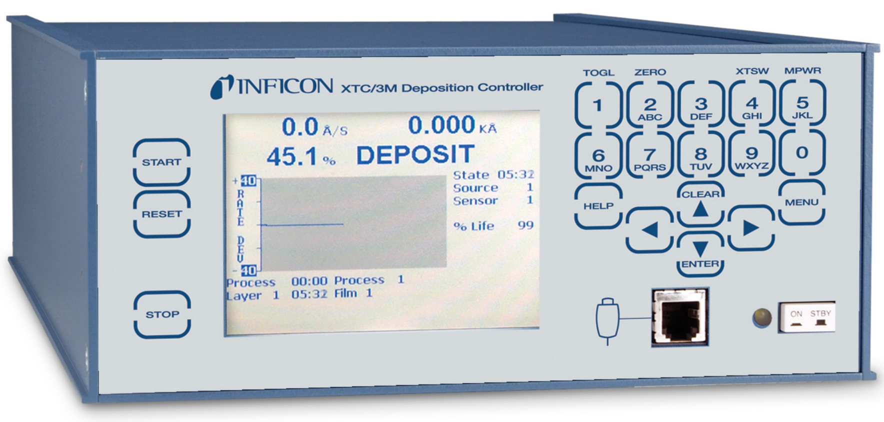
O P E R A T I N G   M A N U A L



XTC/3

Thin Film Deposition Controller

PN 074-446-P1L

INFICON

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DECLARATION OF CONFORMITY

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

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

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

Equipment Description: XTC/3M and XTC/3S Thin Film Deposition Controllers, including the Oscillator Package (XIU)

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

Applicable Standards:

Safety: EN 61010-1: 2010 Safety Requirements for Electrical Equipment For Measurement, Control, And Laboratory Use.
PART 1: General Requirements

Emissions: EN 61326-1: 2013 (Radiated & Conducted Emissions)
(EMC – Measurement, Control & Laboratory Equipment)
CISPR 11/EN 55011 Edition 2009-12 Emission standard for industrial, scientific, and medical (ISM) radio RF equipment

FCC Part 18 Class A emissions requirement (USA)

Immunity: EN 61326-1: 2013 (Industrial EMC Environments)
(EMC – Measurement, Control & Laboratory Equipment)

RoHS: Fully compliant

CE Implementation Date: August 21, 2006 (Updated July, 2015)

Authorized Representative: Steve Schill

Thin Film Business Line Manager
INFICON Inc.

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Table Of Contents

Chapter 4

XTC/3 Programming

Chapter 5

Remote Communications

Chapter 1
Introduction and Specifications

1.1 Introduction

XTC/3 is produced in two versions:

- XTC/3M Multi-Layer Deposition Controller
- XTC/3S Single Layer Deposition Controller

This manual covers both instruments, using the designation XTC/3 when the subject matter applies to both instruments and XTC/3M or XTC/3S when the subject matter applies to a specific instrument.

This operating manual provides user information for installing, programming, and operating the XTC/3.

XTC/3 is a closed loop process controller designed for use primarily in physical vapor deposition. XTC/3 monitors and/or controls the rate and thickness of thin film depositions. Deposition rate and thickness are inferred from the frequency change induced by mass added to a quartz crystal.

This technique positions sensors in the path between, or to the side of, the target substrate and the source of vaporized material. The sensor incorporates an exposed oscillating quartz crystal whose frequency decreases as material accumulates. The change in frequency provides information to determine rate and thickness and to continually control the evaporation power source.

With user-supplied time, thickness, and power limits and with desired rates and material characteristics, XTC/3 is capable of automatically controlling the process in a precise and repeatable manner. User interaction is accomplished through the front panel or serial communications, and consists of selection or entry of parameters to define the process.

The complete system consists of:

- main control unit (XTC/3)
- sensor or sensors
- crystal interface unit (XIU) for each attached sensor

These items are generally bundled at the factory and are also sold separately.

When reading this XTC/3 Operating Manual, please pay particular attention to the NOTES, CAUTIONS, and WARNINGS found throughout the text. The Notes, Cautions, and Warnings are defined in section 1.2.1 on page 1-2.

1.1.1 Related Manuals

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

- PN 074-154 - Bakeable
- PN 074-155 - CrystalSix
- PN 074-156 - Single/Dual
- PN 074-157 - Sputtering
- PN 074-398 - Crystal12

1.2 XTC/3 Safety

1.2.1 Definition of Notes, Cautions and Warnings

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

NOTE: Pertinent information that is useful in achieving maximum XTC/3 efficiency when followed.

CAUTION

Failure to heed these messages could result in damage to XTC/3.

WARNING

Failure to heed these messages could result in personal injury.

WARNING - Risk Of Electric Shock

Dangerous voltages are present which could result in personal injury.

1.2.2 General Safety Information

WARNING - Risk Of Electric Shock

Do not open the XTC/3 case! There are no user-serviceable components within the XTC/3 case.

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

Refer all maintenance to technically qualified personnel.

CAUTION

XTC/3 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.

WARNING

Failure to operate XTC/3 in the manner intended by INFICON can circumvent the safety protection provided by XTC/3 and may result in personal injury.

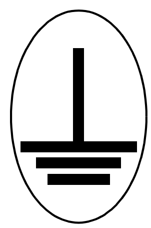
1.2.3 Earth Ground

XTC/3 is connected to earth ground through a sealed three-core (three-conductor) power cable, which must be plugged into a socket outlet with a protective earth terminal. Extension cables must always have three conductors including a protective earth terminal.

WARNING - Risk Of Electric Shock

Never interrupt the protective earth circuit.

Any interruption of the protective earth circuit inside or outside XTC/3, or disconnection of the protective earth terminal is likely to make XTC/3 dangerous.



This symbol indicates where the protective earth ground is connected inside XTC/3. Never unscrew or loosen this connection.

1.2.4 Main Power Connection

WARNING - Risk Of Electric Shock

XTC/3 has line voltage present on the primary circuits whenever it is plugged into a main power source.

Never remove the covers from XTC/3 during normal operation.

There are no operator-serviceable items within XTC/3.

Removal of the top or bottom covers must be done only by a technically qualified person.

1.3 How to Contact INFICON

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

- Sales and Customer Service
- Technical Support
- Repair Service

When communicating with INFICON about a XTC/3, please have the following information readily available:

- The Sales Order or Purchase Order number of the XTC/3 purchase.
- The firmware version and software version (displayed at XTC/3 power-up) of the optional applications software.
- A description of the problem.
- The exact wording of any error messages that may have been received.
- An explanation of any corrective action that may have already been attempted.

1.3.1 Returning Sensor to INFICON

Do not return any sensor component to INFICON before speaking with a Customer Support Representative and obtaining a Return Material Authorization (RMA) number. XTC/3 will not be serviced without an RMA number.

Packages delivered to INFICON without an RMA number will be held until the customer is contacted. This will result in delays in servicing XTC/3.

Prior to being given an RMA number, a completed Declaration Of Contamination (DoC) form will be required. DoC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the XTC/3 be sent to a designated decontamination facility, not to the factory.

Before returning XTC/3, create a record of all user-entered parameters so they may be re-entered, if required.

1.4 XTC/3 Specifications

1.4.1 Measurement

Measurement Frequency Range . . . 6.0 to 5.0 MHz (fixed)

Frequency Resolution . . . . ± 0.028 Hz @ 6 MHz

Thickness and Rate
Resolution/Measurement . . . . ± 0.034 Å @ tooling/density = 100/1
Fundamental frequency = 6 MHz

Measurement Interval. . . . . 0.25 s

Thickness Accuracy . . . . 0.5% typical, (dependent on process conditions, especially sensor location, material stress, temperature and density)

Frequency Accuracy. . . . . ± 2.5 ppm 0 to 50°C

Measurement Frequency . . . . 4 Hz

Measurement Technique . . . . ModeLock

User Interface. . . . . TFT LCD and limited membrane keypad. All parameters accessible through computer communications. Multiple message areas for indication of states and detailed indication of abnormal and stop conditions.

1.4.2 Screens and Parameters

Navigation . . . . Menu key to go between screens. Four cursor keys to go between parameters on screens.

Structure . . . . Separate screens dedicated to:

1) Operate Data Display

2) Film Parameters

3) Process List (XTC/3M only)

4) General Parameters

5) I/O Map

6) Diagnostics

7) Sensor

1.4.3 Process Recipe Storage

	XTC/3M	XTC/3S
Process Programs	99	1
Film Programs	32	9
Process Layers	999 per process	1

1.4.3.1 Film Parameters

Pre/Post Deposit

Power Ramps. . . . . 2 per film

Power Level . . . . 0.0 to 100%

Rise Time . . . . 00:00 to 99:59 min:s

Soak Time . . . . 00:00 to 99:59 min:s

Idle Ramps . . . . 1 per film

Idle Power . . . . 0.0 to 100.0%

Idle Ramp Time . . . . 00:00 to 99:59 min:s

Deposit

Deposition Rate . . . . 0.0 to 999.9 Å/s (display shows three digits)

Final Thickness . . . . 0.0 to 999.9 kÅ

Thickness Set Point . . . . 0.0 to 999.9 kÅ

Rate Ramp . . . . 1 per film

New Rate . . . . 0.0 to 999.9 Å/s (display shows three digits)

Ramp Time. . . . . 00:00 to 99:59 min:s

RateWatcher® . . . . Sample and Hold Feature

RateWatch Accuracy . . . . 1 to 99%

RateWatch Hold . . . . 00:00 to 99:59 min:s

Sensor

Sensor #. . . . . 1 or 2

Tooling . . . . 10.0 to 500.0%

Second Tooling . . . . 10.0 to 500.0%

Crystal Stability, Single . . . . 0, 25 to 9999 Hz (1 to 24 are excluded)

Crystal Stability, Total . . . . 0, 25 to 9999 Hz (1 to 24 are excluded)

Crystal Quality Percent. . . . . 0 to 99%

Crystal Quality Counts . . . . 0 to 99

Source

Source # . . . . 1 or 2

Crucible Selection . . . . 0 to 8, each source (0=disabled)

Control Gain . . . . 0.01 to 100 Å/s / %Power

Control Time Constant . . . . 0.1 to 100.0 s

Control Dead Time . . . . 0.1 to 100.0 s

Maximum Source Power . . . . 0.0 to 100%

Density . . . . 0.50 to 99.99 g/cm^3

Z-Ratio . . . . 0.100 to 9.999

Option

Time Power . . . . Yes / No

Delay Option. . . . . None, Shutter, Control, Both

Transfer Sensor . . . . Yes / No

Transfer Tooling . . . . 10.0 to 500.0%

Control Delay Time. . . . . 00:00 to 99:59 min:s

Ion Assisted Deposit. . . . . Yes / No

Name (XTC/3M only) . . . . provision for 15 alpha numerics

1.4.4 Display

Type/Color/Size . . . . TFT LCD, 3.8 in. diagonal

Format . . . . Quarter VGA

Resolution . . . . 320 H x 240 V

Thickness Display Range. . . . . 0.000 to 999.9 kÅ

Thickness Display Resolution . . . . . 1 Å for 0 to 9.999 kÅ
10 Å for 10.00 to 99.99 kÅ
100 Å for 100.0 to 999.9 kÅ
1 kÅ for 1000 kÅ to 9999 kÅ

Rate Display Range . . . . 0.0 to 99.9 Å/s; 100 to 999 Å/s

Rate Display Resolution . . . . 0.1 Å for 0 to 99.9 Å/s
1 Å for 100 to 999 Å/s

Power Display Range	0.0 to 99.9%
Graphic Display Functions	Rate Deviation at ± 5, 10, 20, or 40 Å/s or Power at 0.0 to 100%
Display Data Update Rate	1 Hz

1.4.5 Source / Recorder Outputs

Quantity	3 BNC, Female
Configuration	Source 1, Source 2, Recorder
Function Ranges	
Source Control	0 to 10 V, 0 to -10 V, 0 to 5 V, 0 to -5 V, 0 to 2.5 V, 0 to -2.5 V
Recorder Output	0 to +10 V
Current rating	25 mA max. per channel on Source 1 and Source 2, 5 mA max. on Recorder
Resolution	15 bits over full range (10 V)
Update Rate	4 Hz, maximum, (dependent on source characteristics).
Recorder Output Functions	Rate or Thickness or Power or Rate Deviation
Recorder Output Ranges	
Power	0 to 100%
Rate	0 to 100 Å/s, 0 to 1000 Å/s
Thickness	0 to 100 Å, 0 to 1000 Å (both ranges modulo)
Rate Deviation	Desired rate ± 50 Å/s
Accuracy	2% full scale

1.4.6 Relays / Inputs

Relays	SPST 2.5 A relays rated @ 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum; 12 standard; D sub connector; relays are normally open in the power off state, may be programmed to normally open or normally closed during operation on XTC/3M.
Relay Ratings	100 VA inductive; 2.5 A maximum.

# of TTL Compatible Outputs . . . . . . 8 standard, Internally pulled up to 5 V (dc). May be pulled up externally to 24 V (dc) through 2.4 k resistor. minimum high level 0.5 mA load @3.75 V maximum low level 10 mA load @1.1 V

Inputs (TTL Compatible). . . . . 9 standard

Input Levels

Maximum High . . . . 24 V

Minimum High. . . . . 2.5 V

Maximum Low . . . . 1.1 V

Scan/Update Rate . . . . 4 Hz

1.4.7 Remote Communications

RS232C Serial Port . . . . Standard; see section 5.1.1 on page 5-1

Baud Rates. 9,600; 19,200; 38,400; 57,600; 115,200

Ethernet TCP/IP Port . . . . Optional. Static address, DHCP not supported.

1.4.8 Accessories

Handheld Power Controller Option. . (connects to jank on front panel)

Functions . . . . Increase or decrease power, Stop, CrystalSwitch

Connector Kit . . . . Connectors for inputs and relays

Operating Manual. . . . . CD, PN 074-5000-G1

1.4.9 Power

Power . . . . 100 - 230 V (ac), 50/60 Hz

Maximum Apparent Power . . . . 60 VA max.

Fuse . . . . 1.25 A, 250 V, Type (T)

Temporary Overvoltages . . . . Short Term: 1430 V, <5 s
Long Term: 480 V, >5 s

1.4.10 Operating Environment

Usage . . . . Indoor only

Temperature . . . . 0 to 50°C (32-122°F)

Humidity . . . . Up to 80% RH. @ 31°C, non-condensing

Altitude . . . . Up to 2000 m

Installation (Overvoltage) . . . . Category II

Measurement Category II

Pollution Degree. 2

1.4.11 Storage Temperature

Storage Temperature . . . . -10 to 70°C (14 to 158°F)

1.4.12 Warm Up Period

Warm Up Period. . . . . None required;
For maximum stability allow five minutes.

1.4.13 Size

H x W x L (not including mounts or user connectors)

89 x 203 x 305 mm (3.5 x 8 x 12 in.)

1.4.14 Connector Clearance Requirements

Front. . . . . Less than 26 mm (1.0 in.)

Rear . . . . Less than 102 mm (4.0 in.)

1.4.15 Weight

With all options. . . . . 2.7 kg (6 lb)

1.4.16 Cleaning

Use a mild, nonabrasive cleaner or detergent taking care to prevent cleaner from entering the unit.

1.5 Unpacking and Inspection

1. If XTC/3 control module has not been removed from its shipping container, do so now.
2. Carefully examine the control module for damage that may have occurred during shipping. This is especially important if you notice obvious rough handling on the outside of the container. *Immediately report any damage to the carrier and to INFICON.*
3. Do not discard the packing materials until you have taken inventory and have at least performed a power-on verification.
4. Take an inventory of your order by referring to the order invoice and the information contained in section 1.6 on page 1-12.
5. To perform a power-on verification (see section 1.7 on page 1-16).
6. For additional information or technical assistance, contact INFICON (refer to section 1.3 on page 1-5).

1.6 Parts and Options Overview

1.6.1 Base Configurations

XTC/3M Control Unit for nom. 120 V (ac) . . . . . PN XC3M-1xxx

XTC/3M Control Unit for nom. 230 V (ac) . . . . . PN XC3M-2xxx

XTC/3S Control Unit for nom. 120 V (ac). . . . . . PN XC3S-1xxx

XTC/3S Control Unit for nom. 230 V (ac). . . . . . PN XC3S-2xxx

Technical Manual . . . . PN 074-446 on 074-5000-G1 CD

Handheld Power Controller . . . . PN 755-262-G1, Optional

Ship Kit . . . . PN 780-603-G1 (120 V (ac)) or
PN 780-603-G2 (230 V (ac))

1.6.2 Accessories

Each sensor requires an oscillator kit to interface to the controller:

XTC/3 4.6 m (15 ft.) Oscillator Kit. PN 780-611-G15

XTC/3 9.2 m (30 ft.) Oscillator Kit. PN 780-611-G30

XTC/3 15.3 m (50 ft.) Oscillator Kit. . . . . PN 780-611-G50

XTC/3 30.5 m (100 ft.) Oscillator Kit. . . . . PN 780-611-G100

Above kits consist of oscillator PN 780-600-G1, 15.2 cm (6 in.) BNC oscillator to feedthrough cable PN 755-257-G6 and multiconductor controller to oscillator cable PN 600-1261-P15, 600-1261-P30, 600-1261-P50 or 600-1261-P100. These kits are designed for use with the standard in-vacuum cables ranging in length from 15.2 cm (6 in.) to 182.9 cm (72 in.). The PN 007-044 standard in-vacuum cable supplied with the non-UHV Bakeable sensor versions are 78.1 cm (30.75 in.) long.

XTC/3 4.6 m (15 ft.) Oscillator Kit, 4 m / 6 in.. . . . . PN 780-612-G15

XTC/3 9.2 m (30 ft.) Oscillator Kit, 4 m / 6 in.. . . . . PN 780-612-G30

XTC/3 15.3 m (50 ft.) Oscillator Kit, 4 m / 6 in.. . . . . PN 780-612-G50

XTC/3 30.5 m (100 ft.) Oscillator Kit, 4 m / 6 in.. . . . . PN 780-612-G100

Above kits consist of oscillator PN 780-600-G2 (4 m), 6 in. BNC oscillator to feedthrough cable PN 755-257-G6, 157.5 in. (4 m) in-vacuum cable PN 321-039-G16 and multiconductor controller to oscillator cable PN 600-1261-P15, 600-1261-P30, 600-1261-P50 or 600-1261-P100.

XTC/3 4.6 m (15 ft.) Oscillator Kit, 4 m / 20 in.. . . . . PN 780-613-G15

XTC/3 9.2 m (30 ft.) Oscillator Kit, 4 m / 20 in.. . . . . PN 780-613-G30

XTC/3 15.3 m (50 ft.) Oscillator Kit, 4 m / 20 in.. . . . . PN 780-613-G50

XTC/3 30.5 m (100 ft.) Oscillator Kit, 4 m / 20 in.. . . . . PN 780-613-G100

Above kits consist of oscillator PN 780-600-G2 (4 m), 20 in. BNC oscillator to feedthrough cable PN 755-257-G20, 138 in. (3.5 m) in-vacuum cable PN 321-039-G15 and multiconductor controller to oscillator cable PN 600-1261-P15, 600-1261-P30, 600-1261-P50 or 600-1261-P100.

The 4 m Oscillator Kits permit the total length of coax cables from the output BNC of the oscillator to the Microdot connector at the sensor head to be in the range of 3 m (118 in.) to 4 m (157.5 in.) In the standard oscillator kit series PN 780-611-Gxx, this length may range from 30.5 cm (12 in.) to 1.98 m (78 in.).

Sensor Emulator Kit (option) . . . . PN 760-601-G2

XTC/3 Monitor / Editor Software. . . . . PN 780-032-G1

XTC/3 DLL . . . . PN 780-034-G1

All shuttered sensors and all multi-position sensors require a feedthrough with an air line and a solenoid valve.

Solenoid Valve . . . . PN 750-420-G1

1.6.3 Replacement Cables & Oscillators

Oscillator to Vacuum Feedthrough
BNC cable, 15.2 cm (6 in.) . . . . PN 755-257-G6

Oscillator to Vacuum Feedthrough
BNC cable, 50.8 cm (20 in.) . . . . PN 755-257-G20

4 m / 6 in. XIU Cable Kit,
consists of PN 755-257-G6,
(6 in. BNC cable) and PN 321-039-G16,
(4.0 m In-Vacuum Sensor Cable). . . . . .PN 760-700-G6

4 m / 20 in. XIU Cable Kit,
consists of PN 755-257-G20,
(20 in. BNC cable) and PN 321-039-G15,
(3.5 m In-Vacuum Sensor Cable). . . . . PN 760-701-G20

XTC/3 Unit to Oscillator Cable, 4.6 m (15 ft.) . . . . PN 600-1261-P15

XTC/3 Unit to Oscillator Cable, 9.2 m (30 ft.) . . . . PN 600-1261-P30

XTC/3 Unit to Oscillator Cable, 15.3 m (50 ft.) . . . . PN 600-1261-P50

XTC/3 Unit to Oscillator Cable, 30.5 m (100 ft.) . . . . PN 600-1261-P100

Standard XTC/3 Oscillator . . . . PN 780-600-G1

4 m XTC/3 Oscillator . . . . PN 780-600-G2

1.6.4 Sensors

XTC/3 is compatible with the following INFICON sensor types:

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

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

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

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

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

Front Load Bakeable Sensor . . . . PN BK-AxF

CrystalSix Sensor. . . . . PN 750-446-G1

Crystal12 Sensor . . . . PN XLI2-1xxxxx

RSH-600 Sensor . . . . PN 15320x-xx

For more information about Inficon's full line of QCM sensors, please contact your local INFICON representative or visit www.inficon.com.

Table 1-1 Crystal12 sensor

Crystal12 Sensor Package XL12-xxxxX	XL12-
Base Unit	
None	0
Crystal 12 Sensor	1
In-Vacuum Cable Assembly Length	
None	0
78 cm (30.75 in.)	1
15.2 cm (6 in.)	2
30.5 cm (12 in.)	3
61 cm (24 in.)	4
91.4 cm (36 in.)	5
121.9 cm (48 in.)	6
152.4 cm (60 in.)	7
182.9 cm (72 in.)	8
Crystal Carousel Assembly	
One (Included in Base Unit)	0
Spare Crystal Carousel Assembly	1
Front Deposition Shield	
One (Included in Base Unit)	0
Spare Front Deposition Shield	1
Mounting Post with Hardware	
None	0
Mounting Post Kit	1
Example: Crystal12 sensor with 78 cm (30.75 in.) cable, spare carousel, spare front deposition shield, mounting post kit, and solenoid valve is PN XL12-11111.	

1.7 Initial Power On Verification

A preliminary functional check of XTC/3 can be made before formal installation. It is not necessary to have sensors, source controls, inputs or relays connected to do this. For more complete installation information, refer to Chapter 2, Installation and Interfaces.

WARNING - Risk Of Electric Shock

There are no user-serviceable components within the XTC/3 case.

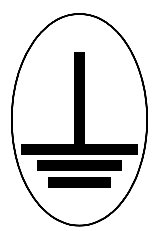
Dangerous voltages may be present whenever the power cord or external input/relay connectors are present.

Refer all maintenance to qualified personnel.

WARNING - Risk Of Electric Shock

Never interrupt the protective earth circuit.

Any interruption of the protective earth circuit inside or outside XTC/3, or disconnection of the protective earth terminal is likely to make XTC/3 dangerous.



This symbol indicates where the protective earth ground is connected inside XTC/3. Never unscrew or loosen this connection.

1. Confirm that AC line voltage is supplied and proper for XTC/3. Set the power switch on XTC/3 rear panel to On.
2. Press the power button on the front panel. A green LED will illuminate next to the power switch.

3 The LCD will display a screen similar to the one shown in Figure 1-1 or Figure 1-2.

Figure 1-1 XTC/3M operate screen

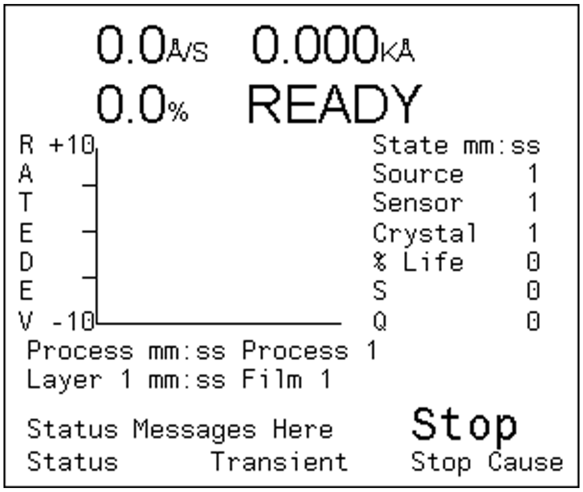
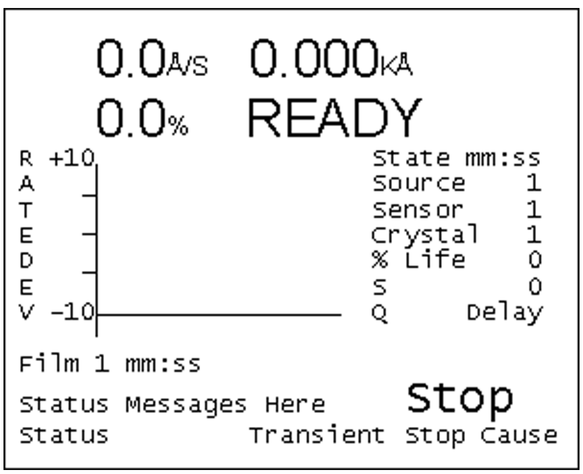


Figure 1-2 XTC/3S operate screen



Chapter 2
Installation and Interfaces

2.1 Location Guidelines

Before permanently installing XTC/3, read this entire chapter on Installation and Interfaces. Follow its recommendations as closely as possible. Failure to adhere to these practices may adversely affect the performance and longevity of XTC/3.

2.1.1 Sensor Types

The choice of sensor type is 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 Data Sheets on the www.inficon.com website.

For specific recommendations, consult your INFICON representative.

NOTE: If the installation replaces an XTC/2 or XTC/C with a dual sensor, and sensor type **CrystalTwo** is selected, PN 779-220-G1 (6 in. BNC Cables) or PN 779-220-G2 (20 in. BNC Cables) and Xtal 2 (CrystalTwo) Switch is required. XTC/3 uses only one Crystal Interface Unit (XIU) signal connection at XTC/3 for the dual sensor. The Xtal 2 Switch is wired in parallel with the solenoid valve (PN 750-420-G1) to route the XIU connection from one to the other crystal at the same time that the shutter is activated. If sensor type **Dual Head** is selected, two XIU packages are required and connected to Sensors 1 and 2.

NOTE: XTC/3 does not support CrystalSix sensor (PN 750-260-G1), which is no longer produced. Current product CrystalSix (PN 750-446-G1) is fully compatible with XTC/3.

CAUTION

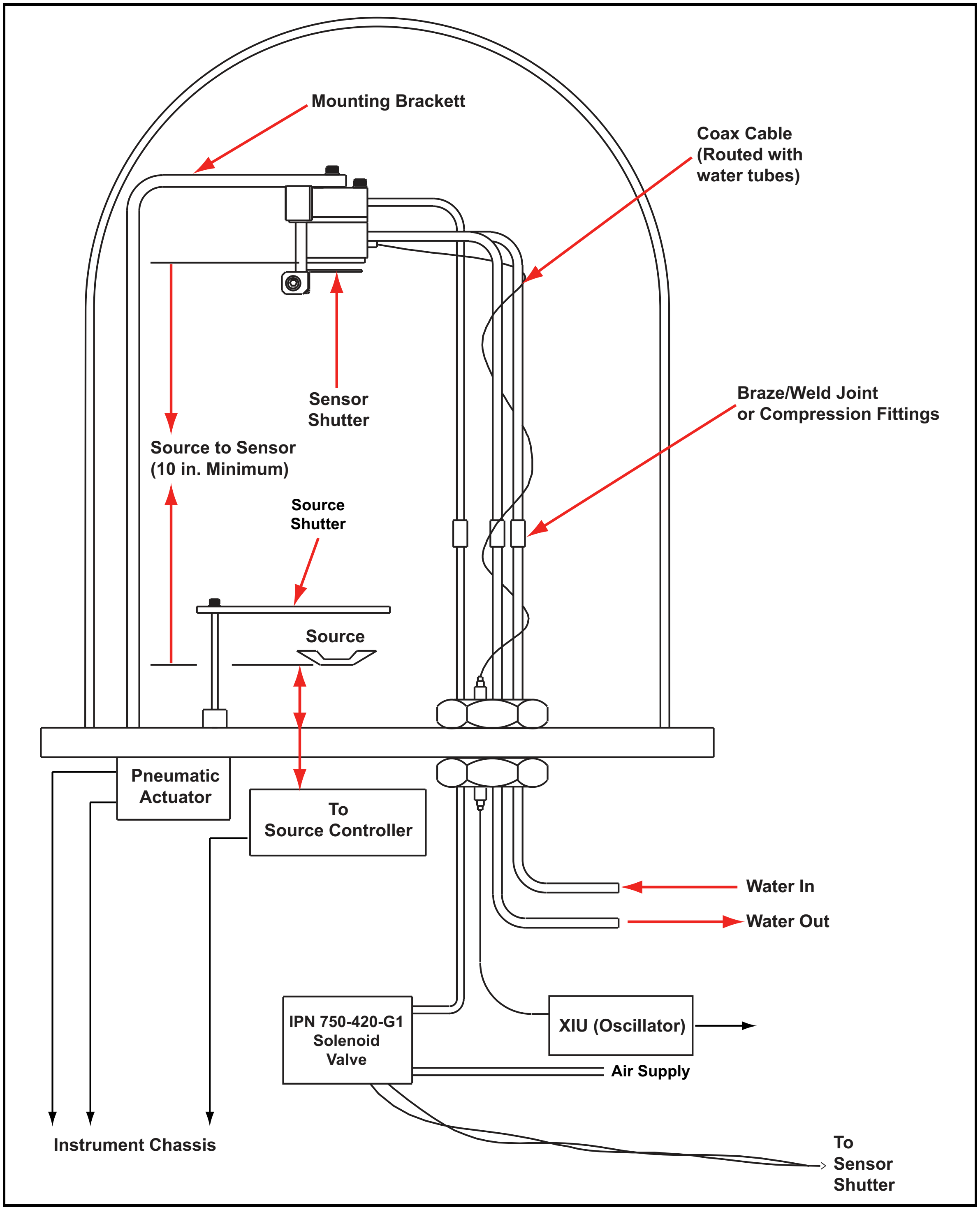
The performance of XTC/3 depends on the careful installation of the chosen sensor.

Improper installation will cause problems with deposition repeatability, crystal life and rate stability.

2.1.2 Sensor Installation

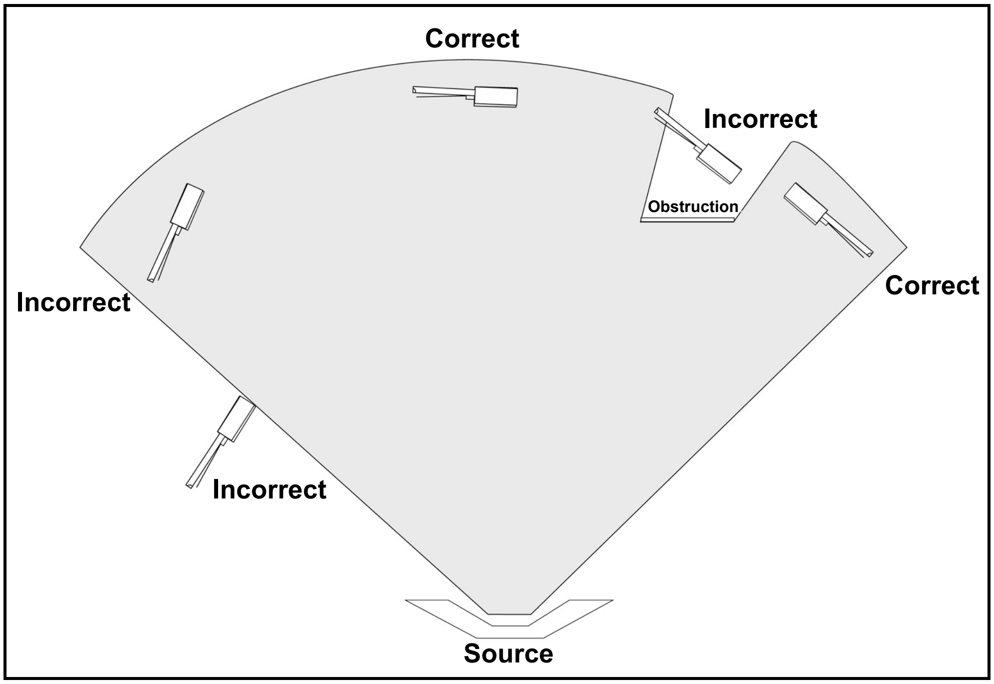
Figure 2-1 shows a typical installation of an INFICON water cooled crystal sensor in the vacuum process chamber. Use the illustration and the following guidelines to install sensors for optimum performance and convenience.

Figure 2-1 Typical installation



Install the sensor as far as possible from the evaporation source (a minimum of 10 in. [254 mm] is recommended) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 2-2 shows proper and improper methods of installing sensors.

Figure 2-2 Sensor installation guidelines



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 small 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.

Follow these precautions:

- 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 ensure 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. Verify that the total length of external and internal coax cable from the standard PN 780-600-G1 oscillator to the sensor does not exceed 100 in. (254 cm). An optional PN 780-600-G2 oscillator is available to handle 118 in. to 158 in. (3 m to 4 m) long in-vacuum coax cables.
- Ensure there is easy access for the exchange of crystals.
- For systems employing two XTC/3 for simultaneous source evaporation (co-deposition), locate the sensors so the evaporant from each source is flowing to only one sensor. It is not generally possible to do this without special shielding or optional material directors.

2.1.3 XTC/3 Installation

XTC/3 is designed to be rack mounted with the optional rack mount kit (PN 780-702-G1). It may be also used on a table. A two-unit rack mount option kit (PN 780-702-G2) is available for mounting two XTC/3 side by side.

Centrally locate the controller to minimize the length of external cabling.

2.2 Avoiding Electrical Interference

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

To maintain the required shielding and internal grounding and ensure safe and proper operation, XTC/3 must be operated with all enclosure covers, sub-panels, and braces in place and fully secured with the screws and fasteners provided.

NOTE: When using XTC/3 with an RF sputtering system, the cable between XTC/3 and oscillator should be kept as far away from the RF transmission cable as possible. Interference from the RF transmission cable may cause an erroneous crystal fail.

2.2.1 Verifying/Establishing Earth Ground

If a ground must be established, 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 a salt solution around to improve the ground’s conduction. A near zero resistance measurement indicates earth ground is achieved.
- Keep connections to this grounding network as short as possible.

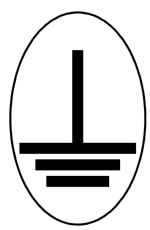
2.2.2 Connections to Earth Ground

There are two earth connections, both must be present:

- The ground connection on the controller is a threaded stud with a hex nut. One suggestion is to connect a ring terminal to the ground strap, thus allowing a good connection to a solid copper bar ground bus, and easy removal and installation. Use at least 0.5 in. copper braid strap or 16 AWG copper wire not exceeding 12 in. in length to achieve best immunity against electrical noise. See Figure 2-3 on page 2-6 for the suggested method of grounding.
- XTC/3 is also connected to earth via a sealed three-core 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. This ground provides for personal safety but is ineffective for suppressing electrical noise.

WARNING - Risk Of Electric Shock

Never interrupt the protective earthing intentionally. Any interruption of the protective earth connection inside or outside XTC/3, or disconnection of the protective earth terminal is likely to make XTC/3 dangerous.



This symbol indicates where the protective earth ground is connected inside XTC/3. Never unscrew or loosen this connection.

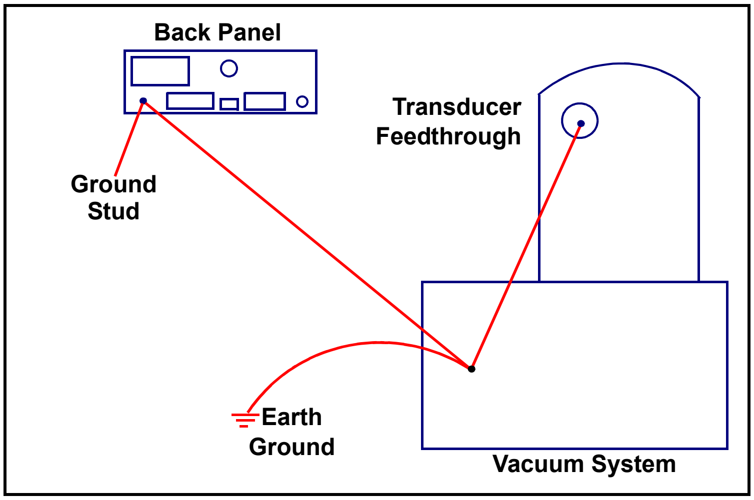
CAUTION

An external ground connection is required to ensure proper operation, especially in electrically noisy environments.

When used with RF powered sputtering systems, the grounding method may have to be modified to 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.

In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030 in. thick x 1 in. wide) is required because of its lower RF impedance.

Figure 2-3 System grounding diagram



2.2.3 Minimizing Noise Pickup from External Cabling

When a XTC/3 is fully integrated into a deposition system, there are many wire connections, each a potential path for noise to reach the inside of XTC/3. The likelihood of these wires causing a problem can be greatly diminished by adhering to the following guidelines:

- Use shielded coax cable or twisted pairs for all connections.
- Minimize cable lengths.
- Avoid routing cables near areas that have the potential to generate high levels of interference. For example, large power supplies such as those used for electron beam guns or sputtering sources can be a source of large, rapidly changing electromagnetic fields. Placing cables as little as one foot away from these problem areas can significantly reduce noise pickup.
- Ensure that a good ground system and straps are in place per the recommendations in section 2.2.2 on page 2-5.
- Ensure all XTC/3 covers and option panels are in place and tightly secured with the provided fasteners.

NOTE: Always use shielded cables when making connections to the XTC/3 rear panel to minimize electrical noise pickup.

2.3 Connecting the Controller

The operation of the XTC/3 depends on the proper connection of power and signal interfaces to owner equipment and sources.

2.3.1 Verifying the Correct Input Voltage

WARNING - Risk Of Electric Shock

XTC/3 has line voltage present on the primary circuits whenever it is plugged into a main power source.

Never remove the covers from XTC/3 during normal operation.

There are no operator serviceable items within XTC/3.

Removal of the top or bottom covers must be done only by a qualified personnel.

XTC/3 is powered by AC line current. The acceptable voltage input ranges and the fuse rating and type are shown in section 1.4.9 on page 1-10.

2.3.2 Routing Oscillator (XIU) Cables

The signals traveling on this cable are both analog and digital. Do not route this cable near areas with high levels of electromagnetic interference, even if its length must be somewhat increased.

2.3.3 Interface Cable Fabrication and Pin-Out

It is necessary to fabricate several cables in order to interface the controller to the deposition system. Refer to section 2.2.3, Minimizing Noise Pickup from External Cabling, on page 2-6.

2.3.3.1 Source Control Connection

Two BNC connectors, labeled **Source 1** and **Source 2**, provide the analog control voltage to your source power supply. Standard 50 ohm coaxial cables may be used.

2.3.3.2 Input and Output Connections

CAUTION

The relay, relay circuit, and associated pins in the I/O connector(s) have a maximum voltage rating of 30 V (dc) or 30 V (ac) RMS or 42 V (peak). The maximum current rating per connector pin or relay contact is 2.5 Amps.

NOTE: I/O functions are fixed in XTC/3S and are identical to the default assignments in XTC/2.

NOTE: In XTC/3M, the I/O functions are user selectable. The default assignments are identical to the default assignments in XTC/2.

2.3.3.2.1 System I/O Connector

Table 2-1 System I/O connector

Description	Pin #	XTC/3S Function
Relay 1	1, 2	Source Shutter 1
Relay 2	3, 4	Source Shutter 2
Relay 3	5, 6	** Sensor Shutter 1
Relay 4	7, 8	** Sensor Shutter 2
Relay 5	9, 10	Stop
Relay 6	11, 12	End of Process
Input 1	18	Start
Input 2	19	Stop
Input 3	20	End deposit
Input 4	21	* Sample Initiate
Input 5	22	* Sample Inhibit
Input 6	23	* Crystal Fail Inhibit
Input 7	24	* Zero thickness
Input 8	25	* Soak 2 Hold
Ground	13,14,15,16,17	Input Common
* These input functions may be reassigned according toTable 2-2. ** Used for Crystal Switching for a XTC/3S.		

Table 2-2 Film Select Option selected in XTC/3S General / Process screen

Input #	Pin #	Function	Description				
			pin22	pin23	pin24	pin25	Film #
4	21	**RESET**					
5	22	**Film Select MSB**	0	0	0	X	1
6	23	**Film Select**	0	0	1	0	2
7	24	**Film Select**	0	0	1	1	3
8	25	**Film Select LSB**	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
			X = Does not matter				

2.3.3.2.2 Aux I/O Connector

Table 2-3 Aux I/O connector

Description	Pin #	XTC/3S Function
Relay 7	1, 2	Thickness Setpoint
Relay 8	3, 4	Soak 2
Relay 9	5, 6	Crystal Fail
Relay 10	7, 8	Alarms
Relay 11	9, 10	Source 1/Source 2
Relay 12	11, 12	End Deposit (Final Thickness)
TTL Output 1 13 Cruc SRC 1 Bin	18	Crucible Select 1 (if active layer is 0 or 1)
TTL Output 2 14 Cruc SRC 1 Bin	19	Crucible Select 2
TTL Output 3 15 Cruc SRC 1 Bin	20	Crucible Select 3
TTL Output 4 16 Cruc SRC 1 Bin	21	Crucible Select 4
TTL Output 5 17 Cruc SRC 1 Bin	22	Crucible Select 5
TTL Output 6 18 Cruc SRC 1 Bin	23	Crucible Select 6
TTL Output 7 19 Cruc SRC 1 Bin	24	Crucible Select 7
TTL Output 8 20 Cruc SRC 1 Bin	25	Crucible Select 8
Input 9	14	Crucible Valid
Ground	13,15,16,17	Common

2.3.3.2.3 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.

2.3.4 RS-232C Communications

RS-232C serial communications is standard in XTC/3. RS-232C is used to remotely control or monitor XTC/3.

Optional Windows® compatible software, INFICON PN 780-032-G1, provides for parameter entry, recipe storage, data logging and monitoring as well as Start, Stop and Reset control.

An industry standard 9-pin D-Sub connector is required for the host computer side connection. The permissible length of the cable is governed by published standards.

The controller interface operates as DCE (Data Communication Equipment), hardware handshaking is not supported.

Pin assignments are for the XTC/3 connector. In most cases, a straight-through serial cable (not a null modem cable) with a female 9 pin D connector on the PC end and a male 9 pin D connector at the XTC/3 end will work, however, only pins 1, 2, 3 and 5 are used.

Table 2-4 RS-232C pin assignments

Signal Name		Pin(s)	EIA Name
TX	Transmit Data	2	BA
RX	Receive Data	3	BB
SG	Signal Ground	5	AB
	Cable Shield	1	
	(Not Used)	4, 6, 7, 8	

2.3.5 TCP/IP Communications Connection (Optional)

NOTE: This section applies only if the optional TCP/IP interface has been installed.

The TCP/IP interface option for XTC/3 accepts a standard ethernet TCP/IP communications connection. If XTC/3 is directly connected from a stand-alone computer, the ethernet cable should be a crossover cable unless the PC has the ability to dynamically reconfigure itself. Static addressing is supported, DHCP is not supported.

2.3.5.1 Network Connection

If XTC/3 is connected through a network or hub connection, a standard straight ethernet cable is required.

2.3.5.2 Change the IP Address in XTC/3

See section 4.4.3.1 on page 4-25.

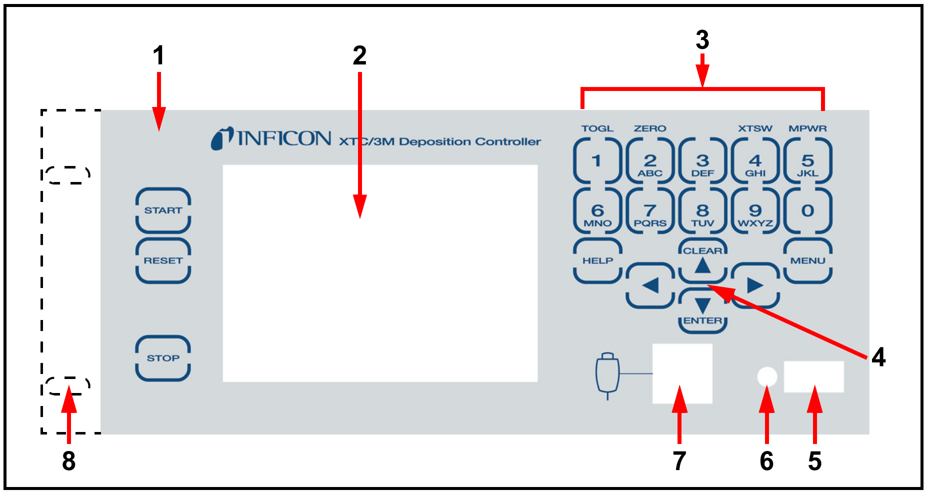
2.3.5.3 PC Setup

See section 5.1.4 on page 5-2.

Chapter 3
Operation

3.1 Front Panel Controls

Figure 3-1 XTC/3M front panel



1 System Switches

START, **STOP** and **RESET** for process control.

2 LCD Screen

Provides graphical displays, set-up menus, status, and error messages.

3 Data Entry Keys

A keypad array with numerics **0** through **9** with telephone-style assigned letters (XTC/3M only) for parameter entry and keys for **HELP**, **CLEAR** ▲ (up cursor), **MENU** and **ENTER** ▼ (down cursor). All numeric entries must be followed by **ENTER**.

CLEAR is used to erase data entry errors. If an illegal value has been entered, **CLEAR** will erase the error message and re-display the last valid data.

MENU is used to navigate through XTC/3 displays.

HELP key brings up context-related text.

4 Cursor Keys

An array of four keys that are used to move the display cursor either up, down, left or right. The keys auto-repeat; the cursor will continue to move as long as the key is held down. Depending on the context, ▲ will function as **CLEAR** and ▼ will function as **ENTER**. The ▼ and ▲ keys are also used to increment or decrement the power level while in Manual operation.

5 Power

This switch controls secondary power to XTC/3 between **ON** and **STANDBY**. Power is provided when the button is in its depressed position.

6 Pilot Light

A green LED, adjacent to the power switch, is illuminated when power is on.

7 Remote Control Jack

Receptacle for the optional wired handheld remote controller PN 755-262-G1.

8 Optional Rack Mount Kit (Not Shown)

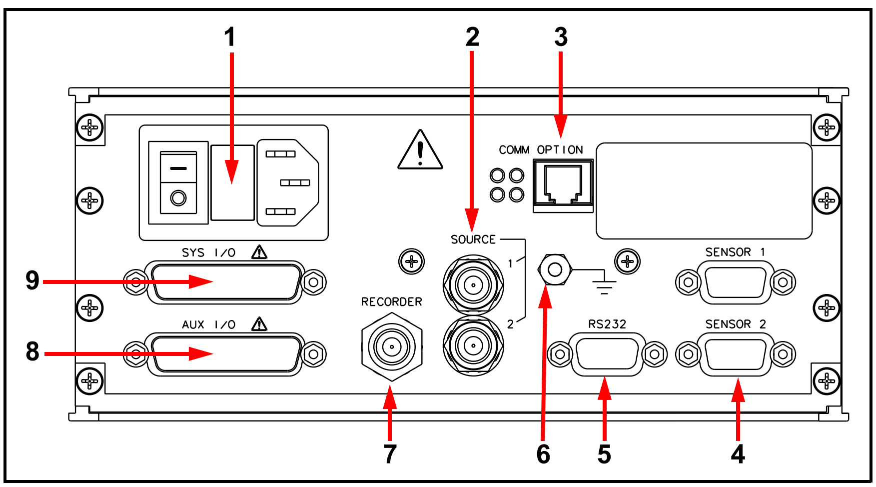
PN 780-702-G1 for one XTC/3.

PN 780-702-G2 for two XTC/3 mounted side by side.

3.2 Rear Panel Interfaces

Interfaces for XTC/3 are located on the rear panel, see Figure 3-2.

Figure 3-2 XTC/3 rear panel



1 AC Power Inlet and Mains Switch

Provides a common connector for various international plug sets.

2 Source Control DAC Outputs

Provides source control voltage for two sources, (BNC connectors). Outputs are programmable for various voltage ranges and polarities.

3 Comm Option Connector (Optional TCP/IP)

Provides connections for TCP/IP interface.

4 Sensor Connectors - Channels 1 & 2

Provides connection for the two sensor channels.

5 RS-232C Remote Communication Connector

Provides a 9-pin RS-232C communications port.

6 Ground Stud

See section 2.2.2, Connections to Earth Ground, on page 2-5.

7 Recorder DAC Output

Provides 0 to 10 V output selectable to correspond to Rate, Rate Deviation, and Thickness at various ranges and Power (BNC connector).

8 Aux I/O Connector

Provides pin connection for 6 Relays rated for 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum, eight logic outputs, and one logic input.

9 System I/O Connector

Provides pin connection for 6 Relays rated for 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum, and 8 logic Inputs.

3.3 Displays

Seven XTC/3 display screens are used for monitoring and programming processes:

- **Operate**
- **Film Parameter**
- **Process List** (XTC/3M only)
- **General Parameter**
- **I/O Map**
- **Diagnostics**
- **Sensor**

To maximize the life of the display, it can be set to dim after a period of 1 to 99 minutes without a key press (see section 4.4.2, Hardware Parameters, on page 4-21, parameter **LCD DIMMER TIME**).

Pressing a key before the dimmer time elapses resets the dimmer interval to start over.

The default setting of 0 disables the dimmer function.

When the display is dimmed, its brightness will be:

- bright if a film is running
- dark if a film is not running (as in Ready or Idle)

All keys remain active. To restore the display to full brightness without inadvertently changing parameters, press either **HELP**: or ◀ or ▶.

3.3.1 Menu Display

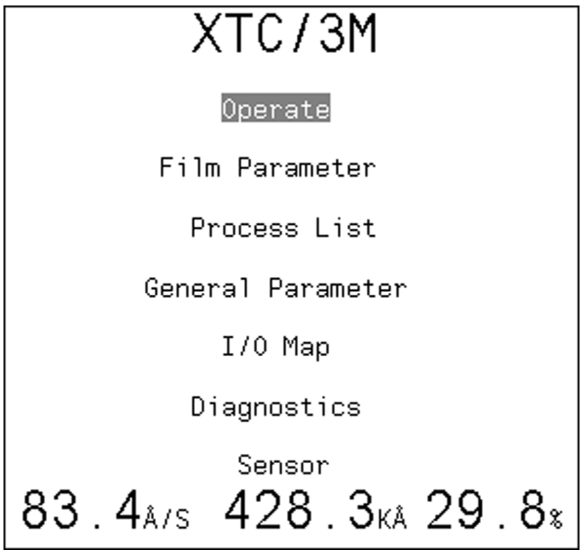
Pressing **MENU** while on any other screen will display to the **Menu** screen. (See Figure 3-3.)

The **Menu** screen allows navigation between all other screens.

1 Using ▲ or ▼, a list of screens can be scrolled through to select the desired screen.

2 Press **MENU** to move the display to the selected screen.

Figure 3-3 Menu Display XTC/3M



If a lock code has been set up from the front panel to prevent unauthorized parameter entry, the lock code **L Lock** message will appear on this screen in the upper right corner.

If a lock code has been set up via Remote Communications, the **R Lock** message will appear instead.

To enable entering or changing parameters, move the cursor to the lock code message (located to the right of **Sensor**), enter the lock code and press **ENTER**. The lock code message will disappear.

XTC/3 will be re-locked after entering the **Operate** screen.

3.3.2 Operate Display

The **Operate** screen will appear on power-up following the temporary initialization screen. It contains information pertinent to the currently active film and process. Information on the **Operate** screen includes the user-entered name of the process and film (XTC/3M only), the Rate, Power, Thickness, State, StateTime, Layer Time, Process Time (XTC/3M only), Source and Sensor in use, Crystal Number, Percent Life, S and Q values. (See Figure 3-4 and Figure 3-5.)

A graphical representation of rate deviation or the power over time will also be displayed. The graph display can be modified by placing the cursor on the Y-axis graph label and pressing **TOGL** to toggle between rate deviation and power. The rate deviation scale can also be toggled between 5,10, 20 and 40 Å/s when the cursor is placed on the graph Y-axis value.

System messages and errors are displayed on all screens except **I/O Map**.

NOTE: On XTC/3M, if there are no Process or Film names—they are replaced by the Process and/or Film number.

Figure 3-4 XTC/3M operate display

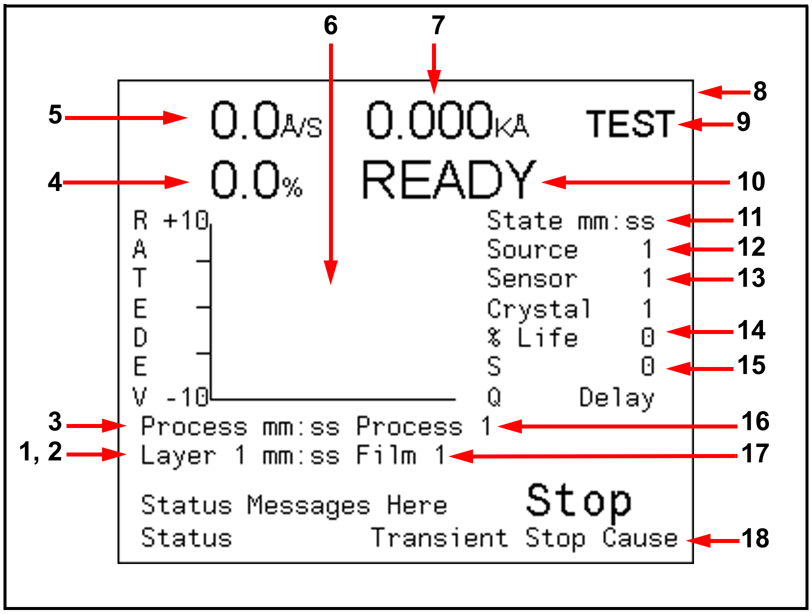
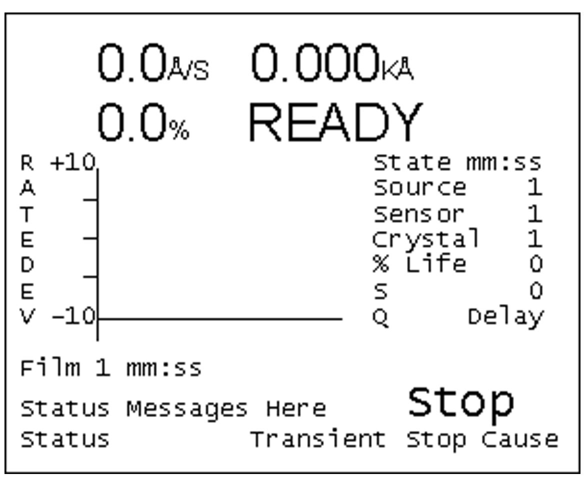


Figure 3-5 XTC/3S operate display



Operate Display Description (See Figure 3-4)

1. **Layer Currently In Process (Film in XTC/3S)**
2. **Layer Time**
3. **Process Time (XTC/3M only)**
4. **% Power**
5. **Rate**
6. **Graphical Display of Rate Deviation or Power**
7. **Layer Thickness**
8. **Lock Status Area**
9. **Test Mode Indicator**
10. **State of Layer**
11. **State Time**
12. **Source Number In Use**
13. **Sensor Number In Use, Crystal in Use** (if multi-position sensor)
14. **% Crystal Life**
15. **S and Q Counters** (if set to non-zero values)
16. **Process Name Being Executed (XTC/3M only)**
17. **Film Name Being Deposited** (Always **Film** in XTC/3S)
18. **Message Area**

3.3.2.1 Crystal Life and Starting Frequency

On the **Operate** display, crystal life is shown as a percentage of the nominal 1 MHz frequency shift, relative to the 5.0 MHz ending frequency allowed by XTC/3. 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 unusual 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. Even for well-behaved materials, such as copper, 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 before reaching the theoretical 100% Life point.

When depositing dielectric or optical materials, the life of a gold, alloy or silver quartz monitor crystal is much shorter—as little 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, Q, of the quartz has very little to do with the monitor crystal's failure.

3.3.2.2 Choosing The Right Crystal

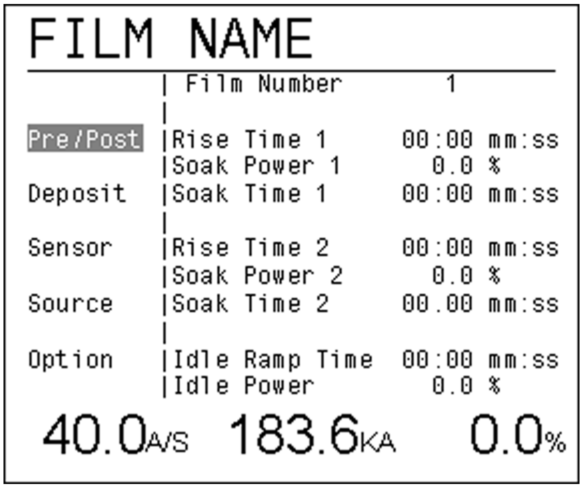
Gold crystals are recommnded for most applications. However, silver crystals will provide superior performance in processes with high heat loads, such as sputtering. Silver crystals may also improve the deposition of oxides, but try gold crystals first. Keep in mind that silver tarnishes and cannot be kept in storage for long periods of time. INFICON silver crystals are shipped in a sealed bag filled with an inert gas to maximize shelf life.

3.3.2.3 Percent Life Auto-Zero

If a new crystal has a starting frequency above 5.92 MHz and is more than 0.04 MHz different from the last valid crystal reading, its % Life will be set to 0. This facilitates using crystals to a uniform known % Life point without wasting usable crystal life. In all cases, reaching 5.0 MHz results in a crystal life-fail even though % Life may not have reached 100%. For example, a crystal with a starting frequency of 5.95 MHz will have a % Life reading of 95% when it reaches 5.0 MHz.

3.3.3 Film Name Display

Figure 3-6 Film Name display



The Film Name display shows the film parameters and their values. Thirty-two films may be programmed in XTC/3M; nine in XTC/3S. **Pre/Post Deposit**, **Deposit**, **Sensor**, **Source** and **Option** screens are accessed from the the **Film Name** screen.

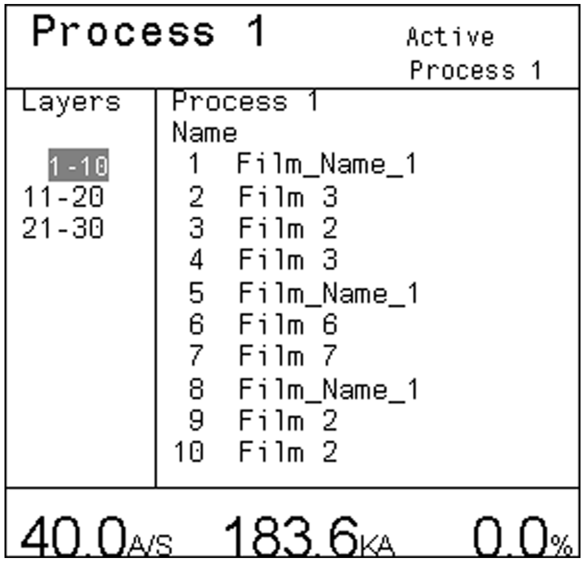
If the parameters are locked, the **L Lock** or **R Lock** message will be displayed in the upper right corner. With the parameters locked, the film number may still be changed to allow viewing of other films.

See section 4.2 on page 4-3 for programming details.

3.3.4 Process List Display (XTC/3M only)

The **Process** screen is present only in XTC/3M.
XTC/3S is a single process, single layer controller.

Figure 3-7 XTC/3M Process display



A process consists of one or more layers, to be run in order. See section 4.3 on page 4-16 for programming details. 99 Processes may be programmed, each with up to 999 Layers.

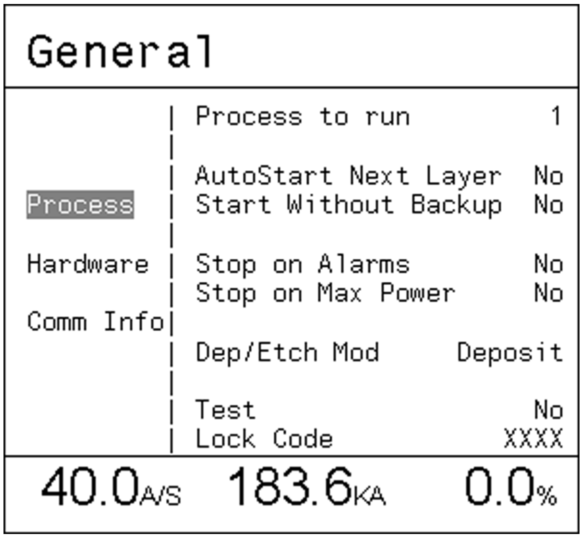
On entering the **Process** screen, the process displayed is the process when the **Process** screen was last displayed. A different process can be displayed by moving to the process number parameter, entering the desired process number and pressing **ENTER**.

If the parameters are locked, the **L Lock** or **R Lock** message will be displayed in the upper right corner. The process list will be displayed, but cannot be changed. However, the process number may still be changed to allow viewing of other processes.

The Select panel contains sets of 10 layers that can be displayed
in the parameter panel.

3.3.5 General Parameter Display

Figure 3-8 XTC/3M General parameter display



NOTE: XTC/3S replaces **Process to Run** with **Film To Run**.
XTC/3S does not support **AutoStart Next Layer**.

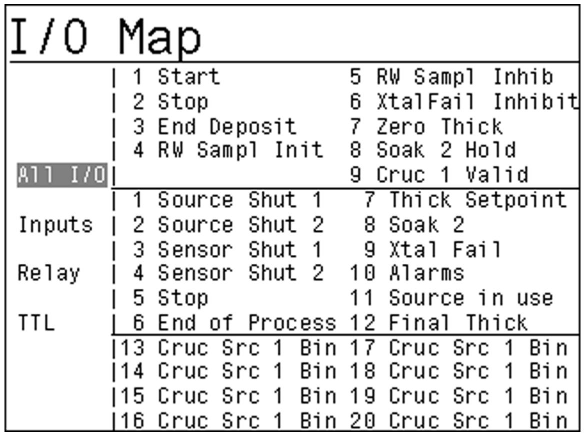
The **General** parameter screen is subdivided into **Process**, **Hardware** and **Comm**unication **Info** screens. The **L Lock** lock code is initially set in the **Process** screen.

If the parameters are locked here, the **L Lock** message will be displayed in the upper right corner. The parameters will be displayed, but cannot be accessed.

See section 4.4 on page 4-18 for programming details.

3.3.6 I/O Map Display

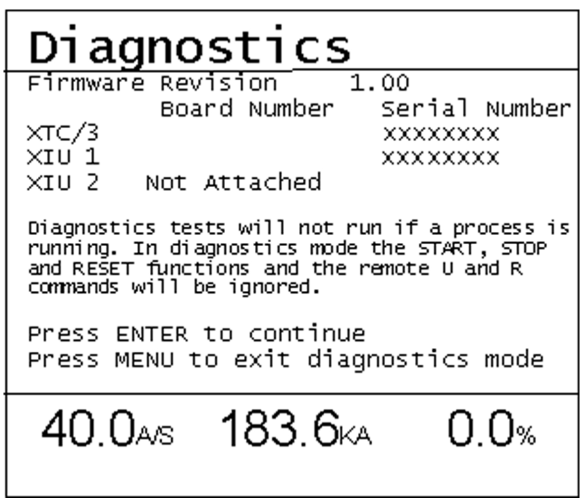
Figure 3-9 XTC/3M I/O Map display



The **I/O Map** screen displays the currently selected programmable I/O functions on XTC/3M or the fixed I/O in XTC/3S. See section 4.5 on page 4-26 for XTC/3M programming details.

3.3.7 Diagnostics Display

Figure 3-10 Diagnostics display

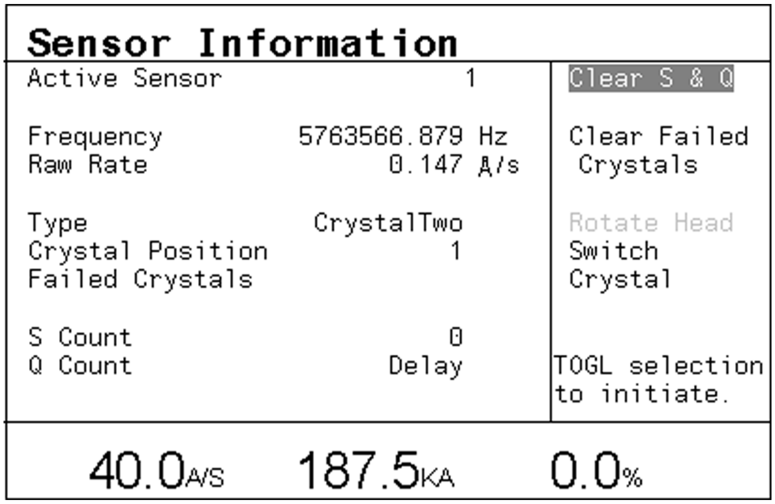


The **Diagnostics** display is described under section 6.2, XTC/3 Diagnostics, on page 6-6. The **Diagnostics** display:

- shows firmware version
- shows main board serial number
- shows Crystal Interface Unit (XIU) serial number
- permits testing the RS 232 interface
- permits testing the active XIU
- allows toggling source and sensor shutters
- allows checking crucible rotation

3.3.8 Sensor Information Display

Figure 3-11 Typical Sensor Information display



Inactive choices will be gray.

If non-zero values have been programmed for the S and/or Q parameters, the accumulated counts can be cleared on this screen.

If a multi-position sensor is in use, it can be switched to the next or rotated through all its positions by positioning the cursor on **Switch Crystal** or **Rotate Head** and pressing **TOGL**.

NOTE: Rotate Head is allowed only in **Ready** or **Idle** at the end of a process.

Frequency indicates the current resonance or the last good value prior to a crystal failure.

3.4 Executing a Process

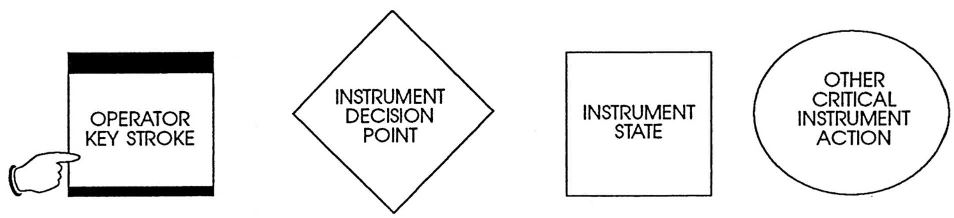
Once a process has been defined as described in Chapter 4, it is ready to execute.

- **START**, pressed once, will start or continue the process from the point at which it was stopped.
- **STOP** freezes a process, the status information on the display is maintained and the control voltage output is set to zero.
- **RESET**, if pressed when XTC/3 is in Stop, takes a process back to the first layer.

HINT: It may be desirable to execute a new process in **TEST** (enabled in **Process** sub-screen of the **General Parameter** display, see section 4.4.1 on page 4-19) before doing an actual deposition to check correct shutter operation, sequencing and limits.

The execution of a process is depicted in the following state diagram. (See Figure 3-12 and Figure 3-13.)

Figure 3-12 Symbols used in flow charts



Solid lines indicate the automatic sequence of steps.
Dotted lines indicate steps the user may select.

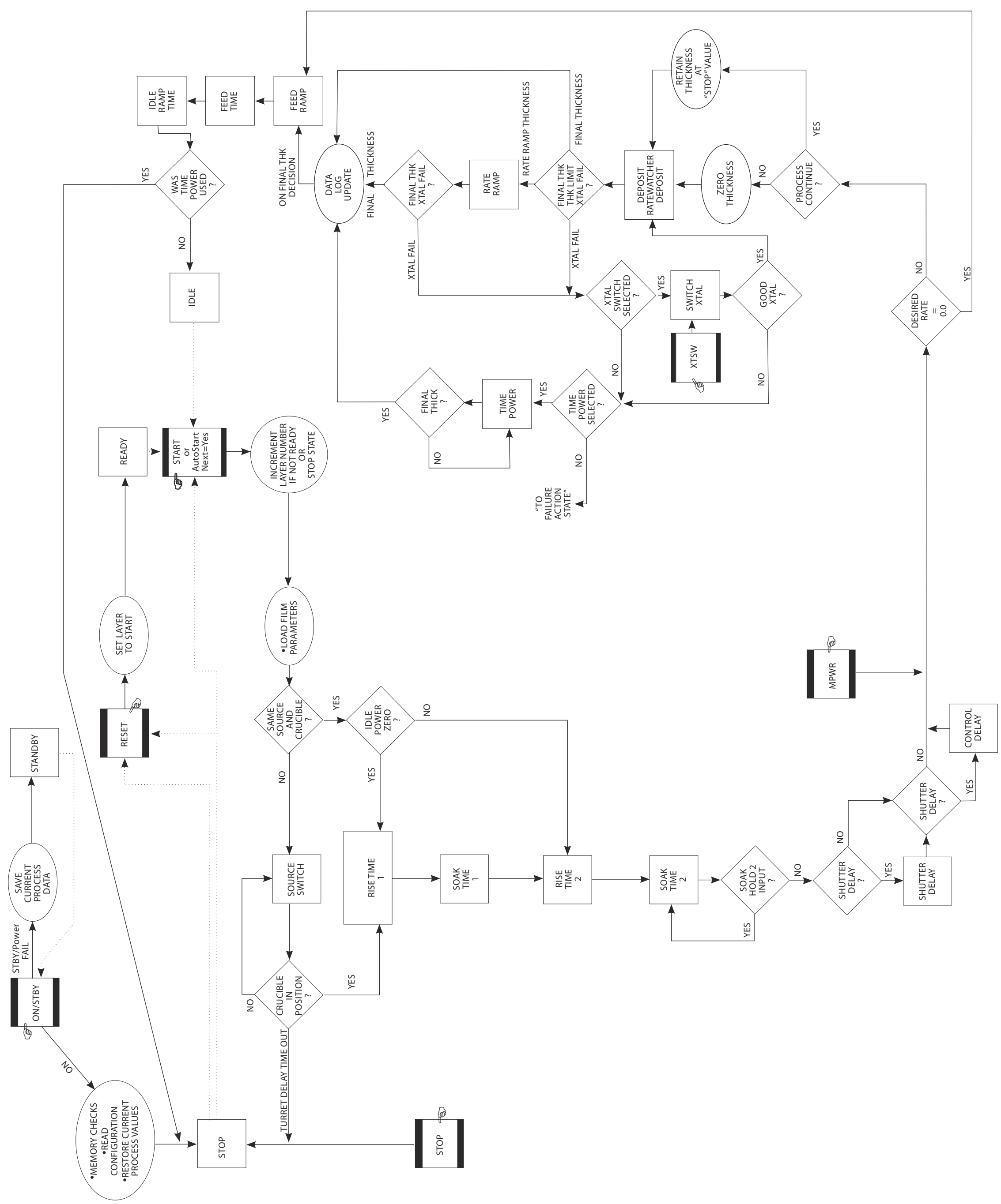


Figure 3-13 XTC/3 state diagram

1 Make sure XTC/3 is in **READY** or **IDLE**.

2 Press **START**. The next layer to be run will enter pre-deposition, and continue on through deposition and post-deposition.

3 When the layer is complete, XTC/3 will go to **IDLE**. If **AutoStart Next Layer** (XTC/3M only) has been set to **Yes** in the **Process** sub-screen of the **General Parameter** display, the next layer, if there is one, will be started automatically. If not, press **START** again to begin the next layer. Repeat until the process is complete.

4 If at some point there is a need to interrupt or discontinue the process, press **STOP**. This will close the sensor and source shutters, set the control voltage output to zero, and freeze the display. The process can be restarted where it left off by pressing **START**. (The pre-deposition phases will be repeated.) To completely abandon the run, press **RESET** after **STOP**.

5 A critical error may occur while a process is running.

For example, a crystal failure on a single crystal sensor head may occur in pre-deposition. XTC/3 will automatically **STOP** or go into **Time-Power** (if the crystal failure occurs while in **Deposit** and the **Time-Power** option is set to **Yes**). Assuming the error has been remedied, the process can be continued where it left off by pressing **START**. Pressing **RESET** will abandon the run.

3.5 State Descriptions

Table 3-1 State descriptions

STATE	CONDITION	RELAY CONTACT STATUS	
		Source Shutter	Sensor Shutter
NOTE: The following are **Pre-Deposit** states. Associated parameters are shown in the CONDITION column surrounded by the [ ] left and right square brackets.			
READY	XTC/3 will accept a START command. Rate is displayed and Thickness is accumulated.	Inactive	Inactive
CRUCIBLE SWITCH	XTC/3 advances to next state when the Cruc Valid input is low. If IDLE PWR of the previous layer using this source is not equal to zero, power is set to zero before the crucible position changes. [Crucible #, Source #]	Inactive	Inactive
RISE 1	Source is rising to Soak Power 1 level. [Rise Time 1]	Inactive	Inactive
SOAK 1	Source is being maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1]	Inactive	Inactive
SOAK HOLD 1 (M only) (Soak 1 state)	Source is being maintained at Soak Power level [Soak Hold 1 input]. Display indicates SOAK 1.	Inactive	Inactive
RISE 2	Source is rising to Soak Power 2 level. [Rise Time 2]	Inactive	Inactive
SOAK 2	Source is being maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2]	Inactive	Inactive
SOAK HOLD 2 (Soak 2 state)	Source is being maintained at Soak Power level [Soak Hold 2 input]. Display indicates SOAK 2.	Inactive	Inactive
SHUTTER DEL(AY)	Rate is being controlled. If TRANSFER SENSOR is set to YES, the second sensor is now in use. Advances to Deposit State once the Source is in Rate Control within the greater of 5% or 0.5Å for 5 seconds. [Delay Option, Shutter Delay ON]	Inactive	Active

Table 3-1 State descriptions (continued)

STATE	CONDITION	RELAY CONTACT STATUS	
		Source Shutter	**Sensor Shutter**
NOTE: The following are **Deposit** states.			
CONTROL DELAY (Deposit state)	Constant Power at Soak Power 2. Begins rate control when the control delay time elapses. [Delay Option, Control Delay, Control Delay Time]	Active	Active
DEPOSIT	Thickness zeroed upon entry or reset to stored value on Stop/Start without Reset. Rate control. [Rate, Final Thickness, PID Control, Process Gain, Primary Time Constant, System Dead Time]	Active	Active
RATEWATCHER (SAMPLE) (Deposit state)	Rate control. [RateWatch Accuracy]	Active	Active
RATEWATCHER (HOLD) (Deposit state)	Constant power, based on last sample's average power. [RateWatch Hold Time]	Active	Inactive
RATE RAMP	Rate control, desired rate changing. [New Rate , Start Ramp, Ramp Time]	Active	Active
MANUAL	Source power controlled by handheld controller or front panel Up/Down cursor keys.	Active	Active
TIME-POWER	Crystal failed; source maintained at average control power prior to crystal failure. [Time Power Yes/No]	Active	Active
NOTE: The following are **Post-Deposit** states.			
IDLE RAMP	Source changing to Idle Power. [Idle Ramp Time, Idle Power]	Inactive	Inactive
IDLE (=0% Power)	Source maintained at zero power; will accept a START command.	Inactive	Inactive
IDLE (>0% Power)	Source resting at Idle Power; will accept a START command. Rise 1 and Soak 1 will be skipped.	Inactive	Inactive
STOP Note: Stop is not a separate state but a suspension of the current state.	Source output set to zero power. The display is frozen at the last rate and thickness values. Ref: Recovering from STOP, see section 3.5.1.3	Inactive	Inactive

Table 3-2 Output states

Output	Active	Inactive
Source Shut 1	In any deposit state	When leaving control states
Source Shut 2		
[1]Sensor Shut 1	In shutter delay or any deposit state. In RateWatcher Sample	Closes when leaving control states. In RateWatcher Hold
[1]Sensor Shut 2		
Note 1: In XTC/3S, Sensor Shut 1 and Sensor Shut 2 outputs are used to perform the crystal switch function if a multi-position sensor has been selected.		
Stop	Enter Stop	Exit Stop
End of Process	When entering Idle if this is last film in the process	When Start or Reset is done
Thick Setpoint	In Deposit or Time Power state, and thickness setpoint is reached	When Start or Reset is done When Idle is entered
Xtal Fail	When active crystal fails	When active crystal becomes valid. Digital Set Crystal Fail Inhibit
Alarms	On Rate Deviation error On Shutter Delay error When Max power reached On Crucible Switch error	As each error is cleared and no other error is set. When Start or Reset is done When Idle ramp is entered
Source in use	When Source 2 is active	When Source 1 is active
Final Thick	Final thickness is reached	When Start or Reset done
End of Film (M only)	Initiate Idle state	When Start or Reset done
In Layer (M only)	When layer is started	Enter Idle or Stop
Ion Assist Dep (M only)	Enter any deposit state and Ion Assist Deposit is enabled	Enter Idle ramp Enter Stop
Xtal Switch 1 (M only)	See crystal switching section 3.6.8	See crystal switching section 3.6.8
Xtal Switch 2 (M only)	See crystal switching section 3.6.8	See crystal switching section 3.6.8

Table 3-2 Output states (continued)

Output	Active	Inactive
Ready (M only)	When each State starts, the old and new state output are set or cleared as necessary	When each State starts, the old and new state output are set or cleared as necessary
Crucib Switch (M only		
Rise 1 (M only)		
Soak 1 (M only)		
Rise 2 (M only)		
Soak 2		
Shutter Delay (M only)		
Deposit (M only)		
Rate Ramp (M only)		
Manual (M only)		
Time Power (M only)		
Idle Ramp (M only)		
Idle (M only)		
Max Power (M only)	When power reaches max power	When power is not at max power
Rate Dev Fail (M only)	When the rate deviation is greater than 5% or 0.5Å of the desired rate for 60 seconds or 20 times the time constant if the time constant is greater than 3 seconds	When rate deviation is within test limits. When Idle Ramp is entered
Xtal Sw Fail (M only)	When an attempted crystal switch fails	When another crystal switch is started
Xtal Switching (M only)	Whenever a crystal switch is active	When the crystal switch is done
Crucib Sw Fail (M only)	No crucible valid input within 30 seconds of a crucible switch	When Start or Reset is done. If Stop on Alarms is set to No, XTC/3 will give the error message but will not do anything else, it stays in Crucible Switch. If the Crucible Valid input becomes set, the output is cleared

Table 3-2 Output states (continued)

Output	Active	Inactive
Shutter Delay Fail (M only)	Shutter delay is enabled and the rate deviation is greater than 5% or 0.5 Å of the desired rate for 60 seconds	When Start or Reset is done If Stop on alarms is set to No, the unit will give the error but will not do anything else. It stays in Shutter Delay and controls power to acquire correct rate. If rate comes into specified range, then the output is cleared. When Idle Ramp is entered
Computer Contl (M only)	Set in remote commands	Cleared through remote commands
Cruc Src 1 Bin Cruc Src 1 BCD (M only) Cruc Src 2 Bin Cruc Src 2 BCD (M only)	When a Start is done Output set and cleared to select crucibles as binary (1 of 8) or BCD	When a Start is done Output set and cleared to select crucibles as binary (1 of 8) or BCD

Table 3-3 Inputs

Input Function	Description
Start	Detection of a falling edge effects a START if a layer is not already running.
Stop	Detection of a falling edge effects a STOP.
End Deposit	Detection of a falling edge terminates the Deposit state just as if the Final Thickness were achieved.
RW Sample Init	Detection of a falling edge initiates a RateWatcher sample if the film is programmed for this feature.
RW Sample Inhib	Application of a ground reference voltage maintains the RateWatcher in the Hold condition.
XtalFail Inhibit	Application of a ground reference voltage prohibits the closure of the Crystal Fail Relay and the associated Stop.
Zero Thick	Detection of a falling edge duplicates the front panel ZERO.
Soak 2 Hold	Application of a ground reference voltage extends the SOAK 2 state until the signal/closure is removed.
Cruc 1 Valid (in XTC/3S, also used for Source 2)	Application of a ground reference voltage from the crucible rotation mechanism is used to signal that the proper crucible for Source 1 (or 2 in XTC/3S) has indexed into position and state sequencing may proceed.

Table 3-3 Inputs (continued)

Input Function	Description
Cruc 2 Valid (M only)	Application of a ground reference voltage from the crucible rotation mechanism is used to signal that the proper crucible for Source 2 has indexed into position and state sequencing may proceed.
Reset (M, **S** if Film Select option used)	Detection of a falling edge effects a RESET if in Stop.
Sel Process (4) (M only)	The state of the two associated inputs determines the process, 1 to 4, to be selected when a START is processed while the unit is in Ready or Idle of the last layer. 00 for 1, 01 for 2, 10 for 3 and 11 for 4.
Sel Process (16) (M only)	As above, except four inputs are used to select process 1 to 16.
Sel Process (64) (M only)	As above, except six inputs are used to select process 1 to 64.
Sel Process (99) (M only)	As above, except seven inputs are used to select process 1 to 99.
Switch Crystal (M only)	Detection of a falling edge duplicates the front panel XTSW.
Non-Dep Hold (M only)	This feature “holds” the state timer during any non-deposit state. Non-deposit states include the pre-deposit states: Ready, Crucible Switch, Rise 1, Soak 1, Rise 2, Soak 2; and the post-deposit states: Idle Ramp and Idle. For the feature to be activated, the state’s time must be non zero. The message NON-DEP HOLD is displayed. If XTC/3 is in the READY or IDLE state and a START command is executed while NON-DEP HOLD is active, XTC/3 will progress to the first pre-deposit state with a non zero state time. If XTC/3 is in the Crucible Switch state, waiting for the Cruc Valid input, and NON-DEP HOLD is activated when the Cruc Valid input is activated, XTC/3 will progress to the next pre-deposit state having a non zero state time. XTC/3 is prevented from continuing state processing until the action is deactivated.
Zero Film Time (M only)	Detection of a falling edge will zero the Layer Deposit time for the Layer being deposited.
Start Inhibit (M only)	Prevents starting a layer as long as the input remains active.
Soak 1 Hold (M only)	Application of a ground reference voltage extends the SOAK 1 state until the signal/closure is removed.
Film Select (**S** only)	See section 4.4.2.1 on page 4-23

3.5.1 Alarms and Stops

There are a number of unusual XTC/3 situations that may require operator attention. These situations are detected and then treated as **ALARMS** or **STOPS**. Both **ALARM**s and **STOP**s can be indicated by a separate relay closure (by default or selected assignment in XTC/3M, by fixed assignment in XTC/3S).

An **ALARM** condition is not fatal, XTC/3 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** parameter in the **Process** sub-screen of the **General Parameter** display to configure XTC/3 to treat an **ALARM** the same as **STOP** (i.e., halt processing upon detection of the abnormal condition).

3.5.1.1 Alarms

The following conditions are considered **ALARM**s by XTC/3 and result in the closure of the **ALARM** relay (if assigned):

- Crucible hearth selection is not validated by the **CRUC VALID** input within thirty seconds.
- Rate control not established during the first sixty seconds of **SHUTTER DELAY** (or twenty times the **TIME CONSTANT** if greater).
- Rate has been out of control in **DEPOSIT** for sixty seconds (or twenty times the **TIME CONSTANT** if greater). Out of control is defined as a rate error >0.5 Å/s and >5% of setpoint deposit rate.
- The source power has exceeded the **Maximum Power** parameter, set in the Source sub-screen of the Film Parameter display, for five continuous seconds.

3.5.1.2 Stops

The following actions or conditions produce a **STOP** state. This condition is indicated by the **STOP** message on XTC/3 and the closure of the **STOP** relay (if assigned):

- An intentional or accidental interruption of power, indicated by the **Power Loss** message.
- A **Switcher Fail** message appears as the result of a failure to detect a valid position in a multi-position sensor.
- Pressing the front panel **STOP** key on XTC/3 or handheld controller.
- Initiating a **STOP** via remote communication.
- 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 Power** parameter (**Option** sub-screen of the **Film Parameter** display) is set to **No** (when crystal switching is not available).
- Following the **POST-DEPOSIT** states of a layer when the **DEPOSIT** state completes in **TIME POWER**.
- Any of the **ALARM** conditions listed in section 3.5.1.1 above if the **Stop on Alarms** or **Stop on Max Power** configuration is activated (**Process** sub-screen of **General Parameter** display).

3.5.1.3 Recovering from STOP

An interrupted process can be completed (recovered) 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. If the **STOP** was generated by a machine induced condition such as a crystal fail, that condition must be corrected before the **START** command will be accepted. 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 accumulated at the time of the generation of the **STOP** is used. Thickness will accumulate in the normal fashion from that point. All processing occurs in the normal fashion from reentry of the **DEPOSIT** state, forward.

If it is not possible to recover as described above, the process may be reset to the beginning of layer one by issuing a **RESET** command prior to a **START** command. The **RESET** command may be given by pressing **RESET**, through the I/O or through the remote communications.

3.6 Special Features

3.6.1 Automating a Process

A process can be automated so that a complete process can be executed without having to press **START** between all the layers. A process can be automated by any of the following three methods:

- **Autostart Next Layer** (XTC/3M only): In the **Process** sub-screen of the **General Parameter** display, set this option to **Yes** by pressing **TOGL**.
- Remote communication control: An external computer could be set up to monitor the status of a process and issue **START** commands at desired times. (See Chapter 5, Remote Communications.)
- Remote input line. A remote input line can be activated to generate a **START** command. (See section 4.5.1 on page 4-27.)

3.6.2 Ion Assisted Deposition

This feature will activate the designated output if the film currently running is in **Deposit** and the **Ion Assist Deposit** parameter in the **Option** sub-screen of the **Film Parameter** display is set to **Yes**.

3.6.3 Control Delay

When the source shutter opens at the start of deposition, there often is a significant rate spike due to the sudden heat load arriving at the crystal. Typically, over a matter of seconds, the crystal equilibrates and becomes stable again. The **Control Delay** feature suspends action of the control loop on the source control power for a programmable time interval to prevent the control loop from responding to this temporary rate spike.

3.6.4 Shutter Delay

This feature ensures that no material is deposited on the substrate until the rate meets certain requirements. The source shutter relay remains in its normal state and the sensor shutter relay is active. The sensor, which must be positioned to sample the source flux with the source shutter closed, provides closed loop rate control. Rate control must be maintained at ± 5% Å/sec or ± 0.5 Å/sec, whichever is greater, of the desired deposition rate for five seconds before XTC/3 will enter the **DEPOSIT** state, opening the source shutter and thus exposing the substrate to a well controlled rate of evaporant flux. If the required rate control accuracy cannot be achieved within sixty seconds, the **Delay Failure** alarm message will appear. If **Stop on Alarms** has been set to **Yes**, the layer will **STOP** at the same time.

3.6.5 Rate Ramp Trigger of Final Thickness

To implement this type of film termination, program the **New Rate** value of the rate ramp to 0.1 Å/sec. When the rate ramp is complete, the film program will proceed as if a **Final Thickness** limit had been reached.

While a **Rate Ramp** is being processed, the **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; the film will complete at the programmed **Final Thickness**.

3.6.6 Transfer Sensor

This function provides for the use of a secondary sensor, specified as the **Transfer Sensor**, to establish rate control in **Shutter Delay** prior to entering **Deposit**, then transferring back to the film's sensor upon entering **Deposit**. The function is selected in the **Option** sub-screen of the **Film Parameter** display. **Delay** option must be set to **Shutter Delay** or **Both** for the **Transfer Sensor** function to be accessible. If rate control is not achieved (see page 4-14) the **Delay Failure** Alarm message appears. If **Stop on Alarms** is in the default setting of **No**, the power continues to increment until **Max Power** is reached.

3.6.7 Crucible Switching

Crucible position output lines can be used to control evaporation sources with up to eight crucible positions. When the **Crucible** parameter for a source is set to be non-zero, power will not be applied to the source until the **Cruc x Valid** input becomes active. A **Crucible Sw** message will be displayed during that time. After thirty seconds without the **Cruc Valid** input becoming true (low), a **Crucible Sw Fail** message will be displayed.

3.6.7.1 Bin Mode

In Bin mode, eight individual sequential outputs, labeled **Cruc Src 1 Bin** for **Source 1** crucibles or **Cruc Src 2 Bin** (XTC/3M only) for **Source 2** crucibles, one per position, are used. See Table 2-3 on page 2-10 for the fixed XTC/3S TTL output assignments. These assignments will apply to the currently active source, 1 or 2. In XTC/3M, either 8 sequential relay outputs or 8 sequential TTL outputs can be assigned (see section 4.5.3 on page 4-29).

3.6.7.2 BCD Mode (XTC/3M only)

In BCD mode, three sequential outputs are used so that 000 represents position 1 and 111 represents position 8. The BCD outputs, labeled **Cruc Src 1 BCD** for **Source 1** crucibles and **Cruc Src 2 BCD** for Source 2 crucibles, can be configured through the **Relay or TTL Outputs** sub-screen of the **I/O Map** screen. (See section 4.5.3 on page 4-29.)

3.6.8 Crystal Switching

XTC/3 offers a choice of Single, CrystalTwo, CrystalSix, Crystal12, Rotary or Dual Head sensors. The CrystalTwo, CrystalSix, Crystal12, Rotary and Dual Head sensors provide one or more backup crystals in case a crystal fails during deposition. Sensor types are specified on the **Hardware** sub-screen of the **General Parameter** display (see page 4-21).

The CrystalTwo option requires the PN 750-212-G2 Dual Sensor with a PN 779-220-G1 or PN 779-220-G2 XTAL 2 Switch.

The Dual Head option requires the PN 750-212-G2 Dual Sensor with a second XIU in place of the PN 779-220-Gx XTAL 2 Switch. The normally uncovered crystal is connected to Sensor 1, the backup crystal normally covered by the shutter is connected to Sensor 2.

All multi-position and shuttered sensors require the Solenoid Valve (PN 750-420-G1) and a feedthrough with an air tube.

A crystal (sensor in the case of Dual Head) switch will automatically occur when:

- XTC/3 is configured for a **CrystalTwo** or **Dual Head** sensor type, a film is **START**ed or running and there is another good crystal available when the active crystal fails.
- XTC/3 is configured for a **CrystalSix** or **Crystal12**, a film is **START**ed or running, and there is at least one good crystal left in the carousel when the active crystal fails.
- XTC/3 is configured for a **Rotary** sensor, the film is **START**ed or running, and there is at least one remaining good position in the Rotary sensor when the active crystal fails.

During a crystal switch while in **Deposit**, the thickness will be accumulated at the setpoint rate. Power will be held constant at the average deposition power during the prior 6.25 seconds, not counting the last two seconds.

A crystal switch will not automatically occur:

- During a state of **STOP**, **READY**, or **IDLE**.
- During deposition, if the secondary crystal of a Dual Sensor fails, or the last good crystal of a Rotary, CrystalSix, or Crystal12 fails, a **TIME-POWER** or **STOP** will occur, depending on whether **TIME-POWER** option **Yes** or **No** is chosen.)

A crystal switch can be manually executed via the front panel **XTSW** key, handheld controller or remote communications when the system is configured for CrystalTwo, CrystalSix, Crystal12, Rotary or Dual Head sensors.

NOTE: The crystal fail message appears when no more good crystals remain.

3.6.8.1 CrystalTwo

In the case of the CrystalTwo (PN 750-212-G2 Dual Sensor with PN 779-220-G1 or PN 779-220-G2 XTAL 2 Switch), the CrystalSwitch output must be wired so that it simultaneously energizes the:

- Solenoid Valve (PN 750-420-G1) which applies the air pressure to actuate the dual sensor shutter mechanism.
- RF relay in the XTAL 2 Switch, exposing crystal #2 while covering crystal #1 and rerouting the RF signal.

This allows the dual sensor to be operated with only one oscillator kit and requires only one sensor connection at the controller. Power-up initialization is performed on a dual sensor to verify that the back-up crystal is good. If a crystal fail occurs while in **Deposit**, the XTC/3 will switch to the backup crystal and continue. If **START** is attempted following completion of the layer and the next layer uses the same sensor, **START** will not be accepted (unless **Start Without Backup** is set to **Yes**), and the message **No Backup Crystal** appears.

The **Crystal Fail** state can be cleared by pressing **TOGL** in the **Sensors** screen with the cursor on **Clear Failed Crystals** or by powering down and up again. In both cases, XTC/3 will run the next layer using the last crystal position it switched to. **Crystal Fail** can also be cleared by executing a crystal switch from the front panel with the **XTSW** key, by pressing **TOGL** in the **Sensors** screen with the cursor on **Switch Crystal** or via communications commands R14 (Crystal Switch) or R26 (Clear All Crystals). A good crystal must be available to switch to in the case of using the crystal switch method.

3.6.8.2 CrystalSix

On power-up, all crystals are read to determine how many good and bad crystals are present. XTC/3 uniquely identifies and tracks all six positions in the CrystalSix.

During deposition, XTC/3 will automatically switch to the next position with a good crystal when there is a crystal failure. When the last good crystal fails, XTC/3 will go directly to **Time Power** or **STOP**, as appropriate.

When the sensor selected is a CrystalSix, the relay contacts are pulsed closed for one second, opened for one second, closed for one second, then opened for each position. 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.

3.6.8.3 Crystal12

When first turn on, XTC/3 will rotate the sensor until position one is detected. Then XTC/3 will continue to rotate through the other eleven positions to determine the state of all crystals. At the conclusion of the sequence, the **Sensor** screen shows the sensor in position one and the position number of any failed crystals.

XTC/3 verifies that the resistance value is correct at each position. If the value is not as expected, XTC/3 pulses again and rechecks the position. If position one is not detected, or after twelve pulses of the wrong value, XTC/3 reports a **Crystal Sw Fail** message. In that case, all crystals are also marked as failed.

When the carousel is removed from the sensor for crystal replacements, XTC/3 displays **Carousel Open**. This message also appears if there is no connection between the XIU (oscillator) and the sensor.

After the carousel is replaced, XTC/3 assumes the current position is twelve and all crystals are failed. A **Crystal Switch** or **Rotate Head** function must be initiated in the **Sensor** screen or via Remote Communication to enable XTC/3 to catalog the state of all crystals and to return to position one. This must also be done after the sensor type has been changed to **Crystal12**. The **Rotate Head** function is permitted only in **Ready** or **Idle** at the end of a process.

During deposition, XTC/3 will automatically switch to the next position with a good crystal when there is a crystal failure. When the last good crystal fails, XTC/3 will go directly to **Time Power** or **STOP**, as appropriate.

When configured for a Crystal12 sensor, the relay contacts are only pulsed closed for one second then opened again once for each position. There is no intermediate position.

3.6.8.4 Rotary Sensor Crystal Switching

Selecting Rotary sensor type enables sequential crystal switching only for six positions. Upon a crystal switch, the Crystal Switch Output will close for one second and then open (i.e., one pulse to move one position); there is no intermediate position. XTC/3 will not keep track of which position the Rotary Sensor is on nor will it keep track of which crystals are good and which are failed. All crystals are assumed to be good following a **START** command. After the one-second pulse, XTC/3 will attempt to find the resonant frequency for the crystal in this position. If XTC/3 is in **Deposit** and does not find a good resonant frequency for this crystal, it will again pulse the Crystal Switch Output for one second and attempt to find a resonant frequency at this new position.

There will be a maximum of five attempts to find a good resonant frequency (i.e., a maximum of five pulses of the crystal switch output). If a good resonant frequency is not found after five attempts, XTC/3 will then enter the **Time Power**, **Idle-Ramp** or **STOP** state depending on whether **Time Power** in the **Option** sub-screen of the **Film Parameter** display is set to **Yes** or **No**.

3.6.8.5 Dual Head

Only Sensor 1 may be configured as a Dual Head, (PN 750-212-G2 Dual Sensor with second XIU). Sensor Shut 1 output must be wired so that it energizes the Solenoid Valve which applies the air pressure to actuate the dual sensor shutter mechanism, exposing crystal #2 (**Sensor 2**) while covering crystal #1 (**Sensor 1**). Power-up initialization is performed to verify that the back-up crystal is good. If a crystal fail occurs while in **Deposit**, the XTC/3 will switch to the backup crystal and continue. There will not be an automatic crystal switch on failure from the backup crystal #2 back to crystal #1 even if crystal #1 was not failed.

If **START** is attempted following completion of the layer and the next layer uses the same sensor, the **START** will not be accepted (unless **Start Without Backup** is set to **Yes**), and the message **No Backup Crystal** appears. The **Crystal Fail** state can be cleared by pressing the **TOGL** key in the **Sensors** screen with the cursor on **Switch Crystal**, by pressing the **XTSW** key from the **Operate** screen, via communications command R14 (Crystal Switch) or by powering down and up again and executing **RESET** or **START**. A good crystal must be available to switch to in all cases. **RateWatcher** is not available with the Dual Head configuration but the **Transfer Sensor** function is allowed.

3.6.8.6 XTC/3S Sensor Shutter / CrystalSwitch Output

Due to limitations imposed by the fixed I/O functions in XTC/3S, the function of the Sensor Shutter outputs depends on the **Sensor Type** setting in the **Hardware** sub-screen of the **General Parameter** display.

If a single head sensor type is chosen, the Sensor Shutter relay contacts are set to be inactive. The Sensor Shutter relay contacts become active (opening the shutter) when entering the **Deposit** state, **Shutter Delay** or **Control Delay**, or during the **Sample** period of the **RateWatcher** function.

If a multi-position sensor type is chosen, the Sensor Shutter relay now functions as a CrystalSwitch relay. The Sensor Shutter relay contacts are active upon initiating a **CrystalSwitch**. Due to the change in function of the relay output from that of Sensor Shutter to one of CrystalSwitch, **RateWatcher** is disabled when XTC/3S is configured for a multi-position sensor.

In XTC/3M, there are separate sensor shutter and crystal switch options so RateWatcher and multi-position sensors may coexist.

3.6.9 Start Layer Without Backup Crystal Configuration

The following applies only when a film specifies a multi-position sensor like a CrystalTwo (PN 750-212-G2 Dual Sensor with PN 779-220-G1 or PN 779-220-G2 XTAL 2 Switch), CrystalSix, Crystal12, Rotary Sensor or Dual Head.

If **Start Without Backup** is set to the default mode **No**, a layer cannot be started unless there are at least two known good crystals present in the multi-position sensor. One of these will be the current crystal in use, the other will be a known good backup crystal.

If **Start Without Backup** is set to **Yes**, a layer with a multi-position sensor can be started even if there is only one good crystal.

Additionally, if **Start Without Backup** is set to **Yes** and XTC/3 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.

3.6.10 RateWatcher

It is easy to automatically sample the deposition rate periodically and then maintain the proper source power level necessary to keep the 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 utility of the crystal monitor for in-line or load-locked systems.

The RateWatcher feature requires entry of two parameters in the **Deposit** sub-screen of the **Film Parameter** display. First, the process engineer must decide on the **RW Accuracy** percent (see RW ACCURACY 1 to 99% on page 4-8). This parameter sets the accuracy that must be maintained for at least five seconds in order to leave the **Sample** state.

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

Second, the **RW Hold** time must be programmed (see RW HOLD 00:00 to 99:59 min:s on page 4-8). 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 mm:ss for automatic operation. If longer intervals or periodic samples are needed, **RW Sampl Init** and **RW Sampl Inhib** inputs are available on the SYSTEM I/O connector. During the **RateWatch Hold** period, thickness is accumulated at the setpoint **Rate** and power is held at the internally computed **Time-Power** value. At the end of the **RateWatch Hold** period, **RateWatch Delay** will be displayed for five seconds before the **RateWatch Sample** message appears. During the **RateWatch Sample** period, the power will be adjusted according to the control loop parameters.

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

NOTE: In XTC/3S, the RateWatcher function is disabled if the sensor type is configured for a multi-position sensor head. Also, RateWatcher cannot be used with the Dual Head configuration.

3.6.11 Hand-held 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 handheld controller is connected to XTC/3 with a coiled cord and attaches with a modular plug to the front panel of XTC/3. The **POWER/STOP** switch located at the top of the controller is asymmetrical to increase awareness of the direction of power increment and decrement.

When XTC/3 is placed in the **Manual Power** mode by pressing the **MPWR** key, power is affected by moving the **POWER/STOP** switch laterally. A **STOP** is produced by pressing **POWER/STOP**.

A crystal switch is activated by pressing the red button on the body of the XTC/3. This action alternates the active crystal of a dual head configuration or advances the multi-position sensor to the next available crystal.

NOTE: Upon leaving the **MANUAL POWER** state, XTC/3 enters the **DEPOSIT** state. The deposition will terminate if the **Final Thickness** parameter value has been exceeded.

The Hand-held Controller includes a convenience hook for the controller that can be attached to XTC/3 or other accessible location.

3.6.12 Lock Code

If a Lock Code has been entered in the **Process** sub-screen of the **General Parameter** screen, the **L Lock** message will be displayed. If XTC/3 has been locked via Remote Communications, the **R Lock** message will be displayed. Parameters may be viewed but not changed from the front panel, unless the lock code is reentered on the **Menu** screen while the cursor is positioned at the **LOCK Code** selection.

A lost lock code may be cleared by pressing the **CLEAR** key immediately on power-up and holding it briefly. User programmed parameters will be retained.

NOTE: If no lock code is present, all parameters will be cleared.

3.6.13 Parameter Clear

If no Lock Code is present, all user-programmed parameters are cleared, except for the IP Address, setting them to their default values, by pressing the **CLEAR** key on power up. Repeat the process if a Lock Code was present.

3.6.14 Datalog

If the communication type is set to **Datalog**, the RS-232 port will become a "send only" port (i.e., will not accept commands from a remote computer). When a layer leaves deposit (either at the end of deposit or following a Stop), a stream of data will be output. The data is a series of ASCII strings, each separated by a carriage return and a line feed, in the order below:

1. Layer x
2. Film x (x = film number or the name if the name (XTC/3M only) is programmed)
3. Rate = xxx.x Å/s (0.0 - 999.9)
4. Thickness x Å (x = 0 - 999999 Angstroms)
5. Deposit Time = xx:xx Min:S

6 Average Power = xx.x %

7 S Value = 0 to 9999

8 Q Value = 0 to 99

9 Begin Frequency = xxxxxxxx.x Hz

10 End Frequency = xxxxxxxx.x Hz

11 Xtal Life = xx % (0 - 99)

12 Normal Completion or

13 End On Time Power or

14 End In Stop from (Stop Reason). Stop Reasons are one of the following:

- Keyboard
- Xtal Fail
- Max Power
- Hand Controller
- Communications
- Digital Input
- Power Loss
- Rate Dev Fail
- Crystal Switch Fail

NOTE: If the layer is the first one of a process, a preface **Begin Process xxx** (xxx is the process number or name (XTC/3M only), if the name is programmed.) is output. If the layer is the last one of the process, a postscript **End Process** is output. The data log information is available via the remote communications S19 command. See Remote Communication status commands, section 5.2.2.5 on page 5-28 or section 5.3.5.5 on page 5-42.

3.6.15 TCP/IP

The optional TCP/IP interface will provide all the commands available through the standard RS232 interface. The interface uses a static address entered via XTC/3 front panel (see section 4.4.3.1 on page 4-25).

DHCP is not supported.

Chapter 4
XTC/3 Programming

4.1 Overview

The following basic procedure is used to program XTC/3. If a lock code has been programmed, it must be entered after cursoring to the Lock Code on the **Menu** screen. (All steps do not necessarily have to be followed in the given order.)

1 **Make sure XTC/3 is in READY.**

Some configuration and process parameters can be changed only while XTC/3 is in **READY**. Parameters such as tooling, rate, final thickness, control loop settings and many others can be changed even while a layer is being executed. For initial configuration, if the **Operate** display does not show **READY**, press **STOP** then **RESET**.

2 **Define Film(s)**

Defining a film consists of entering parameters in five sub-screens:

- **Pre/Post (Deposit)**
- **Deposit**
- **Sensor**
- **Source**
- **Option**

These parameters establish source preconditioning and cool-down, deposition rate, final thickness, control loop characteristics and other details such as density, Z-Ratio, and tooling. Also, a specific sensor and source are associated with each film. In XTC/3M, all films can be given names.

3 **Define Process(es) (XTC/3M only)**

Only one **Process** can be active at any time. All processes can be given a specific name. A process is an ordered set of **Films**. **Films** are entered in the desired layer order on the **PROCESS** display. A Film becomes a layer when it is entered in the **Process**. Only one layer can be active at any time. In XTC/3M, all processes can be given names.

4 Configure General Parameters

From the **General Parameter** display, three sub-screens can be accessed: **Process**; **Hardware**; and **Comm Info**. The **Process** screen provides for a number of selections including which process (XTC/3M) or film (XTC/3S) to run. The **Hardware** screen allows selecting the sensor type, source control voltage range and polarity, chart recorder mode, audio feedback and LCD dimmer time. In the **Comm Info** screen, RS232 baud rate and protocol are selected as well as IP Address and Net Mask for the optional TCP/IP interface.

4a Configure the Sensor(s)

Configuring the sensor type involves designating whether the sensor is a **Single**, **CrystalTwo**, **CrystalSix**, **Crystal12**, **Rotary** or **Dual Head**. These parameters are on the **Hardware** page of the **General Parameter** display.

4b Configure the Source(s)

Configuring the sources involves selecting the digital-to-analog voltage converter (DAC) output voltage range and polarity on the **Hardware** page of the **General Parameter** display. If a source has more than one crucible, this is set up in the **Source** screen of the **Film Parameter** display.

4c Configure Communications

If required, select the appropriate **RS232** baud rate and protocol and optional **Ethernet** interface **IP Address** and **Net Mask** in the **Comm Info** sub-screen of the **General Parameter** display.

5 Configure I/O

In XTC/3S the I/O is fixed. In XTC/3M, inputs and outputs are programmable.

4.2 Film Set Up Overview

4.2.1 Film Set Up

The film screen appears after pressing the **MENU** key, then cursoring down to **Film Parameter** and pressing **Menu**.

Figure 4-1 Main Menu screen XTC/3M

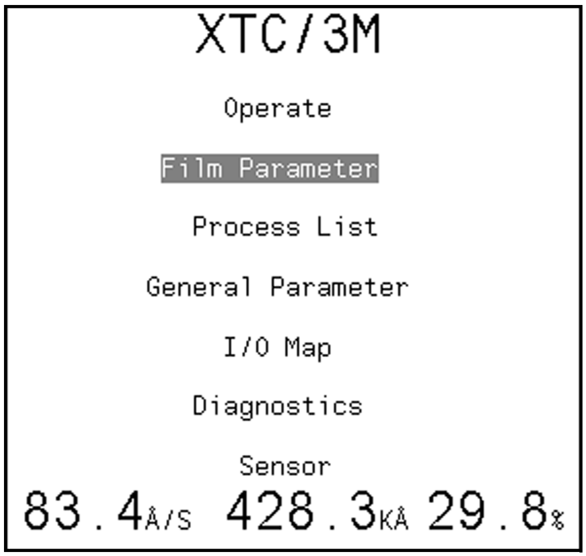
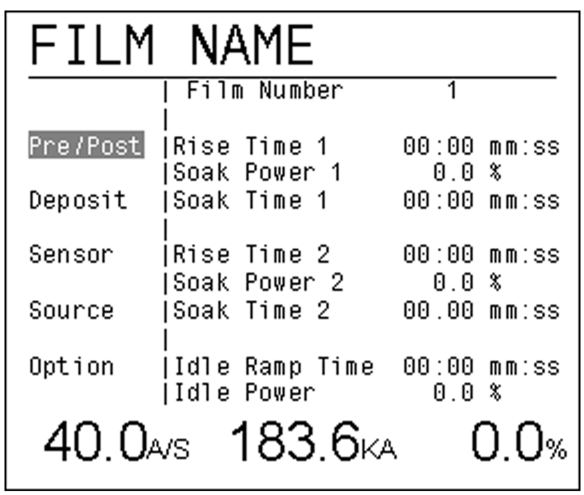


Figure 4-2 Pre/Post Film Programming Screen



From the **Film Parameter** display, **Pre/Post**, **Deposit**, **Sensor**, **Source** and **Option** screens can be entered by cursoring to the respective label. The ◄ ► keys move between the selection (left) panel and the parameter (right) panel. The ▲ ▼ keys are used to move from selection to selection or parameter to parameter. The value of most of the film parameters can be updated using the numeric keypad and **ENTER** key. In a few cases, e.g., **Transfer Sensor**, the **TOGL** key is used to toggle between a list of choices.

4.2.2 Film Definition

A film is defined by the parameters needed to run it, including sensor and source numbers, source heat-up and cool down parameters, deposition rate and final thickness, material parameters, control loop parameters, etc. XTC/3M can define 32 films which can be named. All films will start with defaulted values for the parameters. These can be modified in any order. A film becomes a layer in a process when its film number is selected in the process.

XTC/3S does not have processes or layers. Nine films, 1 to 9, may be defined but not named, and a **General** parameter will indicate which film to run.

On entering the film screen, the film displayed will be the one displayed when this screen was last left. A different film can be displayed by moving to the **Film Number** and entering that film number.

If the parameters are locked from the keyboard, the **L Lock** message will be displayed in the upper right corner. If they are locked via Remote Communications, the **R Lock** message will be displayed. The parameter values will be displayed only and cannot be changed until the lock code is entered. With the parameters locked, the film number may still be changed to allow viewing of other films.

4.2.3 Film Definition Parameters

The Film parameters are entered in the Pre/Post, Deposit, Sensor, Source and Option screens.

4.2.3.1 Pre/Post Deposition Parameters

RISE TIME 1 . . . . 00:00 to 99:59 min:s

This parameter provides the time period over which the source power is ramped from 0 to **SOAK POWER 1**. The default value is 00:00.

SOAK POWER 1 . . . . 0.0 to 100%

This parameter is usually set to the power level at which the source material just begins to melt. XTC/3 ramps the power level from zero to **SOAK POWER 1** linearly over the time period **RISE TIME 1**. The default value is 0%.

SOAK TIME 1 . . . . 00:00 to 99:59 min:s

This parameter provides the time period for which XTC/3 holds at **SOAK POWER 1**. The default value is 00:00.

RISE TIME 2 . . . . 00:00 to 99:59 min:s

This parameter provides the time period over which the source power is ramped to **SOAK POWER 2**. The default value is 00:00.

SOAK POWER 2 . . . . 0.0 to 100%

This parameter is usually set to the power level at which the source material evaporates material at about the target rate. XTC/3 ramps the power level from **SOAK POWER 1** to **SOAK POWER 2** linearly over the time period **RISE TIME 2**. The default value is 0%.

SOAK TIME 2 . . . . 00:00 to 99:59 min:s

This parameter provides the time period for which XTC/3 holds at **SOAK POWER 2**. The default value is 00:00.

Idle Ramp

The next two parameters define an idle ramp provided to maintain the control voltage power level after the **Deposit** state. Control voltage is ramped from the power level at the end of the **Deposit** state to the **Idle Power l**evel. The control voltage is maintained at the **Idle Power** level until XTC/3 enters **STOP** or until the next layer, using the specified source, is started, or the turret source is rotated.

NOTE: If the next layer started uses the source at the non-zero idle power, **Rise 1** and **Soak 1** states are skipped in the pre-deposit sequence.

IDLE RAMP TIME . . . . 00:00 to 99:59 min:s

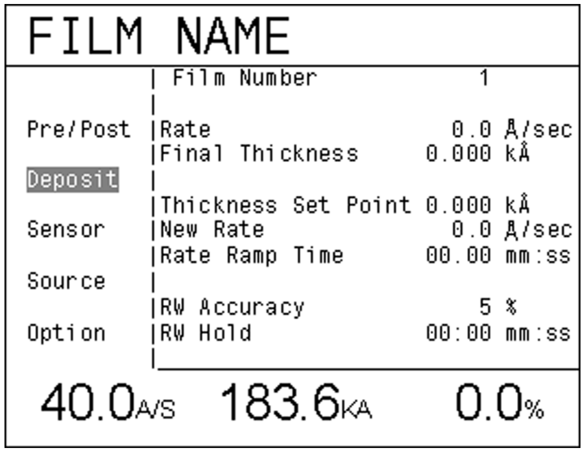
This is the time interval over which the source power is ramped linearly from the power level at the end of **Deposit** to the **Idle Power**. The default value is 00:00.

IDLE POWER . . . . 0.0 to 100%

This is one of two parameters used to effect an **Idle Power Ramp**. This value is the power level at which the source is maintained after the **DEPOSIT** phase. If the material will be used in a subsequent layer, and if it is desired to reduce cycle time, **IDLE POWER** should be set to the same value as **SOAK POWER 1**.
RISE TIME 1 and **SOAK TIME 1** states will be skipped if the **IDLE POWER** is non-zero. The default value is 0%.

4.2.3.2 Deposit

Figure 4-3 Deposit Film Programming screen



FILM NUMBER . . . . 1 to 32 (XTC/3M)
1 to 9 (XTC/3S)

RATE . . . . 0.0 to 999.9 Å/s

This specifies the rate at which the deposition is to be controlled during the **DEPOSIT** and **Shutter Delay** states. A value of 0.0 Å/sec allows skipping of the deposit state. The default value is 0.0 Å/sec.

FINAL THICKNESS . . . . 0.000 to 999.9 kÅ

This is the thickness setting that triggers the end of the **DEPOSIT** state. The Source Shutter and Crystal Shutter relays return to their normal states and the **Layer** enters the **Idle Ramp** state. The default value is 0.000 kÅ.

THICKNESS SET POINT. . . . . 0.000 to 999.9 kÅ

This sets the thickness at which the **Thickness Set Point** is triggered and the **New Rate** (if non-zero) is initiated. This thickness begins to accumulate after entering the **Deposit** state. The state remains active after reaching the **Thickness Set Point** until the beginning of the **IDLE** state.
The default value is 0.000 kÅ.

NEW RATE. 0.0 to 999.9 Å/sec

This value sets the newly desired control rate when the **Thickness Set Point** is reached. The default value is 0.0 Å/sec which disables the feature. A value of 0.1 Å/sec triggers **Final Thickness** at the end of the **Rate Ramp Tim**e, see section 3.6.5 on page 3-25.

RATE RAMP TIME. . . . . 00:00 to 99:59 min:s

This value determines the time period over which to ramp the rate from the original rate to the **New Rate**. The default value is 00:00.

RW ACCURACY . . . . 1 to 99%

During the rate sampling period, the deposition rate is measured by the crystal and source power control is active. When the measured rate is within the desired accuracy continuously for five seconds, the shutter is closed and the deposition state returns to **HOLD**. The minimum accuracy is 1% or 0.5 Å/s, whichever is greater. The default value is 5%.

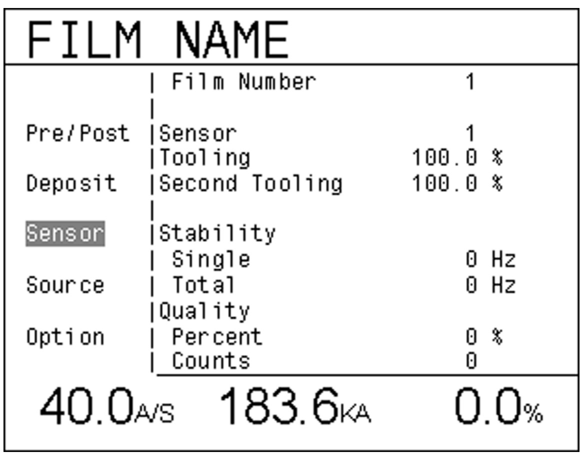
RW HOLD . . . . 00:00 to 99:59 min:s

RW HOLD determines the time interval between sample periods. The crystal shutter relay is in its normal state during this time.
The default value is 00:00, which disables the function.

During a **Rate Ramp**, the **Sample** and **Hold** feature is inactive; the crystal shutter is open and the rate is controlled by the crystal.

4.2.3.3 Sensor Parameters

Figure 4-4 Sensor Film Programming screen



SENSOR 1, 2

Selects the sensor to use for the film. Default value is 1.

TOOLING. . . . . 10.0 to 500.0%

The **TOOLING** parameter applies to the primary crystal.

SECOND TOOLING. . . . . 10.0 to 500.0%

The **SECOND TOOLING** parameter applies when the Crystal Two's crystal switch relay becomes active. This parameter is not accessible unless a Crystal Two sensor is in use.

The default value for both is 100%.

Tooling is a correction factor used for correlating the rate and thickness accumulation on the crystal with the thickness accumulation on the substrate. This thickness difference is due to the geometric distribution of material flux from the source.

The tooling factor is calculated using the equation:

$$\text{Tooling} = TF_i \times \left(\frac{T_m}{T_x}\right) \quad [1]$$

where TF_i = Initial Tooling Factor, T_m = Actual Thickness at the Substrate, and T_x = Thickness on the Crystal.

If the **TOOLING** parameter is changed, the new **TOOLING** value is used for subsequent calculation of the rate and thickness. Also, the thickness accumulated thus far will be re-scaled based on the change to the **TOOLING**.

4.2.3.3.1 Setting S&Q Parameters (Soft Crystal Failures)

At some point during deposition the crystal may become unstable or erratic yet continue to oscillate within XTC/3 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 **Stability** and/or **Quality**, various improvements in process control can be achieved if one or more backup crystals are available. XTC/3 can be made to automatically switch to a different crystal and continue the deposition normally, or complete the run in the **TIME-POWER** mode or even terminate the process if a backup crystal is not available.

4.2.3.3.2 Stability

Under ideal conditions, the crystal's frequency will only decrease during a deposition due to the added mass of the material accumulating on the crystal. Occasionally however, the crystal's frequency may increase during a deposition as a result of an undesired external influence. **Stability** selects the permissible increase in frequency between successive measurements of the sensor before the crystal is declared failed and an automatic crystal switch is initiated (if a backup crystal or sensor is available) or the layer is completed in **TIME-POWER** mode or ends in **STOP**.

There are many reasons for a crystal to exhibit an increase in frequency. 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, an increase in frequency may occur due to film stress relieving or a film tearing off a crystal. Additionally, temperature effects may cause an increase in frequency. 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 increase until thermal equilibrium is obtained. When the active process ends and/or the shutter closes, the crystal frequency will decrease due to cooling. Because small increases in frequency may normally and unavoidably occur, values of 1 to 24 are not allowed for the **Single** and **Total** Stability parameters to prevent false triggering of crystal fails.

NOTE: Stability is disabled in **Etch** mode.

SINGLE . . . . 0 Hz and 25 to 9999 Hz (Values 1 to 24 are not allowed)

This sets the maximum permissible increase in frequency from one measurement to the next. The default value is 0 Hz which disables the function.

TOTAL . . . . 0 Hz and 25 to 9999 Hz (Values 1 to 24 are not allowed)

This sets the maximum total permissible increase in frequency accumulated during the active layer. The default value is 0 Hz which disables the function.

NOTE: After a crystal fails due to exceeding the allowable Hz value, the **Crystal Fail** state can be cleared by installing a new crystal or pressing the **TOGL** key in the Sensors screen with the cursor on **Clear S & Q**.

4.2.3.3.3 Quality

Quality selects the permissible rate deviation in percent of the measured rate relative to the desired rate and how many measurements must be outside the range before the crystal is declared failed.

PERCENT . . . . 0 to 99% and > 0.5 Å/sec

This sets the deviation that must be exceeded to cause the **COUNTS** to increment. The default value is 0% which disables the function.

COUNTS . . . . 0 to 99

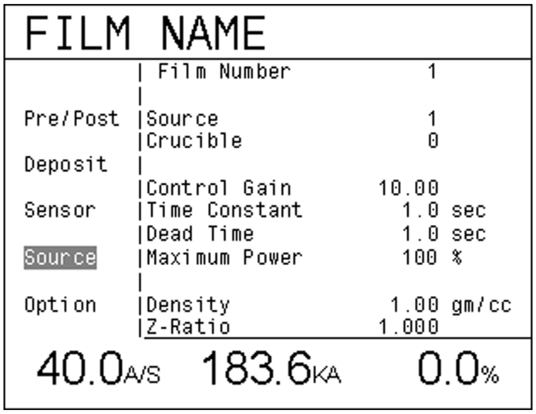
This sets the number of measurements that must be outside the allowed Percent before the crystal is declared failed. If the rate deviation relative to the programmed rate is greater than the programmed threshold limit, the **COUNTS** value is incremented. If the rate deviation is less than the programmed threshold, the **COUNTS** value is decremented. **COUNTS** is not allowed to have negative values. If **COUNTS** exceeds the value programmed, XTC/3 will automatically crystal switch, complete the process on **TIME-POWER** or **STOP** the process. The rate deviation is computed on each individual rate measurement during the deposit phase, i.e., every 250 ms. Upon entering **Deposit**, the **Quality Count** is delayed by a time equal to four times the **Time Constant** plus the **Dead Time**, to allow for normal control loop stabilization. The **Q Count** on the **Operate** screen will show **Delay** when in pre-deposit, and during the delay period at the beginning of **Deposit**.

The default value is 0, which disables the function.

NOTE: After a crystal fails due to exceeding the **COUNTS** value, the **Crystal Fail** state can be cleared by installing a new crystal or pressing the **TOGL** key in the **Sensors** screen with the cursor on **Clear S & Q**.

4.2.3.4 Source Parameters

Figure 4-5 Source Film Programming screen



SOURCE 1, 2

This parameter determines which source output is to be used for source control voltage for the material being defined. The default is 1. This parameter cannot be changed while the film is running.

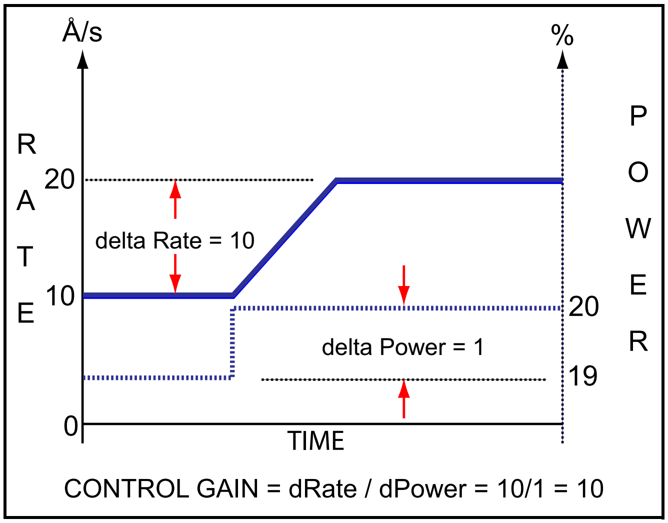
CRUCIBLE. . . . . 0 to 8

This parameter can be used to automatically index the turret position when using a multiple pocket turret source. The value selected denotes which pocket of the turret source to use on this film. The default value is 0 and indicates a single pocket source. If a non-zero value is entered, the appropriate outputs are activated automatically. Source power will not be applied until the appropriate **Cruc Valid** input is activated.

CONTROL GAIN . . . . . . 0.01 to 100.0 Å/sec/% Pwr

This parameter determines the change in % Power for a given rate deviation (dRate/dPower). The larger the process gain value, the smaller the change in power for a given rate error. The default is 10 Å/s/% Pwr.

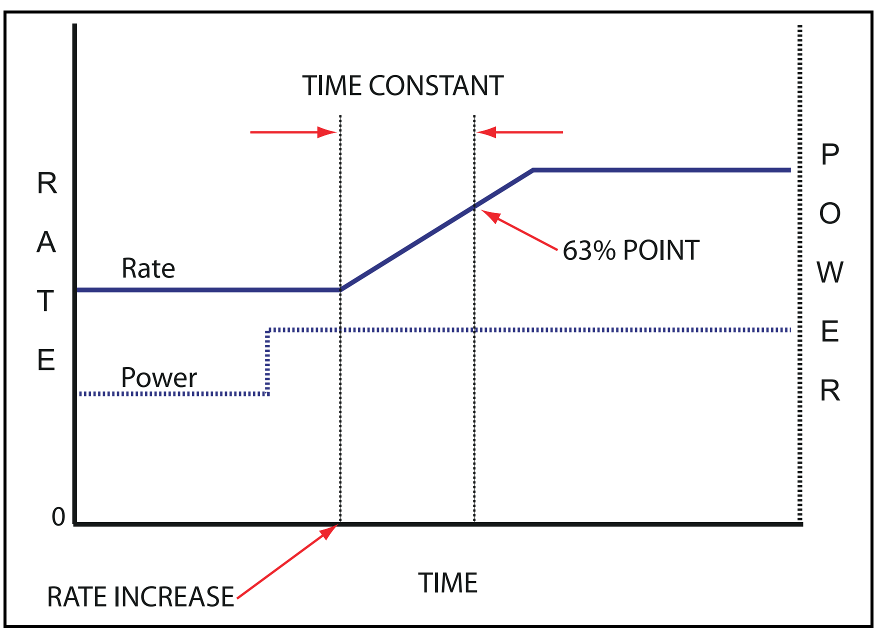
Figure 4-6 Control Gain



TIME CONSTANT . . . . . 0.1 to 100.0 sec

This is the evaporation source's time constant. This value is defined as the time difference between the actual start of a change in rate and the time at which 63% of the rate step is achieved. This value may be measured according to the above criterion or it may be determined empirically. The default value is 1.

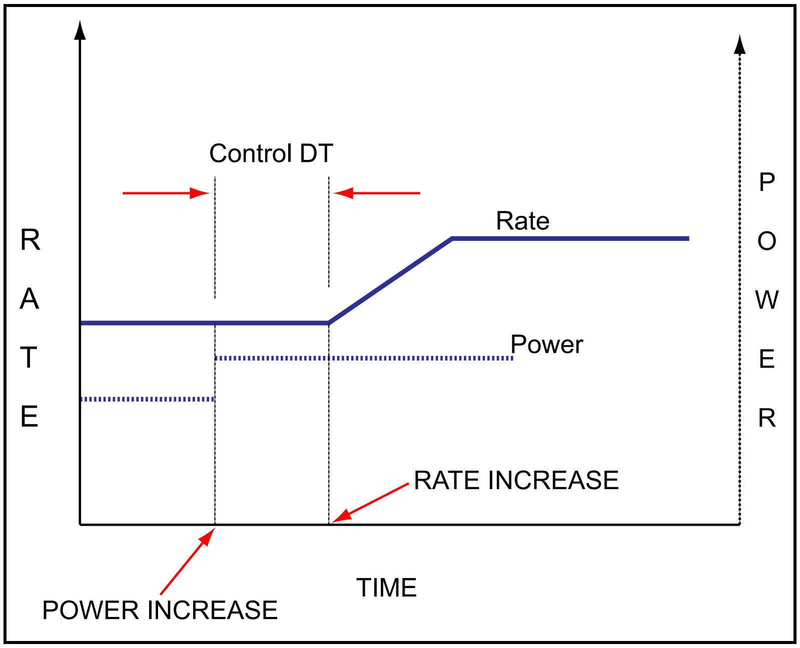
Figure 4-7 Time Constant



DEAD TIME . . . . 0.1 to 100.0 sec

This value is defined as the time difference between a change in % power and the start of an actual change in rate. The default value is 1.

Figure 4-8 Dead Time



MAXIMUM POWER . . . . 0.0 to 100.0%

This parameter is used to set the maximum permissible % power level. The control voltage output will not exceed this limit. The default value is 100.0%.

DENSITY . . . . 0.50 to 99.99 g/cm^3

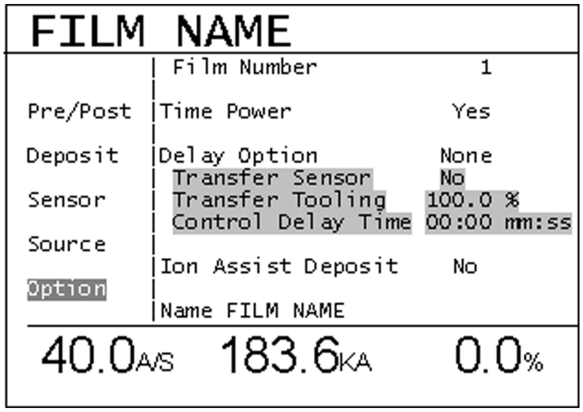
This parameter is specific to the material being deposited onto the crystal. It is one of two parameters that relate the mass loading on the crystal to a thickness.
The default value is 1.00 g/cm^3.

Z-Ratio . . . . 0.100 to 9.999

This parameter is specific to the material being deposited. It is one of two parameters that relate the mass loading on the crystal to a thickness.
The default value is 1.000. See Chapter A for material density and Z-Ratio values.

4.2.3.5 Option

Figure 4-9 XTC/3M Option Film Programming screen



TIME POWER . . . . Yes / No using TOGL key. Default is No.

The **Time-Power** state will only be entered while XTC/3 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 when there is no backup crystal. If a crystal fail is detected during the pre-deposit states XTC/3 will not sequence further, causing an XTC/3 **STOP** even if the complete on **Time-Power** (**Yes**) option is selected.

Once in the **Time-Power** state, the source power will remain at the four seconds average power value of the source control output computed two seconds prior to the failure. (These times are appropriately modified for PID control.) Thickness is accumulated at the programmed deposition **RATE** value. The **Time-Power** state will terminate when the **FINAL THICKNESS** value has been exceeded.
Any post-deposit states will be executed exactly as if a normal deposition had occurred. When the post-deposit states are complete, XTC/3 will end the layer and display **STOP**. A **RATE RAMP** cannot be executed in **Time-Power** and that state is consequently skipped.

DELAY OPTION. . . . . None, **Shutter**, **Control**, **Both**.

Press the **TOGL** key to move through the choices. The default value is **None** for no delay chosen.

Shutter. . . . . **Shutter Delay** state immediately following **Soak Power 2** and preceding **DEPOSIT**. The source shutter relay remains in its normal state and the sensor shutter relay is active. The sensor, which must be positioned to sample the source flux with the source shutter closed, provides closed loop rate control.

Rate control must be maintained at +/-5% or +/- 0.5 Å/sec, whichever is greater, of the desired deposition rate for five seconds before XTC/3 will enter the **DEPOSIT** state, opening the source shutter and thus exposing the substrate to a well controlled rate of evaporant flux. If the required rate control accuracy cannot be achieved within sixty seconds, the **Delay Failure** alarm message will appear. If **Stop on Alarms** has been set to **Yes**, the layer will **STOP** at the same time.

Control . . . . **Control Delay** state. The **Deposit** state is entered and the **Control Delay** suspends control loop action on the source control power for the time interval programmed in **Control Delay Time.**

Source and sensor shutters are activated during **Control Delay**. After the **Control Delay Time** elapses, control loop action is initiated.

Both . . . . XTC/3 will first enter a **Shutter Delay** state followed by **Control Delay**.

TRANSFER SENSOR . . . . Yes / No

Press the **TOGL** key to move through the choices. Default is **No**. This feature can only be enabled when the **Delay** option **Shutter** or **Both** has been enabled. In addition, a second sensor must be available to use this feature. If set to **Yes**, XTC/3 will use the second sensor for rate control during the shutter delay time and revert back to the primary sensor after the shutter delay time has expired.

TRANSFER TOOLING. . . . . 10.0 to 500.0%

This parameter is enabled if **Transfer Sensor** has been set to **Yes**. Sets the tooling factor to use with the **Transfer** sensor. See **Tooling** under section 4.2.3.3, Sensor Parameters, on page 4-8. Default is 100.0%.

CONTROL DELAY TIME . . . . 00:00 to 99:59 mm:ss

If **Control Delay** or **Both** were selected under the **Delay Option**, this parameter is enabled upon entering **Deposit** and sets the time for which control will be suspended and the power maintained at the **Soak 2** power level. Default is 00:00.

ION ASSIST DEPOSIT . . . . Yes / No

Press the **TOGL** key to move through the choices. Default is **No**. **Yes** activates the **Ion Assist Output** upon entering **Deposit** and deactivates it on leaving **Deposit**.

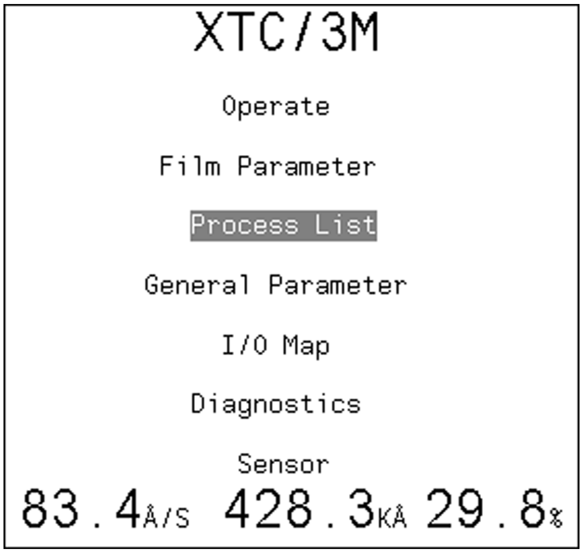
NAME (XTC/3M only) . . . . 15 alphanumeric characters

Accepts up to 15 alphanumeric characters to uniquely identify a film. The film name can be entered by moving to the **Film Name** and using the keypad in a manner similar to a cell phone. For instance, to enter the letter S, press the **PQRS** key four times. To enter the letter A, press the **ABC** key once. Figure 4-9 shows a film with the name: **FILM NAME**.

Names that have been entered via Communications may contain characters beyond the 15 alphanumeric ones that can be entered from the front panel.

4.3 Process Set-Up Overview (XTC/3M only)

Figure 4-10 Main Menu screen



In XTC/3M, the Process display appears after pressing the **MENU** key, then cursoring down to **Process List** and pressing Menu. XTC/3S does not have the **Process List** menu option.

XTC/3M can have up to 99 pre-programmed processes. Each process can have a list of up to 999 layers, to be run in order. Additionally, a process can be named, with a name up to 15 alphanumeric characters long. Any of the 99 processes can be programmed or deleted in any order (e.g., process 5 can be created, even if process 4 is empty).

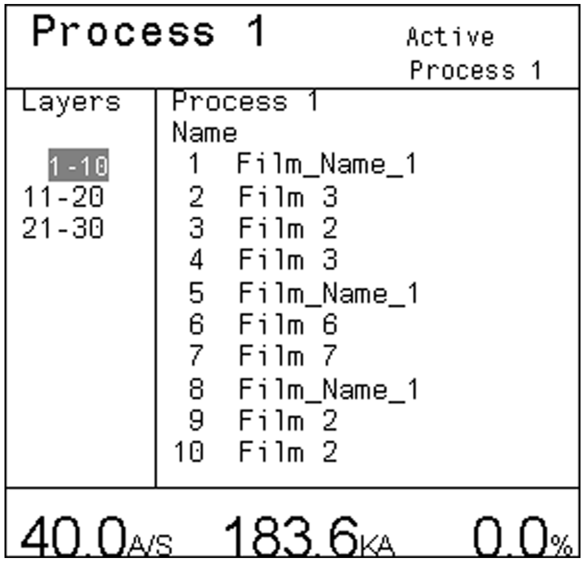
To delete a film, cursor to the film to be deleted in the process list. Press the **0** key followed by the **ENTER** key. The only restriction on deletion is that the **Process to Run** found on the **General Screen Process** page can not be empty.

If the parameters are locked, the **L Lock** or **R Lock** message will be displayed in the upper right corner of the **Process** screen. The process list will be displayed, but cannot be changed. With the parameters locked, the process number may still be changed to allow viewing of other processes.

Pressing ◀or ▶ keys will move between the selection panel and the parameter panel.

4.3.1 Process Definition

Figure 4-11 Process screen



4.3.1.1 Process Number

PROCESS . . . . 1 to 99

Upon entering the **Process** screen, the process displayed will be the one displayed when this screen was last left. A different process can be displayed by moving to the process number parameter and entering the new process number.

4.3.1.2 Process Name

NAME. . . . . Accepts up to 15 alphanumeric characters.

The process name can be programmed by moving to the process Name and using the keypad in a manner similar to a cell phone. For instance, to enter the letter S, press the **PQRS** key four times. To enter the letter A, press the **ABC** key once. If no name is entered, the process number (1 to 99) will be displayed.

Names that have been entered via Remote Communications may contain characters beyond the 15 alphanumeric ones that can be entered from the front panel.

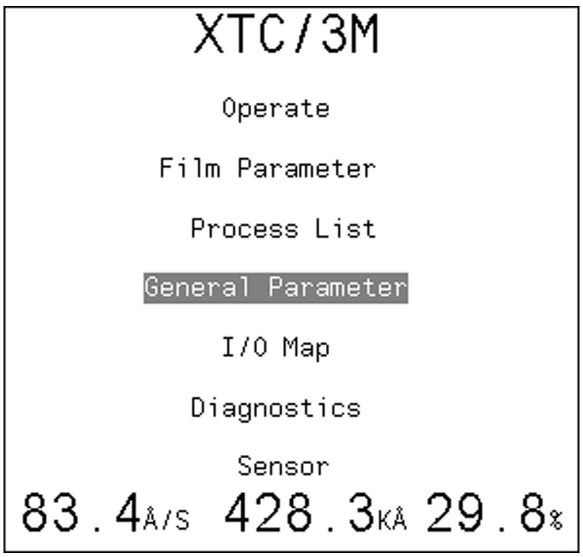
4.3.1.3 Building the Layer Sequence

The Select Panel contains sets of 10 layers that can be displayed in the parameter panel. The ▲or ▼ arrow keys are used to position the cursor at a specific layer in the process, or at the blank space after the last defined layer.

Entering a film number between 1 and 32 next to a layer number, followed by the **ENTER** key, will place the desired film in that layer. If a film number was previously entered, it will be replaced. Entering a 0 will delete the specified film and shift all following films up. It is possible to insert a film into an existing film sequence by cursoring to the desired layer and selecting the right arrow key. This action will shift the layer list down to accommodate the added layer. Using the keyboard, input the film number to be inserted followed by **ENTER**. Pressing the **CLEAR** button will cancel the layer insertion. If the film is named, the film name will appear in the list, otherwise the film number will appear.

4.4 General Parameters

Figure 4-12 Main Menu screen XTC/3M



NOTE: The **Process List** line is not present in XTC/3S.

The **General Parameter** display appears after pressing the **MENU** key, then cursoring down to **General Parameters** and pressing **MENU**.

The **General Parameter** screen is subdivided into the following screens:

- **Process**
- **Hardware**
- **Comm**(unications) **Info**

The ▲ or ▼ arrow keys are used to move from parameter to parameter. The ◀ or ▶ keys are used to move from selection panel to parameter panel and back. In most cases, the value can be updated using the **TOGL** key to toggle between a series of choices. For a few parameters, the numeric keypad and **ENTER** key are used.

If the parameters are locked, the **L Lock** or **R Lock** message will be displayed in the upper right corner. The parameter values will be displayed, but cannot be changed.

4.4.1 Process Parameters

Figure 4-13 XTC/3M Process screen

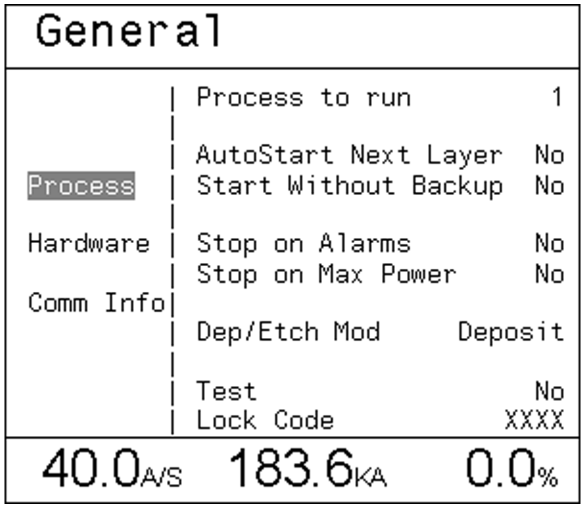
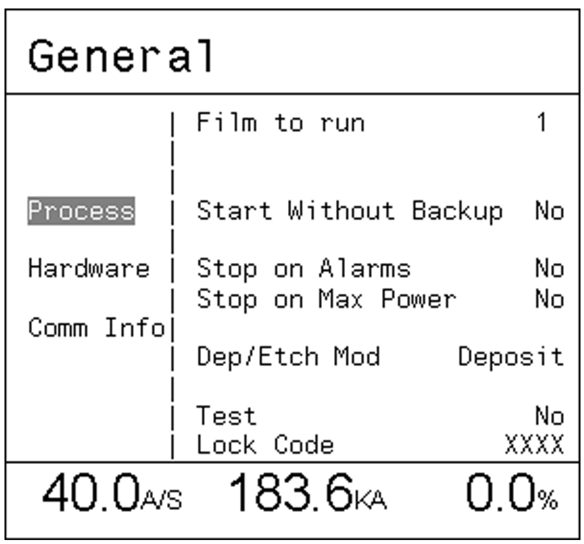


Figure 4-14 XTC/3S Process screen



PROCESS TO RUN . . . . 1 to 99 (XTC/3M only)

Selects the process to be run. Only processes with layers may be entered. The default is 1. This function is not available in XTC/3S.

FILM TO RUN . . . . 1 to 9 (XTC/3S only)

Selects the film to be run. The default is 1. This function is not available in XTC/3M.

AUTOSTART NEXT LAYER Yes / No (XTC/3M only)

Press the **TOGL** key to move through the choices. Default is **No**.
Yes enables automatically starting the next layer in the process when the previous layer reaches the Idle state, unless that layer is the last layer in the process. This function is not available in XTC/3S.

START WITHOUT BACKUP Yes / No

Press the TOGL key to move through the choices. This option is pertinent only when a multi-position sensor is in use. In the default mode **No**, a layer cannot be started unless there is at least one known working backup crystal available. If set to **Yes**, a layer may be started without a working backup crystal.

STOP ON ALARMS. . . . . . . Yes / No

Press the **TOGL** key to move through the choices. Default setting is **No**.
Alarm conditions are defined in section 3.5.1 on page 3-23.

STOP ON MAX POWER . . . Yes / No

Press the **TOGL** key to move through the choices. Default setting is **No**. If set to **Yes**, XTC/3 will stop if **Max Power** condition has been true for 5 seconds continuously.

DEP/ETCH MODE . . . . Deposit / Etch

Press the **TOGL** key to move through the choices. Default mode is **Deposit**. By setting the mode to **Etch**, XTC/3 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 unit is operated normally, with the **ZERO** key used to zero the displayed thickness. The **FINAL THICKNESS** parameter may be programmed to terminate the process.

TEST . . . . Yes / No

Press the **TOGL** key to move through the choices. The default is **No**. XTC/3 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:

$$\text{Displayed Rate} = \frac{40}{\textbf{DENSITY}\ (\text{gm/cc})} \times \frac{\textbf{TOOLING}\ (\%)}{100\%}\ \text{Å/sec} \qquad [2]$$

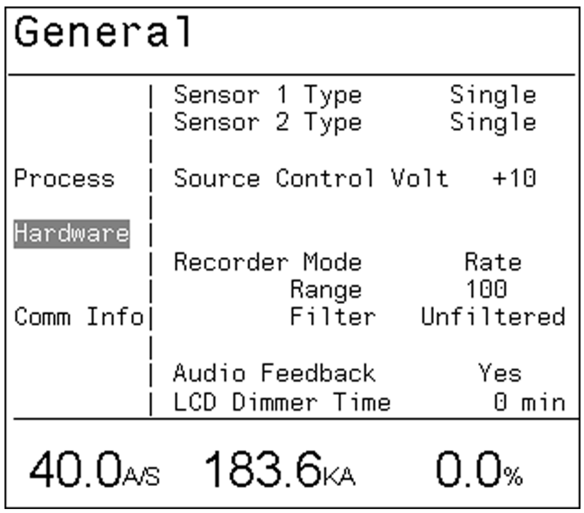
Relays, inputs, source and recorder outputs operate normally during **Test Mode** but Crystal fails are ignored.

LOCK CODE . . . . 1 to 9999

The **L Lock** lock code is set by moving to the **Lock Code XXXX** and entering the desired code of up to 4 digits. If no lock code is desired, no entry needs to be made. Entering a 0 will clear a previously set lock code and allow open access to all parameters. (Note, if there was previously a lock code programmed, the code must first be entered on the **Menu** screen, with the cursor positioned on **Lock Code**.) The lock code can also be cleared by depressing the **CLEAR** key on power-up, however, if no lock code has been programmed, this will reset all parameters to their default values.

4.4.2 Hardware Parameters

Figure 4-15 XTC3/M Hardware screen



SENSOR 1 TYPE . . . . . . **Single**, **CrystalTwo**, **CrystalSix**, **Crystal12**, **Rotary**, **Dual Head**. Press the **TOGL** key to move through the choices. Default is **Single**.

SENSOR 2 TYPE . . . . . . **Single**, **CrystalTwo**, **CrystalSix**, **Crystal12**, **Rotary**. Press the **TOGL** key to move through the choices. Default is **Single**.

NOTE: When a multi-position sensor type has been chosen, an output must be selected for the **Xtal Switch 1** or **Xtal Switch 2** function to enable switching to the next position. For XTC/3S, see section 3.6.8.6, XTC/3S Sensor Shutter / CrystalSwitch Output, on page 3-30. For XTC/3M, see section 4.5.3, XTC/3M Outputs, on page 4-29.

SOURCE CONTROL VOLT . . . . 0 to +10, 0 to -10, 0 to +5, 0 to -5, 0 to +2.5, 0 to -2.5
Press the **TOGL** key to move through the choices. Default is **0 to -10**.

RECORDER MODE. . . . Rate, Thickness, Power, Rate Deviation.
Press the TOGL key to move through the choices.
Default is **Rate**.

RANGE 100, 1000

Press the **TOGL** key to move through the choices. Default is **1000**.

Rate clips at range value. Thickness is done modulo the range, meaning each time the full scale value is exceeded, the recorder output returns to 0 and starts to ramp up again to produce a sawtooth output. The Recorder output voltage is 0 to +10 V.

This parameter is ignored if the recorder mode is power or rate deviation. Power will always be full-scale 100%.

Rate deviation will always be full scale ±50 Angstroms/sec. Unit must be in **Deposit** and not in **Stop** to show a rate deviation.

FILTER. . . . . Smooth / Unfiltered (Rate)

Press the **TOGL** key to move through the choices. Default is **Unfiltered** rate. **Unfiltered** provides 1/4 second measurement value. **Smooth** provides a 1 second averaged rate value.

This parameter is ignored if the recorder mode is **Thickness**, **Power**, or **Rate** deviation.

AUDIO FEEDBACK. . . . Yes / No

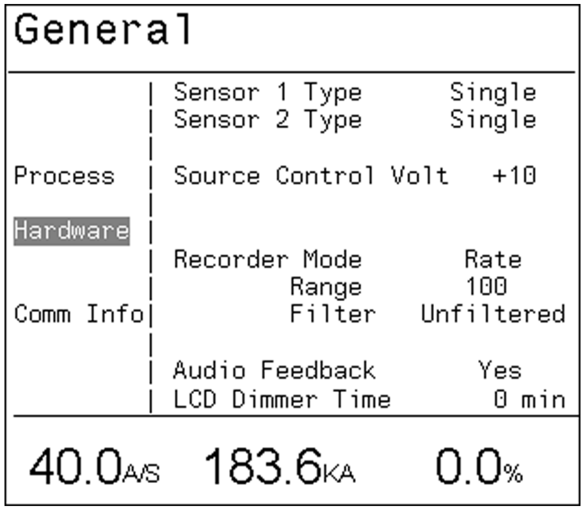
Press the **TOGL** key to move through the choices. Default is **No** for beep off. Turns the audible feedback for front panel or handheld controller key depression on or off.

LCD DIMMER TIME. . . . 0 to 99 min

Determines the time before the backlight dims to conserve lamp life. Default is **0** min which disables the dimmer function. If a process is running, the LCD is illuminated. If a process is not running, the LCD is extinguished.

4.4.2.1 XTC/3S Film Select Option

Figure 4-16 XTC/3S Film Select



INPUT OPTION . . . . Standard, Film Select (XTC/3S only)

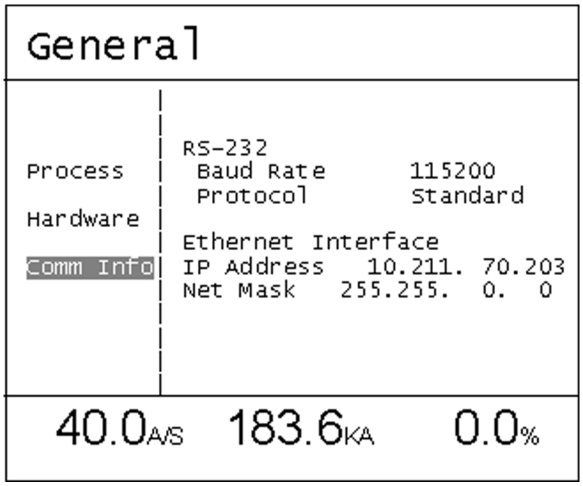
Press the **TOGL** key to move through the choices. Default is **Standard**. Selecting the **Film Select** option allows selecting one of the 9 films based on the state of the **Film Select** inputs 5, 6, 7 and 8 as shown in the table below. In addition, input # 4 is reassigned to perform the **RESET** function.

Table 4-1 XTC/3S Film Select

Input #5 --MSB	Input #6	Input #7	Input #8 --LSB	Film #
0	0	0	0 or 1	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	0 or 1	1	0 or 1	1

4.4.3 Comm Info

Figure 4-17 Comm Info Screen with TCP/IP Option installed



NOTE: IP address and net mask are initialized 1 minute after power-up.
IP address and net mask text are grayed if no TCP/IP option is installed or if communication cannot be established. See section 6.3.3 on page 6-18.

4.4.3.1 Remote Communication Parameters

<u>**RS-232**</u>

BAUD RATE. 9600, 19200, 38400, 57600, 115200

Press the TOGL key to move through the choices. Default is 115200

PROTOCOL RS232 . . . . Standard, Datalog, XTC/2 Ck Sum, XTC/2 No Ck Sum, XTC/C Ck Sum, XTC/C No Ck Sum

Press the **TOGL** key to move through the choices. **Default** is Standard.
See section 5.2 on page 5-6.

Datalog returns response described under section 5.2.2.5 on page 5-28, S19 command whenever the layer leaves the **Deposit** state.
See also section 3.6.14, Datalog, on page 3-32.

XTC/2 Ck Sum, **XTC/C Ck Sum**, see section 5.3.2 on page 5-37.

XTC/2 No Ck Sum, **XTC/C No Ck Sum**, see section 5.3.3 on page 5-37.

CAUTION

Upon changing the protocol to XTC/2 Ck Sum, XTC/C Ck Sum, XTC/2 No Ck Sum, or XTC/C No Ck Sum, it is highly recommended to check all prior parameters entered to verify that they are compatible with the reduced parameter set available in the XTC/2 protocols. Otherwise, unexpected behavior may result.

<u>**Ethernet Interface Option**</u>

The optional TCP/IP interface supports static addresses; DHCP is not supported.

NOTE: IP address and net mask are initialized 1 minute after power-up. After this time, they may be changed and XTC/3 must be power-cycled for the new values to become active.

IP ADDRESS and **NET MASK** are 32 bit numbers, they are written out as 4 8-bit numbers, separated by decimals.

IP ADDRESS . . . . nnn.nnn.nnn.nnn

Use the up and down cursor keys to scroll through the address and the numerics keys to enter the desired address. The default address is **10.211.70.203**.

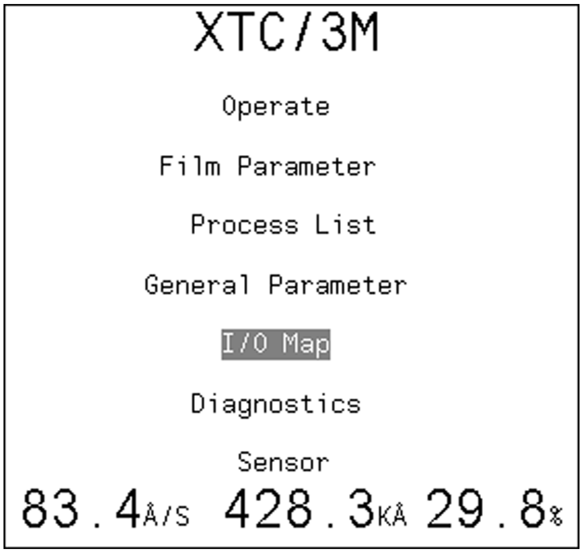
NET MASK. nnn.nnn.nnn.nnn

The net mask is some number of leading bits set to 1, followed by all 0.
The default net mask value is **255.255.0.0**:

255 .	255 .	0 .	0
11111111	11111111	00000000	00000000

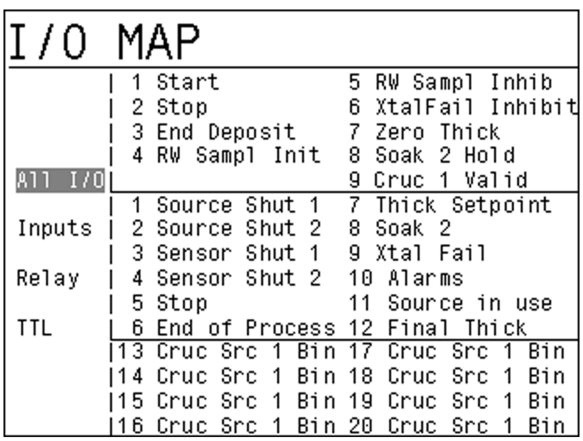
4.5 I/O Overview

Figure 4-18 XTC3/M Main Menu screen



The **I/O Map** display appears after pressing the **MENU** key, then cursoring down to **I/O Map** and pressing **MENU**.

Figure 4-19 XTC/3M All I/O screen



The **All I/O** screen displays the complete digital I/O map. The functions of inputs 1 to 9 are shown in the upper portion of the screen and the status of the outputs is shown on the lower portion of the screen. Active outputs are highlighted.

In XTC/3M, the selection panel permits selecting **All I/O**, **Inputs**, **Relays** or **TTL** screens. Selecting anything but the **All I/O** on XTC/3M will allow update of the corresponding inputs or outputs.

If the parameters are locked, the **L Lock** or **R LOCK** message will be displayed in the upper right corner. The **Input**, **Relay**, and **TTL (Output)** screens will not be available for programming.

4.5.1 XTC/3S Inputs and Outputs

In XTC/3S, the fixed I/O will be displayed on the **I/O Map** screen. The assignment of the 9 fixed inputs corresponds to the default assignments in XTC/2.
Also, refer to section 4.4.2.1, XTC/3S Film Select Option, on page 4-23 for inputs.

All relay (1 to 12) and TTL Open Collector outputs (13 to 20) are fixed to perform the functions shown on the screen. These function assignments are identical to the default configuration provided in XTC/2 per section 2.3.3.2.1 on page 2-9.

Figure 4-20 XTC/3S I/O Map screen, Standard Input option

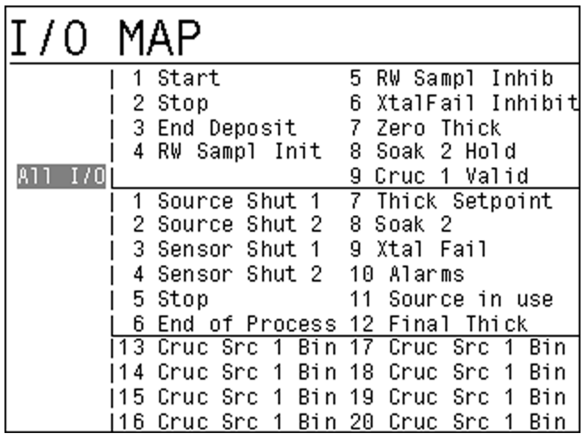
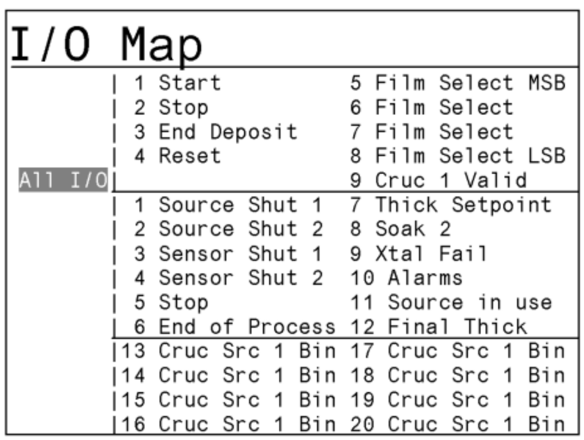


Figure 4-21 XTC/3S I/O Map screen, Film Select option



The fixed functions of inputs 1 to 9 are shown in the upper portion of the screen and the status of the fixed outputs is shown on the lower portion of the screen. Active outputs are highlighted.

4.5.2 XTC/3M Inputs

Figure 4-22 Inputs screen 1 (XTC/3M only)

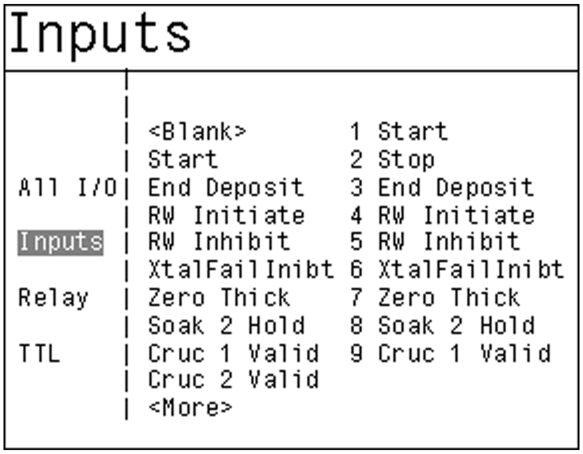
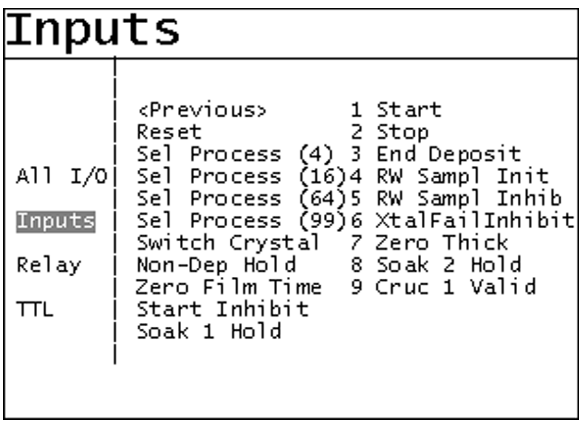


Figure 4-23 Inputs screen 2 (XTC/3M only)



In XTC/3M, this screen allows modification of the 9 inputs. On the right side of the parameter panel will be a column of the inputs as they are currently programmed. There will be blanks if the input is not defined. For the complete list of input functions available for XTC/3M, see Table 3-3 on page 3-21.

The scrollable list of allowed input functions will be displayed on the left side of the parameter panel. The ▲▼◄► keys will cursor through this list. Entering a number (1-9), followed by the **ENTER** key, will assign the selected input function to that input number. Any number of inputs may be assigned to the same function, except **Sel Process (XX)** which is limited to a single instance.

The ◄► arrow keys will go back and forth between the **Inputs** choices and the selection panel. The process selected via inputs will become active during **Idle End of Process** and **Ready**.

NOTE: If an input is used to select an empty process, the selection will be ignored. **Process to Run** will become the active process. If a layer or layers are subsequently inserted into this previously empty process, its selection by digital input will not be accepted until a **Reset** is done.

4.5.3 XTC/3M Outputs

The **Relay Outputs** and **TTL Outputs** screens allow modification of the 12 relays or the 8 TTL outputs, respectively. All relays (1 to 12) and TTL Open Collector outputs (13 to 20) are selectable to perform the functions shown on the screen. Any number of outputs may be assigned to the same function. The default assignments are identical to the default configuration provided in XTC/2 and referenced above.

On the right side of the parameter panel will be a column of the outputs as they are currently programmed. There will be blanks if the output is not defined.

The scrollable list of allowed output functions will be displayed on the left side of the parameter panel. The ▲▼◄► keys will cursor through this list. With the cursor on **<More>**, press the ▼arrow to access additional functions. With the cursor on **<Previous>**, press the ▲ arrow to return. Entering a number (1-12 for relays, or 13-20 for TTL), followed by the **ENTER** key, will assign the selected output function to that output number. Moving the cursor to the extreme right column permits changing the output between **NO** (Normally Open) and **NC** (Normally Closed) by using the **TOGL** key. With the unit powered off, the outputs will always be open.

The◄►arrow keys will go back and forth between the selection panel and the parameter panel. For the complete list of output functions available for XTC/3M, see Table 3-2 on page 3-19.

Figure 4-24 Relay Outputs 1

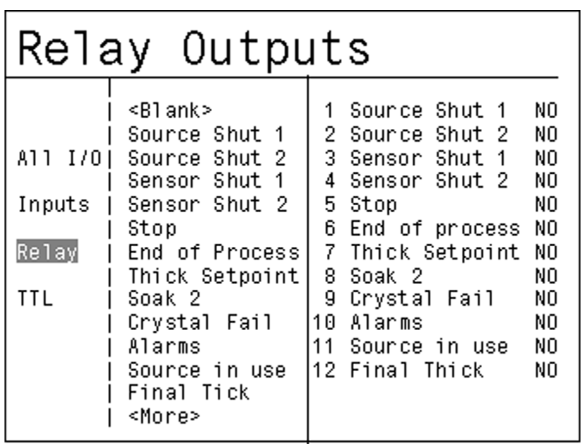


Figure 4-25 Relay Outputs 2

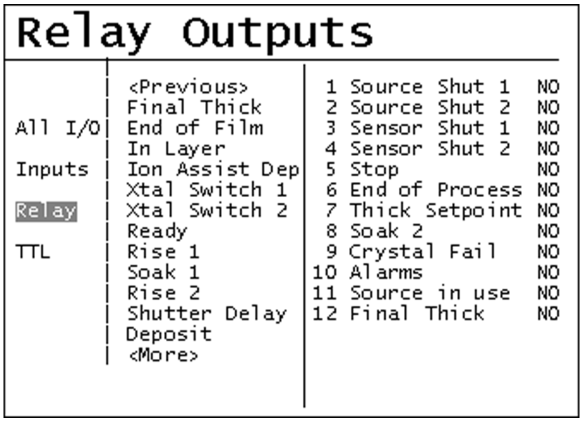


Figure 4-26 Relay Outputs 3

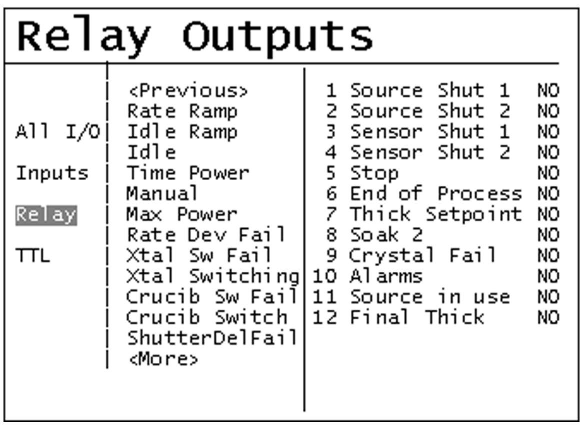


Figure 4-27 Relay Outputs 4

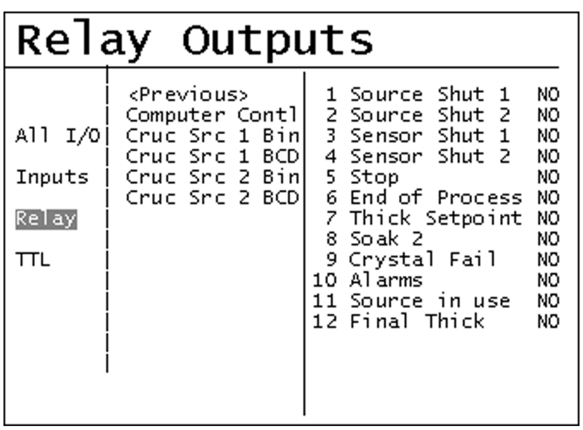
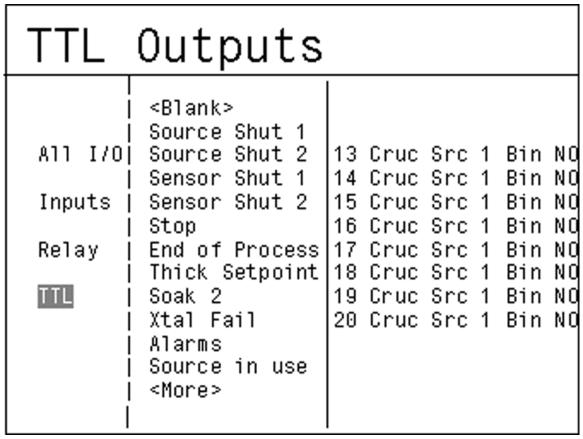


Figure 4-28 TTL Outputs



NOTE: Three additional selection screens, identical to those for the Relay outputs, are available for selecting additional TTL Outputs.

NOTE: Three consecutive relay or TTL outputs must be available when selecting the BCD output function, **Cruc Src 1 BCD** or **Cruc Src 2 BCD**.
All three outputs will be inactive for position 1, all three outputs will be active for position 8. The first output in the sequence is the LSB.
Eight consecutive relay or TTL outputs must be available when selecting the Bin output function, **Cruc Src 1 Bin** or **Cruc Src 2 Bin**. In BIN mode, only one of these eight outputs will be active at any given time, for example, output 13 for position 1, output 14 for position 2 etc.

4.5.4 Clear Input or Output

To clear an input or output assignment, cursor to the **<Blank>** selection on the appropriate screen and enter the input or output number to be cleared.

Chapter 5
Remote Communications

5.1 Remote Communications Overview

XTC/3 may be remotely controlled, programmed or interrogated. This is accomplished through remote communications and the use of a remote command set. XTC/3 will respond to messages that contain these commands. It will accept and operate on messages one at a time. It will respond to each command by carrying out valid operations and/or returning a message to the sender. A host/server relationship is established in remote communications. XTC/3, as server, responds to the remote host's commands.

NOTE: Unpredictable RS-232 hardware/software combinations may occasionally cause a command to not be recognized by XTC/3. Consequently, all communications should include an automatic retry procedure. If a command sent via RS-232 does not produce a response from XTC/3 within three seconds, it should be sent again.

5.1.1 Message Protocols

The message protocol serves as a structure for the contained command or response information. It also can provide a level of acknowledgment between the host and server and a mechanism for verifying the information content. In addition to the optional TCP/IP interface, XTC/3 supports the following RS-232 protocols: **Standard**, **Datalog**, **XTC/2 Ck Sum**, **XTC/2 No Ck Sum**, **XTC/C Ck Sum** and **XTC/C No Ck Sum**. The **Datalog** protocol only provides for one-way transmission of layer data from XTC/3 as described at section 3.6.14 on page 3-32. The last four protocols are intended to permit an XTC/3S or XTC/3M to respond to commands previously sent to an XTC/2 to facilitate changeover from an XTC/2 or XTC/C to an XTC/3 without extensive reprogramming to the external computer or PLC.

NOTE: Unlike XTC/2 and XTC/C, XTC/3 does not support hardware handshaking.

CAUTION

Due to the reduced parameter set accessible under XTC/2 protocols, some parameters entered previously or subsequently from the front panel, RS-232 or via TCP/IP will be invisible to XTC/2 protocols but will remain active. For instance, if the active process is programmed to contain more than three layers by means other than via XTC/2 protocols, any Start command issued after layer 3 is in Idle will execute layer 4.

NOTE: TCP/IP will always operate using the **Standard** protocol command set. It is not affected by the RS-232 Protocol selection.

5.1.2 Physical Connections

Two types of data communications hardware ports are available.
Standard equipment includes a bit serial RS-232C port. Optionally, a TCP/IP port may be added. Generally speaking, both the host and server must have the same form of communications equipment and complementary set-up. For serial communications, baud rates must match and so must the data word format.
The word format for bit serial lines (RS-232C) is comprised of ten signal bits — eight data bits, one start bit, one stop bit and no parity. The eight data bits comprise a byte of information or character whose ASCII value ranges from 0 to 255.

Both RS-232C and TCP/IP ports can be used simultaneously.

5.1.3 RS-232C Serial Port

RS-232C serial communications are accomplished through an industry standard 9-pin female connector found on the rear panel of XTC/3. A mating male connector is required for attachment of a host interface. The host and XTC/3 can be separated by up to fifty feet using multiconductor shielded data cable.
XTC/3 is configured as DCE or Data Communications Equipment. The PC or other host device should be set for no parity, 8 data bits and 1 Stop bit. Hardware handshaking is not supported in XTC/3. Refer to section 2.3.4 on page 2-11 for cable connections and pin-outs.

5.1.4 TCP/IP Ethernet Port

XTC/3 communicates via TCP/IP on TCP port number 2101 and uses a variety of binary commands as described at section 5.2. See section 2.3.5 on page 2-11 and section 2.3.5.1 for the appropriate ethernet cable type and section 4.4.3.1 on page 4-25 for determining or changing the IP address. The interface supports static addressing, DHCP is not supported.

5.1.4.1 Network Connection

If XTC/3 is connected through a network or hub connection, a standard straight ethernet cable is required.

5.1.4.2 How to Set Up the Network Protocol on the PC

Most personal computers are configured to obtain the IP address, an address which defines the computer on the Internet, automatically from a server.

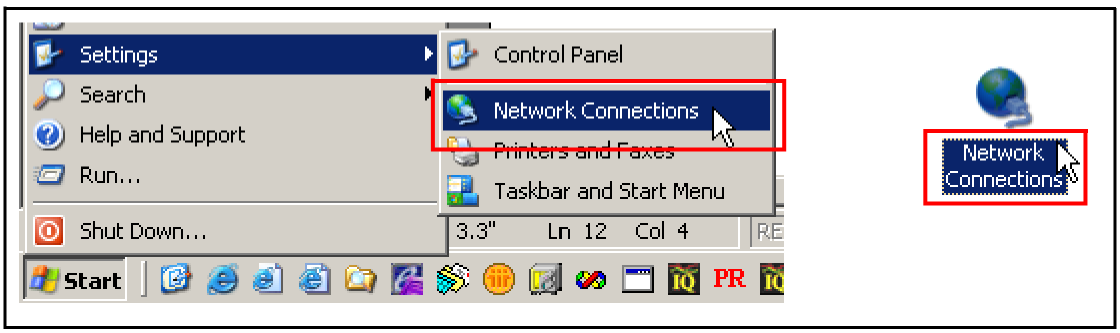
To communicate directly with XTC/3, the Internet protocol (IP) on the PC must be configured manually and an ethernet crossover cable (PN 600-1211-P5) must be connected between the PC and XTC/3. Some PC's will autoconfigure and work with either straight or crossover cable. Instructions are provided here for manually configuring the Internet protocol.

NOTE: If the personal computer only has one ethernet port (i.e., one network connection) then setting the PC for direct communications will prohibit it from accessing the Internet until that setting is reversed.

NOTE: These instructions will set two values — the IP address and the Subnet mask — which will most likely prohibit access to the Internet. If these values already contain information then this information should be recorded somewhere for use in restoring the Internet connection.

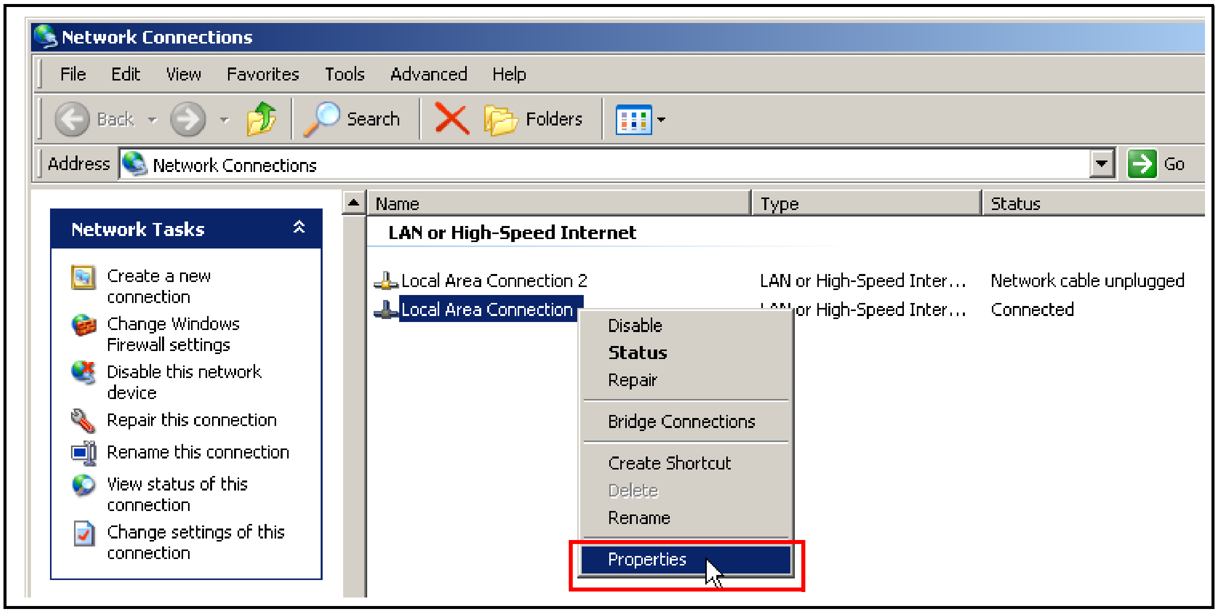
To access the Network Connection on the PC, select **Network Connections** from the **Start** menu or from the **Control Panel**, as shown in Figure 5-1.

Figure 5-1 Accessing Network Connections



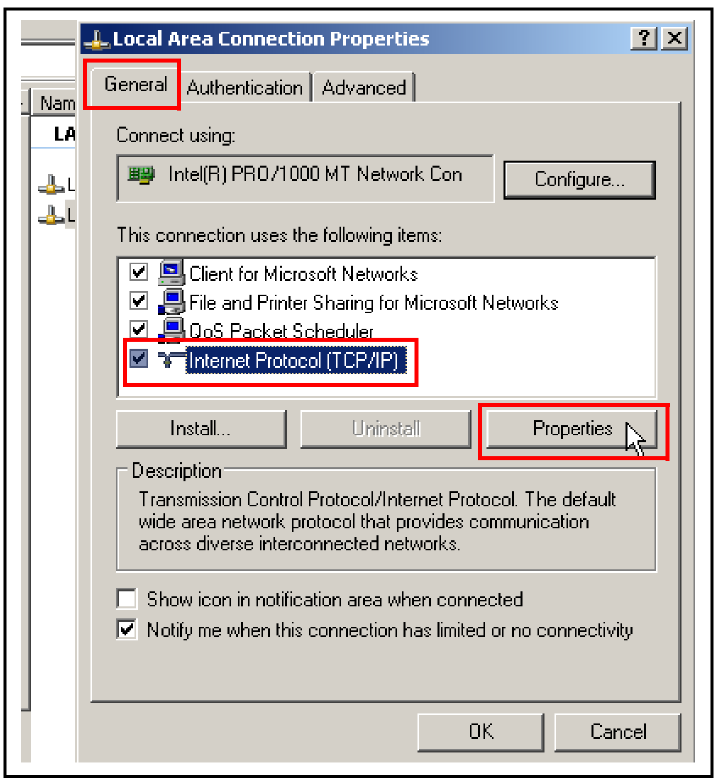
Select the **Local Area Connection** to be changed, right-click and select **Properties**, as shown in Figure 5-2.

Figure 5-2 Local Area Connection Properties



On the **General** tab, select **Internet Protocol (TCP/IP)** and press the **Properties** button, as shown in Figure 5-3.

Figure 5-3 Internet Protocol (TCP/IP) Properties

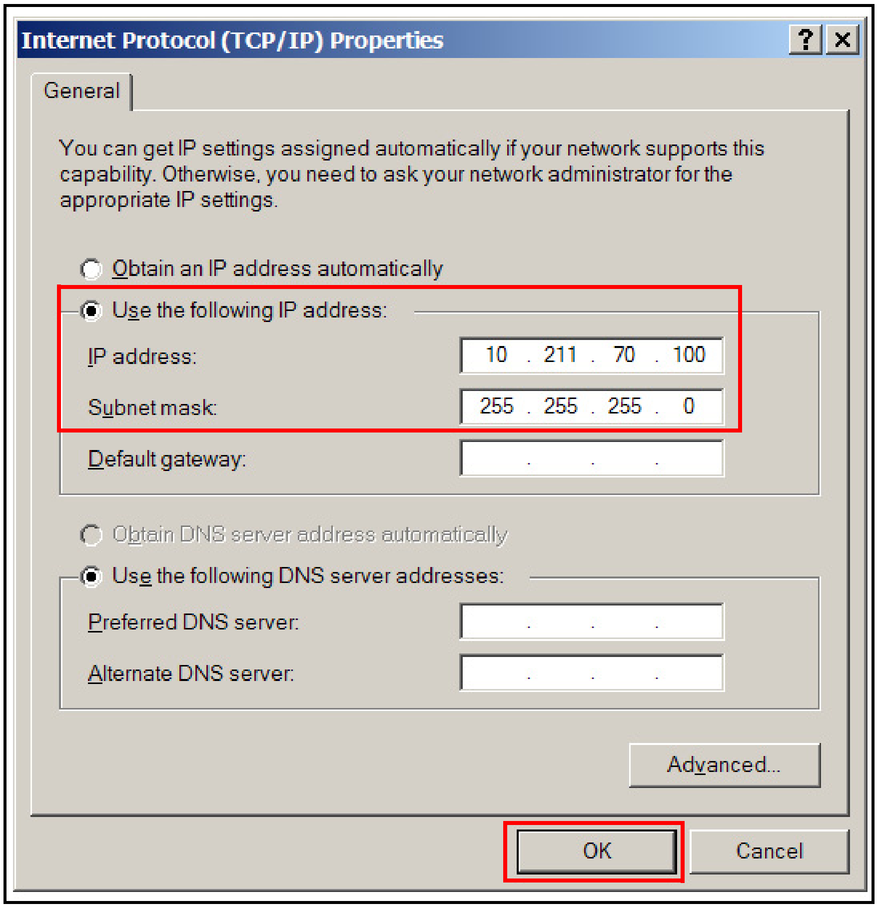


Select the button for **Use the following IP address**, enter the **IP address:** and **Subnet mask:** shown in Figure 5-4, and press **OK**. With this selection, the PC is assigned an IP address to use when communicating with XTC/3.

XTC/3 is shipped from INFICON with a pre-assigned address of 10.211.70.203.

To communicate directly with XTC/3 from a PC, the PC must also be assigned an address that starts with 10.211.70 but cannot be set to 10.211.70.203.
The example in Figure 5-4 uses the address 10.211.70.100 for the PC.

Figure 5-4 Entering the IP Address and Subnet mask



Click **OK** to all open dialogs to close out the Internet Protocol setup for the Local Area Connection.

5.2 Standard Protocol Message Format

This message format is in effect if **Standard** has been selected under the RS-232 Protocol parameter and is always in effect for the TCP/IP port. All messages are comprised of serial byte information. The byte values represent command or response characters, control characters, or numeric values.

Mnemonics will be used to describe portions of each message format.

NOTE: These mnemonics are not part of the message stream; they are used to represent specific ASCII codes, characters or numeric values that comprise the message stream.

5.2.1 Standard Protocol

Key:

<> . . . . Enclosed element further defined below (or above, if repeated use)

() . . . . Optional Element

I. . . . . Or

x...x. . . . . One or more of x included

5.2.1.1 Standard Command Packet (Host to XTC/3 Message)

<length><message><checksum>

Length . . . . . 2 bytes Low / High (not including checksum or length bytes). Numeric value from 0 to 57,800 (two bytes) representing the number of characters in the command. In order of transmission, the low byte will precede the high byte. For most commands, the number for characters will be less than 256.
In this situation the low byte will contain the character count while the high byte will have zero value.

Message. . . . . <Command>(<Command>...<Command>)

Command = <Command Group> (<Command Sub-group>) (<Command ID>) (<Parameter>...<Parameter>)

Command Group = 1 ASCII byte, specifying category of command:

E - Echo

H - Hello

Q - Query

R - Remote action

S - Status

U - Update

Command Sub-group = 1 ASCII byte, used with some command groups to further specify commands.

For command Q and U:

F – Film

G - General

I - Input

N - Film Name

O - Output

P - Process

T - Output Type

No sub-groups are allowed for H, E, S or R.

Command ID = 1 binary byte. Defines specific command within some command groups and sub-groups.

Parameter = <Byte>|<Integer>|<Float>|<String>|

Byte = 1 byte

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

String = Null terminated series of ASCII characters

Checksum . . . . 1 byte, sum, modulo 256, of all bytes, not including length.

5.2.1.2 Standard Response Packet (XTC/3 to Host Message)

<Length><CCB><Timer><Response Message><Checksum>

Length . . . . 2 bytes Low / High (not including checksum or length bytes). Numeric value from 0 to 57,800 (two bytes) representing the number of characters in the Response Packet including CCB, Timer, and Response Message. Length bytes and Checksum are not included in Length Count. Two byte values, high and low order, represent this number. In order of transmission, the low byte will precede the high byte.

CCB . . . . (Condition Code Byte) = 1 byte binary. MSB set (hex 80) indicates command packet error.

Timer . . . . 1 byte binary, number between 0 and 255, (hex 00 to FF) increments every quarter second.

Response Message . . . . <Command Response>...<Command Response>|<Packet Error Code>

NOTE: Number of command responses equals number of commands sent.

If CCB MSB is set, (hex 80) indicating a command packet error, the response message will be a single packet response error.

If the CCB MSB is clear (hex 00), the command packet was parsed and a valid command packet format was detected.

Command Response = <ACK><response>|<response error code>

NOTE: ACK is the ASCII code with decimal or hex value 6 indicating Positive Acknowledgement of a command. It is not sent when a Response Error Code is returned.

Response =

(<integer>|<float>|<string>|<other>......<integer>|<float>|<string>|<other>)

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

String = Null terminated series of ASCII characters

Response Error Code = 1 byte ASCII

A= Illegal Command

B = Illegal parameter value

C = Illegal ID

D = Illegal format

E = Data not available

F = Cannot do now (some commands require XTC/3 to be in Ready/Stop).

L = Length Error, must be greater than 0 and equal to or less than 57,800.

O = Not enough room for response size.

P = Prior command failed (if one command of a multiple command packet fails, none of the following commands will be done, and this error code will be returned).

Packet Error Code = 1 byte ASCII.

C – invalid checksum

F – illegal format (too many bytes for the commands requested or missing value in command)

I – invalid message

L – Length Error, must be greater than 0 and equal to or less than 57,800.

M – too many commands (Only 100 allowed)

Checksum . . . . 1 byte, sum, modulo 256, of all bytes, including CCB, Timer, and Response Message but not including length.

Timeouts. . . . . If more than 3 seconds pass between characters of a command packet, XTC/3 will time out. No response packet is sent, XTC/3 will clear its buffers and assume any future characters are the beginning of a new packet.

5.2.2 Standard Communication Commands

NOTE: The following only include the “command” portion of the command packet and the “response” portion of the response packet. The headers/trailers are assumed. (See Protocol documentation above for their definition.)

General definitions

<Float> = 4 byte, single precision ANSII standard floating point, low end first

<Integer> = 4 byte, signed integer, low end first

<String> = variable length, null terminated ASCII characters

5.2.2.1 Standard ECHO Command

Command

E <String>

Response:

<String> The same string that was sent.

String = Null terminated series of ASCII characters

5.2.2.2 Standard HELLO Command

Command:

H <Command ID>

Response:

<String>) | <float>

String = Null terminated series of ASCII characters

Float = 4 byte, ANSII standard, single precision, low to high

Table 5-1 Hello command response

Standard Command ID	Meaning	Response
1	ASCII name and version	<String> = “XTC/3*x* Version y.yy” *x* = M or S y.yy = Firmware version
2	Structure number Compatibility number Range number Unit Type	< Integer>< Integer>< Integer>< Integer> (0 = XTC3/M, 1 = XTC3/S) (77 = XTC3/M, 83 = XTC3/S)
3	Firmware version number	<Float>

5.2.2.3 Standard QUERY Commands

5.2.2.3.1 Query Block

Command:

QB<Command ID>

Command ID = See listing below

Response:

Depends on Command ID. See listing that follows

Command ID = 1 ”All Parameters”

The command will return all parameters in the following order. Formats are listed in the individual commands. Maximum bytes allowed in the response are 57,800. A Command Length error code L is returned if there is too much data.

Response:

<Number of Bytes in Response><General Parameters><Film 1 Parameters>…<Film32 Parameters><Inputs><Outputs><Output Types><Film 1 Name>…<Film 32 Name> <Process One>…<Process 99><Process 1 Name>…<Process 99 Name>

Number of Bytes in Response (2 bytes)

All General parameters (4 bytes per parameter)

All parameters for each film (4 bytes per parameter) (9 or 32 films based on XTC/3S or XTC/3M)

All input definitions (9) (1 byte per input) (XTC/3M only)

All output definitions (20) (1 byte per output) (XTC/3M only)

All output types (20) (1 byte per output) (XTC/3M only)

All Film Names (null terminated) (32 films) (XTC/3M only)

Every process layer list for each process (99) (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer) (XTC/3M only)

All process Names (null terminated) (99) (XTC/3M only)

Command ID = 2 ”All Parameters without Process Layer lists and Process Names”.

Will return all parameters in the following order, with formats as listed in the individual commands.

Response:

<Number of Bytes in Response><General Parameters><Film 1 Parameters>…<Film32 Parameters><Inputs><Outputs><Output Types><Film 1 Name>…<Film 32 Name>

Number of Bytes in Response (2 bytes)

All General parameters (4 bytes per parameter)

All parameters for each film (4 bytes per parameter) (9 or 32 films based on XTC/3S or XTC/3M)

All input definitions (9) (1 byte per input) (XTC/3M only)

All output definitions (20) (1 byte per output) (XTC/3M only)

All output types (20) (1 byte per output) (XTC/3M only)

All Film Names (null terminated) (32 films) (XTC/3M only)

Command ID = 3 “Lower 50 Processes Information” (XTC/3M only)

Response:

<Number of Bytes in Response><Process One>…<Process 50><Process 1 Name>…<Process 50 Name>

Number of Bytes in Response (2 bytes)

Process 1 – 50 layer list (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer)

Process 1 – 50 Names (null terminated)

Command ID = 4 “Upper 49 Processes Information” (XTC/3M only)

Response:

<Number of Bytes in Response><Process 51>…<Process 99><Process 51 Name>…<Process 99 Name>

Number of Bytes in Response (2 bytes)

Process 51 – 99 layer list (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer)

Process 51 – 99 Names (null terminated)

5.2.2.3.2 Standard Query Film Name (XTC3/M only)

Command:

QN <Film Number>

Film Number = <Byte> 1-32

Response:

<String> (maximum 15 characters, plus terminating null character)

String = Null terminated series of ASCII characters

5.2.2.3.3 Standard Query Film Parameters

Command:

QF <Command ID> <Film Number>

Command ID = <Byte> See “UF Command ID” column in Table 5-2 on page 5-22.

Film Number = <Byte> 1-9 (XTC/3S) or 1-32 (XTC/3M)

Response:

<Integer> | <Float>

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

Description: Type of response depends on command ID, see “DataType / Format” column of Table 5-2 on page 5-22.

Special Case: QF255 <Film Number> will return all film parameters for the given film, in numeric order.

5.2.2.3.4 Standard Query General Parameter

Command:

QG <Command ID>

Command ID = <Byte> See “UG Command ID” column in Table 5-3 on page 5-25.

Response:

<Integer> | <Float>

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

Description: Type of response depends on command ID, see “DataType / Format” column of Table 5-3 on page 5-25.

Special Case: QG255 will return all general parameters, in numeric order

5.2.2.3.5 Standard Query Input Definition (XTC/3M Only)

Command:

QI <Input Number>

Input Number = <Byte> 1-9, 255 (255=All 9 inputs)

Response:

If Input Number was 1 – 9:

<Input Definition>

If Input Number was 255:

<Input 1 Definition> <Input 2 Definition> … <Input 9 Definition>

Input Definition = < Byte > As decoded below

0 Blank (Input not used)

1 Start

2 Stop

3 End Deposit

4 Rate Watcher Hold Initiate

5 Rate Watcher Hold Inhibit

6 Crystal Fail Inhibit

7 Zero Thickness

8 Soak 2 Hold

9 Crucible 1 Valid

10 Crucible 2 Valid

11 Reset

12 Select Process 1-4, 2 bits*

13 (Select Process 1-4, 2 bits, bit 2)

14 Select Process 1-16, 4 bits*

15 (Select Process 1-16, 4 bits, bit 2)

16 (Select Process 1-16, 4 bits, bit 3)

17 (Select Process 1-16, 4 bits, bit 4)

18 Select Process 1-64, 6 bits*

19 (Select Process 1-64, 6 bits, bit 2)

20 (Select Process 1-64, 6 bits, bit 3)

21 (Select Process 1-64, 6 bits, bit 4)

22 (Select Process 1-64, 6 bits, bit 5)

23 (Select Process 1-64, 6 bits, bit 6)

24 Select Process 1-99, 7 bits*

25 (Select Process 1-99, 7 bits, bit 2)

26 (Select Process 1-99, 7 bits, bit 3)

27 (Select Process 1-99, 7 bits, bit 4)

28 (Select Process 1-99, 7 bits, bit 5)

29 (Select Process 1-99, 7 bits, bit 6)

30 (Select Process 1-99, 7 bits, bit 7)

31 Switch Crystal

32 Non-Deposit Hold

33 Zero Film Time

34 Start Inhibit

35 Soak 1 Hold

* Querying an input that corresponds to a secondary bit of one of the select processes will return the corresponding number. For individual updates, only the primary bit can be set. The corresponding secondary bits will be set automatically. For a block update (UI 255 or UB x, see below), when a select process is set, the primary bit must be set. Each additional bit corresponding to the select process must have the proper corresponding number, or 0.

5.2.2.3.6 Standard Query Output Definition (XTC/3M Only)

Command:

QO <Output Number>

Output Number = <Byte> 1-20, 255 (255=all outputs)

Response:

If Output Number was 1 – 20:

<Output Definition>

If Output Number was 255:

<Output 1 Definition><Output 2 Definition>…<Output 20 Definition>

Output Definition = <Byte> as decoded below

0 Blank (Output not used)

1 Source Shutter 1

2 Source Shutter 2

3 Sensor Shutter 1

4 Sensor Shutter 2

5 Stop

6 End of Process

7 Thickness Setpoint

8 Crystal Fail

9 Alarms

10 Source in use (Open=1; closed=2)

11 Final Thickness

12 End of Film

13 In Layer

14 Ion Assisted Deposition

15 Crystal Switcher 1

16 Crystal Switcher 2

17 Ready

18 Crucible Switching

19 Rise 1

20 Soak 1

21 Rise 2

22 Soak 2

23 Shutter Delay

24 Deposit

25 Rate Ramp

26 Manual

27 Time Power

28 Idle Ramp

29 Idle

30 Max Power

31 Rate Deviation Error

32 Crystal Switcher Fail

33 Crystal Switching

34 Crucible Switcher Fail

35 Shutter Delay Error

36 Computer Control

37 Crucible Select Source 1 Binary (8 outputs required, one/position)*

38 (Crucible Select Source 1 Binary, bit 2)

39 (Crucible Select Source 1 Binary, bit 3)

40 (Crucible Select Source 1 Binary, bit 4)

41 (Crucible Select Source 1 Binary, bit 5)

42 (Crucible Select Source 1 Binary, bit 6)

43 (Crucible Select Source 1 Binary, bit 7)

44 (Crucible Select Source 1 Binary, bit 8)

45 Crucible Select Source 1 BCD (3 outputs required BCD)*

46 (Crucible Select Source 1 BCD, bit 2)

47 (Crucible Select Source 1 BCD, bit 3)

48 Crucible Select Source 2 Binary (8 outputs required, one/position)*

49 (Crucible Select Source 2 Binary, bit 2)

50 (Crucible Select Source 2 Binary, bit 3)

51 (Crucible Select Source 2 Binary, bit 4)

52 (Crucible Select Source 2 Binary, bit 5)

53 (Crucible Select Source 2 Binary, bit 6)

54 (Crucible Select Source 2 Binary, bit 7)

55 (Crucible Select Source 2 Binary, bit 8)

56 Crucible Select Source 2 BCD (3 outputs required BCD)*

57 (Crucible Select Source 2 BCD, bit 2)

58 (Crucible Select Source 2 BCD, bit 3)

* Querying an output that corresponds to a secondary bit of one of the crucible select will return the corresponding number. For individual updates, only the primary bit can be set. The corresponding secondary bits will be set automatically. For a block update (UO 255 or UB x, see below), when a Crucible Select is set, the primary bit must be set. Each additional bit corresponding to the Crucible Select must have the proper corresponding number, or 0.

5.2.2.3.7 Standard Query Output Type Definition (XTC/3M Only)

Command:

QT <Output Number>

Output Number = <Byte> 1-20, 255 (255=all outputs)

Response:

If Output Number was 1 – 20:

<Output type>

If Output Number was 255:

< Output 1 type > < Output 2 type > … < Output 20 type >

Output type = <Byte>

0 = Normally open

1 = Normally closed

5.2.2.3.8 Standard Query Process Parameters (XTC/3M Only)

Command:

QP <Command ID> <Process Number>[<Parameter>]

Command ID = See listing below

Process Number = <Byte> 1-99

<Parameter> = Depends on Command ID (See listing that follows)

Response:

Depends on Command ID. See listing that follows

Command ID = 1 "Layer List"

Response:

<Number of Layers> <Layer 1> <Layer 2> … <Layer n>

Number of Layers = <2 Bytes> n = Number of layers in this process

Layer n = <Byte>Film number of each layer, 1 to n, when n = Number of Layers

Command ID = 2 "Name"

Response:

<Process Name>

Process Name = <String> maximum 15 characters plus null terminating character.

Command ID = 3 "Specific Layer"

<Parameter> = <2 Bytes>Desired Layer

Response:

<Byte> 1-32, film number of given layer

5.2.2.4 Standard UPDATE Commands

5.2.2.4.1 Update Block

Command:

UB< Command ID> <List of parameters>

Response:

None (Just header and trailer)

List of parameters for Command ID 1 =

<Number of Bytes in Response><General Parameters><Film 1 Parameters>…<Film32 Parameters><Inputs><Outputs><Film 1 Name>…<Film 32 Name> <Process 1>…<Process 99><Process 1 Name>…<Process 99 Name>

Number of Bytes in Response (2 bytes)

All General parameters (4 bytes per parameter)

All parameters for each film (4 bytes per parameter) (9 or 32 films based on XTC/3S or XTC/3M)

All input definitions (9) (1 byte per input) (XTC/3M only)

All output definitions (20) (1 byte per output) (XTC/3M only)

All output types (20) (1 byte per output) (XTC/3M only)

All Film Names (null terminated) (32 films based on XTC/3M only)

Every process layer list for each process (99) (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer) (XTC/3M only)

All process Names (null terminated) (99) (XTC/3M only)

Note: maximum allowed bytes are 57,800. If there are more bytes in the command then the data should be broken into the following commands.

List of parameters for Command ID 2 =

<Number of Bytes in Response><General Parameters><Film 1 Parameters>…<Film32 Parameters><Inputs><Outputs><Film 1 Name>…<Film 32 Name

Number of Bytes in Response (2 bytes)

All General parameters (4 bytes per parameter)

All parameters for each film (4 bytes per parameter) (9 or 32 films based on XTC/3S or XTC/3M)

All input definitions (9) (1 byte per input) (XTC/3M only)

All output definitions (20) (1 byte per output) (XTC/3M only)

All output types (20) (1 byte per output) (XTC/3M only)

All Film Names (null terminated) (32 films based on XTC/3M only)

List of parameters for Command ID 3 = (XTC/3M only)

<Number of Bytes in Response><Process 1>…<Process 50><Process 1 Name>…<Process 50 Name>

Number of Bytes in Response (2 bytes)

Every process layer list for each process 1 through 50 (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer)

All process Names (null terminated) (1 - 50)

List of parameters for Command ID 4 = (XTC/3M only)

<Number of Bytes in Response><Process 51>…<Process 99><Process 51 Name>…<Process 99 Name>

Number of Bytes in Response (2 bytes)

Every process layer list for each process 51 through 99 (2 byte length (for the number of layers programmed) followed by 1 byte for each programmed layer)

All process Names (null terminated) (51 - 99)

5.2.2.4.2 Standard Update Film Name (XTC/3M only)

Command:

UN <Film Number><Name>

Film Number = <Byte> 1-32

<Name> = string, (maximum 15 characters, characters are restricted to hex values 20 to 7E inclusive, plus terminating null character)

Response:

None (Just header and trailer)

5.2.2.4.3 Standard Update Film Parameters

Command:

UF <Command ID> <Film Number> <Parameter Value>

Command ID = <Byte>. See “UF Command ID” column of Table 5-2.

Film Number = <Byte> 1-9 (XTC/3S) or 1-32 (XTC/3M)

Parameter Value = <Integer> | <Float>

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

Description: Type of parameter value depends on command ID, see “DataType / Format” column of Table 5-2.

Response:

None (Just header and trailer)

Special Case: UF255 <Film Number> <List of all Film Parameter Values in order> will update all film parameters for the given film, in numeric order.

NOTE: Some limitations apply as to when specific film parameters may be updated, e.g., Hardware used by a film cannot be redefined while that film is active. All parameters may be updated in Ready state.

Table 5-2 Standard film parameters

UF (0x5546) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
0 (0x00)	Rise Time 1	MM:SS (Seconds)	Int	0	99:59 (5999)
1 (0x01)	Soak Power 1	%	Float xxx.x	0.0	100.0
2 (0x02)	Soak Time 1	MM:SS (Seconds)	Int	0	99:59 (5999)
3 (0x03)	Rise Time 2	MM:SS (Seconds)	Int	0	99:59 (5999)
4 (0x04)	Soak Power 2	%	Float xxx.x	0.0	100.0
5 (0x05)	Soak Time 2	MM:SS (Seconds)	Int	0	99:59 (5999)
6 (0x06)	Idle Ramp	MM:SS (Seconds)	Int	0	99:59 (5999)
7 (0x07)	Idle Power	%	Float xxx.x	0.0	100.0
8 (0x08)	Deposition Rate	Å/sec	Float xxx.x	0.000	999.9
9 (0x09)	Final Thickness	kÅ	Float x.xxx xx.xx xxx.x	0.000	999.9
10 (0x0a)	Thickness Set Point	kÅ	Float x.xxx xx.xx xxx.x	0.000	999.9
11 (0x0b)	New Rate	Å/sec	Float xxx.x	0.0	999.9
12 (0x0c)	Rate Ramp Time	MM:SS (Seconds)	Int	0	99:59 (5999)
13 (0x0d)	RateWatcher Accuracy	%	Int	1	99

Table 5-2 Standard film parameters (continued)

UF (0x5546) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
14 (0x0e)	RW Hold Time	MM:SS (Seconds)	Int	0	99:59 (5999)
15 (0x0f)	Sensor	Cannot change if film is running	Int	1	2
16 (0x10)	Tool Factor 1	%	Float xxx.x	10.0	500.0
17 (0x11)	Tool Factor 2	% (only active if sensor type = CrystalTwo	Float xxx.x	10.0	500.0
18 (0x12)	Xtal Stability Single	Values 1 to 24 are not allowed	Int	0	9999
19 (0x13)	Xtal Stability Total	Values 1 to 24 are not allowed	Int	0	9999
20 (0x14)	Xtal Quality Percent	%	Int	0	99
21 (0x15)	Xtal Quality Counts		Int	0	99
22 (0x16)	[2]Source		Int	1	2
23 (0x17)	[2]Crucible		Int	0	8
24 (0x18)	Control Gain	Å/sec / %	Float xx.xx	00.01	100.0
25 (0x19)	Control Time Constant	Seconds	Float xxx.x	0.1	100.0
26 (0x1a)	Control Dead Time	Seconds	Float xxx.x	0.1	100.0
27 (0x1b)	Max Power	%	Float xxx.x	0.0	100.0
28 (0x1c)	Density	g/cm^3	Float x.xx xx.xx	0.50	99.99

Table 5-2 Standard film parameters (continued)

UF (0x5546) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
29 (0x1d)	Z-Ratio		Float x.xxx xx.xx xxx.x	0.100	9.999
30 (0x1e)	Time Power	1=Yes, 0 = No	Int	0	1
31 (0x1f)	Delay option	0 = None 1 = Shutter 2 = Control 3 = Both	Int	0	3
32 (0x20)	[1]Transfer Sensor	1=Yes, 0 = No Cannot change if film is running	Int	0	1
33 (0x21)	[1]Transfer Tooling	%	Float xxx.x	10.0	500.0
34 (0x22)	[1]Control Delay Time	MM:SS (Seconds)	Int	0	99:59 (5999)
35 (0x23)	[2]Ion Assisted Deposit	1=Yes, 0 = No	Int	0	1
36 (0x24)	Graph Label	0 = Rate Dev 1 = Power	Int	0	1
37 (0x25)	Graph Scale	0 = 5 1 = 10 2 = 20 3 = 40	Int	0	3
255 (0xff)	[2]All Parameters				

1 See section 4.2.3.5, Option, on page 4-14
2 Cannot change when a film is running.

5.2.2.4.4 Standard Update General Parameters

Command:

UG <Command ID> <Parameter Value>

Command ID = <Byte> See “UG Command ID” column of Table 5-3.

Parameter Value = <Integer> | <Float>

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

Description: Type of parameter value depends on command ID, see “DataType” column of Table 5-3.

Response:

None (Just header and trailer)

Special Case: UG255<List of all General Parameter Values in order> will update all general parameters in numeric order.

NOTE: Some limitations may apply as to when general parameters may be updated.

Table 5-3 Standard general parameters

UG (0x5547) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
0 (0x00)	[1]Process to run (XTC/3M only)	Can be changed only in Ready or Idle in last layer	Int	1	99
	[1]Film to run (XTC/3S only)			1	9
1 (0x01)	Start Layer Without Backup Xtal	1 = Yes, 0 = No	Int	0	1
2 (0x02)	Stop on Alarms	1 = Yes, 0 = No	Int	0	1
3 (0x03)	Stop On Max Power	1 = Yes, 0 = No	Int	0	1
4 (0x04)	[1]Dep/Etch Mode	0 = Deposit 1 = Etch	Int	0	1
5 (0x05)	[1]Test	1 = Yes, 0 = No	Int	0	1
6 (0x06)	[1]Sensor 1 Type	0 = Single 1 = CrystalTwo 2 = CrystalSix 3 = Crystal12 4 = Rotary 5 = Dual Head	Int	0	5

Table 5-3 Standard general parameters (continued)

UG (0x5547) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
7 (0x07)	[1]Sensor 2 Type	0 = Single 1 = CrystalTwo 2 = CrystalSix 3 = Crystal12 4 = Rotary (On Query only: 5 = Dual Head)	Int	0	4 (5 for Query comm-and)
8 (0x08)	[1]Source Control Voltage	0 = 0 to +10 1 = 0 to -10 2 = 0 to +5 3 = 0 to -5 4 = 0 to +2.5 5 = 0 to -2.5	Int	0	5
9 (0x09)	Recorder Mode	0 = Rate 1 = Thickness 2 = Power 3 = Rate Deviation	Int	0	3
10 (0x0a)	Recorder Range	0 = 100 1 = 1000	Int	0	1
11 (0x0b)	Recorder Filter	1 = Smooth 0 = Unfiltered	Int	0	1
12 (0x0c)	Audio Feedback	1 = Yes, 0 = No	Int	0	1
13 (0x0d)	Dim LCD	Minutes	Int	0	99
14 (0x0e)	RS232 Baud Rate	0 = 9600 1 = 19200 2 = 38400 3 = 57600 4 = 115200	Int	0	4
15 (0x0f)	RS232 Communi-cations Protocol	0 = Standard RS232 1 = Datalog 2 = XTC/2 w/checksum 3 = XTC/2 no checksum	Int	0	3

Table 5-3 Standard general parameters (continued)

UG (0x5547) Command ID	Name	Units / Allowed Values / Notes	Data Type / Format	Low Limit	High Limit
16 (0x10)	Auto Start Next Layer (XTC/3M only)	1 = Yes, 0 = No	Int	0	1
	Input Option (XTC/3S only)	0 = Standard 1 = Film Select			
255 (0xff)	[1]All Parameters (Must be in Ready)				

[1] Cannot change when a film is running.

5.2.2.4.5 Standard Update Input Definition (XTC/3M only)

Command:

UI <Input Number> <Input Definition>|<Input Number = 255> <Input 1 Definition>

<Input 2 Definition> … <Input 9 Definition>

Input Number = <Byte> 1-9 (255=All Inputs)

Input Definition= <Byte> refer to section 5.2.2.3.5 on page 5-14

Response:

None (Just header and trailer)

5.2.2.4.6 Standard Update Output Definition (XTC/3M only)

Command:

UO <Output Number> <Output Definition>

Output Number = <Byte> 1-20 (255=All Outputs)

Output Definition = < Byte > refer to section 5.2.2.3.6 on page 5-15

Response:

None (Just header and trailer)

5.2.2.4.7 Standard Update Output Type Definition (XTC/3M Only)

Command:

UT <Output Number> < Output Type>|< Output Number = 255> < Output 1 Type > < Output 2 Type > … < Output 20 Type >

Output Number = <Byte> 1-20 (255=All Outputs)

Output Type = <Byte> (0 = Normally open, 1 = Normally closed)

Response:

None (Just header and trailer)

5.2.2.4.8 Standard Update Process Parameters (XTC/3M only)

Command:

UP <Command ID> <Process Number> <Parameter List> [<Parameter Value >]

Command ID = See listing below

Process Number = <Byte> 1-99

Parameter List = Depends on the Command ID (See listing that follows)

Parameter Value = Depends on the Command ID (See listing that follows)

Response:

None (Just header and trailer)

Command ID = 1 "Layer List"

Parameter List = <Number of Layers> <Layer 1> <Layer 2> … <Layer n>

Number of Layers = <2 Bytes> Number of layers in this process

Layer n = Film number the layer is to be programmed with. (1 – 32)

n = Number of Layers

Command ID = 2 "Name"

Parameter List = <Process Name>

Process Name = <String> maximum 15 characters, characters are restricted to hex 20 - hex 7E inclusive, plus null terminating character.

Command ID = 3 "Specific Layer"

Parameter List = Layer to be updated<2 Bytes>

Parameter Value = Film number for given layer to be programmed <Byte> (1 – 32)

5.2.2.5 Standard STATUS Commands

Command:

S <Command ID> (<Action Value>) - see special case S0 below.

Command ID = <Byte> See “S Command ID” column in Table 5-4.

Action Value = <Byte>, only required for S0.

S0 command: The S0 command requires a timer tick to be sent. Timer ticks increment internally from 0 to 256 (0x00 to 0xFF) at a rate of 4x per second. XTC/3 stores the S0 data set valid for each timer tick and returns that specific data set when the S0 command is sent with that particular timer tick. If the timer tick sent is not the current one, the data returned will be old data and may be as old as 64 seconds (256 timer ticks / 4 per second). Therefore, to get current data, the timer tick must first be extracted from a prior command and then incremented every 250 msec and inserted in the S0 as the <Action Value>.

Response:

<Byte|Integer|Float>(<Byte|Integer|Float>…<Byte|Integer|Float>

Integer = 4 byte, low to high

Float = 4 byte, ANSII standard, single precision, low to high

Table 5-4 Standard Status commands

S (0x53) Command ID	**Description**	**Response: Description (Data Format) Units -Detail-**
0 (0x00)	Process Information: (only valid for specific timer tick requested)	Returns the following **for the timer tick (0x00 to 0xFF) sent** Crystal Status (1 byte) Bit 0 - 0 = Good, 1 = Failed Crystal Bit 1 - 0 = Not Switching, 1 = Switching crystal Bit 2 - 0 Good Reading, 1 = Invalid Reading (reading is invalid during resonance recovery time of several seconds following loss of sensor crystal frequency measurement) State (1 byte) Active Sensor (1 byte) Active Crystal (1 byte) * Rate (Float) -One second average- Thickness (Float) Power (Float) *Rate Deviation (Float) Frequency (Int DDS units). -Multiply by 0.0034924596 to convert to hertz. Returns No Data if the requested timer tick has no new data to send.- * If in Stop or not in Deposit, Rate and Rate Deviation return values of zero.
	Procedure for extracting the Invalid Reading byte from the Crystal Status byte: 1. Send the S1 command to get the rate. 2. From the resulting response packet, find the timer tick value in the fourth byte of the response packet. 3. Append this timer tick value to the S0 command and send it. 4. Extract the first byte from the Response Message part of the Response Packet. 5. If bit 2 of that byte is 1, the Crystal Status is invalid, meaning the crystal is in recovery mode. (The status correlates with the specific rate just received.) 6. Repeat steps 1 to 5	

Table 5-4 Standard Status commands (continued)

S (0x53) Command ID	Description	Response: Description (Data Format) Units -Detail-
1 (0x01)	* Current Rate	(Float) Å/Sec -One second rolling average-
2 (0x02)	Current Power	(Float) %
3 (0x03)	Current Thickness	(Float) kÅ
4 (0x04)	Current State	(Byte) - Decoded as follows: - 0 = Ready 1 = Crucible Switch 2 = Rise 1 3 = Soak 1 4 = Rise 2 5 = Soak 2 6 = Shutter Delay 7 = Deposit 8 = Rate Ramp 9 = Manual 10 = Time Power 11 = Idle Ramp 12 = Idle
5 (0x05)	Current State Time	(Int) - Number of seconds -
6 (0x06)	Active Layer	(Int)
7 (0x07)	Active Film	(Byte)
8 (0x08)	Active Sensor	(Byte) (1 or 2)
9 (0x09)	Crystal Life	(Byte)
10 (0x0a)	Power Source	(Byte) (1 or 2)
11 (0x0b)	Output Status Byte	(4 Byte) - Each bit represents an output - (0 = not set, 1 = set) Output 1 = LSB, Output 20 = 20th bit

Table 5-4 Standard Status commands (continued)

S (0x53) Command ID	Description	Response: Description (Data Format) Units -Detail-
12 (0x0c)	Input Status Byte	(2 Byte) - Each bit represents an input - (0 = not set, 1 = set) Input 1 = LSB, Input 9 = 9th bit 0x0100 = Input 1 0x0200 = Input 2 0x0400 = Input 3 0x0800 = Input 4 0x1000 = Input 5 0x2000 = Input 6 0x4000 = Input 7 0x8000 = Input 8 0x0001 = Input 9 0x0300 = Input 1 & 2 0x0101 = Input 1 & 9 0x3800 = Input 4, 5 & 6 etc
13 (0x0d)	Raw Frequency	(Int DDS units). - Multiply by 0.0034924596 to convert to hertz.-
14 (0x0e)	Xtal Fail	(Byte) 0 = good crystal / not in Xtal Fail; 1 = failed crystal / in Xtal Fail
15 (0x0f)	Max Power	(Byte) 0 = false not in max power; 1 = true in max power
16 (0x10)	Crystal Switching	(Byte) 0 = not switching; 1 = switching
17 (0x11)	End of process	(Byte) 0 = False; 1 = True
18 (0x12)	Stop	(Byte) 0 = False; 1 = True

Table 5-4 Standard Status commands (continued)

S (0x53) Command ID	Description	Response: Description (Data Format) Units -Detail-
19 (0x13)	Data Log	Returns data as follows Layer # (Int) Film # (Int) Rate (Float) Å/Sec - One second average- Thickness (Float) kÅ Deposit time (Int) Seconds Average power (Float) % S Value (Int) Q Value (Byte) Begin Frequency (Float) HZ End Frequency (Float) HZ Crystal Life (Byte) % Layer end type (Byte) -Normal end (0), Time power end (1) or Stop (2) - Cause of stop: (Byte) 0 = No stop 1 = Keyboard 5 = Crystal Fail 6 = Max Power 7 = Hand Controller 8 = Communications 9 = Digital Input 10 = Power Loss 11 = Rate Dev Error 12 = Crystal Switcher fail
20 (0x14)	Active Process	(Byte)
21 (0x15)	Power up error flag	(Byte) Bit is set indicating error as follows: 0 = Parameter loss on power cycle 1 = Process variables loss on power cycle 2 = Power down/up cycle
30 (0x1e)	Crystal Status	(2 Bytes) Each bit indicates one crystal of a multi-head sensor. 1 = Good Crystal, 0 = Failed Crystal. LSB is Crystal 1. All bits > number of crystals on sensor are 0.
31 (0x1f)	Rolling Average	(Float) Å/Sec Returns a rolling 6.25-second average of the measurement rate. Updated every 0.25 seconds.
32 (0x20)	Active Crystal	(Byte) Crystal of the current sensor that is in use.

Table 5-4 Standard Status commands (continued)

S (0x53) Command ID	Description	Response: Description (Data Format) Units -Detail-
33 (0x21)	Status Messages	(4 bytes) Each bit indicates which status message is displayed. 0x80000000 = Max Power 0x40000000 = Crystal Fail 0x20000000 = Crystal Switch Fail 0x10000000 = Crystal Switching 0x08000000 = Carousel Open 0x04000000 = Control Delay 0x02000000 = Transfer Delay 0x01000000 = Delay Failure 0x00800000 = End of Process 0x00400000 = RateWatcher Delay 0x00200000 = RateWatcher Hold 0x00100000 = RateWatcher Sample 0x00080000 = Crucible Switch Fail 0x00040000 = Soak Hold 0x00020000 = Non Deposit Hold 0x00010000 = Etch Mode 0x00008000 = Local Lock 0x00004000 = Remote Lock 0x00002000 = Test 0x00001000 = Delayed Start 0x00000800 = Testing XIU 0x00000400 = Layer Insert 0x00000200 - 0x00000001 not defined
34 (0x22)	Raw Rate	(Float) Rate Å/Sec
35 (0x23)	Ethernet parameters	(8 bytes) First 4 bytes = IP address (xx.xx.xx.xx) Second 4 bytes = Net Mask (xx.xx.xx.xx) where the left most xx group is the MSB in both

5.2.2.6 Standard REMOTE Commands

R <Command ID> (<Action Value>)

Command ID = <Byte>. See "R Command ID" column in Table 5-5.

Action Value = <Byte> | <Float>

Float = 4 byte, ANSII standard, single precision, low to high

A few commands have a value with them. See Table 5-5.

Response = None (Just header and trailer)

Table 5-5 Standard remote commands

R (0x52) Command ID	Function	Description
0 (0x00)	Start	Starts the next layer of the active process.
1 (0x01)	Stop	Stops the layer, puts power to zero, closes shutters, etc.
2 (0x02)	Reset	If in Stop, resets XTC/3 to the Ready state, at the beginning of the process.
3 (0x03)	Remote lock on	Prevents the update of parameters via the front panel.
4 (0x04)	Remote lock off	Removes the remote lock.
5 (0x05)	Crystal fail inhibit on	Prohibits the crystal fail relay from activating.
6 (0x06)	Crystal fail inhibit off	The crystal fail relay will act normally.
7 (0x07)	Soak Hold 2 on	Will cause the unit to stay in Soak 2 state, once entered, until the Soak Hold is removed (R8)
8 (0x08)	Soak Hold 2 off	Will allow the unit to leave the Soak 2 state.
9 (0x09)	Manual on	Places the unit in the Manual power state.
10 (0x0a)	Manual off	Removes the unit from Manual power state, and puts it into the Deposit state.
11 (0x0b)	Set power to <Value> vv	Active layer to vv % power. vv = <Float> 0 - 100 (Note: Only allowed if current state is Manual)

Table 5-5 Standard remote commands (continued)

R (0x52) Command ID	Function	Description
12 (0x0c)	Zero thickness	Zeroes the thickness of the current layer.
13 (0x0d)	Final thickness trigger	Causes the active film to react as if the final thickness was reached.
14 (0x0e)	Crystal switch	If a multi-crystal sensor is attached to the unit, it will switch to the next position.
15 (0x0f)	Enter comm. I/O mode XTC/3S only.	This indicates that all digital outputs are under remote communications control, and their normal functions are overridden. XTC/3 must be in this mode to remotely set or clear relays (R17 and R18). If the unit is an XTC/3M an Illegal ID error is returned.
16 (0x10)	Exit comm. I/O mode Used in XTC/3S only.	Exits the Communication I/O mode, returns all digital outputs to normal, XTC/3 controlled operation. If the unit is an XTC/3M an Illegal ID error is returned.
17 (0x11)	Set (close) digital output <Value> vv	vv = <Byte> (output # 1- 20). In XTC/3S the Communication I/O mode must be active for this command to operate. In XTC/3M, the selected output must be set to Computer Control for this command to operate.
18 (0x12)	Clear (open) digital output <Value> vv	vv = <Byte> (output # 1-20). In XTC/3S the Communication I/O mode must be active for this command to operate. In XTC/3M, the selected output must be set to Computer Control for this command to operate.
19 (0x13)	Turn Backlight on	Turns the LCD backlight full on
20 (0x14)	Turn Backlight off	Turns the LCD backlight full off
21 (0x15)	Trigger beeper	Sounds an audible beep
22 (0x16)	Clear power up error flag	Clears the power up error.
26 (0x1a)	Clear All Crystals	Sets the crystal status for all the crystals in the current sensor to good.

Table 5-5 Standard remote commands (continued)

R (0x52) Command ID	Function	Description
27 (0x1b)	Rotate head	If the current sensor selected is a CrystalSix, Crystal12, Rotary or Dual Head, the sensor will perform a full rotation and all crystals will be verified. Returns an A response error code if configured for a Single, Crystal Two or Dual Head. Returns a F response error code if no output is defined.
28 (0x1c)	Clear S and Q counts	Clears the accumulated stability and quality counts.

5.3 XTC/2 Protocols

One of these protocols is in effect if **XTC/2 Ck Sum**, **XTC/2 No Ck Sum, XTC/C Ck Sum** or **XTC/C No Ck Sum** has been selected under the RS-232 Protocol parameter. TCP/IP always uses the **Standard** protocol. Unlike XTC/3's standard protocol, which is binary based, XTC/2 protocols are ASCII based. That is, numbers are represented by their ASCII codes, not as "floats" or "ints".

5.3.1 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.

The send and receive protocol formats are described below .

NOTE: When transmitting commands directly by typing on a keyboard, the entire command, including the ACK, must be entered quickly. Otherwise, XTC/3 will fail to recognize the transmission as a valid command.

5.3.2 XTC/2 Serial Communication with Checksum

This portion of the protocol is in effect in addition to the portion described under section 5.3.1 above if **XTC/2 Ck Sum** or **XTC/C Ck Sum** has been selected under the RS-232 Protocol parameter.

ACK . . . . Command acknowledged character, ASCII character value d06, Control F from keyboard.

NAK . . . . Command not acknowledged character, ASCII character value d21.

STX . . . . Start of transmission character, ASCII character value d02

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.

CS . . . . Checksum, modulo 256 value of message_string and ACK or NAK

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)

5.3.3 XTC/2 Serial Communications - No Checksum

This portion of the protocol is in effect in addition to the portion described under section 5.3.1 above if **XTC/2 No Ck Sum** or **XTC/C No Ck Sum** has been selected under the RS-232 Protocol parameter.

ACK . . . . Command acknowledged character, ASCII character value d06, Control F from keyboard.

NAK . . . . Command not acknowledged character, ASCII character value d21.

To XTC: message_string ACK

From XTC: message_string ACK (if success)

- or -

error_code NAK (if failure)

5.3.4 XTC/2 Error Codes

Table 5-6 XTC/2 error codes

Code	Description
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

5.3.5 XTC/2 Message Strings

5.3.5.1 XTC/2 ECHO Command

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

The format is: E message string

5.3.5.2 XTC/2 HELLO Command

The HELLO command will return the string **XTC/y VERSION x.xx** where y is 2 or C, depending on the RS232 protocol set, and x.xx is the software revision code.

The format is: H

5.3.5.3 XTC/2 QUERY Command

The Query command returns information concerning current XTC/3 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 5-7 XTC/2 parameter definition table (for QUERY and UPDATE commands)

XTC/2 PP	XTC/3	Parameter Range
0	Rise Time 1	0 - 5999 or 00:00 - 99:59
1	Soak Power 1	0.0 - 100.0
2	Soak Time 1	0 - 5999 or 00:00 - 99:59
3	Rise Time 2	0 - 5999 or 00:00 - 99:59
4	Soak Power 2	0.0 - 100.0
5	Soak Time 2	0 - 5999 or 00:00 - 99:59
6	Shutter Delay	0 to 1
7	New Rate	0.0 - 999.9
8	Rate Ramp Time	0 - 5999 or 00:00 - 99:59
9	Idle Ramp	0 - 5999 or 00:00 - 99:59
10	Idle Power	0.0 - 100.0
11	Time Power	1 or 0 or 'Y' or 'y' or 'N' or 'n'
12	Xtal Switch S	0 - 9 (See XTC/2 manual section 4.6)

Table 5-7 XTC/2 parameter definition table (for QUERY and UPDATE commands)

XTC/2 PP	XTC/3	Parameter Range
13	Xtal Switch Q	0 - 9 (See XTC/2 manual section 4.6)
14	Tool Factor 1	10 - 500.0
15	Tool Factor 2	10 - 500.0
16	Deposition Rate	0 - 999.9
17	Final Thickness	0.0 - 999.9
18	Thickness Spt	0.0 - 999.9
19	Density	0.5 - 99.99
20	Z-Ratio	0.1 - 9.999
21	Sensor	1 - 2
22	Source	1 - 2
23	Crucible	0 - 8
24	Control Gain	0.01- 100.0
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	0 - 5999 or 00:00 - 99:59
30-39 **	NOT USED **	
40	Layer	1-3[1] 0-9[2]
99	All	

1) May be 0 for Q command; if 0, will return values for layers 1 - 3.
In an XTC3/S there is only one layer. Q 40 2 or Q 40 3 returns an error. Q 40 0 returns 1 0 0. In XTC/3M, if there is no film in the layer, Q 40 2 or Q 40 3 will return a NO DATA error.
2) Only applies to U 40 command. 0 is not allowed for layer 1.

Table 5-8 Q40 command responses

Command	XTC/3S Response	XTC/3M Response
Q40 0	"a 0 0 " (a = 1 to 9, 0 = no film in layer)	"a b c" (a = 1 to 32, b = 0 to 32, c = 0 to 32)
Q40 1	"a" (a = 1 to 9)	"a" (a = 1 to 32)
Q40 2	"No Data" error	"b" if b = 1 to 32 "No Data" error if b = 0
Q40 3	"No Data" error	"c" if c = 1 to 32 "No Data" error if c= 0

a = Film # in Layer 1
b = Film # in Layer 2
c = Film # in Layer 3		

5.3.5.4 XTC/2 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. Refer to Table 5-7 for a numbered list of parameters and their limits. If value vvv is left blank, the command will be accepted and a value of 0 will be transmitted.

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.

NOTE: In XTC/2 one can program a zero film number in layer two and a good film number in layer three. This is not allowed in XTC3. If a zero is programmed in layer two and there is a good film number in layer three the film in layer three is then placed in layer two. Layer three is then empty.

U 40 2 v or U 40 3 v is not allowed in XTC3S since only one film is allowed in XTC3S.

5.3.5.5 XTC/2 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 sensor. x

S9. . . . . . Crystal life (%). x % to xx %

S10. . . . . Power source number. x (1 or 2)

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.

Response Format (Non-Checksum):

Byte1............Byte16<ACK> where byte 1 corresponds to output 1.

Table 5-9 XTC/2 Output Status bits

<table>
<tr><th>Output#</th><th>Output Default function</th><th>Output state</th></tr>
<tr><td>1</td><td>Source Shutter 1</td><td>1=open, 0=closed</td></tr>
<tr><td>2</td><td>Source Shutter 2</td><td>1=open, 0=closed</td></tr>
<tr><td>3</td><td>Sensor Shutter 1</td><td>1=open, 0=closed</td></tr>
<tr><td>4</td><td>Sensor Shutter 2</td><td>1=open, 0=closed</td></tr>
<tr><td>5</td><td>Stop</td><td>1=Stop, 0=not stop</td></tr>
<tr><td>6</td><td>End of Process</td><td>1=End of process, 0=not end of process</td></tr>
<tr><td>7</td><td>Thickness Setpoint</td><td>1=Thk Setpoint</td></tr>
<tr><td>8</td><td>Soak 2</td><td>1=Soak 2 phase</td></tr>
<tr><td>9</td><td>Crystal Fail</td><td>1=Xtal Fail</td></tr>
<tr><td>10</td><td>Alarms</td><td>1=Alarm Cond.</td></tr>
<tr><td>11</td><td>Source 1/Source 2, (toggle)</td><td>1=Source 2, 0=Source 1</td></tr>
<tr><td>12</td><td>End Deposit (Final Thickness)</td><td>1=End Deposit (Final Thickness) reached</td></tr>
<tr><td>13</td><td>Crucible Select LSB (XTC/2)</td><td rowspan="3">BCD value representing crucible position of active source:

000 = Position 0 or 1
111 = Position 8</td></tr>
<tr><td>14</td><td>Crucible Select (XTC/2)</td></tr>
<tr><td>15</td><td>Crucible Select MSB (XTC/2)</td></tr>
<tr><td>16</td><td>unused</td><td></td></tr>
</table>

S12 . . . . . Input status - returns 9 ASCII bytes in order byte 1 to 9, 1 byte per input. Each byte has an ASCII value of 0 or 1, corresponding to the input's status. 0 = grounded (active), 1 = open or high (inactive).

Table 5-10 S12 Command Input status

Input # Byte #	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

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, refer to section 5.2.2.5, S19 command 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 1 or 0 respectively. Also, when using the S19 command the Begin Process and End Process messages are not returned.

S20 . . . . . Present Configuration Selections - returns 16 ASCII bytes with a value of 0 or 1.

Data byte order (Non-checksum): 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 <ACK>

1 = Selection active, 0 = default state for selection

Also see S22 below.

NOTE: In the default configuration, bits 8 and 9 will return values of 1 whereas the defaults for these bits was 0 in XTC/2. If it is desired to make the S20 response equal to XTC/2 default response, change the Recorder Range to 100 and the Audio Feedback to Yes, both per section 4.4.2 on page 4-21.

Table 5-11 S20 Command Input status

Byte #	Function	State
# 1	Test Mode	(0 = off, 1 = on)
# 2	Parameter Lock	(0 = off, 1 = on)
# 3	Control Mode	(0 = deposit, 1 = etch)
# 4	Stop On Alarms	(0 = no, 1 = yes)
# 5	Stop on Max Power	(0 = no, 1 = yes)
# 6 **# 7** **# 8**	Recorder Type (in order: Byte 6, 7, 8)	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, 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
# 9	Beep On/Off	(0=on, 1=off)
# 10	Backlight Dim	(0 = no, 1 = yes)
# 11	Start Layer without backup crystal	(0 = no, 1 = yes) NOTE: See section 3.6.9 on page 3-30 for description
# 12	Input Option	0 = Standard, 1 =Film Select
# 13	Not used, returns 0	
# 14 **# 15**	Sensor Type (in order: Byte 14, 15)	00 = Single Head(s) 10 = Single CrystalSix on sensor 1 11= Two CrystalSix sensors
# 16	Source Control Voltage polarity	0 = neg, 1 = pos

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 . . . . . XTC/3 configuration readout, same as S20.

S30 . . . . . Returns status of each crystal of a multi-head sensor.

S31 . . . . . Returns a rolling 6.25 second average (updated every 0.25 seconds) of the measurement rate.

5.3.5.6 XTC/2 REMOTE Commands

The format of the Remote command is:

R xx vvv (a space is required between the xx and the 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% if unit is in Manual mode.

R12. . . . . Zero thickness. Simulates remote input or front panel ZERO keystroke.

R13. . . . . Final thickness-end deposit trigger. Simulates remote input.

R14. . . . . CrystalSwitch. Equivalent to front panel XTSW keystroke.

R15. . . . . XTC/3S only. Enter communication I/O mode — See R16 (Only applies when in communication I/O mode)

R16. . . . . XTC/3S only. Exit communication I/O mode — See R15 (Only applies when in communication I/O mode)

R17. . . . . Set (close) relay xx (xx = 1-12) (Works also in XTC/3M if that output has been selected as "Computer Contl" type)

R18. . . . . Clear (open) relay xx (xx = 1-12) (Works also in XTC/3M if that output has been selected as "Computer Contl" type)

R19. . . . . Turn backlight ON

R20. . . . . Turn backlight OFF

R21. . . . . Trigger beeper

R22. . . . . Clear Error Flag

R23. . . . . Not supported

R24. . . . . Not supported

R25. . . . . Set upper frequency limit to 6.027 MHz. (This command is accepted but not executed since the default upper frequency limit exceeds 6.027 MHz.)

The following additional commands were available on 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. . . . . Not supported

R40. . . . . Not supported

R41. . . . . Not supported

R42. . . . . Not supported

R43. . . . . Not supported

5.3.5.7 XTC/2 Sample Host Programs

5.3.5.7.1 XTC/2 Program Without Checksum

```
10 '----XTC/3 RS232 COMMUNICATIONS PROGRAM WITHOUT CHECKSUM----
20 '
30 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO XTC/3 AND
ACCEPT THE APPROPRIATE RESPONSE FROM XTC/3, 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/3
90 GOSUB 130 :'--GOTO TRANSMIT COMMAND
SUBROUTINE.
100 PRINT RESPONSE$ :'--PRINT XTC/3 RESPONSE
110 GOTO 80 :'--LOOP BACK FOR ANOTHER
COMMAND.
120 '
130 '----TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE----
140 '
150 '----SEND COMMAND MESSAGE STREAM TO XTC/3----
160 PRINT #1, CMD$ + ACK$;
170 '
180 '----RECEIVE RESPONSE MESSAAGE FROM XTC/3----
190 RESPONSE$ = "" :'--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.
```

5.3.5.7.2 XTC/2 Program With Checksum

```
10 '--XTC/3 RS232 COMMUNICATIONS PROGRAM WITH CHECKSUM USING THE INFICON
FORMAT--
20 '
30 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO XTC/3
AND ACCEPT THE APPROPRIATE RESPONSE FROM XTC/3, 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/3
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/3 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 XTC/3--
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 XTC/3----
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 :'--RECEIVE HIGH ORDER BYTE
350 SIZE = 256 * ASC(I$) :' OF TWO BYTE RESPONSE SIZE.
360 TOUT = 3: GOSUB 510 :'--RECEIVE LOW ORDER BYTE
370 SIZE = SIZE + ASC(I$) :' 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.
```

Chapter 6
Troubleshooting, Status and Error Messages

6.1 Status and Error Messages

ALREADY RUNNING

This message appears if a **START** command is given to the layer and the layer is already in progress.

ALREADY SWITCHING

An attempt is being made to switch a crystal or switch a crucible while a crystal switch or crucible switch is already in progress.

CAN'T EMPTY ACTIVE PROCESS

Can't delete all layers in the active process.

CAROUSEL OPEN

The crystal carousel assembly has been removed from a Crystal12 sensor.

COMMUNICATION

Unit has gone into **STOP** because a Stop command was received.

CONTROL DELAY

Indicates that XTC/3 is in the Control Delay state.

CRUCIBLE FAIL

Unit has gone into **STOP** because of a Crucible Switch error.

CRUCIBLE SW

Indicates a crucible switch is in progress.

CRUCIBLE SW FAIL

This error occurs when a layer has been in the Crucible Switch state for greater than 30 sec. without receiving a Cruc Valid feedback input signal.

CRYSTAL FAIL

Unit is unable to detect a resonance or a crystal has exceeded its allowed S or Q thresholds.

CRYSTAL SWITCH

Crystal switching is in progress.

CRYSTAL SW FAIL

Crystal switching failed to complete.

DELAY FAILURE

Indicates that XTC/3 was unable to achieve rate control during the Shutter Delay state.

DELAYED START

Start will be executed after XTC/3 completes internal processing.

DIGITAL INPUT

Unit has gone into **STOP** because the designated Stop Input was activated.

EMPTY PROCESS

Indicates that the selected process has no layers and therefore cannot be selected to run.

END OF PROCESS

Indicates that the last layer in the process has reached the Idle state.

ETCH MODE

Indicates that XTC/3 is in the etch mode.

ETHERNET IN USE

Ethernet values cannot be changed at this time.

ETHERNET VALUES HAVE CHANGED

Changes take effect on power up.

FRONT PANEL

Indicates that XTC/3 was stopped by pressing **STOP** on the front panel.

HANDCONTROL

Indicates that XTC/3 was stopped by pressing **STOP** on the Handheld Controller.

INCORRECT TIME

Incorrect value was entered.

INPUT INCORRECT

Incorrect lock code was entered to unlock the unit.

INVALID MASK

Gateway mask value is Incorrect.

L LOCK

Indicates XTC/3 is in a Local Program Lock mode. This prohibits any parameter from being entered from the front panel until the Program Lock Code is entered.

LAYER INSERT

Appears in Process List to indicate that Layer Insert was successful.

MAX POWER

Indicates the specified maximum power has been reached. The power value will be displayed in red.

NO BACKUP CRYSTAL

An attempt is being made to start a layer and there are no good crystals remaining in the sensor head. This message will appear unless ’Start without Backup’ is enabled.

NO GOOD XTAL TO SW

There are no good crystals available to switch to.

NO MANUAL XTAL FAIL
Unable to enter Manual operation.

NO MANUAL IN STOP
Unable to enter Manual operation.

NO MANUAL IN IDLE
Unable to enter Manual operation.

NO OUTPUT FOR SW
A rotate or switch crystal head function cannot be performed if no output has been set for the function.

NO SWITCH SINGLE
A crystal switch function cannot be done on a single sensor.

NON-DEP HOLD
Indicates the Non-Dep Hold input is set and will maintain the layer in the non-deposit hold state if the layer is not already in Deposit or Shutter Delay.

NOT RELAY OUTPUT
This message appears when attempting to set a TTL output on the Relay screen.

NOT TTL OUTPUT
This message appears when attempting to set a Relay output on the TTL screen.

ONE SEL PROC ONLY
This message appears when attempting to set more than one Select Process input event.

ONE WIRE READ FAIL
(Diagnostic Page) Contact INFICON.

PARAMETER DEFAULT
Indicates XTC/3 parameters have been set to their default values. Any previously programmed values will have been changed to the default values.

POWER LOSS
Indicates XTC/3 lost line power immediately prior to the current power on cycle.

PROCESS RUNNING
Message appears if trying to enter the Diagnostics mode while a process is running.

PROCESS VAR DEFAULT
Indicates XTC/3 process variables have been set to their default values. Any previous process variables will have been changed to the default values.

R LOCK

Indicates XTC/3 is in a Remote Program Lock mode. This prohibits any parameter from being entered from the front panel until the lock is released via remote communications.

RATE DEV ERR

Indicates XTC/3 entered the Stop mode because rate control was not achieved within 60 seconds.

RATEWATCH DELAY

The RateWatcher feature is active. The sensor is stabilizing for 5 seconds before **SAMPLE**. The previous sample period's Average Rate is being integrated for thickness. The previous sample period's Average Power is being held constant.

RATEWATCH HOLD

The RateWatcher feature is active. The sensor shutter is closed. The previous sample period's Average Rate is being integrated for thickness. The previous sample period's Average Power is being held constant.

RATEWATCH SAMPLE

The RateWatcher feature is active. The sensor shutter is open. The source rate is being measured and it's power controlled.

RS-232 FAILED

Indicates the self test with the loop back connector failed. Indicates a hardware defect either in XTC/3 or the loop-back connector.

RS-232 PASSED

Indicates the self test with the loop back connector passed.

SHUTTER DELAY

The layer is in the Stop state because rate control was not achieved within 60 seconds while in the Shutter Delay state.

SOAK HOLD

The current source has paused execution and will maintain the current power level until the hold is turned off.

START INHIBITED

The Start command was not processed because the Start Inhibit input is set.

STOP

The layer is in the **STOP** state. There will always be another message on the screen at the same time to indicate the cause of the Stop.

SWITCHER FAIL

Indicates defect in multi-position sensor.

TEST

Indicates XTC/3 is in TEST mode.

TESTING XIU

XIU test in progress.

TIME POWER

Indicates XTC/3 entered the Time Power mode due to a crystal failure of the last good crystal and Time Power was set to Yes.

TRANSFER DELAY

Indicates XTC/3 is in the transition from the pre-deposit sensor to the deposit sensor.

VALUE TOO LOW

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press **CLEAR** to delete the value and enter again.

VALUE TOO HIGH

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press **CLEAR** to delete the value and enter again.

XIU NOT ATTACHED

(Diagnostics Page) XIU and XIU cable are not attached for the specific sensor channel.

XIU TEST FAILED

The Crystal Interface Unit (XIU) has failed the XIU test.

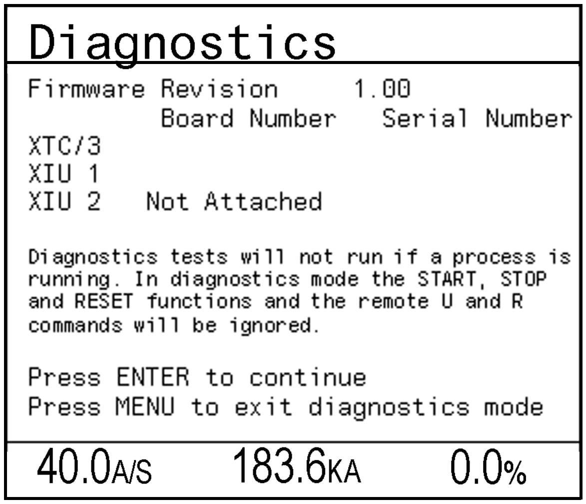
XIU TEST PASSED

The Crystal Interface Unit (XIU) has passed the XIU test.

6.2 XTC/3 Diagnostics

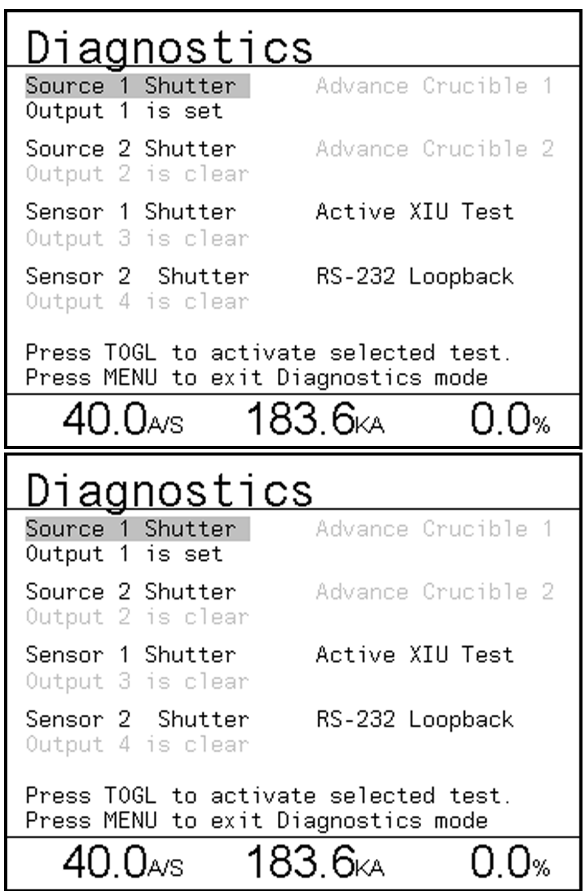
The initial page shows the revision level of the firmware as well as serial numbers.

Figure 6-1 Diagnostics display



Pressing **Enter** permits various test and maintenance functions.

Figure 6-2 Diagnostics Test/Maintenance display



Output Set or Clear

To verify operation of outputs, cursor to the desired output and press the **TOGL** key. The output state and the set/clear display will change accordingly. Only active outputs, like **Source 1 Shutter**, **Source 2 Shutter**, **Sensor 1 Shutter** and **Sensor 2 Shutter** in the Figure 6-2 example above, can be toggled. The cursor will skip over greyed out, indicating they are inactive, outputs like **Advance Crucible 1** and **Advance Crucible 2** in the Figure 6-2 example above.

Active XIU Test

To initiate the XIU Self Test, disconnect the XIU BNC cable at the sensor feedthrough, move the cursor onto the item and press the **TOGL** key. The XIU Self Test determines whether the Crystal Interface Unit (XIU), interconnect cable and Measurement circuit for the active sensor are operating properly.

NOTE: The XIU (PN 780-600-GX) must have the 15 cm (6 in.) BNC cable (PN 755-257-G6) attached and must be disconnected from the sensor feedthrough. The XIU Self Test is not compatible with a 50 cm (20 in.) BNC cable.

RS-232 Loopback

To initiate the RS-232C COMM PORT self test, install the Loop Back connector, move the cursor onto the item and press the **TOGL** key. Upon completion of the test, the unit will display a message indicating the test was successful and the COMM PORT is okay; or the test failed and the COMM PORT is bad.

NOTE: The RS-232C Loop Back connector, PN 760-406-P1 must be installed on XTC/3 RS-232C port for the self-test to work properly.

6.3 Troubleshooting Guide

If XTC/3 fails to work, or appears to have diminished performance, the following Symptom/Cause/Remedy chart may be helpful.

CAUTION

There are no user serviceable components within the XTC/3 case.

WARNING - Risk Of Electric Shock

Potentially lethal voltages are present when the line cord, Inputs or Outputs are connected.

CAUTION

Refer all maintenance to technically qualified personnel.

CAUTION

XTC/3 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 Troubleshooting XTC/3

Table 6-1 Troubleshooting XTC/3

SYMPTOM	CAUSE	REMEDY
1. power on LED not illuminated	a. blown fuse/circuit breaker tripped	a.have qualified personnel replace fuse/reset circuit breaker
	b. electrical cord unplugged from wall or back of XTC/3	b. reconnect power cord
	c. incorrect line voltage	c. have qualified personnel verify line voltage
2. XTC/3 "locks" up	a. cover or back panels not attached to XTC/3	a. ensure all covers and panels are in place and securely fastened
	b. high electrical noise environment	b. reroute cables to reduce noise pickup (1 ft away from high power conducting lines makes a sizable reduction in the amount of noise entering XTC/3), 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 XTC/3 grounding
3. XTC/3 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. If your XTC/3 has an SRAM problem contact INFICON
	b. power supply problem	b. contact INFICON
	c. dead battery	c. contact INFICON
4. some keys on front panel function while others do not	a. faulty keypad or faulty keypad ribbon cable	a. contact INFICON
5. all keys on the front panel fail to function	a. XTC/3 is "locked" up	a. turn power to OFF or to STBY, then to ON, see item 2 above

Table 6-1 Troubleshooting XTC/3 (continued)

SYMPTOM	CAUSE	REMEDY
6. control voltage output does not function properly	a. XTC/3 damaged from applying voltage to the control voltage output	a. ensure cable connection to the Source output does not have a potential across the contacts, contact INFICON
	b. reversed polarity of control voltage relative to that accepted by the source power supply	b. verify Source output polarity and the required input polarity of the source power supply, refer to the instruction manual to reconfigure XTC/3 if necessary
	c. improper control cable fabrication	c.check for correct cable wiring in the appropriate section of the manual
7. LCD display blank	a. LCD or CRT/power supply problem	a. contact INFICON
	b. LCD Dimmer Time has elapsed.	b. press the cursor key to redraw the screen.
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 XTC/3 measurement frequency	b. adjust the sweep frequency so it is not a multiple of XTC/3 measurement frequency (4 Hz)
9. power-on LED blinking	a. internal hardware defect	a. contact INFICON

Table 6-1 Troubleshooting XTC/3 (continued)

SYMPTOM	CAUSE	REMEDY
10. crystal fail message is 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
	c. defective cable from feedthrough to XIU/oscillator or from XTC/3 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
	g. frequency of crystal out of range	g. verify that the crystal frequency is within the required range, use INFICON crystals.
	h. Xtal failed due to S or Q failure.	h. clear S & Q values on Sensor page

6.3.2 Troubleshooting Transducers/Sensors

Many sensor head problems may be diagnosed with a DVM (Digital Volt Meter). Disconnect the short oscillator cable from the feedthrough and measure the resistance from the feedthrough's center pin to ground. If the reading is less than 1-2 MΩ, 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 Ω from the feedthrough to the transducer contact indicates a problem. Cleaning contacts or replacing the in-vacuum cable may be required.

A more thorough diagnosis may be performed with the optional Crystal Sensor Emulator, PN 760-601-G2. See section 6.5 on page 6-25 for a discussion of its use and diagnostic capabilities.

6.3.2.1 Verifying Crystal Switching and Rotation

The Sensor Information screen allows checking active sensor function from XTC/3 front panel. Refer to section 3.3.8, Sensor Information Display, on page 3-13.

6.3.2.2 Verifying Sensor Shutter Operation

To exercise the shutter on a Crystal Two, use the Switch Crystal function as described under section 3.3.8. To exercise the shutter on a shuttered sensor, (Standard, Compact, Sputtering, CrystalSix, Crystal12, Rotary or UHV Bakeable sensor with shutter), use the **Diagnostics** screen **Toggle Shutter** function for the appropriate sensor per Figure 6-2 on page 6-6 above.

NOTE: A more detailed troubleshooting guide is shipped with the sensor. Refer to the sensor operating manual.

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Table 6-2 Troubleshooting transducers/sensors

SYMPTOM	CAUSE	REMEDY
1. large jumps of thickness reading during deposition	a. mode hopping due to defective crystal	a. replace crystal
	b. stress causes film to peel from crystal surface	b. replace crystal
	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
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

Table 6-2 Troubleshooting transducers/sensors (continued)

SYMPTOM	CAUSE	REMEDY
NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition.		
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. bend leaves to approximately 45°
	c. RF interference from sputtering power supply	c. verify earth ground, use ground strap adequate for RF ground, change location of XTC/3 and oscillator cabling away from RF power lines, connect XTC/3 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
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

Table 6-2 Troubleshooting transducers/sensors (continued)

SYMPTOM	CAUSE	REMEDY
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 tube to body (CrystalSix or Crystal12 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

Table 6-2 Troubleshooting transducers/sensors (continued)

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 XTC/3 measurement frequency
7. large drift in thickness (greater than 200 A 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 (CD PN 074-5000)
	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

Table 6-2 Troubleshooting transducers/sensors (continued)

SYMPTOM	CAUSE	REMEDY
8. CrystalSix and Crystal12: 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 PSIG
	b. operation has been impaired as a result of material accumulation on cover	b. clean material accumulation as needed, refer to either the CrystalSix manual PN 074-155 or Crystal12 manual PN 074-398 on CD PN 074-5000 for maintenance
	c. improper alignment	c. realign as per instructions in either the CrystalSix manual PN 074-155 or Crystal12 manual PN 074-398 on CD PN 074-5000
	d. 0.0225 in. diameter orifice not installed on the supply side of solenoid valve assembly.	d. install orifice as shown in either the CrystalSix manual PN 074-155 or Crystal12 manual PN 074-398 on CD PN 074-5000
9. Crystal12: Carousel Open and Xtal Fail messages remain after installing carousel	a. open circuit	a. initiate a Crystal Switch or Rotate Head function
10. Crystal12: Unit indexes twelve times and displays Xtal Switch Error, Xtal Fail, and Carousel Open message	a. loss of electrical signal	a. check for electrical continuity and isolation
	b. resistor #1 is open	b. check for electrical continuity and isolation
	c. no carousel installed	c. install carousel
	d. torsion spring of electrical connection assembly broken	d. replace electrical connection assembly — refer to Crystal12 manual PN 074-398 on CD PN 074-5000

6.3.3 Troubleshooting Computer Communications

Table 6-3 Troubleshooting computer communications

SYMPTOM	CAUSE	REMEDY
1. communications cannot be established between the host computer and XTC/3	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 XTC/3	b. verify BAUD rate in the host's applications program, verify BAUD rate in XTC/3
	c. incompatible protocols being used	c. verify that XTC/3 protocol: RS232, TCP/IP, matches host
	d. incorrect device address (TCP/IP)	d. verify device address in host's applications program and verify XTC/3 address
2. **'Standard'** protocol: Error code returned in Packet Error byte or Response Error byte	a. various	a. Refer to section 5.2.1.2 on page 5-8
3. **'XTC/2'** protocol: Error code returned	a. various	a. Refer to section 5.3.4 on page 5-38

6.3.3.1 TCP/IP Module LED Diagnostics

Table 6-4 TCP/IP module LEDs

LED	Description
Green (Top left)	Serial port activity: Off - serial port is idle; On - serial data is transmitted or received
Green (Top right)	Network link status: Off - no link has been detected; On - a link has been detected
Red (Bottom left)	Diagnostics: Blinking 1-1-1 - starting the operating system; Blinking 1-5-1 - configuration has been returned to factory default; contact INFICON Service if other blinking patterns occur; On - normal operation
Yellow (Bottom right)	Blinking - network data is transmitted or received

6.4 Replacing the Crystal

The procedure for replacing the crystal is basically the same with all transducers, except the Cool Drawer, RSH-600, CrystalSix and Crystal12.

CAUTION

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.

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

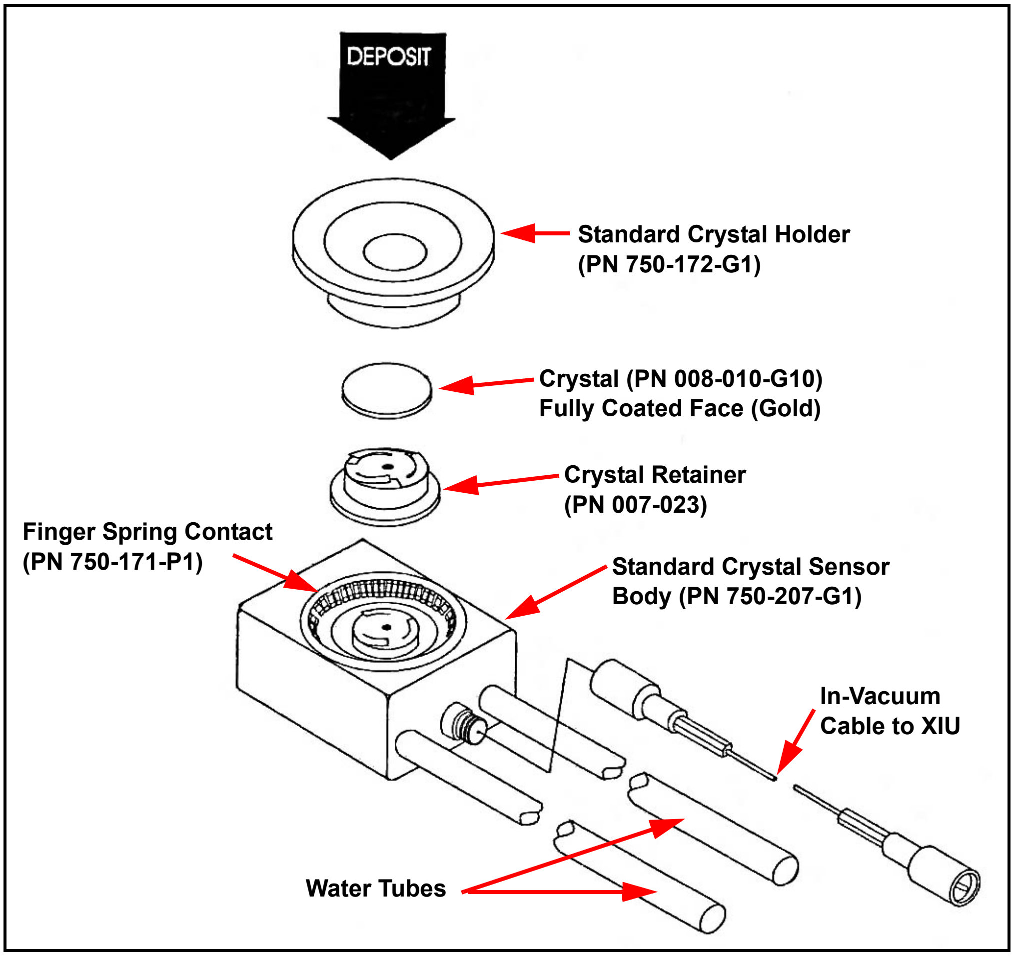
NOTE: Thick deposits of some materials, such as SiO, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, replace the crystals.

6.4.1 Front Load Single Sensors

Follow the procedure below to replace the crystal in the Front Load Single sensor (see Figure 6-3):

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 the Crystal Snatcher; see Figure 6-8 on page 6-24).
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 6-3 Front load single sensor (exploded)



6.4.2 Shuttered Front Load Single and Front Load Dual Sensors

There is no difference in the crystal replacement procedure between shuttered and non-shuttered Front Load Single sensors, since the shutter pivots away from the crystal opening when the shutter is in the relaxed state.

6.4.3 Cool Drawer Sensor

Follow the procedure below to replace the crystal in a Next Generation Cool Drawer™ sensor:

1 Using your thumb and index fingers, gently squeeze the sides of the retainer at the mid section then lift it up, away from the drawer.
See Figure 6-4 on page 6-21.

2 Hold the drawer by the handle and turn it upside down to remove the spent crystal.

3 Install a new crystal in the drawer. Observe its orientation. The pattern electrode should face upward as shown in Figure 6-5.

4 Hold the retainer by its sides. Align its orientation notch with the drawer then gently and evenly push the retainer down until it snaps firmly into the drawer. see Figure 6-5. Never push down (or pull up) on the contact spring, doing so may permanently damage it.

Inspect the whole assembly. The retainer should be even and engage the drawer at all four corners.

Figure 6-4 Cool drawer - removing the crystal

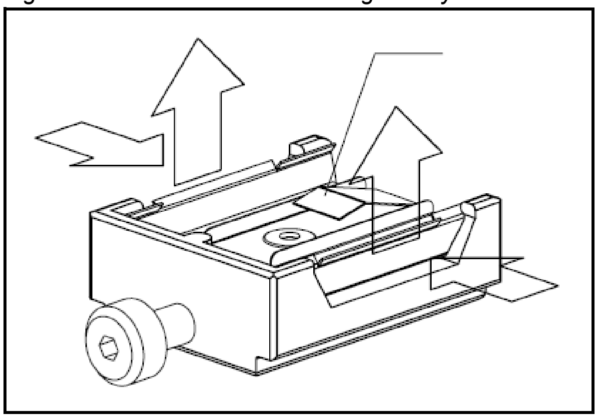
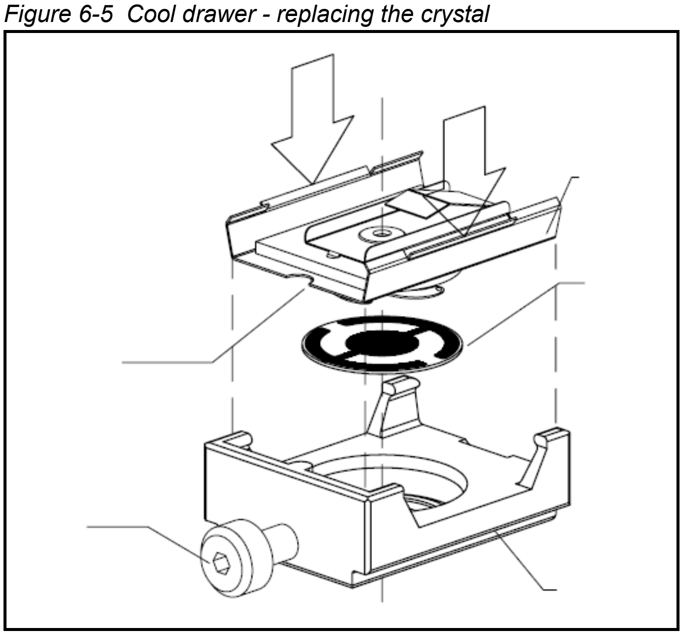


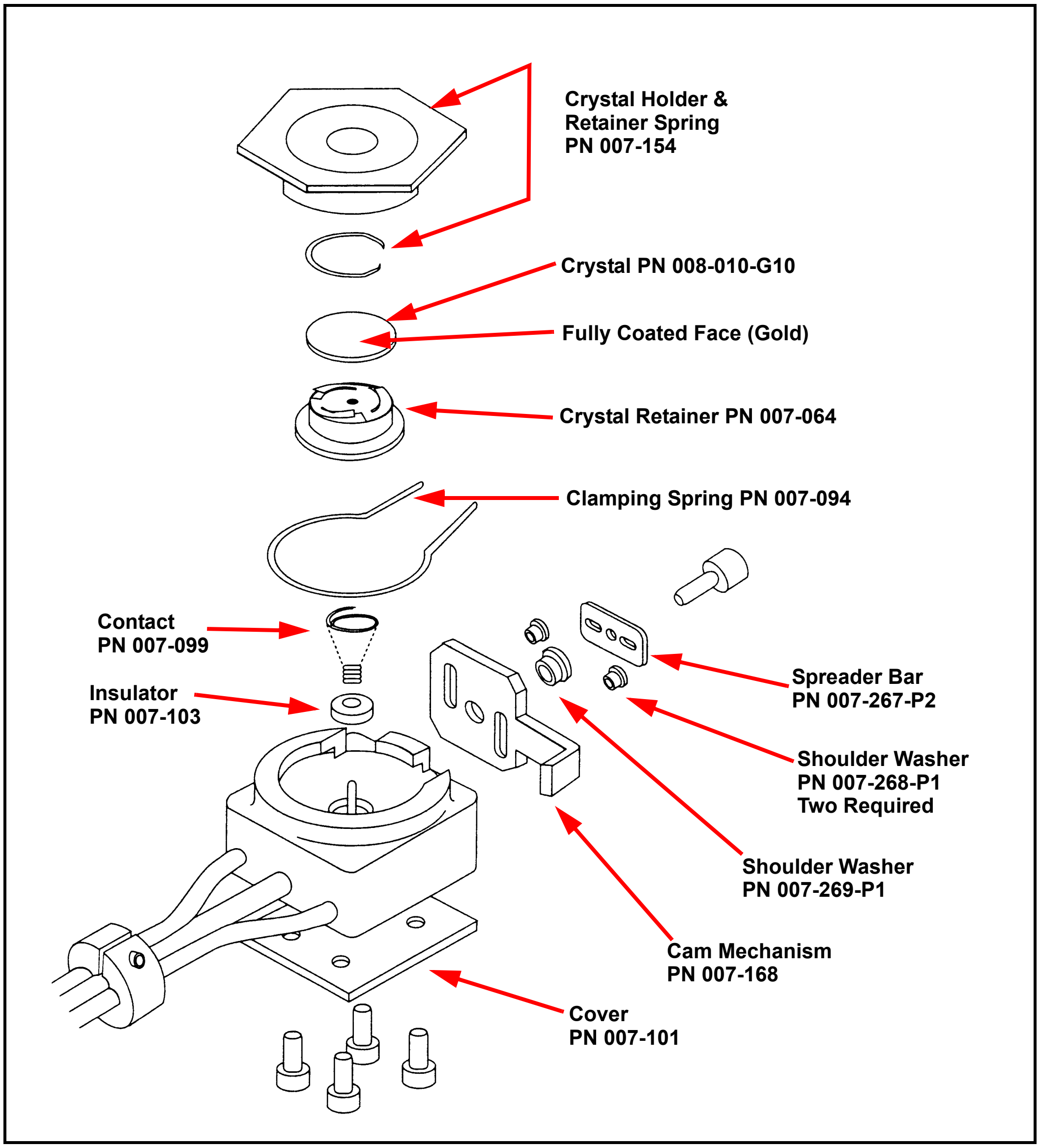
Figure 6-5 Cool drawer - replacing the crystal



6.4.4 Bakeable Sensor

For the Bakeable sensor, the procedure is the same as the Front Load Single sensor except that the cam assembly must be unlocked 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. See Figure 6-6.

Figure 6-6 Bakeable crystal sensor

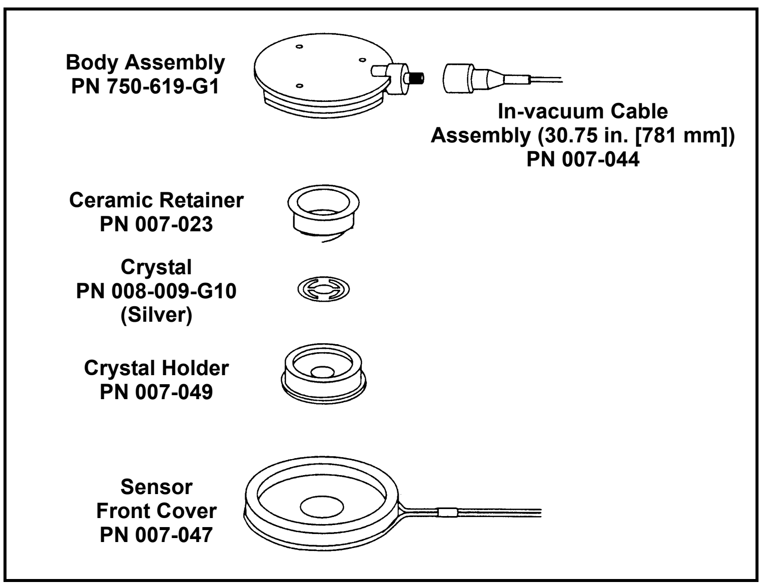


6.4.5 Sputtering Sensor

Observe the general precautions 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 6-7.
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 (see section 6.4.6 on page 6-24).
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, PN 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 6-7 Sputtering crystal sensor

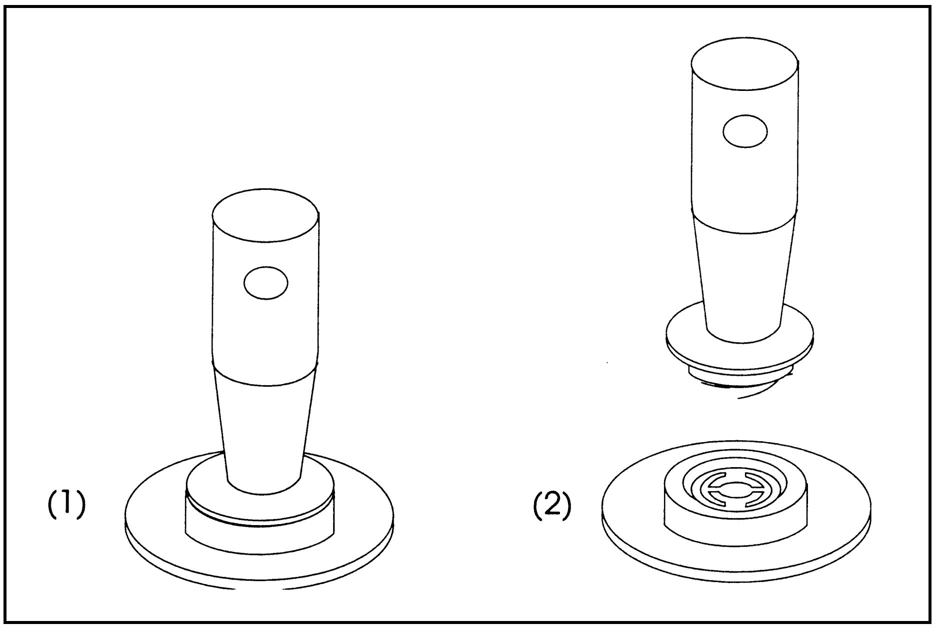


6.4.6 Crystal Snatcher

Use the crystal snatcher, supplied with the sensor (excluding Cool Drawer sensors), as follows:

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. Reinsert the retainer into the holder after the crystal has been replaced.
3. Release the crystal snatcher with a slight side-to-side motion.

Figure 6-8 Use of the crystal snatcher



6.4.7 CrystalSix

Refer to the *CrystalSix Operating Manual* (PN 074-155 on CD PN 074-5000-G1) for specific instructions for this device.

6.4.8 Crystal12

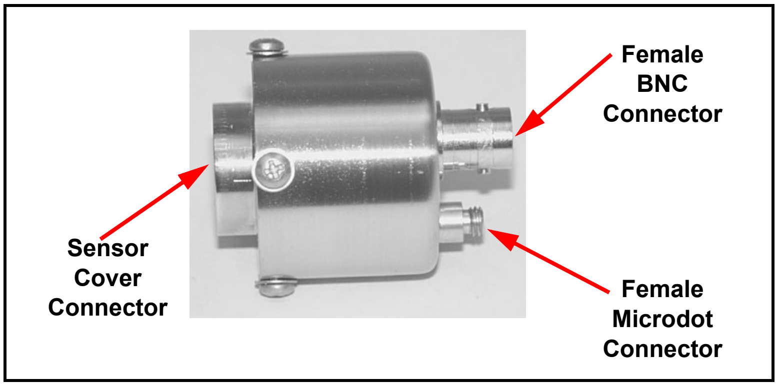
Refer to the *Crystal12 Operating Manual* (PN 074-398 on CD PN 074-5000-G1) for specific instructions for this device.

6.5 Crystal Sensor Emulator PN 760-601-G2

NOTE: 760-601-G2 is fully compatible with all INFICON thin film deposition controllers.

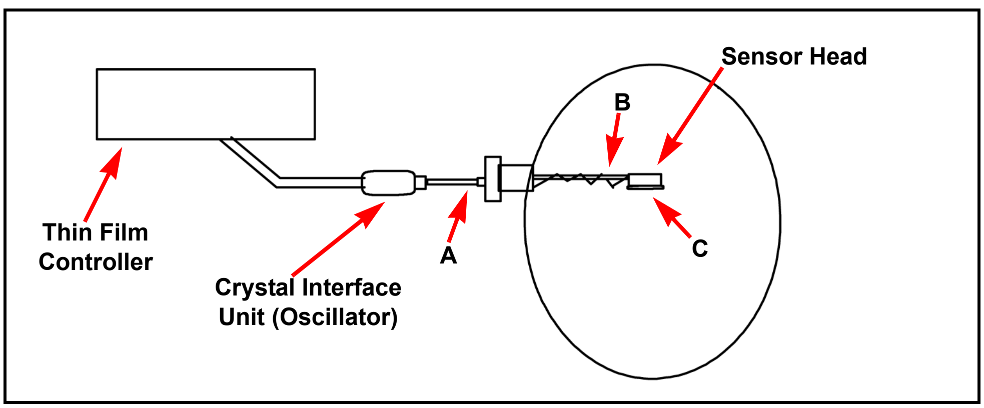
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See Figure 6-9.

Figure 6-9 Crystal sensor emulator



The Crystal Sensor Emulator may be attached at various points in the measurement system, from the oscillator to the sensor head. It provides a known good monitor crystal with known good electrical connections. Using the emulator and the controller in a systematic manner provides a fast means of isolating measurement system, cable, or sensor problems. See Figure 6-10.

Figure 6-10 Crystal sensor emulator attachment points



CAUTION

This product is designed as a diagnostic tool, and is not intended for use in vacuum. Do not leave the Crystal Sensor Emulator installed in the vacuum system during processing.

6.5.1 Diagnostic Procedures

The following diagnostic procedures employ the Crystal Sensor Emulator to analyze a constant Crystal Fail message. The symptom is a Crystal Fail message that is displayed by the Deposition Controller even after the monitor crystal has been replaced with a new “good” monitor crystal.

6.5.1.1 Measurement System Diagnostic Procedure

1. Refer to Figure 6-10 on page 6-25. Remove the 6 in. BNC cable from the Feed-Through at point A.
2. Connect the Crystal Sensor Emulator to the 6 in. BNC cable at Point A.
   - If the XTAL Fail message disappears after approximately five seconds, the measurement system is working properly. Re-install the 6 in. BNC cable to the Feed-Through. Go to section 6.5.1.2.
   - If the XTAL Fail message remains, continue at step 3.
3. Disconnect the 6 in. BNC cable from the Oscillator and from the Emulator.
4. Visually inspect the 6 in. BNC cable to verify that the center pins are seated properly.
5. Use an Ohm meter to verify the electrical connections on the 6 in. BNC cable.
   - There must be continuity (<0.2 Ω) between the center pins.
   - There must be isolation (>10 MΩ) between the center pins and the connector shield.
   - There must be continuity between the connector shields.

   Replace the 6 in. BNC cable if it is found to be defective and repeat Step 2 of this procedure.
6. If the 6 in. BNC cable is not defective, re-connect the 6 in. cable to the oscillator and to the Crystal Sensor Emulator. If the XTAL Fail message remains, contact INFICON (refer to section 1.3 on page 1-5).

6.5.1.2 Feed-Through Or In-Vacuum Cable Diagnostic Procedure

1 Refer to Figure 6-10 on page 6-25. Remove the In-Vacuum cable from the Sensor Head at point B.

2 Connect the Crystal Sensor Emulator to the In-Vacuum cable.

- If the XTAL Fail message disappears after approximately five seconds, the Feed-Through and In-Vacuum Cable are working properly. Re-install the In-Vacuum cable to the Sensor Head. Go to section 6.5.1.3 on page 6-28.
- If the XTAL Fail message remains, continue at step 3.

3 Disconnect the In-Vacuum cable from the Feed-Through and the Emulator. Disconnect the 6 in. BNC cable from the Feed-Through.

4 Using an Ohm Meter, verify electrical continuity from the BNC center pin on the Feed-Through to the Microdot center pin on the Feed-Through. A typical value would be less than 0.2 Ω.

5 Verify electrical isolation of the center pin on the Feed-Through from the electrical ground (Feed-Through body). A typical value would be in excess of 10 MΩ.

If the Feed-Through is found to be defective, replace the Feed-Through, re-attach the BNC and In-Vacuum cables, and repeat this procedure starting at Step 2, otherwise continue at step 6.

6 Verify electrical continuity from center pin to center pin on the In-Vacuum cable.

7 Verify that the center pin of the In-Vacuum cable is electrically isolated from the In-Vacuum cable shield.

If the In-Vacuum cable is found to be defective, replace the In-Vacuum cable. Re-attach the BNC and In-Vacuum cables, and repeat this procedure starting at Step 2, otherwise continue at step 8.

8 Connect the In-Vacuum Cable to the Feed-Through.

9 Verify electrical continuity from the center pin on the BNC connector of the Feed-Through to the center pin on the un-terminated end of the In-Vacuum cable.

10 Verify electrical isolation from the center pin to electrical ground (Feed-Through body).

If the Feed-Through/In-Vacuum cable system is found to be defective, look for defective electrical contacts at the Feed-Through to In-Vacuum cable connection. Repair or replace the Feed-Through as necessary. Re-attach the BNC and In-Vacuum cables and repeat this procedure starting at step 2. Otherwise, continue at step 11.

11 Connect the 6 in. BNC cable to the Feed-Through and disconnect it from the Crystal Interface Unit (or Oscillator)

12 Verify electrical continuity from the center pin of the Microdot connector on the Feed-Through to the un-terminated end of the 6 in. BNC cable.

13 Verify electrical isolation from the center pin to electrical ground (Feed-Through body).

If the Feed-Through/6 in. BNC cable system is found to be defective, look for defective contacts at the Feed-Through to BNC cable connection. Repair or replace the Feed-Through as necessary, re-attach the BNC cable to the XIU and In-Vacuum cable to the Crystal head and repeat this procedure starting at step 2.

6.5.1.3 Sensor Head Or Monitor Crystal Diagnostic Procedure

1 Remove the Crystal Cover from the Sensor Head.

2 Refer to Figure 6-10 on page 6-25. Connect the Crystal Sensor Emulator to the Sensor Head at Point C.

- If the XTAL Fail message disappears after approximately five seconds, the the Sensor Head is operating properly. Re-insert the Crystal Cover into the Sensor Head and go to section 6.5.1.4 on page 6-29.
- If the XTAL Fail message remains, continue at step 3.

3 Disconnect the In-Vacuum cable from the Sensor Head and the Feed-Through. Remove the Crystal Sensor Emulator from the Sensor Head.

4 Using an Ohm meter, verify the electrical connections on the Sensor Head.

- Verify there is electrical continuity from the center pin contact on the Microdot connector on the Sensor Head to the finger spring contact in the Sensor Head.
- There must be electrical isolation between the center pin of the Microdot connector and the Sensor Head body.

If the Sensor Head is found to be defective, contact INFICON to have the Sensor Head repaired. Refer to section 1.3 on page 1-5.

5 Connect the In-Vacuum Cable to the Sensor Head.

- Verify there is continuity (<0.2 Ω) from the finger spring contact in the Sensor Head to the center pin on the un-terminated end of the In-Vacuum cable.
- Verify there is isolation (>10 MΩ) between the finger spring contact and the In-Vacuum cable shield.

If the Sensor Head or the In-Vacuum cable system is found to be defective, look for defective contacts at the In-Vacuum cable to Sensor Head connection, repair or replace the Sensor Head as necessary. Re-attach the In-Vacuum cable to the Feed-Through and repeat this procedure starting at step 2.

6 Ensure that the leaf springs in the Sensor Head and those in the ceramic retainer are bent to an angle of approximately 60 degrees.

6.5.1.4 System Diagnostics Pass But Crystal Fail Message Remains

If the system is operating properly, yet the Crystal Fail message is still displayed, perform the following tasks.

1 On the ceramic retainer verify that the center rivet is secure. Repair or replace the ceramic retainer as necessary.

2 Inspect the inside of the Crystal Cover for build-up of material. Clean or replace the Crystal Cover as necessary.

After verifying the Sensor Head contacts, the Sensor Head/In-Vacuum cable connection, and the ceramic retainer contacts, re-assemble the system. If the Crystal Fail message remains, replace the monitor crystal with a good monitor crystal. Verify that the monitor crystal works properly by inserting it into a known good measurement system. If you continue to experience problems, contact INFICON, refer to section 1.3 on page 1-5.

6.5.2 % XTAL Life

The Crystal Sensor Emulator contains a quartz crystal having a fundamental frequency at 5.5 MHz. With the Crystal Sensor Emulator connected, the % XTAL Life display should read approximately 50%.

6.5.3 Sensor Cover Connection

The Crystal Sensor Emulator can be used to verify the measurement system for INFICON Thin Film Deposition Controllers and Monitors.

However, the Crystal Sensor Emulator's Sensor Cover Connector is compatible with some sensor heads, and is incompatible with others. This is discussed in the following sections.

6.5.3.1 Compatible Sensor Heads

The Sensor Cover Connection will fit the sensor heads shown in Table 6-5.

Table 6-5 Compatible sensor heads

Sensor Head	Part Number
Front Load Single Sensor Head	SL-XXXXX
Front Load Dual Sensor Head	DL-AEXX

6.5.3.2 Incompatible Sensor Heads

The Sensor Heads for which the Crystal Sensor Emulator's Sensor Cover Connector will not fit are shown in Table 6-6.

Table 6-6 Incompatible sensor heads

Sensor Head	Part Number
Front Load UHV Bakeable Sensor Head	BK-AXX
Cool Drawer Single Sensor Head	CDS-XXXXX
Sputtering Sensor Head	750-618-G1
CrystalSix Sensor Head	750-446-G1
Cool Drawer Dual Sensor Head	CDD-XXXX
Crystal12 Sensor Head	XL12-XXXXXX
RSH-600 Sensor Head	15320X-XX

NOTE: The Crystal Sensor Emulator’s Sensor Cover will not fit the crystal holder opening of the older style INFICON transducers that have the soldered finger springs.

6.5.4 Specifications

Dimensions

1.58 in. diameter x 1.79 in.
(40.13 mm diameter x 45.47 mm)

Temperature Range

0 to 50°C

Frequency

PN 760-601-G2: 5.5 MHz ± 1 ppm at room temperature

Materials

304 Stainless Steel, Nylon, Teflon®, brass. Some internal components contain zinc, tin, and lead.

Chapter 7
Calibration Procedures

7.1 Importance of Density, Tooling and Z-Ratio

The quartz crystal microbalance (QCM) is capable of precisely measuring the mass added to the face of the oscillating quartz crystal sensor. XTC/3 knowledge of the density of this added material (specified in the density parameter in the Film/Source parameters set up) 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 7.2.

Because the flow of material from a deposition is not uniform, it is necessary to account for the different amount of material flow onto the sensor compared to the substrates. This factor is accounted for in the tooling parameter in the Film/Sensor Parameters set up. The tooling factor can be experimentally established by following the guidelines in section 7.3.

If the Z-Ratio is not known, it could be determined from the procedure outlined in section 7.4, estimated as outlined in section 7.5 or set to the default value of 1.0. The resulting thickness error due to an estimated value will be non-linear and increases with the total thickness, number of layers of alternate materials and the difference from the actual Z-Ratio. Generally, if the crystal is replaced before crystal life reaches 10%, the size of the thickness error will be small enough to be disregarded in most applications.

7.2 Determining Density

NOTE: The bulk density values retrieved from the Material Library 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 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:

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

where:

D_1 = Initial density setting

T_x = Thickness reading on Cygnus

T_m = Measured thickness

7 A quick check of the calculated density may be made by programming XTC/3 with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that XTC/3's thickness 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 $T_x = T_m$.

7.3 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:

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

where

T_m = Actual thickness at substrate holder

T_x = Thickness reading on Cygnus

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 evaporations be made when calibrating tooling. Variations in source distribution and other system factors will contribute to slight thickness variations. An average value tooling factor should be used for final calibration.

7.4 Laboratory Determination of Z-Ratio

A list of Z-values for materials commonly used is available in the Material Library. For other materials, Z can be calculated from the following formula:

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

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

where:

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

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

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

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

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. Establish the correct density value as described in section 7.2 on page 7-1.
2. Install a new crystal and record its starting frequency F_{co}. It will be necessary to send the S13 command to get this information (refer to Chapter 5, Remote Communications).
3. Make a deposition on a test substrate such that the percent crystal life display will read approximately 50%, or near the end of crystal life for the particular material, whichever is smaller.
4. Stop the deposition and record the ending crystal frequency F_c using the S13 command.
5. Remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.
6. Using the density value from step 1 and the recorded values for F_{co} and F_c, adjust the Z-Ratio value in thickness equation [5] to bring the calculated thickness value into agreement with the actual thickness. If the calculated value

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

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

where:

T_f = thickness of deposited film (kÅ)

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

F_c = Final frequency of the sensor crystal (Hz)

F_q = Nominal blank frequency = 6045000 (Hz)

z = Z-Ratio of deposited film material

Z_q = Specific acoustic impedance of quartz = 8765000 (MKS units)

p = density of deposited film (g/cc)

7.5 Estimating Z-Ratio

For multiple layer deposition (for example, two layers), the Z-value used for the second layer can be estimated based on the relative thickness of the two layers. For most applications the following three rules will provide reasonable accuracies:

- If the thickness of layer 1 is large compared to layer 2, use material 1 Z-value for both layers.
- If the thickness of layer 1 is thin compared to layer 2, use material 2 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.

Chapter 8
Measurement and Control Theory

8.1 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 piezoelectric crystal, the crystal is distorted and changes shape in proportion to the applied voltage. At certain discrete frequencies of applied voltage, a condition of 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 precisely understood for specific oscillating modes of quartz. This heuristically easy-to-understand phenomenon is the basis of an indispensable measurement and process control tool that can easily detect the addition of less than an atomic layer of an adhered foreign material.

In the late 1950's it was noted by Sauerbrey[1,2] and Lostis[3] that the change in frequency, $\Delta F = F_q - F_c$, 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:

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

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:

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

where the film thickness, T_f, is proportional (through K) to the frequency change, ΔF, and inversely proportional to the density of the film, d_f. The constant, $K = N_{at} d_q / F_q^2$; where d_q (= 2.649 g/cm^3) is the density of single crystal quartz and N_{at} (=166100 Hz cm) is the frequency constant of AT cut quartz. A crystal with a starting frequency of 6.0 MHz will display a reduction of its frequency by 2.27 Hz

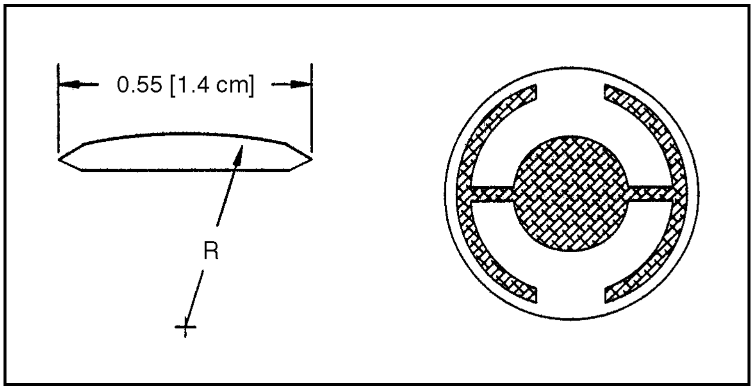
1. G. Z. Sauerbrey, Phys. Verhand .8, 193 (1957)
2. G. Z. Sauerbrey, Z. Phys. 155,206 (1959)
3. P. Lostis, Rev. Opt. 38,1 (1959)

when 1 angstrom of Aluminum (density of 2.77 g/cm^3) is added to its surface. In this manner the thickness of a rigid adlayer is inferred from the precise measurement of the 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.

8.1.1 Monitor Crystals

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

Figure 8-1 Quartz resonator



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

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

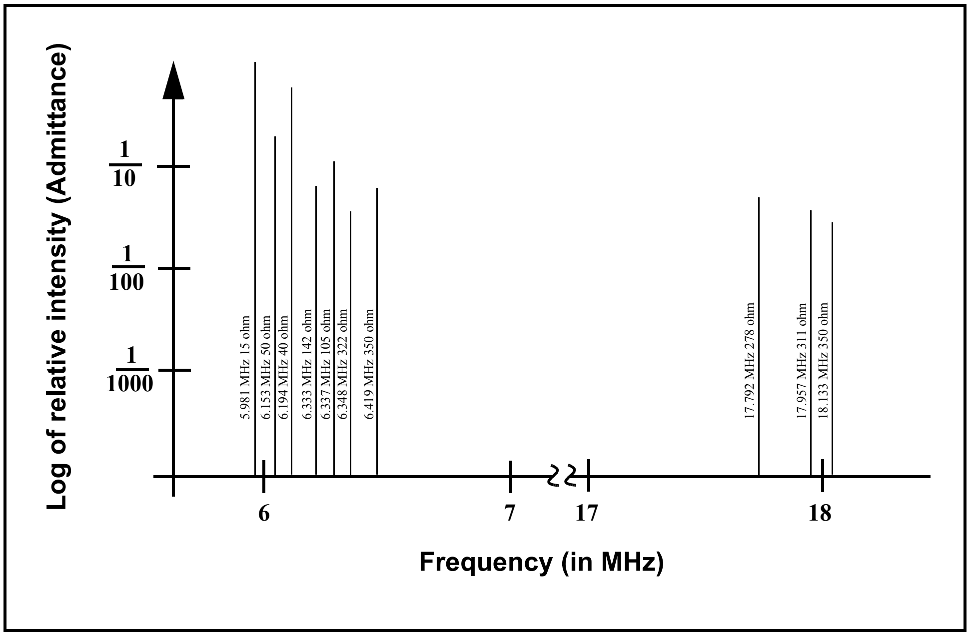
The monitor crystal design depicted in Figure 8-1 is the result of several significant improvements from the square crystals with fully electroded plane parallel faces that were first used.

The first improvement was to use circular crystals. This 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.

Contouring dissipates the energy of the traveling acoustic wave before it reaches the edge of the crystal. Energy is not reflected back to the center where it can interfere with other newly launched waves, essentially making a small crystal appear to behave as though it is infinite in extent. With the 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; hence,
the potential for an oscillator to sustain an unwanted oscillation is substantially reduced.

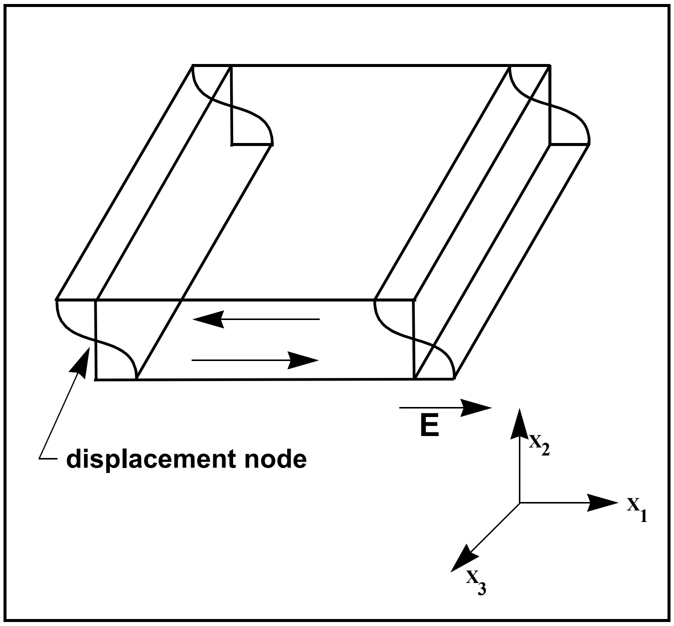
Figure 8-2 Frequency response spectrum



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

The "AT" resonator is usually chosen for deposition monitoring because at room temperature it can be made to exhibit a very small frequency change due to temperature changes. Since there is presently no way to separate the frequency change caused by added mass (which is negative) or even the frequency changes caused by temperature gradients across the crystal or film induced stresses, it is essential to minimize these temperature-induced changes. It is only in this way that small changes in mass can be measured accurately.

Figure 8-3 Thickness shear displacement



8.1.2 Period Measurement Technique

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

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

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

The period measurement technique was the outgrowth of two factors; first, the digital implementation of time measurement, and second, the recognition of the mathematically rigorous formulation of the proportionality between the crystal's thickness, l_q, and the period of oscillation, $T_q = 1/F_q$.

Electronically, the period measurement technique uses a second crystal oscillator, or reference oscillator, not affected 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 turned on at the same time and accumulates cycles from the reference oscillator until m counts are accumulated in the first.

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

Since the frequency of the reference is stable and known, the time to accumulate the m counts is known to an accuracy equal to ± $2/F_r$ 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 be counteracted only by longer time constants. Long time constants cause the correction of rate errors to be very slow, resulting in relatively long term deviations from the desired rate. These deviations may not be important for some simple films, but can cause unacceptable errors in the production of critical films such as optical filters or very thin layered superlattices grown at low rates. In many cases the desired properties of these films can be lost if the layer to layer reproducibility exceeds one, or two, percent. Ultimately, the practical stability and frequency of the reference oscillator limits the precision of measurement for conventional instrumentation.

8.1.3 Z-Match Technique

After learning of fundamental work by Miller and Bolef [5], which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis[6] developed the simplifying Z-Match™ equation in 1972. Advances in electronics taking place at the same time, namely the micro-processor, made it practical to solve the Z-Match equation in "real-time". Most deposition process controllers sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown in equation [4].

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

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.

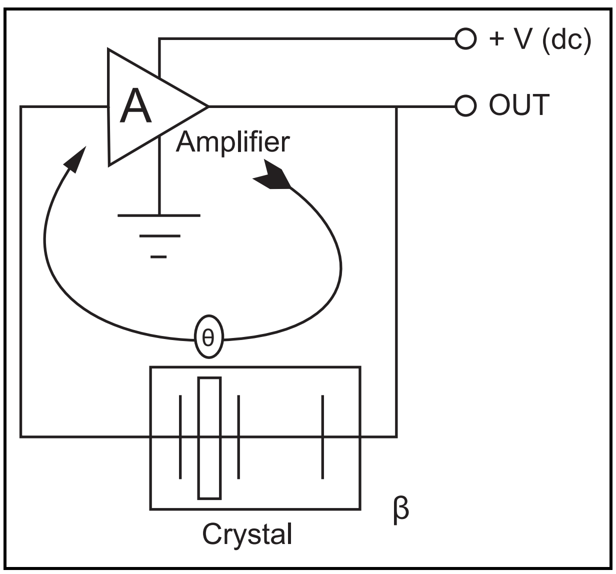
5.J. G. Miller and D. I. Bolef, J. Appl. Phys. 39, 5815, 4589 (1968)
6.C. Lu and O. Lewis, J Appl. Phys. 43, 4385 (1972)

To achieve this new level of accuracy requires only that the user enter an additional material parameter, Z, for the film being deposited. This equation has been tested for a number of materials, and has been found to be valid for frequency shifts equivalent to $F_f = 0.4F_q$. Keep in mind that equation [2] was valid to only $0.02F_q$ and equation [3] was valid only to $\sim 0.05F_q$.

8.1.4 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 8-4. 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 the gain provided by the amplifiers is sufficient to offset losses in the crystal and circuit and the crystal can provide the required phase shift. 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 8-5.

Figure 8-4 Active oscillator circuit

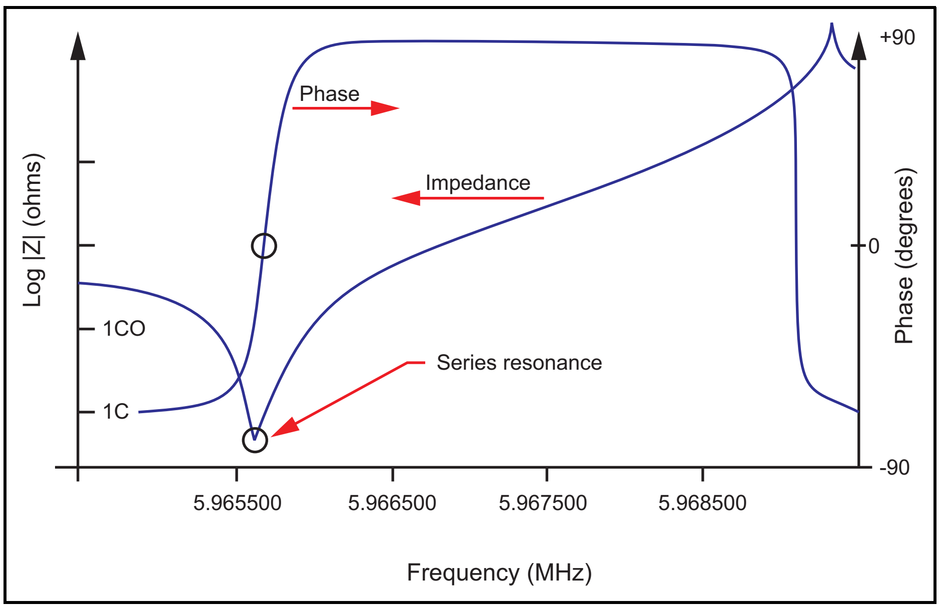


The active oscillator circuit is designed so the crystal is required to produce a phase shift of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain 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 8-6 on page 8-8 is the same plot as Figure 8-5 overlaid with the response of a heavily loaded crystal. The crystal has lost the steep slope displayed in Figure 8-5. 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 and 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 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 8-5 Crystal frequency near series resonance point

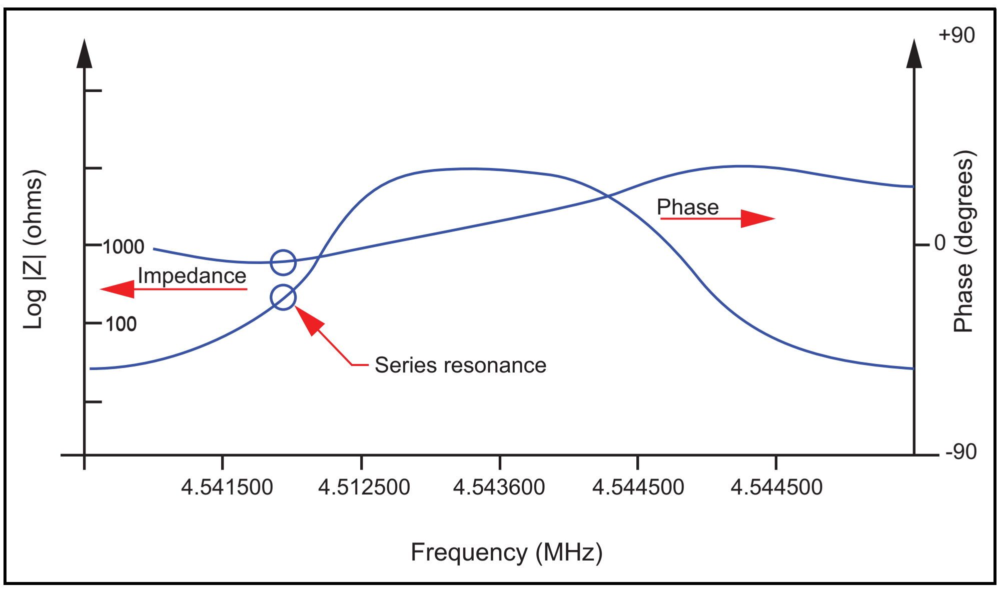


8.1.5 ModeLock Oscillator

INFICON has created a new technology 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 also to 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 .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 whether 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 when 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.

Figure 8-6 Heavily loaded crystal



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 and precision of measurement.

8.1.6 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 controller model most commonly chosen, 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. The responsiveness of an 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.

Techniques for calculating optimum source control parameters can be classified by the type of data used for tuning. They fall into basically three categories:

- Closed Loop Methods
- Open Loop Methods
- Frequency Response Methods

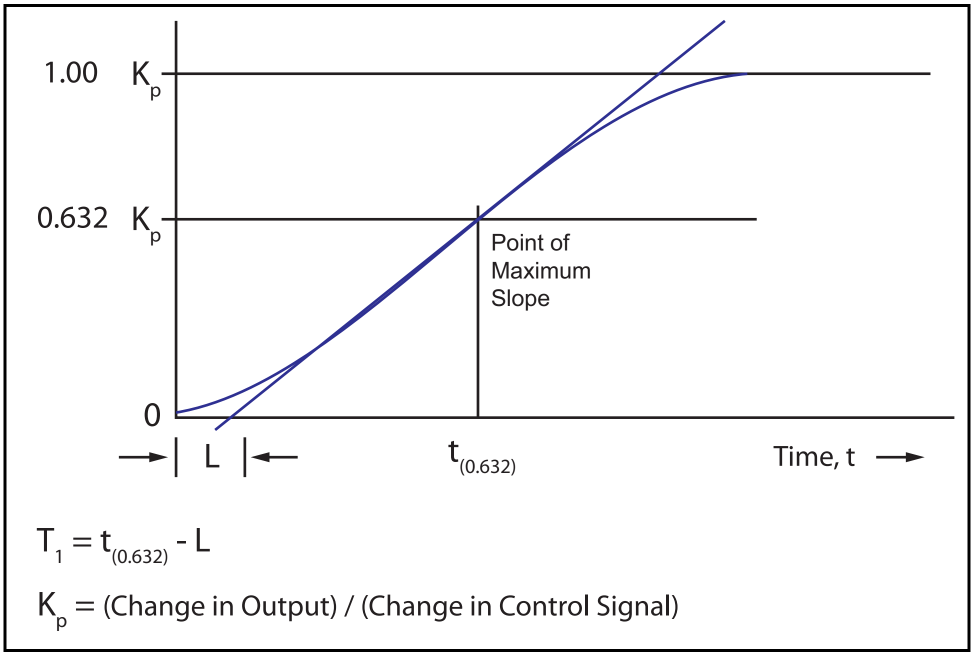
Of these categories, the open loop methods are considered superior. They are considered superior because of the ease with which the necessary experimental data can be obtained and because of the elimination (to a large extent) of trial and error when the technique is applied. The important response characteristics are determined as shown in Figure 8-7.

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:

$$\frac{\text{Output}}{\text{Input}} = \frac{K_p \exp(-Ls)}{T_1 s + 1} \qquad [5]$$

Three parameters are determined from the process reaction curve. They are the steady state gain, K_p, the dead time, L, and the time constant, T_1. Several methods have been proposed to extract the required parameters from the system response as graphed in Figure 8-7. These are: a one point fit at 63.2% of the transition (one time constant); a two point exponential fit; and a weighted least-square-exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be customized.

Figure 8-7 Response of process to an open loop step change (at t=0 control signal is increased)



A controller model used extensively is the PID type, shown in Laplace form in equation [6].

$$M(s) = K_c\left(1 + \frac{1}{T_i s} + T_d s\right)Es \qquad [6]$$

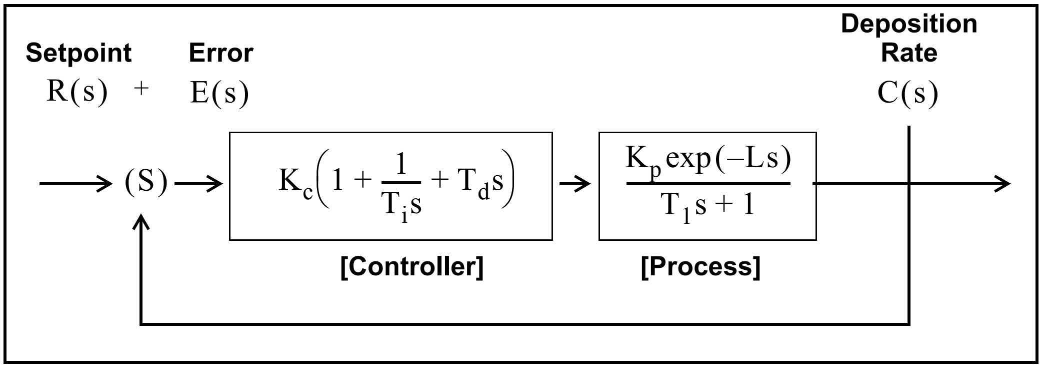
Where

- $M(s)$ = manipulated variable or power
- K_c = controller gain (the proportional term)
- T_i = integral time
- T_d = derivative time
- $E(s)$ = process error

Figure 8-8 represents the controller algorithm and a process with first order lag plus a 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 8-8 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:

$$ISE = \int e^2(t)dt \qquad [7]$$

where error = e = setpoint minus the 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 been frequently proposed as a criterion of performance:

$$IAE = \int |e(t)|dt \qquad [8]$$

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

Graham and Lathrop[7] introduced the integral of time multiplied by the absolute error (ITAE) as an alternate criterion of performance:

$$ITAE = \int t|e(t)|dt \qquad [9]$$

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

ITAE is insensitive to the initial and somewhat unavoidable errors, but it will weight heavily any 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.

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.

$$K_c = (1.36/K_p)(L/T_1)^{-0.947} \quad [10]$$

$$T_i = (1.19T_1)(L/T_1)^{0.738} \quad [11]$$

$$T_d = (0.381T_1)(L/T_1)^{0.995} \quad [12]$$

For slow systems, in order to help avoid controller windup (windup is 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, and 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.

Chapter A
Material Table

CAUTION

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

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

Table A-1 Material table

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

Table A-1 Material table (continued)

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

Table A-1 Material table (continued)

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

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Hf	13.090	0.360	hafnium
HfB_2	10.500	*1.000	hafnium boride
HfC	12.200	*1.000	hafnium carbide
HfN	13.800	*1.000	hafnium nitride
HfO_2	9.680	*1.000	hafnium oxide
$HfSi_2$	7.200	*1.000	hafnium silicide
Hg	13.460	0.740	mercury
Ho	8.800	0.580	holmium
Ho_2O_3	8.410	*1.000	holmium oxide
In	7.300	0.841	indium
In_2O_3	7.180	*1.000	indium sesquioxide
In_2Se_3	5.700	*1.000	indium selenide
In_2Te_3	5.800	*1.000	indium telluride
InAs	5.700	*1.000	indium arsenide
InP	4.800	*1.000	indium phosphide
InSb	5.760	0.769	indium antimonide
Ir	22.400	0.129	iridium
K	0.860	10.189	potassium
KBr	2.750	1.893	potassium bromide
KCl	1.980	2.050	potassium chloride
KF	2.480	*1.000	potassium fluoride
KI	3.128	2.077	potassium iodide
La	6.170	0.920	lanthanum
La_2O_3	6.510	*1.000	lanthanum oxide
LaB_6	2.610	*1.000	lanthanum boride
LaF_3	5.940	*1.000	lanthanum fluoride
Li	0.530	5.900	lithium
LiBr	3.470	1.230	lithium bromide
LiF	2.638	0.778	lithium fluoride
$LiNbO_3$	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

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
$MgAl_2O_6$	8.000	*1.000	spinel
MgF_2	3.180	0.637	magnesium fluoride
MgO	3.580	0.411	magnesium oxide
Mn	7.200	0.377	manganese
MnO	5.390	0.467	manganese oxide
MnS	3.990	0.940	manganese (II) sulfide
Mo	10.200	0.257	molybdenum
Mo_2C	9.180	*1.000	molybdenum carbide
MoB_2	7.120	*1.000	molybdenum boride
MoO_3	4.700	*1.000	molybdenum trioxide
MoS_2	4.800	*1.000	molybdenum disulfide
Na	0.970	4.800	sodium
Na_3AlF_6	2.900	*1.000	cryolite
$Na_5Al_3F_{14}$	2.900	*1.000	chiolite
NaBr	3.200	*1.000	sodium bromide
NaCl	2.170	1.570	sodium chloride
$NaClO_3$	2.164	1.565	sodium chlorate
NaF	2.558	0.949	sodium fluoride
$NaNO_3$	2.270	1.194	sodium nitrate
Nb	8.578	0.492	niobium (columbium)
Nb_2O_3	7.500	*1.000	niobium trioxide
Nb_2O_5	4.470	*1.000	niobium (V) oxide
NbB_2	6.970	*1.000	niobium boride
NbC	7.820	*1.000	niobium carbide
NbN	8.400	*1.000	niobium nitride
Nd	7.000	*1.000	neodymium
Nd_2O_3	7.240	*1.000	neodymium oxide
NdF_3	6.506	*1.000	neodymium fluoride
Ni	8.910	0.331	nickel
NiCr	8.500	*1.000	nichrome
NiCrFe	8.500	*1.000	Inconel
NiFe	8.700	*1.000	permalloy
NiFeMo	8.900	*1.000	supermalloy

Table A-1 Material table (continued)

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

Table A-1 Material table (continued)

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

Table A-1 Material table (continued)

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

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
ZrN	7.090	*1.000	zirconium nitride
ZrO_2	5.600	*1.000	zirconium oxide

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