

IC6

Thin Film Deposition Controller

PN 074-505-P1K



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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: IC6/Cygnus 2 Deposition Controller (including all options).

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)

RoHS2: Fully Compliant

CE Implementation Date: June 2010 (Revised August, 2015)

Authorized Representative: Steven Schif

Thin Film Business Line Manager
INFICON, Inc.

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Chapter 1

Introduction and Specifications

1.1 Introduction

IC6 is a closed loop process controller designed for use primarily in physical vapor deposition. IC6 monitors and/or controls the rate and thickness of the deposition of thin films. 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 source of the vaporized material and the target substrate. 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 programmed time, thickness and power limits and with desired rates and material characteristics, IC6 is capable of automatically controlling the process in a precise and repeatable manner. User interaction is accomplished via the IC6 front panel or remote communication and consists of selection or entry of parameters to define the process.

A complete system consists of a main electronics unit also called IC6, sensor heads and a crystal interface unit (XIU) for each attached sensor. These items are generally bundled at the factory and are also sold separately.

This IC6 Operating Manual provides user information for installing, programming and operating the main electronics unit.

When reading the IC6 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](#).

You are invited to comment on the usefulness and accuracy of this manual by visiting our website at www.inficon.com.

1.1.1 Related Manuals

Sensors are covered in separate manuals.

- ◆ 074-154 - Front Load Bakeable
- ◆ 074-155 - CrystalSix (XtalSix)
- ◆ 074-398 - Crystal12 (Xtal12)
- ◆ 074-156 - Front Load Single/Dual
- ◆ 074-157 - Sputtering

1.2 IC6 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 IC6 efficiency when followed.



CAUTION

Failure to heed these messages could result in damage to IC6.



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 IC6 case! There are no user-serviceable components within the IC6 case.

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

Refer all maintenance to qualified personnel.



CAUTION

This IC6 contains delicate circuitry which is susceptible to transient power line voltages. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.

1.2.3 Earth Ground

IC6 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 IC6, or disconnection of the protective earth terminal is likely to make IC6 dangerous.



This symbol indicates where the protective earth ground is connected inside IC6. Never unscrew or loosen this connection.

1.2.4 Main Power Connection



WARNING - Risk Of Electric Shock

This IC6 has line voltage present on the primary circuits whenever it is plugged into a main power source.

Never remove the covers from IC6 during normal operation.

There are no operator-serviceable items within this IC6.

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

In order to comply with accepted safety standards, IC6 must be installed into a rack system which contains a mains switch. This switch must break both sides of the line when it is open and it must not disconnect the safety ground.

1.3 How To Contact INFICON

Worldwide customer support information is available under Support at www.inficon.com where you can contact:

- ♦ a Technical Support Engineer with questions regarding applications for and programming IC6.
- ♦ a Service Engineer with questions regarding troubleshooting, diagnosing or repairing a defective IC6.
- ♦ Sales and Customer Service, to find the INFICON Sales office nearest to you.
- ♦ Repair Service, to find the INFICON Service Center nearest to you.

If you are experiencing a problem with your IC6, please have the following information readily available:

- ♦ the serial number and firmware version for your IC6,
- ♦ a description of your problem,
- ♦ an explanation of any corrective action that you may have already attempted,
- ♦ and the exact wording of any error messages that you may have received.

1.3.1 Returning Your IC6

Do not return any component of your IC6 to INFICON without first speaking with a Customer Support Representative. You must obtain a Return Material Authorization (RMA) number from the Customer Support Representative.

If you deliver a package to INFICON without an RMA number, your package will be held and you will be contacted. This will result in delays in servicing your IC6.

Prior to being given an RMA number, you may be required to complete a Declaration Of Contamination (DOC) form if your sensor has been exposed to process materials. DOC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the sensor be sent to a designated decontamination facility, not to the factory.

1.4 IC6 Specifications

1.4.1 Measurement

Measurement Frequency Range . . .	6.0 to 4.5 MHz (fixed)
Frequency Resolution	± 0.0035 Hz @ 6 MHz
Thickness and Rate	
Resolution/Measurement	± 0.00433 Å @ tooling/density = 100/1 Fundamental frequency = 6 MHz
Measurement Interval.	0.10 s
Thickness Accuracy	0.5% typical, (dependent on process conditions, especially sensor location, material stress, temperature and density)
Frequency Accuracy.	± 2 ppm 0 to 50°C
Measurement Frequency	10 Hz
Measurement Technique	ModeLock with Auto-Z
User Interface.	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 Hierarchy

a) Navigation	Menu driven, four soft keys
b) Structure.	Separate screens dedicated to
	1) Operate
	2) Sensor Information
	3) Sensor Parameters
	4) Source Parameters
	5) Material Parameters
	6) Process Parameters
	7) General Parameters
	8) Digital I/O Display
	9) Logic
	10) Maintenance
	11) Counter/Timer
	12) USB Storage

1.4.3 IC6 Features

1.4.3.1 Recipe Storage and Datalogging

USB Memory Device

1.4.3.2 Sensor Parameters

Up to 8 sensors can be averaged together

(Sensor) Shutter Output 0 to 38

Sensor Type Single, XtalTwo, XtalSix, Xtal12, Generic

(Sensor) Switch Output 0 to 38

Auto-Z. Yes/No

of Positions (for Generic Sensor type). 1 to 12

of Pulses (for Generic Sensor type) 1 to 10

Pulse On (Time for Generic Sensor type) 0.1 to 9.9 s

Pulse Off (Time for Generic Sensor type). 0.1 to 9.9 s

Recorder Output 0 to 12

Recorder Function Rate, Thickness, RateDeviation

Recorder Range 0 to 99999

1.4.3.3 Source Parameters

Up to 6 sources may be controlled at the same time

DAC Output 0 to 12

(Source) Shutter Output 0 to 38

Crucible Selection. Turret is indexed to selected position on a Start. Turret feedback is checked whenever a source is started. Range is from 1 to number of crucibles.

Number of Crucibles. 1, 4, 8, 16, 32 or 64

Crucible Output. 0 to 38

Turret Feedback Yes / No

Turret Input 0 to 28

Turret Delay 2 to 180 s (Time-out period with feedback, delay time without feedback)

1.4.3.4 Material Parameters

32 materials can be specified and given unique names (15 character max.).

Density	0.100 to 99.999 g/cm ³
Z-ratio	0.100 to 15.000
Master Tooling	1.0 to 999.9%
Control Loop types	Non-PID, PI, PID
Process Gain	0.01 to 999.99 Å/s/%Power
Time Constant	0.010 to 9999.99 s
Dead Time	0.010 to 9999.99 s
Source	1 to 6
Maximum Source Power	0.01 to 99.99%
Minimum Source Power	0.00 to 99.98%
Maximum Power Option	Continue, Post-Deposition, Stop Process, Suspend Material — can be selected for each Material individually
Power Ramps	3 per Material
Power Level	0.00 to 99.99%
Rise Time	00:00 to 99:59 min:s
Soak Time	00:00 to 99:59 min:s
Auto Soak 2	Yes / No
Deposit After Pre-Deposit	Yes / No Yes = go to Deposit No = go to Non-Deposit Rate Control
(Control) Delay Option	None, Shutter, Control, Both
Control Delay Time	00:00 to 99:59 min:s
Shutter Delay Accur(acy)	1 to 99%
Transfer Sensor	0 to 8
Transfer Tooling	1 to 999.9%
Feed Power	0.00 to 99.99%
Feed Ramp Time	00:00 to 99:59 min:s
Feed Time	00:00 to 99:59 min:s

Idle Ramp	1 per Source
Idle Power	0.00 to 99.99%
Idle Ramp Time	00:00 to 99:59 min:s
Rate	0.000 to 999.9 Å/s
Time Limit (in Deposit)	00:00 to 99:59 min:s
Rate Filter Time	0.1, 0.4, 1.0, 4.0, or 10.0, 20.0, 30.0 s
Time Power Averaging Time	0 to 30 minutes
Ion Assist Deposit	Yes/No
On Final Thickness	Continue, Post-Dep(osit), NonDep(osit)Cont(rol)
New Rate while in Deposit	2 Rate Ramps per Material
New Rate 1 or 2	0.000 to 999.9 Å/s
Start Ramp 1 or 2	0.000 to 999.9 kÅ
Ramp Time 1 or 2	00:00 to 99:59 min:s
RateWatcher	Sample and Hold Feature
(RateWatcher) Option	Yes/No
(RateWatcher) Time	00:00 to 99:59 min:s
(RateWatcher) Accuracy	1 to 99%
Multipoint	Yes/No (average up to 8 sensors)
Aggregate Multiply	Yes/No
(Sensor) Failure Action	Unused, PostD(e)p(osit), Stop, Susp(e)nd, TimeP(o)w(er)
(Sensor) Failure Trigger	OnFail (when this sensor fails) or Last (when the last sensor fails)
(Sensor) Weight	1 to 400.0%
(Sensor) Tooling (Factor)	1.0 to 999.9%
CrystalTwo Tooling	1.0 to 999.9%
Cal(ibration) Thickness	0.000 to 999.9 kÅ (for Crosstalk correction)
CrystalSix (XtalSix) and Crystal12 (Xtal12) sensor selections to specify a subset of available crystal positions:	
Xtal Position First	0 to 6 (XtalSix) or 12 (Xtal12)
Xtal Position Last	0 to 6 (XtalSix) or 12 (Xtal12)

Backup Sensor	0 to 8
Backup Tooling	1.0 to 999.9%
(Crystal) Quality Percent	0 to 99%
(Crystal) Quality Counts	0 to 99
(Crystal) Stability Single	0 to 9999 Hz
(Crystal) Stability Total	0 to 9999 Hz
Recorder Output	0 to 12
Recorder Function	Rate, Thick(ness), RateDev(iation), Power
Recorder Range	0 to 99999

1.4.3.5 Process Layer Parameters

50 processes can be created and given unique names (15 character max.).

Each process can contain 200 layers.

Material.	0 to 32
Final Thick(ness)	0.000 to 999.99 kÅ
Thick(ness) Limit	0.000 to 999.99 kÅ
Cruc(ible)	1 to 64
Co-Dep(osition)	Yes/No
Ratio C(o)ntrol	0 to 999.9% (if CoDep)

1.4.3.6 General Global Parameters

Active Process	1 to 50
Layer To Start	1 to 200
Run #	1 to 9999
Auto Start Next (Layer).	Yes / No
Max Concurrent Layer	1 to 6
Layers Displayed	Auto, 4 Layers, 6 Layers
Active Layer Output	First of eight consecutive outputs encoded to indicate the number of the loaded layer (first if multiple layers) that will be executed on a Start. 00000001 indicates layer 1, 00010011 indicates layer 200.
Date Format	DDMMYYYY or MMDDYYYY

LCD Dimmer Time	0 for Always On or # of Minutes till Off 0 to 99 minutes
Graph Scale	Power, +/-10 Å/s, +/-20 Å/s
Graph Scan Rate	Auto, Slow, Medium, Fast
Test	On / Off
Advanced Test	On / Off
Time Compressed	Yes / No
Audio Feedback	Yes / No
RS232 Baud Rate.	9600, 19200, 38400, 57600, 115200
RS232 Protocol	Standard, D(ata)log Page, D(ata)log Comma
DataLog XTAL History	Yes / No
USB Datalog Format	Log Off (No datalogging), Page, Comma
Thickness Eq(uation) 1.	Up to 6 Source numbers can be specified, each Source number can be used only once in the equation.
Thickness Eq(uation) 2.	Up to 6 Source numbers can be specified, each Source number can be used only once in the equation.
Thickness Eq(uation) 3.	Up to 6 Source numbers can be specified, each Source number can be used only once in the equation.
DAC 1 to 12 Scale	0.1 to 10.0
DAC 1 to 12 Polarity.	Positive / Negative
Source DAC Required	Yes/No (to allow 6 Rate and 6 Thickness DACs option)

1.4.4 Display

Type/Color/Size	LCD/Color/TFT/7 inch diagonal
Dimming Feature	Always Full on or Full on when in use. Full off when no process running and no key interaction for dimming time
Format	WVGA
Resolution	800 W x 480 H
Backlighting	LED
Thickness Display Range	0.000 to +/-9999 kÅ
Thickness Display Resolution	1 Å for 0.000 to +/-9.999 kÅ, 10 Å for +/-10.00 to +/-99.99 kÅ 100Å for +/-100.0 to +/-999.9 kÅ 1 kÅ for +/-1000 to +/-9999 kÅ
Rate Display Range	0.000 to +/-999.9 Å/s
Rate Display Resolution	0.001 Å/s for 0.000 to +/-9.999 Å/s if Rate Filter Time is 10 s or greater, otherwise 0.01 Å/s for 0.00 to +/-99.99 Å/s 0.1 Å/s for +/-100.0 to +/-999.9 Å/s
Power Display Range	0.00 to 99.99%
Graphic Display Functions	Rate Deviation at ±10 or ±20 Å/s or Power at 0 to 100%
Display Data Update Rate	1 Hz

1.4.5 DAC Outputs

Quantity and Type	6 with BNC, 6 optional with 15 pin miniature D-sub providing analog outputs for Rate and Thickness.
Configuration	User programmable for recorder or source control.
Function and Ranges	Power, Rate, Rate Deviation, Thickness Full scale voltage value fully selectable up to + or - 10V relative to 0 V at 0 output
Current rating	20 mA per channel
Resolution.	15 bits over full range (10 V)
Update Rate	10 Hz, maximum, (dependent on source characteristics).
Recorder Output Functions	Aggregate Rate, Thickness or Rate Deviation; Individual Sensor Rate, Thickness or Rate Deviation; or Source Power.
Recorder Output Ranges	
Rate	0 to up to 99999 Å/s programmable
Thickness	0 to up to 99999 Å programmable, [Function modulo (Thickness Range, Thickness)output is "saw-tooth" like with increasing thickness.]
Rate Deviation	Desired rate ± 50 Å/s
Accuracy.	$\pm 1\%$ relative to Full Scale 10 V

1.4.6 Logic Processing

Type	If/Then statements
Logical Functions	And; Or; Not; Parentheses; ON
Depth	5 "If" conditions and 5 "Then" results/actions per statement
# of Statements	100 If/Then
Selectable events	Deposition monitor events, states, external inputs, relays, timers, and counters.
Hierarchy	Statements evaluated in numerical order at 10 Hz any time IC6 is on.
Partitioning	None
Initialization.	All outputs transition to their normal states as early as possible during power-on initialization sequence.

1.4.7 Relays / Inputs

Relays	SPST 2.5 A relays rated @ 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum; (8 standard, up to 16 optional with 2 additional I/O cards); D sub connector; relays are normally open in the power off state, but may be programmed to normally open or normally closed during operation.
Relay Ratings	100 VA inductive; 2.5 A maximum.
# of TTL Compatible Outputs	14 with optional I/O card. 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).	(14 standard, 14 additional optional)
Input Levels	
maximum high	24 V
minimum high	2.5 V
maximum low	1.1 V
Scan/Update Rate	10 Hz
Input/Output Name	Those that are Non-Hardware reserved may be named. (15 character max.)

1.4.8 Remote Communications

RS232C Serial Port	Standard; INFICON binary protocol
Baud Rates	115,200, 57,600, 38,400, 19,200, 9,600
Ethernet	Optional, Programmable IP Address and Net Mask
USB port	Print screen bitmap (.bmp) files, Datalogging file, Configuration file store/retrieve

1.4.9 Accessories

Connector Kit	Connectors for inputs and relays
Operating Manual	074-5000-G1 CD-ROM

1.4.10 Power

Power	100-230 V (ac) +15% / -10% V (ac); 50/60 Hz ±3 Hz
Maximum apparent power	150 VA
Fuse	use 250 V 4 Amp, 5 x 20, Slow Blow
Temporary Overvoltages	Short Term: 1430 V, <5 s Long Term: 480 V, >5 s

1.4.11 Operating Environment

Usage	Indoor only
Temperature	0 to 50°C (32-122°F)
Humidity	Up to 85% RH, non-condensing
Altitude	Up to 2000 meters
Installation (Overvoltage)	Category II per IEC 60664
Pollution Degree	2 per EN 61010

1.4.12 Storage Temperature

Storage Temperature	-10 to 60°C (14 to 140°F)
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1.4.13 Warm Up Period

Warm Up Period	None required; For maximum stability allow 5 minutes.
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1.4.14 Size

Height-Width-Depth, not including mounts or user connectors

133.4 x 447.7 x 330 mm (5.25 x 17.625 x 13 in.)

Height-Width-Depth including mounts, but no user connectors

133.4 x 482.6 x 330 mm (5.25 x 19 x 13 in.)

1.4.15 Installation Clearance Requirements

1.4.15.1 Connector Clearance

Front 25 mm (1.0 in.) minimum without USB,
64 mm (2.5 in.) minimum dependent on size
of USB storage device

Rear 100 mm (4.0 in.) minimum

1.4.15.2 Cooling Clearance

Rear 100 mm (4.0 in.) minimum

Sides 7 mm (1/4 in.) minimum

1.4.16 Weight

With all options 5.9 kg (13 lb.)

1.4.17 Cleaning

Use a mild, nonabrasive cleaner or detergent taking care to prevent cleaner from entering IC6.

1.5 Unpacking and Inspection

- 1 If IC6 has not been removed from its shipping container, do so now.
- 2 Carefully examine IC6 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 your order invoice and the information contained in [section 1.6 on page 1-18](#).
- 5 To perform a power-on verification, see [section 1.7 on page 1-20](#).
- 6 For additional information or technical assistance, contact INFICON, refer to [section 1.3, How To Contact INFICON, on page 1-6](#).

1.6 Parts and Options Overview

1.6.1 Base Configurations

IC6 Control Unit	781-500-G1 North America, 781-500-G2 Europe
Ship Kit	781-020-G1 North America, 781-020-G2 Europe
Operating Manual on CD ROM	074-505 on 074-5000-G1 CD ROM included in Ship Kit
I/O Relay.	Contains Input/Relay Interface Connectors (8 relay outputs, 14 TTL inputs). Included in Ship Kit.

1.6.2 Pre-installed Options or Spares

Additional Sensor Module	781-132-G1 (up to 3 extra)
------------------------------------	----------------------------

The following contain board and interface connector

I/O Relay Card	781-122-G1 (8 relay outputs, 14 TTL inputs) 781-122-G2 (8 relay outputs, 14 TTL outputs)
DAC Option Board and Kit	781-162-G1
Ethernet	781-102-G2

1.6.3 Optional Accessories

Pneumatic Shutter	
Actuator Control Valve	750-420-G1
Sensor Emulator Kit	760-601-G2
Handheld Controller	755-262-G1
Function	Power Increase/Decrease/Stop/ Switch Crystal
Adapter Cables	
IC6 to IC/4 Kit	600-1084-P1 (Relays and Inputs - for IC/4 or IC/4 PLUS)

1.6.4 Oscillator Packages

IC6 Oscillator, 15 ft. and 6 in. cable pkg.	781-611-G15
IC6 Oscillator, 30 ft. and 6 in. cable pkg.	781-611-G30
IC6 Oscillator, 50 ft. and 6 in. cable pkg.	781-611-G50
IC6 Oscillator, 100 ft. and 6 in. cable pkg.	781-611-G100
4 Meter Oscillator, 15 ft. and 6 in. cable pkg.	781-612-G15
4 Meter Oscillator, 30 ft. and 6 in. cable pkg.	781-612-G30
4 Meter Oscillator, 50 ft. and 6 in. cable pkg.	781-612-G50
4 Meter Oscillator, 100 ft. and 6 in. cable pkg.	781-612-G100
4 Meter Oscillator, 15 ft. and 20 in. cable pkg.	781-613-G15
4 Meter Oscillator, 20 ft. and 20 in. cable pkg.	781-613-G20
4 Meter Oscillator, 50 ft. and 20 in. cable pkg.	781-613-G50
4 Meter Oscillator, 100 ft. and 20 in. cable pkg.	781-613-G100

1.6.5 Sensors

Contact INFICON for a complete listing of sensors.

1.6.6 Replacement Cables

Oscillator to vacuum	755-257-G6
feedthrough cable, 6 in.	
IC6 Unit to Oscillator Cable 15 ft. . .	600-1261-P15
IC6 Unit to Oscillator Cable, 30 ft. . .	600-1261-P30
IC6 Unit to Oscillator Cable, 50 ft. . .	600-1261-P50
IC6 Unit to Oscillator Cable, 100 ft. .	600-1261-P100

1.7 Initial Power-On Verification

A preliminary functional check of IC6 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 and to Chapter 12, Maintenance and Calibration Procedures.



WARNING - Risk Of Electric Shock

There are no user-serviceable components within the IC6 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 IC6, or disconnection of the protective earth terminal is likely to make IC6 dangerous.



This symbol indicates where the protective earth ground is connected inside IC6. Never unscrew or loosen this connection.

- 1 Confirm that AC line voltage is supplied and proper for IC6.
- 2 Confirm that the back panel (main) AC switch is in the ON position.
- 3 Press the ON/STBY button on the front panel. A green pilot light should be seen next to the power switch.
- 4 The fan at the back of IC6 should be exhausting air.
- 5 After the initial temporary boot-up screen which can be viewed in Maintenance Sys Status, see section 12.8 on page 12-22, the LCD monitor will display an image similar to the one shown in Figure 1-1.

Figure 1-1 Operate Screen



Chapter 2

Installation and Interfaces

2.1 Location Guidelines

Before permanently installing IC6, read this entire chapter on installation and interfaces and follow its recommendations as closely as possible. INFICON has taken numerous steps to ensure its equipment will operate in a variety of harsh situations. Failure to adhere to these simple practices may adversely affect the performance and longevity of IC6.

2.1.1 Sensor Types

The choice of sensor type must be dictated by the Process, the deposition material and the physical characteristics of the process chamber. General guidelines for each sensor type produced by INFICON are outlined in the Sensor Data Sheets on the www.inficon.com website. For specific recommendations, consult your INFICON representative.



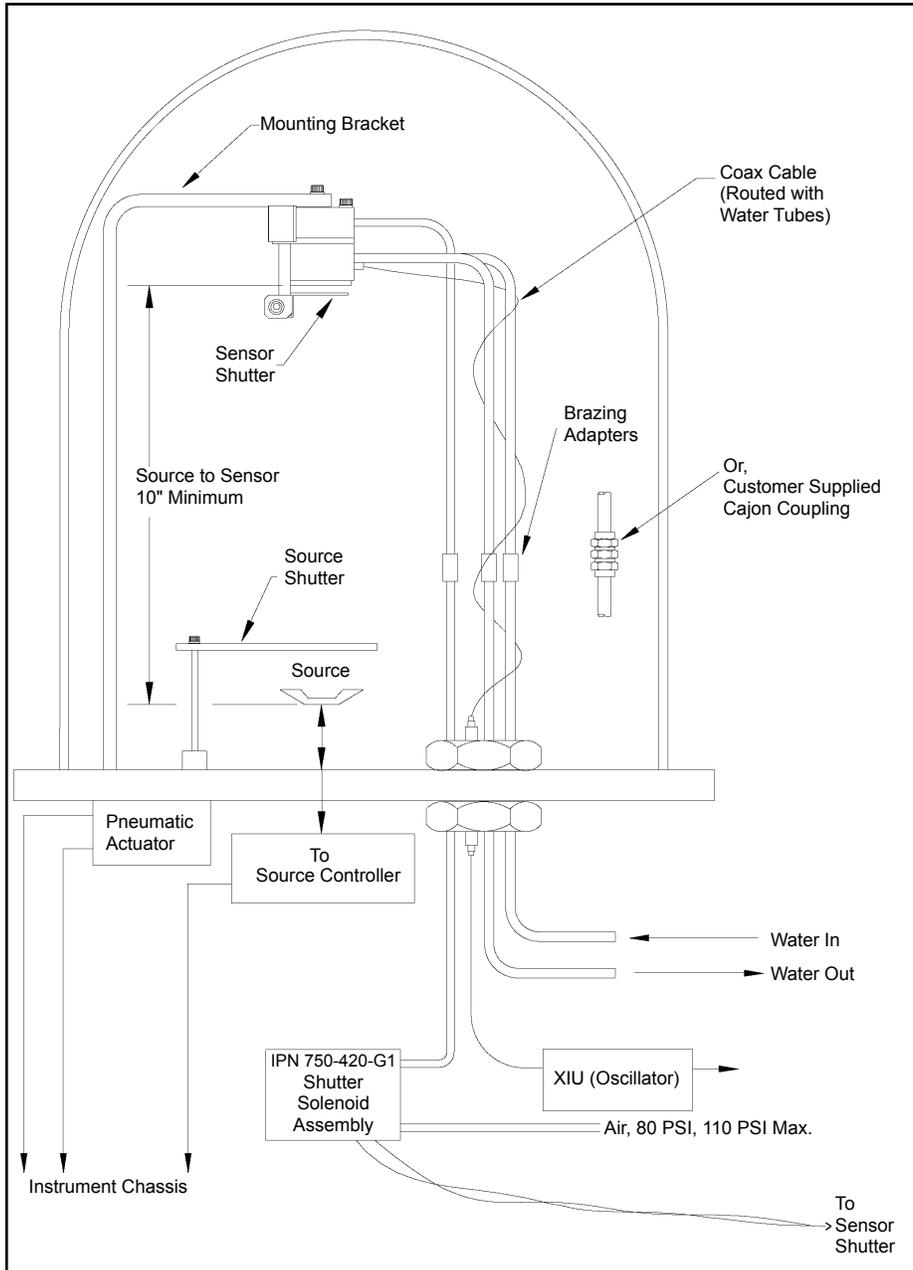
CAUTION

The performance of this IC6 depends on the careful installation of the chosen transducer. Improper installation will cause problems with deposition repeatability, crystal life and rate stability.

2.1.2 Sensor Installation

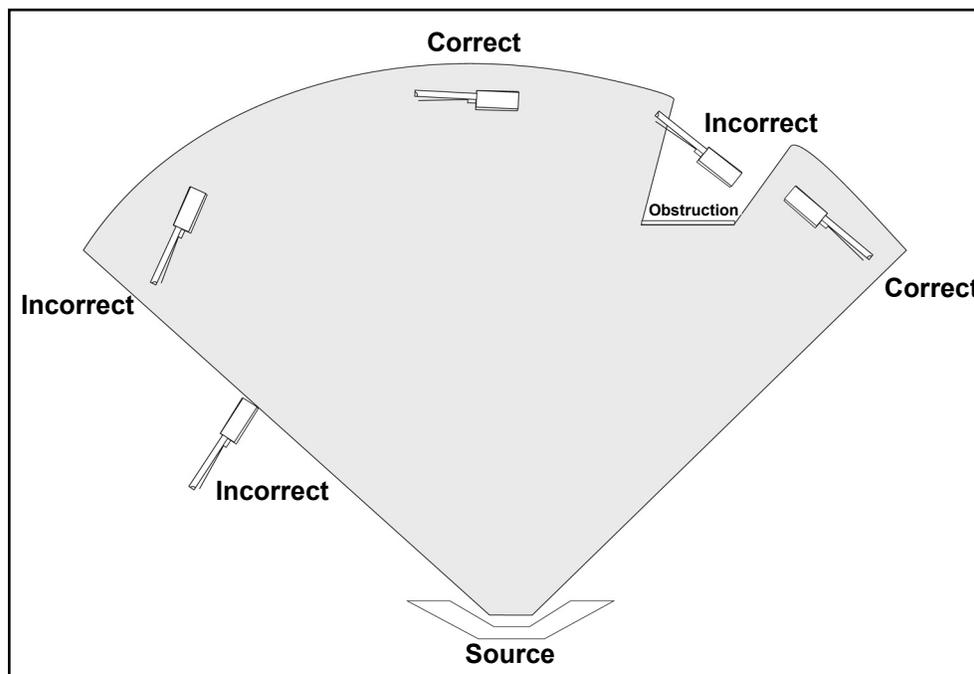
Figure 2-1 shows a typical installation of an INFICON water cooled crystal sensor in the vacuum process chamber. Use the illustration and the following guidelines to install your sensors for optimum performance and convenience.

Figure 2-1 Typical installation



Generally, install the sensor as far as possible from the evaporation source (a minimum of 10 in. (25.4 cm) 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 crystal during the initial soak periods. If the crystal is hit with even a minute particle of molten material, it may be damaged and stop oscillating. Even in cases when it does not completely stop oscillating, it may become unstable. 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 insure 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 face) is aimed directly at the virtual source being monitored.
- ◆ Be sure there is easy access for the exchange of crystals.
- ◆ For systems employing simultaneous source evaporation (co-deposition), try to 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 IC6 Installation

IC6 is designed to be rack mounted. It may be also used on a table. IC6 is forced-air cooled, with the air flow exiting the rear of IC6 for clean room convenience.

It is generally advisable to centrally locate IC6, minimizing the length of external cabling. The cable from the Sensor card to the XIU is typically fifteen feet. Thirty, fifty and one hundred foot cables are available.

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, IC6 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 IC6 with an RF sputtering system, the cable between IC6 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 each rod 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 required earth ground connections:

- ♦ The earth ground connection on IC6 is a threaded stud with a hex nut. Connect a ring terminal to the ground strap, thus allowing a good connection and easy removal and installation. This connection must be made at installation. For best protection against high frequency noise, the length-to-width ratio of the earth conductor should not exceed 5:1.
See Figure 2-3 for the suggested method of grounding.
- ♦ This IC6 is also connected to earth ground via a sealed three-core power cable, which must be plugged into a socket outlet with a protective earth ground terminal. Extension cables must always have three conductors including a protective earth ground conductor.



WARNING - Risk Of Electric Shock

Never interrupt the protective earth ground intentionally. Any interruption of the protective earth ground connection inside or outside IC6 or disconnection of the protective earth ground terminal is likely to make IC6 dangerous.



This symbol indicates where the protective earth ground is connected inside IC6. Never unscrew or loosen this connection.



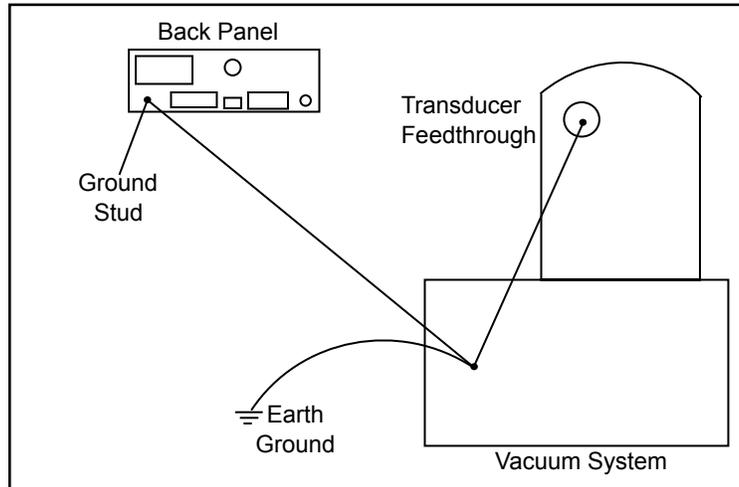
CAUTION

An external earth 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 and 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 IC6 is fully integrated into a deposition system, there can be many wire connections, each a potential path for electrical noise to reach the inside of IC6. 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.
- ◆ Be sure that a good ground system and straps are in place per the recommendations in [section 2.2.2 on page 2-5](#).
- ◆ Ensure that all IC6 covers and option panels are in place and tightly secured with the provided fasteners.

NOTE: Always use shielded cables when making connections to the IC6 rear panel to minimize electrical noise pickup.

2.3 Connecting the Controller

The operation of IC6 depends on the proper connection of power and signal interfaces to owner equipment and sources.



WARNING - Risk Of Electric Shock

This IC6 has line voltage present on the primary circuits whenever it is plugged into a mains power source.

Never remove the cover from IC6 during normal operation.

There are no operator serviceable items within this IC6.

Removal of the cover must be done only by a technically qualified person.

In order to comply with accepted safety standards, IC6 must be installed into a rack or system which contains a mains switch. This switch must break both sides of the line when it is open and it must not interfere with the safety earth ground.

IC6 is initially powered by AC line current. The line voltage provided in your facility must be within the voltage range of 100-230 V (ac) +/-15% V (ac).

2.3.1 Routing XIU Cables

The signals traveling on this cable are both analog and digital. It is suggested that it not be routed near areas with high levels of electromagnetic interference, even if its length must be somewhat increased.

2.3.2 Interface Cable Fabrication and Pin-Out

It is necessary to fabricate several cables in order to interface IC6 to the deposition system. Refer to section 2.2.3, [Minimizing Noise Pickup From External Cabling](#), on page 2-6.

2.3.2.1 Source Control Connection

Six digital to analog (DAC) outputs are provided as standard equipment with IC6. These standard 6 DAC channels with BNC connectors and six optional DAC outputs on a 15 pin sub-D connector may be programmed for source control or chart recorder functions as desired.

2.3.2.2 Crucible Indexer Connections

Example: 4 pocket crucible using outputs 6 and 7

Number of crucibles = 4

Crucible output = 6

For this example, wiring to the controller is based on Table 2-1. Only relays 6 and 7 are needed to encode the four possible positions.

Table 2-1 Wiring to the controller

Crucible Position	Contact Status	
	Relay #6	Relay #7
1	Open	Open
2	Closed	Open
3	Open	Closed
4	Closed	Closed

2.3.2.3 DAC Option Kit 781-504-G1

An optional Digital to Analog Converter (DAC) card can be installed into IC6. This card provides six additional DAC outputs, numbered 7 through 12, for Thickness and/or Rate as determined by the DAC Output Option parameters. The pin assignments for DAC outputs 7 through 12 are shown in Table 2-2.

Table 2-2 Optional DAC pin assignments

Output Number	Pin
7	1, 6 (GND)
8	2, 7 (GND)
9	3, 8 (GND)
10	4, 9 (GND)
11	5, 10 (GND)
12	11, 12 (GND)

A mating connector is included with the DACOption.

2.3.2.4 I/O Expansion Options

One I/O Relay module is included as standard equipment with IC6 and is used to interface with other machinery of the vacuum system. It can control components such as heaters, rotators or shutters through its 8 relays. It can respond to external instructions through its 14 isolated input lines. Standard equipment provides 8 relays and 14 input lines. Optionally, this can be expanded to 24 relays, 28 TTL inputs, and 14 open collector type outputs with the addition of another Relay I/O module 781-502-G1 and a TTL Relay module 781-503-G1 having 8 relays and 14 TTL open collector outputs.

The module provides separate connectors for relay outputs and input lines. A 25-pin D-sub, male connector is used for the eight relays. A 15-pin D-sub, male connector is used for the input lines. Mating connectors are provided in ship kits IPN 781-502-G1 and 781-503-G1. Refer to [Figure 3-2 on page 3-3](#) for connector locations and [Table 2-3 on page 2-10](#) for connector pin assignments. Relay connections are rated at 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum; 2.5 A maximum.

Inputs are activated by pulling the specific input terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS Logic having current sink capability of 2 mA (1 low power TTL load).



WARNING - Risk Of Electric Shock

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.

Table 2-3 Input/Relay pin connections

I/O Board #1				
Relay #	Pins		TTL Input #	Pin
1	7, 6		1	15
2	9, 8		2	14
3	11, 10		3	13
4	13, 12		4	12
5	5, 4		5	11
6	3, 2		6	10
7	1, 14		7	9
8	15, 16		8	8
			9	7
			10	6
			11	5
			12	4
			13	3
			14	2
			GND	1

I/O Board #2				
Relay #	Pins		TTL Input #	Pin
9	7, 6		15	15
10	9, 8		16	14
11	11, 10		17	13
12	13, 12		18	12
13	5, 4		19	11
14	3, 2		20	10
15	1, 14		21	9
16	15, 16		22	8
			23	7
			24	6
			25	5
			26	4
			27	3
			28	2
			GND	1

I/O Board #3				
Relay #	Pins		TTL Output #	Pin
17	7, 6		25	9
18	9, 8		26	10
19	11, 10		27	11
20	13, 12		28	12
21	5, 4		29	13
22	3, 2		30	14
23	1, 14		31	15
24	15, 16		32	1
			33	2
			34	3
			35	4
			36	5
			37	6
			38	7
			GND	8

2.3.2.5 RS-232C Communications

RS-232C serial communication is included in IC6 as standard equipment. It can be used to remotely control or monitor IC6. An industry standard 9-pin D-Sub connector is required for the host computer side connection. Depending on the computer source, all connections may not be necessary. The length of the cable is limited to fifty feet according to published standards. IC6 interface operates as DCE (Data Communication Equipment). Pin assignments are for the IC6 connector.

Table 2-4 RS-232C pin connections

Signal Name		Pin	EIA Name
TX	Transmit Data	2	BA
RX	Receive Data	3	BB
SG	Signal Ground	5	AB
GND	Shield Ground	1	

2.3.2.6 Isolated +24 V (dc) Supply

An isolated +24 V (dc) power supply is available on a 9-pin D-Sub connector on the IC6 back panel. This supply is rated for 1.75 A maximum.

The pin assignments for this connector are shown in Table 2-5.

Table 2-5 +24 V (dc) pin connections

Pin	Function
1	Return
2	Return
3	Return
4	Not Connected
5	Not Connected
6	+24 Volts
7	+24 Volts
8	+24 Volts
9	Not Connected



CAUTION

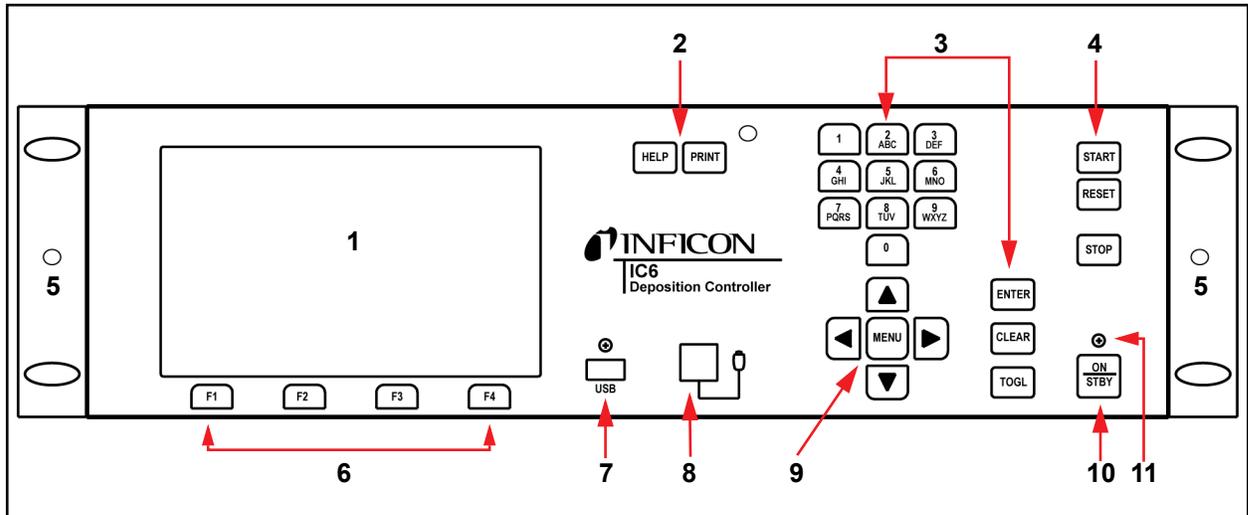
Both the isolated 24 V (dc) supply and the RS-232C remote communications port use a 9-pin D-sub connector. Care must be taken not to inadvertently connect the RS-232C remote communications cable to the 24-volt supply connector. Also, care must be taken not to inadvertently connect the 24 V (dc) supply cable to the RS-232C remote communications connector.

Chapter 3 Operation

3.1 Front Panel Controls

Operational controls for IC6 are located on the front panel, see Figure 3-1.

Figure 3-1 IC6 front panel



1 LCD Screen

Provides graphical displays, setup menus, status and error messages.

2 HELP and PRINT Function Keys

The HELP key brings up context-related text. The PRINT key sends the LCD screen content to the USB storage device.

3 Data Entry Keys

A keypad array with numerics 0 through 9 with telephone-style assigned letters for parameter entry. All numeric entries need to 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. Pressing TOGL moves through selection options such as Yes or No or others such as sensor types. Pressing ENTER continues with the selected choice.

4 System Switches

An array of three keys that provide START, STOP and RESET for process control.

5 Handheld Controller Mount

Tapped hole for attaching support bracket.

6 F1, F2, F3, F4 Function Keys

The function keys. They are used to select displays or menu items. Their function is indicated on the display and is described in subsequent sections.

7 USB

Receptacle for a storage device.

8 Remote Control Jack

Receptacle for the optional wired Handheld Controller (IPN 755-262-G1). For more information on the [Handheld Controller](#), see section 3.6.6 on page 3-41.

9 Cursor Keys

An array of five keys used to move the display cursor either up, down, left or right. The MENU key is used to navigate through IC6 displays. The keys auto-repeat; the cursor will continue to move as long as the key is held down.

10 Power

This switch controls secondary power to IC6 between ON and STANDBY.

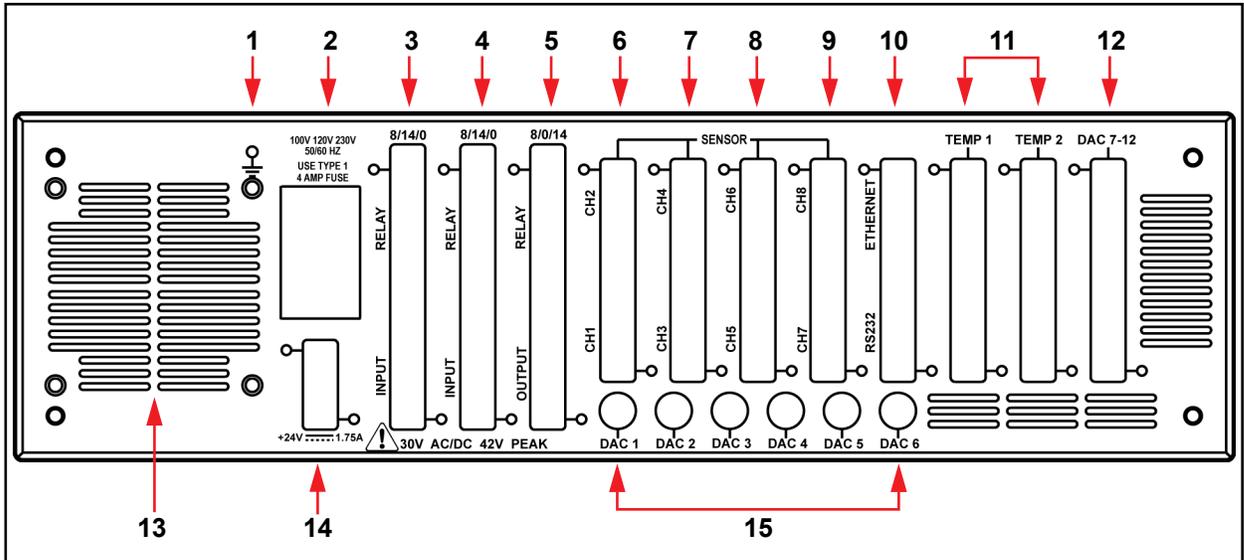
11 Pilot Light

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

3.2 Rear Panel Interfaces

Interfaces for IC6 are located on the rear panel, see Figure 3-2.

Figure 3-2 IC6 rear panel



1 Ground Stud

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

2 AC Power Inlet, Fuse and Mains Switch

Provides a common connector for international plug sets.

3 8 Relay x 14 Input I/O Card (standard)

Provides pin connection for 8 Relays rated for 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum, and 14 TTL inputs.

4 8 Relay x 14 Input I/O Card (optional)

Provides pin connection for 8 relays rated for 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum, and 14 TTL inputs.

5 8 Relay x 14 Output I/O Card (optional)

Provides pin connection for 8 relays rated for 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum, and 14 open collector type outputs.

6 Sensor Connectors - Channels 1 and 2 (standard)

Provides connection for two sensor channels

7 Sensor Connectors - Channels 3 and 4 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 3 and 4.

8 Sensor Connectors - Channels 5 and 6 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 5 and 6.

9 Sensor Connectors - Channels 7 and 8 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 7 and 8.

10 TCP/IP Connector (Optional)

Provides connections for TCP/IP interface.

RS-232C Remote Communication Connector (standard)

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

11 For future expansion options**12 6-Channel DAC (optional)**

Provides recorder output for six channels (15 pin miniature D-sub connector). Outputs are programmable for recorder function.

13 Fan Outlet

Exhaust opening for the IC6's miniature fan; **Do not block!**

14 24-Volt Supply (standard)

Provides three 24 V (dc) supplies rated at 1.75 Amps. See [Table 2-5 on page 2-12](#).

15 6-Channel DAC (standard)

Provides source control voltage or recorder output for 6 channels (BNC connectors). Outputs are programmable for Source Control or Recorder Voltage.

3.3 Displays

IC6 has many display screens for monitoring and programming processes. The six main types of displays are: Operate, Sensor, Source, Material, Process, and General.

To move from one display to another, use the cursor and MENU keys. Figure 3-3 provides an overview of the Main Menu display hierarchy. Figure 3-4 provides an overview of the Operate display hierarchy.

To maximize the life of the display, it can be set to turn off after a period of 1 to 99 minutes without a key press. See section 7.9, AUDIO / VISUAL Page Set Up, on page 7-10. 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, the START, RESET and STOP keys remain active. To restore the display to full brightness without stopping or starting the instrument, do not press the STOP or START key.

3.3.1 Main Menu Display

From the Main Menu screen, see Figure 3-3, move to any IC6 display by positioning the cursor to highlight the desired display and press the MENU key. A second pressing of the MENU key returns to the Main Menu display.

Figure 3-3 Main menu

0.00 $\text{\AA}/\text{s}$		0.000 $\text{k}\text{\AA}$		0.00%		READY	
Operate				General			
Sensor Information				Digital I/O			
Sensor				Logic			
Source				Maintenance			
Material				Counter/Timer			
Process				USB Storage			
Main Menu						Crystal Fail 1	
04/12/2010 08:40							

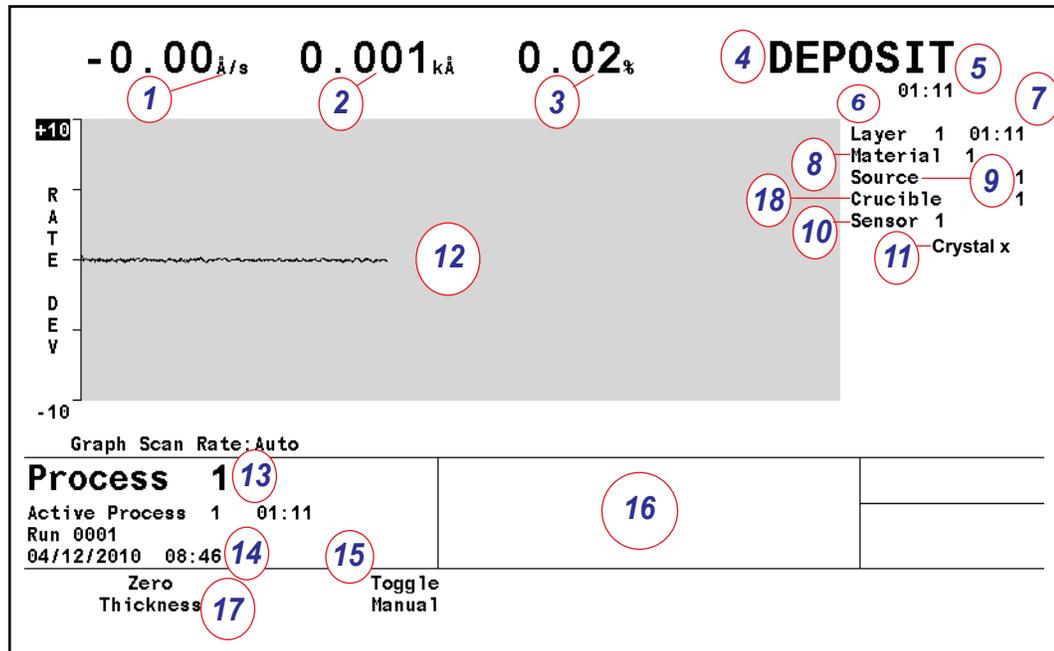
3.3.2 Operate

The Operate display, see Figure 3-4, provides information about the current layer(s) in process. This includes the layer #, material, source #, and sensor # currently in process. The rate, thickness, power level, state, state time, layer time, and process time are updated once a second.

The graph gives an analog display of the Power% level or the rate deviation from the desired rate while depositing. With the cursor on the upper Y-axis value, use the TOGL key to choose Rate Deviation or Power% graphing. Similarly, with the cursor on the X-axis label, use the TOGL key to choose the desired Graph Scan Rate.

Below the graph is a message area consisting of five lines. The Status Messages area, see section 15.1, occupies the first four lines. Transient Messages, see section 15.5 and Input Error Messages, see section 15.6, share the fifth line. This area displays error messages, custom user messages and system status information, such as indicating IC6 is in Test mode. Status messages are displayed as long as a status is true. They are put up and taken down as the condition that set them changes. Since there is limited space for the status messages, if too many status messages are displayed at the same time (greater than 4), newer messages will be displayed if they are cleared, the old messages will appear again assuming the condition is still applicable.

Figure 3-4 Operate screen



Operate Display Description

- 1 **Aggregate Rate**
- 2 **Layer Thickness**
- 3 **Power Level**
- 4 **State of Layer**
- 5 **State Timer**
- 6 **Layer Currently In Process**
- 7 **Layer Timer**
- 8 **Material Being Deposited**
- 9 **Source Number In Use**
- 10 **Sensor Number(s) In Use**
- 11 **Crystal Position In Use**
- 12 **Graphical Display of Rate Deviation or Power**
- 13 **Process Being Executed and Process Time**
- 14 **Run Number**
- 15 **Date and Time**
- 16 **Message Area**
- 17 **Function Key Definitions**
- 18 **Crucible Position**

During the OPERATE display, the function keys below the screen function as explained in Table 3-1.

Table 3-1 Operate display function keys

Key	Function	Description
F1	ZERO THICKNESS	Pressing F1 resets the displayed thickness of the current layer and the sensor thickness values to zero.
F2	TOGGLE MANUAL	Press F2 to put the layer in manual control so that the power level is controlled by the Handheld Controller (section 3.6.6). When in Manual, press F2 again to remove the layer from the Manual state and place it into the DEPOSIT state.
F3	SHOW ALL LAYERS/ SHOW GRAPH	Press F3 to toggle between showing all layers (if more are running) or showing only one layer

In addition to the standard operational screen, if the system is configured for co-deposition, or multi-layer deposition, the operational screen will be divided to show information for all layers as shown in Figure 3-5, Figure 3-6 or Figure 3-7.

Figure 3-5 Co-deposition operate display

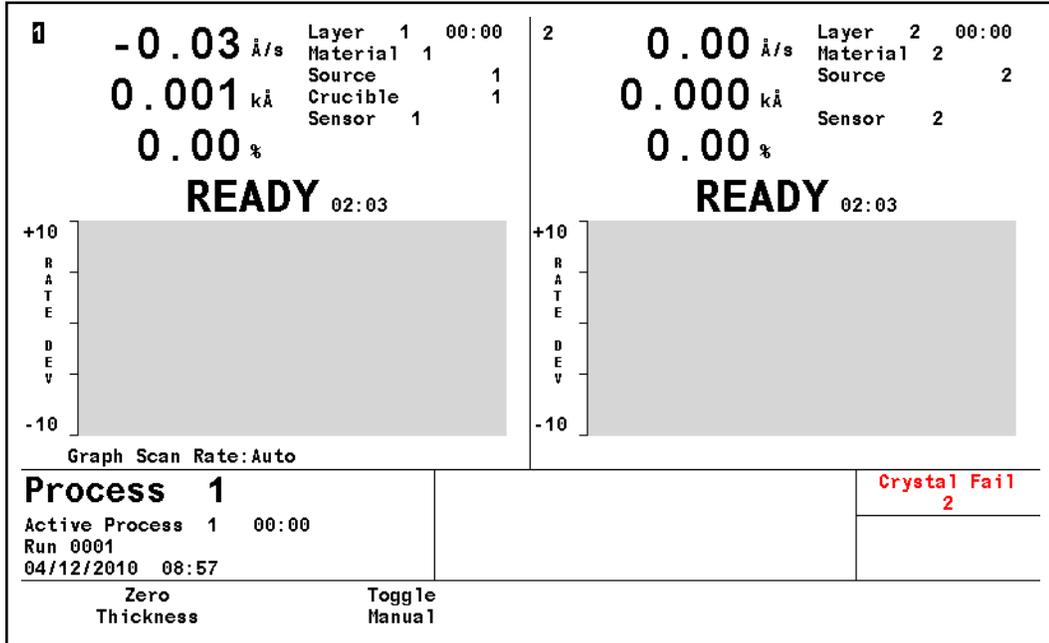


Figure 3-6 4 layer display

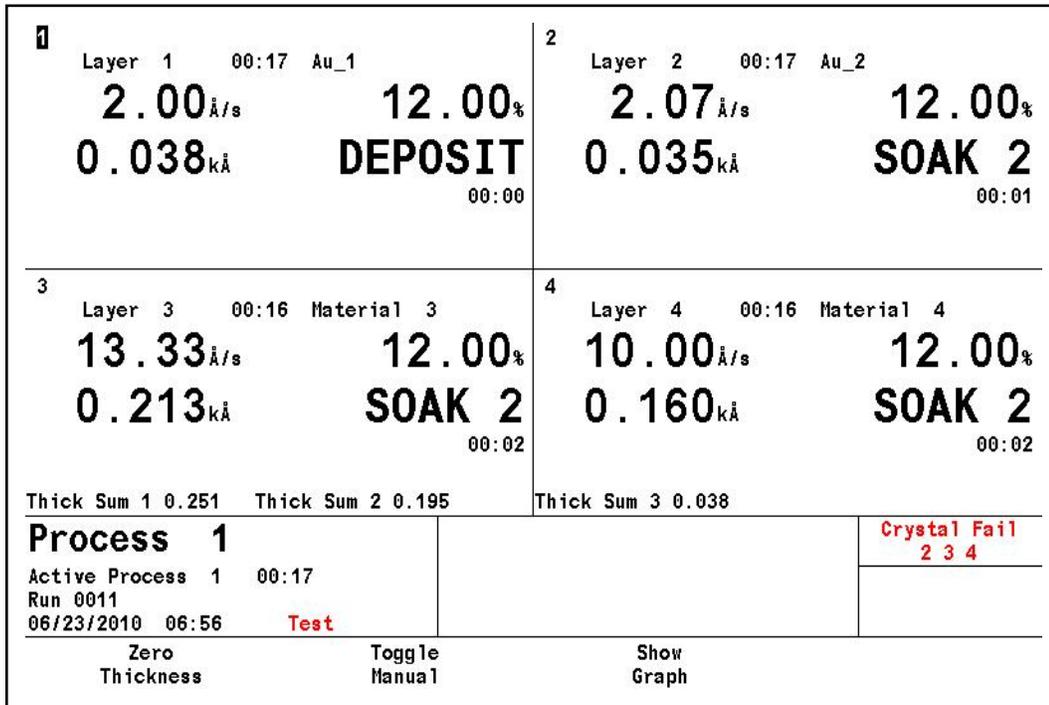


Figure 3-7 6 layer display

1 Layer 1 00:19 Au_1 2.00 Å/s 8.80% 0.003 kÅ DEPOSIT 00:01	2 Layer 2 00:18 Au_2 2.07 Å/s 11.95% 0.002 kÅ DEPOSIT 00:00
3 Layer 3 00:17 Material 3 13.33 Å/s 12.00% 0.239 kÅ DEPOSIT 00:00	4 Layer 4 00:17 Material 4 10.00 Å/s 12.00% 0.179 kÅ DEPOSIT 00:00
5 Layer 5 00:17 Material 5 8.00 Å/s 10.00% 0.137 kÅ SOAK 2 00:01	6 Layer 6 00:17 Material 6 6.67 Å/s 12.00% 0.114 kÅ SOAK 2 00:01
Thick Sum 1 0.378 Thick Sum 2 0.295 00:01 Thick Sum 3 0.117 00:01	
Process 1 Active Process 1 00:19 Run 0011 06/23/2010 06:24 Test	
Zero Thickness Toggle Manual Show Graph	
Crystal Fail 2 3 4 5 6	

3.3.3 Sensor Information

3.3.3.1 Sensor Information Rate/Xtal Display Description

NOTE: N/A (not available) will be displayed in these fields for disabled features or for sensors not in use.

Figure 3-8 Rate/Xtal display

2.00 Å/s 0.085 kÅ 0.00% READY										
Rate/Xtal Type/Freq	Sensor	Average Rate	Raw Rate	% Life	Curr	Next	Crystal Failed	Q Count	S Single	S Total
	1	2.000	2.000	31				N/A	N/A	N/A
	2	N/A	N/A	0				N/A	N/A	N/A
	3	N/A	N/A	0				N/A	N/A	N/A
	4	N/A	N/A	0				N/A	N/A	N/A
	5	N/A	N/A	0				N/A	N/A	N/A
	6	N/A	N/A	0				N/A	N/A	N/A
	7	N/A	N/A	0				N/A	N/A	N/A
	8	N/A	N/A	0				N/A	N/A	N/A
Sensor Information										
06/25/2010 10:54 Test										
Switch Crystal			Rotate Sensor			Clear S & Q Counts			Clear Failed Crystals	

Sensor (Number field)

These numbers correspond to the sensor connector channel numbers on the rear panel of IC6. Use the cursor keys to position the box cursor over the desired sensor number. When either Switch Crystal, Rotate Sensor, Clear S and Q Counts, or Clear Failed Crystals is pressed, that function will be performed on the sensor indicated by the box cursor if IC6 is in Ready, Stop or all active layers are in Idle or Suspend. Text will only be shown for installed cards, unless you are in TEST.

Average Rate

This average is calculated based on a 1 second average of the Filtered Rate.

Raw Rate

Shows the instantaneous rate measurement. The rate fields are useful in identifying if a sensor's rate measurements are becoming erratic.

% Life

IC6 allows a 1.5 MHz frequency shift on the monitor crystal corresponding to 100% crystal life. The value shown represents the amount of crystal life consumed. The amount of useful crystal life is highly dependent on the nature of the material being deposited as well as deposition conditions.

Crystal

This field is subdivided into three categories; current position (**Curr**), next position (**Next**), and **Failed**. Information is displayed in these fields only if the sensor has more than one position.

Curr: For a XtalTwo sensor, the Curr field will show either 1 or 2. 1 indicates the active crystal of the dual sensor head. 2 indicates the inactive (shuttered) crystal of the dual sensor head. For a multi-position sensor, the Curr field indicates the current position of the sensor head.

Next: The Next field indicates the position to which the sensor head will rotate upon pressing the CrystalSwitch function key.

Failed: The Failed field indicates the sensor head positions containing failed crystals.

Q Count (Crystal Quality value field)

This field displays the value currently accumulated in the Crystal Quality counter when active. Delay indicates the Crystal Quality counter is not active. The Crystal Quality counter will become active five seconds after entering DEPOSIT and if the Crystal Quality parameter is non-zero, see page 5-11.

S Single (Crystal Stability value field)

This field displays the positive single frequency shift currently in the Crystal Stability counter, see page 5-12.

S Total (Crystal Stability value field)

This field displays the positive total frequency shift currently accumulated in the Crystal Stability counter, see page 5-12.

3.3.3.2 Crystal Life and Starting Frequency

On the Sensor Information RATE/XTAL display, crystal life is shown as a percentage of the monitor crystal's frequency shift, relative to the 1.50 MHz frequency shift allowed by IC6. 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 usually not possible to use a monitor crystal to 100% of crystal life. Useful crystal life is dependent on the type of material being deposited and the resulting influence of this material on the quartz monitor crystal. For well-behaved materials, such as copper, at about 100% crystal life the inherent quality, Q, of the monitor crystal degrades to a point where it is difficult to maintain a sharp resonance and therefore the ability to measure the monitor crystal's frequency deteriorates.

When depositing dielectric or optical materials, the life of a gold, aluminum or silver quartz monitor crystal is much shorter—as much as 10 to 20%. This is due to thermal and intrinsic stresses at the quartz-dielectric film interface, which are usually exacerbated by the poor mechanical strength of the film. Many organic materials deposit as non-rigid films which causes the crystal's Q to fall rapidly. For these materials, the %Life of the quartz has very little to do with the monitor crystal's failure.

3.3.3.3 Percent Life Auto-Zero

If a new crystal has a starting frequency above 5.945 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 4.50 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 97% when it reaches 4.5 MHz.

3.3.3.3.1 Function Key Selection Choices for the Sensor Information Rate/Xtal Display

To enable the function keys, move the cursor key to a Sensor number.

F1 Switch Crystal

To initiate a crystal switch for the sensor number selected, press F1. The crystal switch will be done on the sensor indicated by the box cursor. Use the cursor arrow keys to position the box cursor.

F2 Rotate Sensor

If the sensor number chosen is a XtalSix, Xtal12 or Generic sensor type, press F2 to sequentially rotate the sensor head through all positions. This is useful to initialize a multi-position sensor after replacing failed crystals. The action is taken on the sensor indicated by the box cursor if IC6 is in Ready, Stop or all active layers are in Idle or Suspend. Failed crystal numbers are shown in the Failed column under Crystal.

Generic Sensor Status showing which crystals are good and which are failed relative to the current position is displayed in the bottom region of the table. This information is not retained upon leaving the Sensor Information display. To re-gain this information, press F2 again.

F3 Clear S and Q Counts

Press F3 to clear the Quality and Stability counters for the sensor chosen by the box cursor.

F4 Clear Failed Crystals

Pressing F4 resets the status of the sensor that the box cursor is on for failed sensors and crystal positions.

3.3.3.4 Sensor Information Type/Freq Display Description

Figure 3-9 Type/Freq display

2.00 Å/s		0.132 kÅ		0.00 %		READY	
Rate/Xtal Type/Freq	Sensor	Sensor Type	Z-Ratio		Act	Frequency	
			Type	Value		Fundamental	Anharmonic
	1	Single	Mat1	0.381	613	5499470.348	0.000
	2	Single	Mat1	0.381	0	0.000	0.000
	3	Single	Mat1	0.381	0	0.000	0.000
	4	Single	Mat1	0.381	0	0.000	0.000
	5	Single	Mat1	0.381	0	0.000	0.000
	6	Single	Mat1	0.381	0	0.000	0.000
	7	Single	Mat1	0.381	0	0.000	0.000
	8	Single	Mat1	0.381	0	0.000	0.000
Sensor Information							
06/25/2010 11:48 Test							
Test XIU							

Sensor

Sensor identifies the sensor channel. Failed sensor numbers appear in red.

Sensor Type

Shows the sensor type configured for the sensor channel.

Z-RATIO

This two-column field displays the type and value of the Z-Ratio being used for the given sensor. Three Z-Ratio types are possible: **Mat1**, **Auto** and **Sens**.

Mat1 indicates the Z-Ratio being used for thickness calculation is the value found in the Material parameter Z-Ratio. If the Auto-Z parameter is set to No in the Sensor menu, the Z-Ratio Type displayed on the Sensor Information screen will always be Mat1.

Auto indicates the Auto-Z parameter in the Sensor menu is set to Yes. Auto-Z continually calculates the Z-Ratio for the "as deposited" film. If IC6 suddenly lost the ability to calculate Auto-Z, Auto would change to either Mat1 or Sens. Mat1 has the same meaning as described above,

Sens indicates the last calculated Auto-Z value (prior to failure) is used for thickness calculations for this sensor.

IC6 determines to use Mat1 or Sens depending on the frequency of the fundamental resonance. If the fundamental frequency closely matches the last valid fundamental frequency prior to Auto-Z failure, IC6 will use the Sens value. Otherwise IC6 will use the Mat1 value.

Act(ivity)

Activity is a measure of the sensor circuit health or ability to conduct current. The values range from a maximum of 800 (healthiest) to a minimum of 0 (least healthy).

The Activity value is useful for predicting when a crystal needs to be replaced. If a crystal is about to fail, its series resistance will increase, allowing less current to flow through the crystal and hence the Activity value will decrease. The closer the Activity value is to zero the more imminent a crystal failure.

Activity also can be used to gauge the health of the sensor head electrical contacts. For example, if a new monitor crystal is placed into the sensor head and has a crystal life of near 0%, but the Activity value for this crystal is lower than 550, this indicates the sensor head or in-vacuum cable is in need of repair.

Frequency

This field is subdivided into two categories: **Fundamental** and **Anharmonic**. The Fundamental frequency will be shown for all working sensors. If Auto-Z is in effect for the sensor, the Anharmonic frequency will also be shown. Frequency value will be displayed.

3.3.3.4.1 TEST XIU

To test any XIU (Crystal Interface Unit), move the cursor onto the respective Sensor number. Pressing F1 then initiates the XIU self test. The XIU self test determines whether the XIU and measurement card pair is operating properly. "XIU Test Passed" message will appear to indicate this. "XIU Test Failed" message will appear when there is a defect in the XIU itself, the XIU interface cable or the measurement card.

For the XIU self test to work properly, the XIU must have the six inch BNC cable (IPN 755-257-G6) attached and must be disconnected from the sensor feedthrough.

3.3.4 Sensor Screen

From the main MENU display, placing the cursor on Sensor and pressing MENU brings up the Sensor display.

The Sensor Overview display, see [Figure 3-10](#), shows the current configuration for all eight sensors.

Figure 3-10 Sensor overview display

		0.01 Å/s 0.000 kÅ		0.00 % READY		0.00 Å/s 0.000 kÅ			0.00 % READY	
Overview	Sensor #	1 Single	2 XtalTwo	3 Single	4 XtalSix	5 Xtal12	6 Generic	7 Single	8 Single	
Sensor	Switch Out	0	1	0	3	4	5	0	0	
	Shutter Out	0	0	2	0	0	0	0	0	
	Auto-Z	No	No	No	No	No	No	No	No	
	Recorder									
	Output	11	0	0	0	0	0	0	0	
	Function	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate	
	Range	100	100	100	100	100	100	100	100	
	# Positions	1	1	1	1	1	10	1	1	
	# Pulses	1	1	1	1	1	1	1	1	
	Pulse On s	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
	Pulse Off s	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Sensor								Crystal Fail 2		
04/12/2010 09:07										
Select Sensor										

Moving the cursor onto one of the sensor numbers and pressing F1 Select Sensor brings up the Sensor display

See section 4.1.2, Sensor Parameters, on page 4-2 for programming details.

3.3.5 Source

The Source Overview display, see Figure 3-11, shows the current configuration for all six sources.

Figure 3-11 Source overview display

		0.01 $\text{\AA}/\text{s}$	0.001 $\text{k}\text{\AA}$	0.00%	READY		
Overview	Source #	1	2	3	4	5	6
Source	DAC Output	1	2	3	4	5	6
	Shutter Output	9	10	11	12	13	14
	Number of Crucibles	Four	One	One	One	One	One
	Crucible Output	20	0	0	0	0	0
	Turret Feedback	Yes	No	No	No	No	No
	Turret Input	1	0	0	0	0	0
	Turret Delay s	5	5	5	5	5	5
Source							
04/12/2010 11:58							
Select Source							

Once the right cursor key has been used to move to one of the six sources, the Select Source function key will appear. Pressing F1 will then display the source's parameter screen.

The Source display allows configuring the selected source.

See section 4.2.2, Source Parameters, on page 4-5 for programming details.

3.3.6 Material

This display is organized into eight sub pages accessible thru the Select Menu described below.

See Chapter 5, Material Setup for programming details and screen displays.

3.3.6.1 Overview Page

The Material Overview display, see Figure 3-12, shows all 32 available materials. Materials are initially shown as Material 1 to Material 32. Once a chemical formula or other name has been assigned, that name will be shown. See section 5.1.2, Material Definition, on page 5-2

Figure 3-12 Material overview page

0.00 Å/s		0.000 kÅ		0.00%		READY	
Overview	1 Ag	9 Material 9	17 Material 17	25 Material 25			
Source	2 Al	10 Material 10	18 Material 18	26 Material 26			
Sensor	3 Au	11 Material 11	19 Material 19	27 Material 27			
Pre/Post	4 Zr	12 Material 12	20 Material 20	28 Material 28			
Deposit	5 Material 5	13 Material 13	21 Material 21	29 Material 29			
Lib A-Hf	6 Material 6	14 Material 14	22 Material 22	30 Material 30			
Lib Hf-Sc	7 Material 7	15 Material 15	23 Material 23	31 Material 31			
Lib Sc-Z	8 Material 8	16 Material 16	24 Material 24	32 Material 32			
Zr							
04/12/2010 09:22							
Select Material		Copy Material		Paste Material		Default Material	

3.3.6.2 Source Page

The Material Source page allows entering or editing Density, Z-Ratio, Control Loop type and associated control loop parameters. One of the six Source BNC analog control outputs is selected and the operating limits for that output such as Min. and Max Power are defined here. If desired, a Recorder Output (one of the unused standard six or optional additional six analog outputs) can be selected for Rate, Thickness, Rate Deviation or Power and the full scale Range value selected. See section 5.1.3, Material Screen Source Page Parameters, on page 5-3.

3.3.6.3 Sensor Page

The Material Sensor page, see Figure 3-13, allows selecting the Tooling factor and which sensor (Multipoint Yes/No) or group of sensors (up to eight) is used or are to be averaged together to control the deposition rate and final thickness for the

material. If Multipoint is set to No, a Backup Sensor and its Tooling factor can be specified. Other choices will be shown according to the Sensor Type. If the sensor is a XtalTwo, the Tooling factor for the secondary crystal can be specified. In the case of a multi-position rotary sensor head, the range of crystal positions to use can be specified.

In addition, Quality and Stability settings are available to force a crystal switch to a backup crystal or sensor when the primary crystal starts to become unstable.

Cal Thickness can be used to manually enter correction factors to subtract crosstalk when multiple materials are being co-deposited. After performing the Cross Talk calibration procedure entered from the Main Menu/Maintenance screen, the correct values will be imported here and shown. See section 5.1.4 on page 5-6.

Figure 3-13 Material sensor page

- 0.00 Å/s 0.000 kÅ 0.00 % READY																																									
Overview Source Sensor Pre/Post Deposit Lib A-Hf Lib Hf-Sc Lib Sc-Z	<table border="1"> <tr> <td>Material Number</td> <td>3</td> <td>Quality Percent</td> <td>0 %</td> </tr> <tr> <td>Multipoint</td> <td>No</td> <td>Quality Counts</td> <td>0</td> </tr> <tr> <td>Sensor</td> <td>1</td> <td>Stability Single</td> <td>0 Hz</td> </tr> <tr> <td>Master Tooling</td> <td>100.0 %</td> <td>Stability Total</td> <td>0 Hz</td> </tr> <tr> <td>Backup Sensor</td> <td>0</td> <td></td> <td></td> </tr> <tr> <td>Backup Tooling</td> <td>100.0 %</td> <td></td> <td></td> </tr> <tr> <td>Xtal Position First</td> <td>0</td> <td></td> <td></td> </tr> <tr> <td>Xtal Position Last</td> <td>0</td> <td></td> <td></td> </tr> <tr> <td>Failure Action</td> <td>PostDp</td> <td></td> <td></td> </tr> <tr> <td>CrystalTwo Tooling</td> <td>100.0 %</td> <td></td> <td></td> </tr> </table>	Material Number	3	Quality Percent	0 %	Multipoint	No	Quality Counts	0	Sensor	1	Stability Single	0 Hz	Master Tooling	100.0 %	Stability Total	0 Hz	Backup Sensor	0			Backup Tooling	100.0 %			Xtal Position First	0			Xtal Position Last	0			Failure Action	PostDp			CrystalTwo Tooling	100.0 %		
Material Number	3	Quality Percent	0 %																																						
Multipoint	No	Quality Counts	0																																						
Sensor	1	Stability Single	0 Hz																																						
Master Tooling	100.0 %	Stability Total	0 Hz																																						
Backup Sensor	0																																								
Backup Tooling	100.0 %																																								
Xtal Position First	0																																								
Xtal Position Last	0																																								
Failure Action	PostDp																																								
CrystalTwo Tooling	100.0 %																																								
	<table border="1"> <tr> <td>Sensor</td> <td>1</td> <td>2</td> <td>3</td> <td>4</td> <td>5</td> <td>6</td> <td>7</td> <td>8</td> </tr> <tr> <td>Cal Thickness</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> <td>UNCAL</td> </tr> </table>	Sensor	1	2	3	4	5	6	7	8	Cal Thickness	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL																						
Sensor	1	2	3	4	5	6	7	8																																	
Cal Thickness	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL																																	
Au																																									
04/12/2010 09:27																																									

3.3.6.4 Pre/Post Page

Up to three pre-deposition phases with rise times, power levels and soak times can be specified. Also, Auto Soak 2 can be enabled as well as Shutter or Control Delay. See section 5.1.5, Pre/Post Screen Deposit Page Parameters, on page 5-12.

3.3.6.5 Deposit Page

Set the desired deposition rate, Time Limit, Rate Filter Time, Time Power Avg Time, Ion Assist Deposit, and the state to enter after reaching Final Thickness.

Two new rates can be specified while in Deposit and RateWatcher can be enabled.

See section 5.1.7, Deposit Page Parameters, on page 5-16.

3.3.6.6 Lib A-Hf, Lib Hf-Sc, Lib Sc-Z Sub-Displays

These three libraries allow convenient selection of a material by its chemical formula along with the correct density and Z-Ratio values. Cursor to a Material formula, then press F1 Define Material to select that material. The Material/Source display will be shown where the remaining parameters can be entered. See section 5.1.2, Material Definition, on page 5-2.

3.3.7 Process

This display is organized into three pages described below. See Chapter 6, Process Setup, for programming detail and page displays.

3.3.7.1 Overview Page

The Process Overview display, see Figure 3-14, shows all 50 processes. Processes with layers are identified by an > preceding the process name. Cursoring to a Process and selecting it with F1 displays the layer sequence in the process. Cursoring to a Process and pressing F2 makes that Process the **active** Process. This process' layer sequence will be executed when a Start is activated.

Figure 3-14 Process overview display

0.00 Å/s		0.000 kÅ		0.00%		READY	
Overview	1 > Process 1	18 Process 18	35 Process 35	2 Process 2	19 Process 19	36 Process 36	
	3 Process 3	20 Process 20	37 Process 37	4 Process 4	21 Process 21	38 Process 38	
Curr Proc	5 Process 5	22 Process 22	39 Process 39	6 Process 6	23 Process 23	40 Process 40	
1 - 10	7 Process 7	24 Process 24	41 Process 41	8 Process 8	25 Process 25	42 Process 42	
	9 Process 9	26 Process 26	43 Process 43	10 Process 10	27 Process 27	44 Process 44	
	11 Process 11	28 Process 28	45 Process 45	12 Process 12	29 Process 29	46 Process 46	
	13 Process 13	30 Process 30	47 Process 47	14 Process 14	31 Process 31	48 Process 48	
	15 Process 15	32 Process 32	49 Process 49	16 Process 16	33 Process 33	50 Process 50	
	17 Process 17	34 Process 34					
Process 1							
Active Process 1							
04/12/2010 09:29							
Select Process		Set Active Process				Default Process	

Press F4 to clear a Process of all programmed values. Move the cursor to a Process to be cleared.

Press F4 Default Process. This will set the Process parameter values, including its name, to their default values as well as remove all layers from the process.

3.3.7.2 Current Process

The Curr(ent) Proc(ess) display, see Figure 3-15, shows the layer sequence for the last process edited, not necessarily the Active Process. A 15 character name can be entered here by cursoring to the Name and using the keys in cell phone style to enter characters and numbers. See section 6.3, Curr(ent) Proc(ess) Page, on page 6-2.

Figure 3-15 Current process display

- 0.00 Å/s 0.001 kÅ 0.00 %		READY
Overview Curr Proc 1 - 10	Process Number 1 Name TWO LAYERS PROCESS 1: Ag, A1	Layers Defined 2
TWO LAYERS Active Process 1 04/12/2010 09:49		
Set Active Process		

3.3.7.3 1 - 10, 11 - 20 etc. Screen

This screen shows the programmed layers in groups of 10. Layer parameters Final Thick(ness), Thick Limit, Cruc(ible) number, CoDep (Yes/No) and related parameters are entered here. With the cursor in the Material # column, enter the material number to use for the first layer. To add to the layer sequence, with the cursor in the Material # column use the down arrow key to move to the empty line and enter the material number to use for that layer. See section 6.4, Process Layers 1 - 10 etc., on page 6-3.

3.3.8 General

The General Process screen is organized into eight sub screens described below. See Chapter 7, General Parameters for programming details and screen displays.

3.3.8.1 Process Page

The Process page shows global parameters and allows editing them.

Figure 3-16 Process page

0.17 Å/s		0.001 kÅ		0.00%		READY	
Process							
DACs	Active Process	1					
Comm	Layer To Start	1		Active Layer Output	0		
Message	Source DAC Required	Yes		Run Number	1		
Date/Time	Auto Start Next	No		Thickness Eq 1	0		
Test	Max Concurrent Layer	2		Thickness Eq 2	0		
Lock	Layers Displayed	Auto		Thickness Eq 3	0		
Audio/Visual							
General					Crystal Fail 1		
04/12/2010 14:22							

Active Process specify which of the 50 processes to execute.

Layer To Start when Start is initiated, this layer # will be executed.

Source DAC Required specifies whether a Source DAC is required for a layer to be active.

Auto Start Next start the next layer when a layer reaches Idle.

Max Concurrent Layer set to 1 to prevent accidental double Starts.

Layers Displayed maximum number of layers displayed on the Operate screen.

Active Layer Output specify the first of 8 consecutive outputs to indicate the number of the layer that will be executed when Start is executed. If multiple layers are active, the outputs will only indicate the lowest numbered one.

Run Number increments at the start of a process.

Thickness Eq 1, 2 and 3 allows summing of thicknesses from up to 6 sources for use in conjunction with a logic statement Thick Sum event.

See section 7.2, General Screen Process Page, on page 7-1

3.3.8.2 DACs Page

Polarity and full scale voltage for all DAC outputs are configured here. 0 output corresponds to 0 Volts. See section 7.3, DACs Page Parameters, on page 7-3.

3.3.8.3 Comm Page

Datalogging of crystal data is enabled here and RS232 and optional Ethernet parameters are entered.

- ◆ Datalog Xtal Info
- ◆ RS232 / Baud Rate/ Protocol
- ◆ Ethernet / IP Address/ Net Mask

See section 7.4, COMM Page Parameters, on page 7-4.

3.3.8.4 Message Page

Ten messages of up to 19 characters each can be entered. Display of messages can be turned on and off using Logic statements.

See section 7.5, MESSAGE Page Setup, on page 7-6.

3.3.8.5 Date/Time Page

Toggle between date formats and enter the current date and time.

Date Format Calendar / Day / Month / Year

System Time. See section 7.6, DATE / TIME Set Up, on page 7-7.

3.3.8.6 Test Page

Allows executing the programmed layer sequence with a dummy rate signal.

Test. On/Off

Time Compressed No/Yes to speed up all times by factor of 10

Advanced Test On/Off. Responds to crystal failures in "On" mode.

See section 7.7, TEST Page Set Up, on page 7-8.

3.3.8.7 Lock Page

Allows setting lock codes to prevent parameter changes or file access.

Program Lock Code / File Access Code

See section 7.8, LOCK Page Code Setup, on page 7-9.

3.3.8.8 Audio/Visual Page

Audio Feedback: turns key beep on or off.

LCD Dimmer Time: 0 disables, sets time in minutes for screen to be turned off after no keys pressed.

See section 7.9, AUDIO / VISUAL Page Set Up, on page 7-10.

3.3.9 Digital I/O

The Digital I/O displays show configuration of all inputs, see Figure 3-17, and outputs, see Figure 3-18, and allows configuring inputs and outputs on the three possible I/O boards.

See Chapter 8, Digital I/O for programming details.

Figure 3-17 All inputs display

-0.01 Å/s 0.001 kÅ 0.00%			READY
	Board 1 Input	Board 2 Input	
All Input	1 TURRET 1	15 DEPO_PR_OK	
	2 MECH_P_ON	16 EVAC_CHH	
All Output	3 FORE_PR_OK	17 VENT_CHH	
	4 FORE_VA_CL	18 AUTO	
I/O Bd 1	5 RUGH_VA_CL	19 CHH_AT_ATM	
	6 HI_VAC_CL	20 ALARM_ANSW	
I/O Bd 2	7 CROS_PR_OK	21 CONNECTORS	
	8 GAUGES	22 ABORT	
I/O Bd 3	9 _____	23 _____	
	10 _____	24 _____	
	11 _____	25 _____	
	12 _____	26 _____	
	13 _____	27 _____	
	14 _____	28 _____	
Inputs			
04/12/2010 11:48			

NOTE: On All Input and All Output pages, active inputs and outputs are displayed in a standard font. Inactive inputs and outputs are displayed in a shadow font.

Figure 3-18 All outputs display

- 0.00 μ/s 0.001 μA 0.00%				
READY				
	Board 1 Relay Output	Board 2 Relay Output	Board 3 Relay Output	Board 3 TTL Output
All Input	1 Xt1 Switching 2	9 SRC SHTR 1	17 _____	25 _____
	2 XTL SHTR 3	10 SRC SHTR 2	18 _____	26 _____
All Output	3 Xt1 Switching 4	11 SRC SHTR 3	19 _____	27 _____
	4 Xt1 Switching 5	12 SRC SHTR 4	20 CRUC (1) 1	28 _____
I/O Bd 1	5 Xt1 Switching 6	13 SRC SHTR 5	21 CRUC (2) 1	29 _____
	6 HI_V_INTER	14 SRC SHTR 6	22 _____	30 _____
I/O Bd 2	7 FILAMENT	15 _____	23 _____	31 _____
	8 FIL_INTER	16 _____	24 _____	32 _____
I/O Bd 3				33 _____
				34 _____
				35 _____
				36 _____
				37 _____
				38 _____
Outputs				
04/12/2010 11:49				

3.3.10 Logic

100 logic statements can be set up. Logic statements are evaluated sequentially, 10 times per second, while IC6 is powered up.

See Chapter 9, Logic Statement Setup for programming details.

3.3.11 Maintenance

The Maintenance display is organized into four subscreens: Auto Tune, Cross Talk, Source Maint(enance) and Sys(tem) Status.

See Chapter 12, Maintenance and Calibration Procedures for programming details.

3.3.12 Counter / Timer

See Chapter 13, Counters and Timers.

3.3.13 USB Storage

Config. allows saving and retrieving configuration files to and from the USB storage device.

Datalog. shows datalog files on USB storage device.

Screen Shot shows Print files on USB storage device.

See Chapter 14, USB Storage.

3.4 Process Description

IC6 allows sequential deposition control for a maximum of 200 layers in all of its 50 processes. Up to six layers can be started and rate controlled at the same time. Two sequential layers can be linked as being co-deposited, enabling crosstalk correction and ratio control. A layer that is linked to another by co-deposition can not be linked to a third layer for co-deposition control or crosstalk correction. Therefore, it is possible to simultaneously control six rates independent of each other or control up to three sets of two layers linked by co-deposition with crosstalk correction and ratio control.

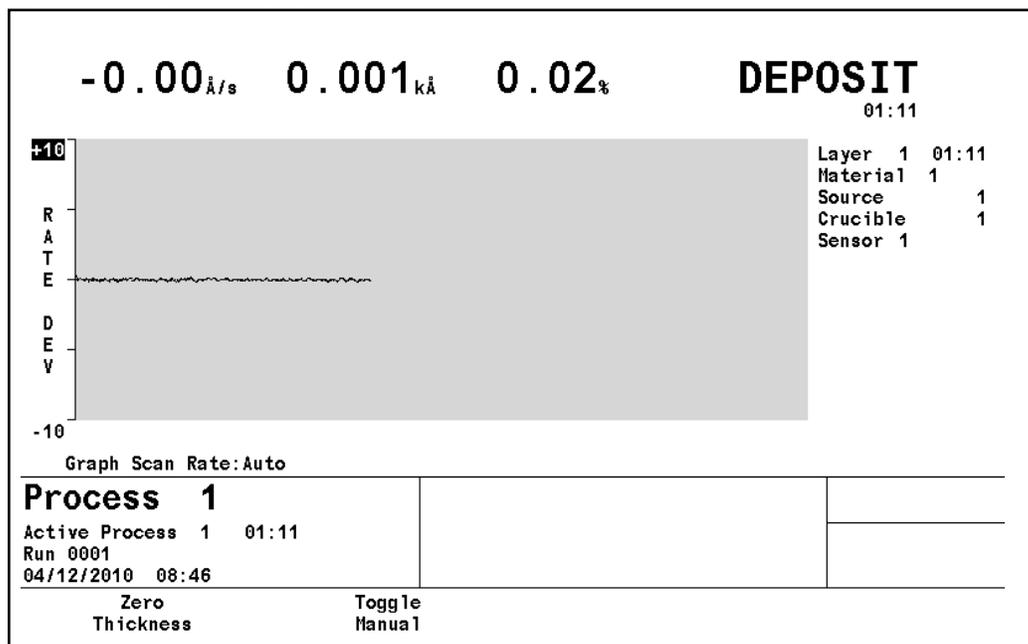
3.4.1 Defining a Process

The following procedure is used to define a process. (All steps do not necessarily have to be followed in the given order.)

- 1 Ensure IC6 is in READY.

Some configuration and process parameters can be changed only while IC6 is in READY. Therefore, before setting parameters, make sure READY appears as the state on the OPERATE display. See Figure 3-19. If READY is not displayed, press STOP then RESET.

Figure 3-19 Operate display - READY



2 Configure the sensors.

Configuring the sensors involves designating whether the sensor is a single or multi-position sensor, and what output relays are connected to the sensor shutter and crystal switcher, if any. Also, the Auto-Z feature is activated or deactivated during sensor configuration. These parameters are on the SENSOR display. See [section 4.1 on page 4-1](#) for a description of programming these parameters. Also see [section 3.6.1 on page 3-34](#) for details on crystal switching.

3 Configure the sources.

Configuring the sources involves selecting the digital-to-analog voltage converter (DAC) output, its polarity and full scale voltage, and selecting the output relay for the source shutter. Also, if a source has more than one crucible, this is set up in the source configuration. The source parameters are programmed on the SOURCE page of the SOURCE screen. See [section 4.2 on page 4-4](#) for a detailed description for programming these parameters. Also see [section 3.6.2 on page 3-37](#) for details on crucible selection. The output voltage full scale range and polarity for the selected source control DAC output is set up in the General screen DACs page.

4 Define materials.

To define materials, the MATERIAL pages of the MATERIAL screen are used. Each distinct material used in the process must be defined. If the same material is going to be used more than once in the process, it needs to be defined only once. The material definition includes rate, density, Z-Ratio, tooling, soak power settings, RateWatcher, rate ramps, time limits and whether to STOP on max power. Control loop characteristics also relate to the material. Also, one source and one or more specific sensors are associated with each material. See [Chapter 5](#) for a detailed description for programming these parameters.

5 Define layer/process.

To define layers and processes, the PROCESS pages are used. A process is an ordered set of layers. Layers are entered in order on the PROCESS display. Each layer consists of a material, chosen by number from the material display, final thickness, and thickness limit. Additional information can be provided here for special process features; these include crucible selection and co-deposition. For a detailed description of layer parameters see [Chapter 6](#).

6 Configure General parameter information.

The final step in defining a process is to program any process related parameters on the GENERAL display. This includes which defined process to execute, what layer to begin the process on (typically 1), and whether to start the next layer automatically. It may also be desirable to modify the definition of the graphical display and analog output. See [Chapter 7](#) for a detailed description of General parameters.

3.4.2 Executing a Process

Once a process has been defined, it is ready to execute.

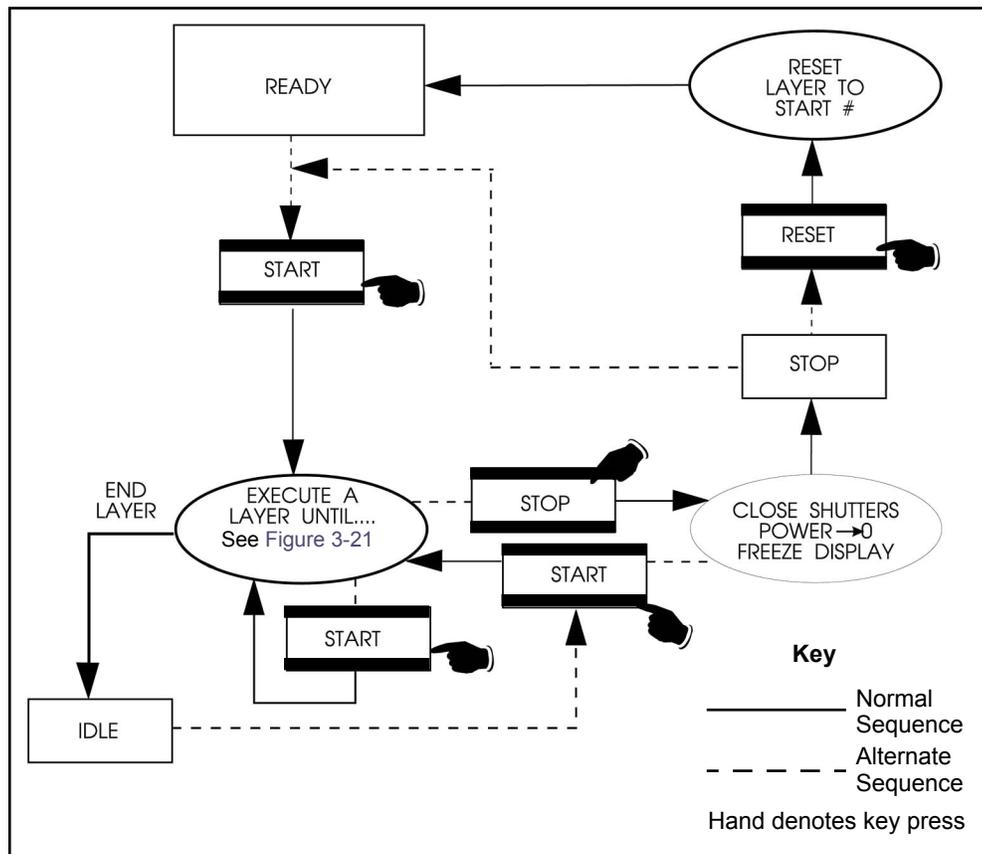
IC6 will not allow certain parameters to be changed while executing a process.

- ◆ A Process is not being executed when IC6 is in the READY state, or when the Last Layer is in the IDLE state (end of process). A Layer is not being executed when IC6 is the READY, STOP, SUSPEND or IDLE state.
- ◆ **STOP** freezes a process, the status information on the display is maintained and all control voltage outputs are set to zero if multiple layers are active.
- ◆ **SUSPEND** is similar to a STOP but only acts on one layer.
- ◆ **START**, pressed once, will continue the process from the point at which it was stopped. If STOP occurred during a Rate Ramp and the layer is continued without a RESET, the setpoint rate on entering Deposit will be replaced with the rate in effect when the STOP occurred. It may be desirable to adjust the SOAK POWER 2 level based on data log history prior to continuing the stopped layer. Subsequent STARTs will start the next sequential layer dependent upon the value set for the General parameter Max Concurrent Layer.
- ◆ **RESET** takes a stopped process back to the beginning of the process at the designated "Layer to START."

HINT: It may be desirable to execute a new process in TEST 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.

Figure 3-20 Process state diagram



- 1 Ensure IC6 is in READY. If not, press STOP then RESET.
- 2 Press START. Assuming there are no configuration problems, the layer to start will enter pre-deposition, and continue on through deposition and post-deposition. (See section 3.5 on page 3-32 for detailed information about the states of a layer.) If there are configuration problems, a message describing the problem will be displayed, see Chapter 15 for Status and Error Message definitions.
- 3 When the first layer is complete, it will go to IDLE. Press START again to begin the next layer unless Auto Start Next layer has been enabled. 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 power 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.
- 5 A critical error may occur while a process is running.

For example, a sensor fail on a single crystal sensor head may occur during pre-deposition. IC6 will automatically follow Materials Failure Action if a critical error occurs. See section 15.1, Status Messages, on page 15-1 for a list of

critical errors. Assuming the error has been remedied, the process can be continued where it left off by pressing START. Pressing RESET will abandon the run.

3.4.3 Pre-conditioning a Layer

It may be desirable to prepare a layer for deposition while the previous layer is in progress. Pressing START while a layer is running will begin the pre-deposition states of the next layer. However, there are certain restrictions and some precautions should be taken.

- 1 The next layer cannot use the same source as the current layer. Pressing START will cause a source conflict and the process will STOP. If pre-conditioning is desired, be sure the sources defined in the two consecutive layers are different and that Max Concurrent Layer in General/Process is set to 2 or more.
- 2 The next layer will enter DEPOSIT while the current layer is in DEPOSIT unless a Soak Hold is activated. A Soak Hold will hold the pre-deposition at the chosen Soak Power level until ready to proceed. To set up a Soak Hold, see [section 9.4, THEN Action Definitions, on page 9-16.](#) or enable using remote communication, see [section 10.4.33, Remote General Action, on page 10-55.](#)

NOTE: If a Soak Hold is not active and two layers attempt to enter DEPOSIT using some of the same sensors, a STOP sensor conflict will occur.

3.4.4 Co-deposition

Co-deposition pertains strictly to depositing two layers at the same time and correcting for any crosstalk due to material from one source arriving at the sensor dedicated to the other source.

A co-deposition is defined on the Layer Definition page of the Process screen. Yes is entered for the co-deposition parameter of the first layer to be co-deposited. This layer is referred to as the primary layer. The primary and secondary layers must both be defined before Yes is entered for the co-deposition parameter of the primary layer. In co-deposition, when the primary layer reaches final thickness, the secondary layer will also leave deposition. However, if the secondary layer reaches final thickness first, the primary layer will continue until reaching its programmed final thickness. There are two other parameters associated with co-deposition. The first is ratio control. This controls the secondary layer's rate at a percentage of the primary layer's desired rate. The second is cross talk, which compensates for interference between the two depositions. See [section 6.4.1, Layer Parameters, on page 6-3](#) and [section 12.6, Determining Cross Talk Calibration For Co-Deposition, on page 12-13](#) for details on programming these parameters.

If two layers are programmed for co-deposition, pressing START once will begin both layers.

3.4.5 Multiple Layer Starts

It is possible to run up to six layers independent of each other at the same time by pressing START six times, but ratio control and cross-sensitivity will not be active. Alternatively, two or three instances of co-deposition are also possible by pressing START two or three times, respectively. The Max Concurrent Layer parameter in the GENERAL/PROCESS page must be set appropriately, see [section 7.2, General Screen Process Page](#), on page 7-1.

3.4.6 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.

- ◆ Setting Auto Start Next in the GENERAL/PROCESS page to Yes will cause a complete process to run by pressing START once.
- ◆ 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 10, Remote Communications](#).)
- ◆ Remote input line. A remote input line can be configured by use of a logic statement to START a layer based on some external event. (See [Chapter 9, Logic Statement Setup](#).)

3.5 State Descriptions

Table 3-2 State descriptions

STATE	CONDITION	RELAY CONTACT STATUS		REMOTE COMM ENCODES
		Source Shutter	Sensor Shutter	
1. READY	IC6 will accept a START command.	Inactive	Inactive	0
2. CRUCIBLE SWITCH (Crucible Sw)	During this state, the crucible turret is being moved from its current position to the one called out for the given material. If the idle power of the source in use is not zero the power is set to zero before the crucible position changes. IC6 advances to next state when turret input goes low for the programmed position or turret delay has elapsed (depending on parameter settings).	Inactive	Inactive	1
3. PRECON RISE	Source power rises to Precondition power level over the precondition rise time. [PreCon Rise Time]	Inactive	Inactive	2
4. PRECON SOAK	Source is maintained at precondition power level for the precondition soak time. [PreCon Soak Time, PreCon Soak Power]	Inactive	Inactive	3
5. RISE 1	Source is rising to Soak Power 1 level. [Rise Time 1]	Inactive	Inactive	4
6. SOAK 1	Source is being maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1]	Inactive	Inactive	5
7. RISE 2	Source is rising to Soak Power 2 level. [Rise Time 2]	Inactive	Inactive	6
8. SOAK 2	Source is being maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2]	Inactive	Inactive	7
9. SHUTTER DLY	Rate is being controlled. Advances to Deposit State once the Source is in Rate Control within Shutter Delay Accuracy for 5 seconds. If the transfer sensor has been set to Yes it will be used during shutter delay [Delay Option].	Inactive	Active	8
10. DEPOSIT	Rate control. [Rate, Final Thickness, PID Control, Process Gain, Primary Time Constant, System Dead Time]	Active	Active	9
11. RATE RAMP 1	Rate control, desired rate changing. [New Rate 1, Start Ramp 1, Ramp Time 1]	Active	Active	10

Table 3-2 State descriptions (continued)

STATE	CONDITION	RELAY CONTACT STATUS		REMOTE COMM ENCODES
		Source Shutter	Sensor Shutter	
12. RATE RAMP 2	Rate control, desired rate changing. [New Rate 2, Start Ramp 2, Ramp Time 2]	Active	Active	11
13. TIME POWER	Crystal failed; source maintained at average control power and average rate prior to crystal failure. [Failure Actions]	Active	Inactive	12
14. Manual	<p>Manual is entered via front panel key or remote communications command.</p> <p>Thickness is incrementing if source shutter is open. The source power is controlled by the hand-held controller or remote communications</p>	Active or Inactive depending on the state when manual is entered. Shutter can be opened or closed by the operator via remote communications during manual.	Active Shutter can be opened or closed by operator via remote communications during manual.	13
15. (Non Deposit Control) NonDep CNTL	The state is entered after the pre-deposit (if "Dep after Pre-dep" parameter set to no) or via external stimulus (remote command, digital input) or after deposit if "On Final Thickness" set to Non-Deposit Control. Thickness is not incrementing. The source power is controlled to the desired rate by the control loop. The state is ended via external stimulus.	Inactive	Active	14
16. NonDep Hold	Non-deposit hold is entered when in non-deposit control and there are no available crystals to continue the control if the time power option had been chosen. Non-deposit hold can also be entered from time power using the RL3 Remote command. Thickness is not incrementing. The source power is maintained at the average control power prior to the crystal failure. Both aggregate rate and power can be adjusted via remote communications. The state is ended via external stimulus.	Inactive	Inactive	15
17. FEED RAMP	Source changing to Feed Power level. [Feed Power, Feed Ramp Time]	Inactive	Inactive	16
18. FEED	Source maintained at Feed Power level. [Feed Time]	Inactive	Inactive	17

Table 3-2 State descriptions (continued)

STATE	CONDITION	RELAY CONTACT STATUS		REMOTE COMM ENCODES
		Source Shutter	Sensor Shutter	
19. IDLE RAMP	Source changing to Idle Power level. [Idle Ramp Time, Idle Power]	Inactive	Inactive	18
20. IDLE	Source resting at Idle Power; will accept a START command.	Inactive	Inactive	19
21. SUSPEND (layer)	The respective layer's source output is set to zero power. The layer's display is frozen at the last rate and thickness values.	Inactive	Inactive	20

NOTE: In STOP or SUSPEND, IC6 will accept a START provided a valid crystal is available for the layer(s) being started.

3.6 Special Features

IC6 has several special features to enhance the performance of the instrument.

3.6.1 Crystal Switching

IC6 offers a choice of Single, XtalTwo (CrystalTwo®), XtalSix (CrystalSix), Xtal12 (Crystal12®), or Generic sensors. The CrystalTwo, CrystalSix, Crystal12, and Generic sensors provide one or more backup crystals in case a crystal fails during deposition. Sensor types are specified on the Sensors screen.

The XtalTwo option requires the 779-220-G1 or 779-220-G2 XTAL2 Switch. The XTAL2 Switch is connected to any sensor input through an XIU package. A Dual Sensor head can also be used by configuring it as two single sensors with the second Dual Head Sensor configured as Backup Sensor by using an XIU in place of the 779-220-Gx XTAL 2 Switch. The normally uncovered crystal is connected to Sensor x, the backup crystal normally covered by the shutter is connected to Sensor y (where y is any available sensor channel). Sensor y is configured as Backup Sensor for Sensor x in the Sensor page of the Material screen and must have a shutter output assigned in the Sensor page of the Sensor screen. The manual Switch Crystal function is not available in this configuration. To calibrate the Backup Sensor, temporarily set it to be the Sensor.

All multi-position and shuttered sensors require the Pneumatic Actuator Control Valve, part number 750-420-G1, and a feedthrough with an air tube.

A crystal switch will automatically occur when:

- ◆ IC6 is configured for a XtalTwo (CrystalTwo) sensor type, a layer is STARTed or running and there is another good crystal available when the active crystal fails.
- ◆ IC6 is configured for a XtalSix, Xtal12 or Generic, a layer is STARTed or running, and there is at least one good crystal left in the carousel when the active crystal fails.
- ◆ A layer is configured with a Backup sensor, a layer is running on the primary sensor, and the last crystal of the primary sensor fails.
- ◆ IC6 is configured for a XtalTwo or single head with Backup, a START is executed and the designated primary sensor is different from the last sensor run.
- ◆ Using a XtalSix or Xtal12 and pressing START if the current position is not within the First/Last Xtal position range listed on the Sensor page of the Material screen.
- ◆ S and Q levels are exceeded while in deposit.

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

- ◆ During a state of STOP, READY or IDLE.
- ◆ When the designated primary sensor and backup sensor fail during pre-deposit. (A SUSPEND will occur if the failure action is configured for Time Power.)
- ◆ During deposition if the secondary crystal of a XtalTwo switch fails, or the Backup sensor, or the last good crystal of a XtalSix, Xtal12 or Generic fails. (In either case a TIME-POWER, SUSPEND, POST DEPOSIT, or STOP will occur, depending on the failure option chosen.)

A crystal switch can be manually executed via the front panel, handheld controller, remote communications, or logic statements when the system is configured for a multi-position sensor.

NOTE: When crystal switching with the handheld controller, IC6 must be on the Sensor Information screen and the cursor on the appropriate sensor number.

3.6.1.1 XtalTwo (CrystalTwo)

In the case of the XtalTwo (a Dual Sensor head with a 779-220-G1 or 779-220-G2 XTAL 2 Switch), the CrystalSwitch output must be wired so that it simultaneously energizes the Pneumatic Shutter Actuator Control Valve which applies the air pressure to actuate the dual sensor shutter mechanism and the 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 IC6.

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, IC6 will switch to the second crystal and continue. The Failed Crystal list can be cleared while in Deposit by pressing the F4 function key on the Sensor Information screen with the cursor positioned on the appropriate sensor number. IC6 will run the next layer using the last crystal position it switched to. While in Ready, the Failed Crystal list can also be cleared by executing a crystal switch with the handheld controller or by pressing the Switch Crystal function key in the Sensor Information screen or via communications command RG23 (Switch Sensor) see [section 10.4.33, Remote General Action, on page 10-55](#). A good crystal must be available to switch to in the case of using the crystal switch method.

3.6.1.2 XtalSix (CrystalSix)

On power-up, all crystals are read to determine how many good and bad crystals are present. IC6 uniquely identifies and tracks all six positions in the CrystalSix.

During deposition, when there is a crystal failure, IC6 will automatically switch to the next position with a good crystal. When the last good crystal fails and a backup sensor is not available, the Xtal Fail message is displayed, the Xtal Fail state becomes true and IC6 will go directly to Time Power, POST DEP, SUSPEND or STOP, as appropriate.

When the sensor selected is a XtalSix, 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.

3.6.1.3 Xtal12 (Crystal12)

On power-up, IC6 will rotate the sensor until position 1 is detected. It will continue to rotate through the other 11 positions to determine the state of all crystals. At the conclusion of the sequence, the Sensor Information screen shows the sensor in position 1 and the position number of any failed crystals. The Crystal12 has resistors electrically in parallel for each of the 12 positions. IC6 verifies that the resistance value is correct at each position. If the value is not as expected, IC6 pulses again and rechecks the position. If position 1 is not detected, or after 13 pulses of the wrong value, IC6 reports a Crystal Sw Fail message. In that case, all crystals are also marked as failed, except for current position status.

When the carousel is removed from the sensor for crystal replacements, IC6 will display Carousel Open. This message also appears if the connection between the XIU (oscillator) and the sensor is absent. After the carousel is replaced, IC6 assumes the current position is 12 and all crystals are failed. A Crystal Switch or Rotate Sensor function must be initiated in the Sensor Information screen or via

Remote Communication to enable IC6 to catalog the state of all crystals and to return to position 1. This must also be done after the sensor type has been changed to Xtal12. The Rotate Head function is permitted only if IC6 is in Ready, Stop or all active layers are in Idle or Suspend.

During deposition, IC6 will automatically switch to the next position with a good crystal when there is a crystal failure. When the last good crystal fails, and no backup sensor is available, the Crystal Fail message is displayed, the Xtal Fail state becomes true and IC6 will go directly to Time Power or STOP, POST DEP, SUSPEND, as appropriate.

When configured for a Xtal12, the relay contacts are only pulsed closed for one second then opened again once for each position. There is no intermediate position.

3.6.1.4 Generic Sensor Crystal Switching

Selecting Generic as the sensor type enables sequential crystal switching for the # Positions selected (maximum of 12). Upon a crystal switch, the Switch Output will first close for the Pulse On time and then open for the Pulse Off time. The setting # Pulses determines how many On/Off pulse sequences will occur for each movement to the next crystal position. IC6 will not keep track of which position the Generic Sensor is on nor will it keep track of which crystals are good and which are failed. The Position Selection feature is not available for the Generic sensor.

After a crystal switch sequence, IC6 will attempt to find the resonant frequency for the crystal in this position. If IC6 does not find a good resonant frequency for this crystal, it will again pulse the Crystal Switch Output and attempt to find a resonant frequency at the next position. The maximum number of attempts to find a good resonant frequency is one less than the # Positions value. If a good resonant frequency is not found after all attempts, IC6 will enter the Time Power, POST DEP, SUSPEND or STOP state depending on the Sensor / Option Action chosen in the Material/Sensor display.

Start resets all crystal fail flags to good.

3.6.2 Source/Crucible Selection

IC6 can control a source with up to 64 crucibles through up to six binary encoded relays. This is configured by setting the Number Of Crucibles, Crucible Outputs, Turret Feedback, Turret Input, and Turret Delay parameters on the SOURCE page of the SOURCE screen. (See [section 4.2.2, Source Parameters](#), on page 4-5 for details on programming the parameters associated with source/crucible selection.)

To define which crucible to use for a layer, set the Cruc(ible) parameter on the PROCESS/Layer screen. When the layer is started, if the current crucible position is different from the one requested, the system's turret controller will move the crucible into position. This will be signified on the OPERATE screen by the state indicator CRUCIBLE SW(ITCH). The layer sequencing will continue on to

Pre-condition Rise Time after either the turret delay time expires or an input indicates the turret is in position, depending on which option is chosen. The specific method used is determined by the parameter Turret Feedback on the SOURCE screen.

NOTE: If the source has been idling at a nonzero power when the START is initiated, the power will be dropped to zero before the crucible is changed.

3.6.2.1 Example: Programming Turret Source Crucible Selection

Interfacing a turret source controller to IC6 requires both hardware connections to the turret controller and properly defining certain IC6 parameters.

Proceed to the SOURCE screen and choose the source that is going to be defined as the turret source. This is accomplished by Editing the chosen source as follows:

- 1 Designate the Number of Crucibles; for example, four.
- 2 Select the Crucible Output. This defines the number of the first relay that encodes the crucible number selected by the active layer. Relays are defined sequentially with the first relay containing the least significant bit (LSB). The greater the number of crucibles selected, the greater the number of relays required. The number required is based on binary encoding (actual coding is binary -1, with 00 representing position 1 and 11 representing position 4). Any unused sequence of relays may be used if it is long enough to provide sufficient selections. Outputs are NO (Normally Open).
- 3 Determine whether Turret Feedback is desired. This allows the turret position controller to stop further IC6 processing until the requested turret position is satisfied. If chosen, a turret input must be connected to the turret position controller's feedback signal.

Enter a Turret Delay Time which allows an adequate time for positioning to take place. Once the delay time has expired, IC6 state processing continues.

- 4 The selection of a particular crucible for a layer is defined in the process page.
- 5 Select the process to modify.
- 6 Program the particular Crucible Number for each layer.

Example:

Layer 1:	Cruc(ible) Number	= 1
Layer 2:	Cruc(ible) Number	= 2
Layer 4:	Cruc(ible) Number	= 4

3.6.3 Auto-Z

The Auto-Z feature of IC6 automatically determines the Z-Ratio of a crystal. This feature is enabled on the SENSOR page of the SENSOR screen. For the theory behind Auto-Z, see section 16.1.6, Auto-Z Theory, on page 16-9.

The following information briefly describes Auto-Z and details the conditions under which a crystal is "unable to Auto-Z."

Auto-Z is calculated based on the slightly different mass sensitivities of the fundamental and the first anharmonic resonances of the quartz crystal oscillator. Therefore, the need to measure the frequencies of both the fundamental and the first anharmonic resonances is critical.

When inserting a monitor crystal and attempting to Auto-Z, the fundamental and anharmonic frequencies are measured to determine the status of the crystal. The crystal status may be classified into four categories:

1 New Crystal

The first category is for a "new" crystal, one that does not have any material deposited onto it. If both frequencies fall within the allowed range for new crystals, IC6 will allow an Auto-Z calculation with this crystal.

2 Known, Used Crystal

The second category is for a "known, used" crystal, to account for the possibility that a person would remove a good monitor crystal and then reinsert the same crystal. Whenever a crystal fail occurs, the last valid crystal frequencies are stored in IC6. Upon inserting a coated monitor crystal, the measured frequencies for this crystal will fall outside of the allowed range for "new" crystals. These frequencies are then compared with the stored values to determine if this crystal is the same one as was in use prior to the crystal fail. If the crystal is the same as used previously, and Auto-Z was calculated previously, IC6 will allow an Auto-Z calculation with this crystal.

3 Unknown, Used Crystal

The third category is for an "unknown, used" crystal. This category is for a used crystal that, upon insertion, shows measured frequencies that are outside of the allowed "new" crystal range and also do not match the frequencies stored within IC6. This results in an "unable to Auto-Z" condition because the initial frequencies of the uncoated monitor crystal are not known.

4 Unable to detect anharmonic frequency.

As mass is deposited onto the crystal, the oscillation is damped. This damping may be severe enough that the resonance can no longer be determined. If IC6 loses the ability to measure the first anharmonic frequency, but is still able to determine the fundamental frequency, the "unable to Auto-Z" message is displayed. IC6 will then continue to use the fundamental frequency to monitor the deposition.

If IC6 loses the ability to measure the fundamental frequency and all available crystals in a multi-position sensor head are flagged as failed, and a backup sensor is not available, the Crystal Fail message is displayed and the Xtal Fail logic state becomes true.

Unable to Auto-Z

An “unable to Auto-Z” condition occurs whenever:

- ◆ The anharmonic frequency cannot be measured.
- ◆ The fundamental and anharmonic frequencies of the monitor crystal have not been continuously measured from the uncoated to the coated state.

3.6.4 Auto Tune — Optimizing the Control Loop

Control loop parameters can often be calculated automatically by IC6. This is done by using the AutoTune feature. See [section 12.5, AutoTuning](#), on page 12-5.

3.6.5 RateWatcher

IC6 includes a sample and hold function which enables periodic sampling of the deposition rate by opening and closing the sensor shutter. If you are controlling inherently stable deposition sources, this function is useful in maximizing crystal life. When RateWatcher is enabled, during deposit, rate control will be established. The sensor shutter will close for a designated amount of time. The shutter will once again be opened to validate and adjust the power level. This procedure is repeated throughout the deposition. Two Material/Deposit parameters—RateWatch Time and RateWatch Accuracy—control this function. See [section 5.1.7, Deposit Page Parameters](#), on page 5-16.

3.6.6 Handheld Controller

An optional Handheld Controller (IPN 755-262-G1), see Figure 3-22, is available as an accessory with IC6. The Handheld Controller serves as a wired remote to manually control power, switch crystals and produce a STOP.

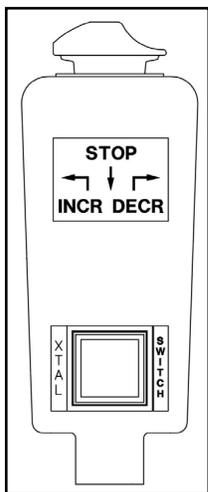
The Handheld Controller is attached to IC6 with a modular plug to the front panel. Power is affected only when in Manual mode by moving the POWER/STOP switch laterally. Pressing to the left as indicated by the INCR arrow, increases the power. Pressing to the right as indicated by the DECR arrow, decreases the power.

A STOP is produced by moving the POWER/STOP switch down.

When on the Sensor Information screen, and an XtalTwo (CrystalTwo), XtalSix (CrystalSix), Xtal12 (Crystal12), or Generic sensor is selected, a crystal switch is activated by pressing the red button on the body of the controller.

The Handheld Controller kit includes a convenience hook for the Handheld Controller that can be attached to the IC6's mounting ears or some other accessible location.

Figure 3-22 Handheld controller



3.6.6.1 Determining Soak Power with the Handheld Controller

The Handheld Controller is a useful tool that can be used to determine the appropriate Soak Power levels. Below is an example of how a typical process Soak 1 and Soak 2 can be determined using the Handheld Controller.

Determining Soak 1

Use the Handheld Controller to slowly increase power, a few percent-per-minute. Watch the rate until some rate increase is detected. Depending on the type of source used, this may take several minutes. Once a non-zero rate is achieved, note the current percent power. Use a percent or more lower than this for the Soak Power 1 parameter.

Determining Soak 2

After ~30 - 60 seconds of Soak 1, using the Handheld Controller, again slowly increase the power a percent at a time until the desired Deposition Rate is reached. Use a percent or two less than this number for the Soak Power 2 parameter.

3.6.7 Test Mode

Test can be turned on or off in the General/Test display page. "Test" will be shown in red while Test mode is active.

3.6.7.1 Standard or Time Compressed

This IC6 contains a software-controlled test mode which simulates actual operation. In Time Compressed mode, all layer times are sped up so that a long process can be simulated in one tenth of the time. The purpose of the test mode is to verify basic operation and to demonstrate typical operation. The rate display during test mode operation is:

$$\text{Rate Display} = \frac{40}{\text{Density (gm/cc)}} \times \frac{\text{Tooling \%}}{100} \text{ \AA/sec} \quad [1]$$

Crystal fails are ignored in these test modes. Auto crystal switching is disabled. All other relays and inputs operate normally.

3.6.7.2 Advanced Test

In Advanced Test mode, crystal fails are recognized and auto crystal switching is enabled.

3.6.8 USB Storage Device

The USB port allows storage of all parameter information, screen shots as well as automatic datalogging information to a storage device. The maximum number of files which may be stored depends on the storage device memory size. IC6 is limited to displaying 120 files as 8 pages of 15. The directories are Config, Datalog and Screen Shot.

The parameter set may be stored under a new or existing filename and retrieved from an existing file. A file containing IC6 parameter set is referred to as a configuration file. Datalog information will be saved only if the USB Datalog Format setting in the Datalog page of the USB Storage screen is set to Comma or Page.

Multiple files may be contained on one storage device. Filenames may be eight characters long; extensions are used to differentiate between configuration files, screen shots and datalogging files. All files must be contained in the appropriate directory. Storage/retrieval from sub-directories is not allowed for screen shots and datalog files.

IC6 supports the writing of filenames using alphanumeric characters selected using the cursor keys. Characters A through Z and numbers 0 through 9 inclusive are available. IC6 has the ability to display the files contained on the memory stick. A scrolling feature is enabled to view those filenames which cannot fit as indicated by +++ on the screen. Error messages include: Disk Full; File Not Found; Disk Write Protected; Media Error; Disk not Found; File is Read Only.

Datalog files are automatically named using the process number and run number. See [section 3.6.10, Datalog](#), on page 3-43 for the Datalog string details. Screen shots are named as DDMMYYXX or MMDDYYXX depending on the date format setting. XX is a number that increments 0-99, resetting to 0 every day.

NOTE: A File Access Code parameter is enabled when IC6 has a Program lock code set. By entering a File Access Code, the IC6 parameters can be saved to, or retrieved from, the USB storage device only without entering the Program Lock Code. (See [Chapter 7, General Parameters](#).)



CAUTION

Do not remove the USB storage device from IC6 while a save or retrieve operation is taking place.

3.6.9 Lock and Access Codes

IC6 has several forms of protection to prevent unauthorized changing of parameters. Refer to the General setup section for a description of parameter and Program lock codes and the File Access Code. In addition, a method of locking the entire display is available through the remote communications. Lock codes are entered on the General display. See [Chapter 7, General Parameters](#).

HINT: To clear any of the locks, except the File Access Code, hold down the CLEAR key on power up. This will clear all lock codes. **HOWEVER**, if no lock codes are present, all parameters will be cleared.

3.6.10 Datalog

If enabled, Datalog automatically sends process information to the RS-232 port or saves it to the USB storage device every time a source shutter closure occurs, an end of deposit occurs, or following a Stop or Suspend. The information will be saved under a filename on the USB storage device.

Datalog files saved to the USB storage device will be automatically named using the process number and run number. The format of the filename is: PXXRXXX.IDL. If the USB storage device already contains a file with the same filename as the new datalog information, the new datalog information will be appended to the old file.

At each source shutter close, the datalog information will be appended to the file (when saved to USB) until the end of the Process.

If two layers are co-deposited, the first layer to have a source shutter close will be data-logged first.

Datalogging to RS-232 is active if the USB Datalog format is set to page or comma in the Datalog page of the USB Storage screen. Datalogging the crystal frequency data is an optional subset of the datalog string and is enabled by selecting Yes for Datalog Xtal Info on the Comm page of the General screen. The Dlog Comma protocol format is actually comma-and-quote delimited intended for file importation into a spreadsheet program. When a spreadsheet program imports a file having the comma delimited format, data groups that are strictly numbers become value entries, data groups surrounded by quotes are stored as labels.

For the Dlog Page protocol format, only those sensors which are used in a particular Material for a particular Layer will be datalogged.

For the comma delimited format, all the data fields are returned for all the sensors and crystals. If a sensor is not used during the deposition, the data field will contain a zero.

The following values make up the data in the datalog. The data is sent in ASCII strings when the RS-232 port is set for data logging. The data is saved as ASCII strings in the datalog files. The ASCII strings are made up of the labels and values in the following list. ASCII strings are CRLF (Carriage Return Line Feed) terminated. When the data log is requested via the remote status layer command the values are sent in the binary format only.

- ◆ Year (Integer)
- ◆ Month (Integer)
- ◆ Day (Integer)
- ◆ Hour (Integer)
- ◆ Minute (Integer)
- ◆ Process x (x = process number or, in data log files, the name if the name is programmed)
- ◆ Run Number X (Integer)
- ◆ Layer x (Integer)
- ◆ Material x (x is the material number or, in data log files, the name if the name is programmed)
- ◆ Process Time seconds (Integer)
- ◆ Layer Time seconds (Integer)
- ◆ Deposit Time seconds (Integer)

- ◆ Ending Thickness kÅ (Float)
- ◆ Average Rate Å/s (Float)
- ◆ Average Rate Deviation Å/s (Float)
- ◆ Ending Power % (Float)
- ◆ Average Power % (Float)
- ◆ Where it goes next (Byte):
 - ◆ 0 = NonDeposit Control or NonDeposit Hold
 - ◆ 1 = Post Deposit
 - ◆ 2 = Stop
- ◆ Termination Reason (Byte) (Matches the "Cause of Stop" Remote encoding comm, see section 15.4, STOP messages, on page 15-7:
 - ◆ 128 = Normal termination,
 - ◆ 127 = Manual source shutter closing,
 - ◆ 126 = Suspend)
- ◆ Time Power Flag (Byte) (0 = No, 1 = Yes)
- ◆ Power Fail Flag (Byte) (0 = No, 1 = Yes)
- ◆ Power Fail Thickness kÅ (Float) (0 if not a power fail, otherwise the thickness when the power was lost.)

NOTE: If Data Log Xtal Info Parameter is set to Yes, the following Crystal History will be sent for each sensor, see Table 3-3. The Crystal history contains the history of every crystal in every sensor used in the layer. In the Remote status command SL17, the crystal history for all twelve crystals in all eight sensors is returned. If the Data Log Xtal History Parameter is set to no, all zeros are sent in the remote status command SL17.

Table 3-3 Sensor 1 to 8

Crystal	Begin Freq	End Freq	BegLife	EndLife	Beg Activity	End Activity	Stability Value	Quality Value
1	<Float>	<Float>	<Integer>	<Integer>	<Integer>	<Integer>	<Integer>	<Integer>
2								
3								
4								
5								
6								

Table 3-3 is extended as necessary to show all crystals in a sensor.

3.6.11 DAC Monitoring

IC6 continually compares the actual output voltages at the DAC BNC connectors with the internally generated values to detect external or internal equipment malfunction. If the values do not agree, IC6 takes the following action:

If the DAC output is assigned for Source control:

- ◆ Stop the process.
- ◆ Display Source Fault message.
- ◆ Set this Source Output to zero.

If the DAC output is assigned for Recorder use:

- ◆ Set this output to zero.
- ◆ Display Recorder Fault message.

Both types of faults remain active until a RESET is performed.

Chapter 4

Sensor and Source Setup

4.1 Sensor Setup Introduction

The basic IC6 has one sensor measurement board with two sensor channels, identified as CH1 and CH2 on the IC6 back panel and as Sensor # 1 and Sensor # 2 on the display screens. Three more sensor measurement boards can be added to support up to eight sensors. The second sensor measurement board will normally be installed in the next slot labeled CH3 and CH4 and the associated sensors will be Sensor# 3 and Sensor# 4 etc. Each sensor connection requires an external oscillator (XIU) package.

Sensor Setup is initiated by moving the cursor to the Sensor heading on the Main Menu and pressing MENU. To return to the Main Menu display, press MENU again.

4.1.1 Sensor Display Navigation

The Sensor Overview display, see Figure 4-1, shows the current configuration of all eight possible sensors even if only one measurement board is installed.

To make changes, use the left/right cursor to move to the appropriate sensor, then press F1 Select Sensor to bring up that sensor's screen. See Figure 4-2.

Figure 4-1 Sensor overview

		0.01 $\text{\AA}/\text{s}$	0.001 $\text{k}\text{\AA}$	0.00%		READY			
Overview	Sensor #	1	2	3	4	5	6	7	8
	Sensor Type	Single	XtalTwo	Single	XtalSix	Xtal12	Generic	Single	Single
Sensor	Switch Out	0	1	0	3	4	5	0	0
	Shutter Out	0	0	2	0	0	0	0	0
	Auto-Z	No	No	No	No	No	No	No	No
	Recorder	11	0	0	0	0	0	0	0
	Output	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate
	Function	100	100	100	100	100	100	100	100
	Range								
	# Positions	1	1	1	1	1	10	1	1
	# Pulses	1	1	1	1	1	1	1	1
	Pulse On s	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Pulse Off s	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sensor									
04/12/2010 11:53									
Select Sensor									

Figure 4-2 Sensor parameter editing

0.00 Å/s		0.001 kÅ		0.00%		READY	
Overview	Sensor Number	2					
Sensor	Sensor Type	XtalTwo		# Positions	1		
	Switch Out	1		# Pulses	1		
	Shutter Out	0		Pulse On	1.0 s		
	Auto-Z	No		Pulse Off	1.0 s		
	Recorder Settings						
Output	0						
Function	Rate						
Range	100						
Sensor							
04/12/2010 11:55							

4.1.2 Sensor Parameters

SENSOR TYPE Single (0), XtalTwo (1), XtalSix (2), Xtal12 (3), Generic (4). Press the TOGL key to move through the choices. Default is "Single."

Values in brackets are used with the remote communication commands. This parameter enables the Crystal Switch feature for the multi-position heads and enables the crystal indexing feature on the handheld controller. If a multi-position sensor is selected, the Switch Out parameter appears. Additional parameters appear for a Generic type. This parameter cannot be changed while executing a process.

SWITCH OUT 0 to 38

This parameter appears when the sensor type is not Single. It designates which of the 38 outputs is to be used as the Crystal Switch output for this sensor. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that the Crystal Switch Output is not used. The default value is 0. If a value other than 0 is entered, the output chosen as the Crystal Switch output is designated as such on the Digital I/O display. The default setting for the contact closure on this output is Normally Open.

SHUTTER OUT 0 to 38

This parameter designates which of the 38 outputs is to be used to activate the Crystal Shutter for this sensor. Values range from 0 to 38. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that a shutter is not used. The default value is 0. If a value other than 0 is entered, the output chosen as the Crystal Shutter output is designated as such on the Digital I/O display. The output is set to be true as long as the layer containing the sensor is in SHUTTER DELAY, DEPOSIT, NON DEPOSIT CONTROL, MANUAL, or in the Sample period of the RateWatcher function. The condition remains true until the end of POST DEPOSIT, TIME POWER, and HOLD, or until a STOP command is received, or during the Hold period of the RateWatcher function.

Auto-Z No (0), Yes (1)

This parameter designates the method in which the Z-Ratio value will be obtained for use in computing thickness with this sensor. No indicates that the Z-Ratio established in Material Definition is used. Yes indicates that the Auto-Z calculation feature of the system is used. Auto-Z cannot be enabled on a crystal which is "unable to Auto-Z". Refer to section 3.6.3 on page 3-39 for details on why a crystal is unable to Auto-Z. The default value is No for the Material Z-Ratio.

Recorder Settings**OUTPUT** 0 to 12

This parameter designates which of the DAC outputs is to be used as this sensor's unfiltered recorder output. Values range from 0 to 12. 0 indicates there is no DAC used with this sensor. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the IC6 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC output card.

FUNCTION Rate (0), Thick (1), RateDev (2)

This parameter determines the function of the Sensor's recorder output. Default is 0 for the unfiltered sensor rate (Rate Filter Time has no effect).

RANGE 0 to 99999

The full scale range value selected corresponds to General Parameter DAC Scale and Polarity. Default is 100.

4.2 Source Setup Introduction

IC6 provides the capability to configure the six source control channels. Each source control channel is treated as an individual device.

Source Setup is initiated by moving the cursor to the Source heading on the Main Menu and pressing MENU. You may return to the Main Menu display by pressing MENU again.

4.2.1 Source Navigation

The Source Overview page shows the current configuration of all six sources.

Figure 4-3 Source overview page

		0.01 Å/s	0.001 kÅ	0.00%	READY		
Overview	Source #	1	2	3	4	5	6
Source	DAC Output	1	2	3	4	5	6
	Shutter Output	9	10	11	12	13	14
	Number of Crucibles	Four	One	One	One	One	One
	Crucible Output	20	0	0	0	0	0
	Turret Feedback	Yes	No	No	No	No	No
	Turret Input	1	0	0	0	0	0
	Turret Delay s	5	5	5	5	5	5
Source							
04/12/2010 11:58							
Select Source							

To make changes, use the left/right cursor to move to the appropriate source, then press F1 Select Source to display that source's screen

4.2.2 Source Parameters

Figure 4-4 Source parameter page

-0.00 Å/s 0.001 kÅ 0.00 % READY	
Overview Source	Source Number 1 DAC Output 1 Shutter Output 9 Number of Crucibles Four Crucible Output 20 Turret Feedback Yes Turret Input 1 Turret Delay 5 s
Source	
04/12/2010 11:59	

The following parameters can be edited for each of the 6 source control channels.

SOURCE NUMBER 1 to 6

Enter the number of the source to be edited.

DAC OUTPUT 0 to 12

This parameter designates which of the DAC outputs is to be used as a source output. Values range from 0 to 12, with 0 indicating there is no DAC identified with this particular source. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the IC6 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card.

SHUTTER OUTPUT 0 to 38



CAUTION

Do not change Source Shutter output assignments while a process is running. Doing so will result in incorrect operation of the source shutter.

This parameter designates which of the 38 outputs is to be used as the Source Shutter relay. Values range from 0 through 38. 0 indicates that a shutter is not used and values 1 through 38 correspond to the appropriate relay or open collector type output. The default value is 0. If a value other than 0 is entered the relay chosen as the Source Shutter relay is designated as such in the

Digital I/O Display. When running a layer containing the source for which the Shutter Output parameter is programmed, the logic condition is set to be true when the Layer is in DEPOSIT, TIME POWER, RATE RAMPS or MANUAL. The condition remains true until the end of DEPOSIT or until a STOP command is received. The same output may be used for multiple shutters.

NUMBER OF CRUCIBLES One(0), Four(1), Eight(2), 16(3), 32(4), 64(5)

Values in brackets are for use with remote communication commands. Refer to section 3.6.2, *Source/Crucible Selection*, on page 3-37 for an example of programming Turret source crucible selection. This parameter can be used to automatically index the turret position when using a multiple pocket turret source. The value is selected using the TOGL and ENTER keys. The default value is 0 and indicates a single pocket source. If a 0 is chosen, the parameters Crucible Output, Turret Feedback and Turret Delay or Turret Input are grayed out on the Display. The number of crucibles determines the number of relays needed for the crucible output. As the relays are binary encoded (actual coding is binary - 1, with 000 representing position 1 and 111 representing position 8), 2 relays are needed for 4 crucibles, 3 for 8, 4 for 16, 5 for 32 and 6 for 64.

CRUCIBLE OUTPUT 0 to 37

This parameter designates which of the outputs are to be used as Crucible Outputs. Values range from 0 to 37. The default is 0 and indicates the Crucible Output is inactive. The value entered into this parameter indicates which of the outputs begins the sequence of outputs used as crucible control outputs. For example, a Four(1) entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1 and 2 as crucible control outputs with the least significant bit of the binary coding in relay output 1. An Eight(2) entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1, 2, and 3 as crucible control outputs with the least significant bit of the binary coding in relay output 1.

TURRET FEEDBACK Yes (1), No (0)

Some turret source indexers provide feedback to signify when the turret is in the proper position. This parameter allows IC6 to accept this input and respond accordingly. Parameter entry may be either Yes or No. Yes indicates that Turret Feedback is expected and the Turret Input parameter is displayed on the screen. No indicates there is no Turret Feedback. The default value is No. See the Turret Input and Turret Delay descriptions below.

NOTE: If the turret feedback is set to Yes and the Process is STARTed, IC6 will proceed to the CRUCIBLE SW state. If the turret input is not received within the Turret Delay time, the process will STOP.

TURRET INPUT 0 to 28

This parameter designates which of the 28 inputs is to be the Turret Feedback input. Values range from 0 to 28. Values 1 through 14 correspond to the appropriate input on I/O Relay Module 1, values 15 to 28 require the I/O Relay Module 2. Value 0 indicates that an input for turret feedback is not used. The default value is 0. However, an input must be assigned or the process will never proceed past the source switching state of the process. If a value other than 0 is entered, the input chosen as the Turret Input is designated as such on the Digital I/O display. Input lines are activated with a contact closure to ground.

TURRET DELAY 2 to 180 s

The Turret Delay time sets the maximum amount of time the Process will remain in CRUCIBLE SW(itch), waiting for rotation to complete without turret feedback before proceeding to the pre-condition state. If a Turret Input signal is expected (Turret Feedback = Yes) this is the time IC6 will wait to receive the input signal. If the signal is not received within this time, IC6 will stop. If the Turret Input becomes active during the delay time, processing continues immediately. Permissible values are 2 to 180 seconds. The default value is 5 seconds.

**CAUTION**

IC6 will proceed to the Pre-Condition state after the Turret Delay time expires. This could result in damage to your equipment if the crucible is not in position after expiration of the Turret Delay time.

4.3 DAC Output Selection Rules

The six standard DAC outputs, DAC1 to DAC 6, located on the back of IC6 and the six optional DAC outputs, DAC 7 to DAC 12, may be used for rate control or to record rate, thickness and rate deviation. Since these outputs can be set up for different functions, certain rules apply.

- ◆ No DAC output can be set up as both a recorder output and a source output. If this is attempted, an error message will be displayed.
- ◆ A DAC output cannot be set up for more than one source. If this is attempted the error message DAC Used Source # will be displayed.
- ◆ A DAC output can be set up for more than one recorder output including any combination of Aggregate Rate/Thickness or Sensor Rate/Thickness.
- ◆ If a DAC output is set up for multiple recorder outputs that are required to be operative at the same time, the error message Recorder Conflict will appear. This is a non-fatal error (that is, it will not cause IC6 to STOP) and the message will remain until the conflict is resolved or a STOP takes place.

The priority of a recorder output that is in conflict is:

- 1** Aggregate Rate/Thickness on the Primary Layer (the first of two co-deposited layers).
 - 2** Aggregate Rate/Thickness on the Secondary Layer (the second of two co-deposited layers).
 - 3** Sensor Rate/Thickness on the Primary Layer (from sensors 1 to 8).
 - 4** Sensor Rate/Thickness on the Secondary Layer (from sensors 1 to 8).
- ◆ For a Sensor's Recorder Output to be active it must be associated with an active Material.

Chapter 5

Material Setup

5.1 Introduction

IC6 can store definition parameters for up to 32 materials. Each layer in a Process references one of these materials by its number, ranging from 1 to 32. Any material that is to be used must be defined. Materials can be defined by referencing the internal Material Library containing more than two hundred cataloged materials and by completing a series of parameter entries at the front panel.

Material Setup is initiated by moving the cursor to the Material heading on the Main Menu and pressing MENU. To return to the Main Menu screen, press MENU again.

5.1.1 Material Screen Overview Page

The Material Overview display, see Figure 5-1, shows all 32 available materials. Materials are initially shown as Material 1 to Material 32. Use the right arrow cursor to move into the material table. Material parameters can be copied from one material number to others for quick duplication using F2 Copy Material and F3 Paste Material

Figure 5-1 Material overview display

0.00 Å/s		0.000 kÅ		0.00%		READY	
Overview	1 Ag	9 Material 9	17 Material 17	25 Material 25			
Source	2 Al	10 Material 10	18 Material 18	26 Material 26			
Sensor	3 Au	11 Material 11	19 Material 19	27 Material 27			
Pre/Post	4 Zr	12 Material 12	20 Material 20	28 Material 28			
Deposit	5 Material 5	13 Material 13	21 Material 21	29 Material 29			
Lib A-Hf	6 Material 6	14 Material 14	22 Material 22	30 Material 30			
Lib Hf-Sc	7 Material 7	15 Material 15	23 Material 23	31 Material 31			
Lib Sc-Z	8 Material 8	16 Material 16	24 Material 24	32 Material 32			
Zr							
04/12/2010 09:22							
Select Material		Copy Material		Paste Material		Default Material	

With the cursor on one of the 32 materials, press F1 Select Material. See Figure 5-3 on page 5-3. The screen changes to show the Material screen. To assign one of the chemical formulas with its correct density and Z-Ratio values to this material #, move the cursor to the appropriate library display: Lib A-Hf, Lib Hf-Sc or Lib Sc-Z.

Press F4 to clear a Material of all programmed values. Move the cursor to a Material to be cleared. Press the "Default Material" function key F4. This will set the Material parameter values, including its name, to their default values.

5.1.2 Material Definition

Figure 5-2 Material Library A - Hf display

- 0.00 Å/s		0.001 kÅ		0.00%		READY	
Overview	Material 3	Density 10.500	Silver				
	Z-Ratio 0.529	(*) Indicates Default Value					
Source	Ag	B203	Bi203	CaTi03	Cr	CuS	GaAs
Sensor	AgBr	B4C	Bi2S3	CaW04	Cr203	Dy	GaN
	AgCl	BN	Bi2Se3	Cd	Cr3C2	Dy203	GaP
Pre/Post	A1	Ba	Bi2Te3	CdF2	CrB	Er	GaSb
	A1203	BaF2	BiF3	CdO	Cs	Er203	Gd
Deposit	A14C3	BaN206	C	CdS	Cs2S04	Eu	Gd203
	A1F3	BaO	C	CdSe	CsBr	EuF2	Ge
Lib A-Hf	A1N	BaTi03	C8H8	CdTe	CsCl	Fe	Ge3N2
	A1Sb	BaTi03	Ca	Ce	CsI	Fe203	GeO2
Lib Hf-Sc	As	Be	CaF2	CeF3	Cu	Fe0	GeTe
	As2Se3	BeF2	CaO	CeO2	Cu20	FeS	Hf
Lib Sc-Z	Au	BeO	CaOSi02	Co	Cu2S	Ga	HfB2
	B	Bi	CaS04	Co0	Cu2S	Ga203	HfC
Au							
04/12/2010 12:07							
Define Material							

The three Material Libraries—Lib A-Hf, Lib Hf-Sc and Lib Sc-Z—provide an alphabetic list of materials by chemical name along with their density and Z-Ratio. Once a material is selected from the library listing by moving the cursor to it, press F1 Define Material. The correct chemical formula and library name, density and Z-Ratio values will now be imported to this Material # and the Material/Source page will appear. To rename this material, cursor to the name and use the keys in cell-phone format to enter up to 15 characters.

To move among and through the materials, use the four cursor keys.

5.1.3 Material Screen Source Page Parameters

Figure 5-3 Material source screen

0.00 Å/s		0.001 kÅ		0.00%		READY	
Overview	Material Number	3					
	Name	Au					
Source	Density	19.300 g/cc		Source	1		
	Z-Ratio	0.381		Maximum Power	90.00 %		
Sensor	Control Loop	PID		Max Power Option	Post-Dep		
Pre/Post	Process Gain	10.000 Å/s/%		Minimum Power	0.00 %		
Deposit	Time Constant	1.000 s		Recorder Output	0		
Lib A-Hf	Dead Time	1.000 s		Recorder Function	Rate		
Lib Hf-Sc				Recorder Range	100		
Lib Sc-Z							
Au							
04/12/2010 12:10							

MATERIAL NUMBER 1 to 32

Change the number to edit or create a different material.

NAME 15 characters max.

The default will be Material #. The default name is returned as a blank entry when queried via communications. Materials selected from the library will be shown by their chemical formula. The Name can be edited using the keys in cell-phone fashion.

DENSITY 0.100 to 99.999 g/cm³

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. If a material is chosen from the Material Library, the density is automatically entered. The default value is 1.000.

Z-RATIO 0.100 to 15.000

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. If a material is chosen from the Material Library the Z-Ratio is automatically entered. The default value is 1.00. This parameter is superseded if Auto-Z-Ratio is selected in Sensor Setup.

CONTROL LOOP NonPID (0), PI (1), PID (2)

The bracketed value is used for changing the setting via the remote communications commands. This parameter establishes the control loop algorithms pertaining to either a slow responding source or a fast responding source. The default value is NonPID (0).

NonPID is best for fast and medium speed responding systems with **high noise** levels (for example, an electron beam gun with or without a liner, having a large sweep amplitude of low frequency, 10 Hz or less).

PI is best for fast, medium, or slow systems with **medium noise** levels (for example, an electron beam gun with medium sweep amplitude frequency, 20 to 100 Hz; also, sputtering and resistive sources).

PID is best for fast, medium or slow systems with **low noise** levels (for example, an electron beam gun with sweep off or at a high frequency, 100+ Hz, and sputtering and resistive sources).

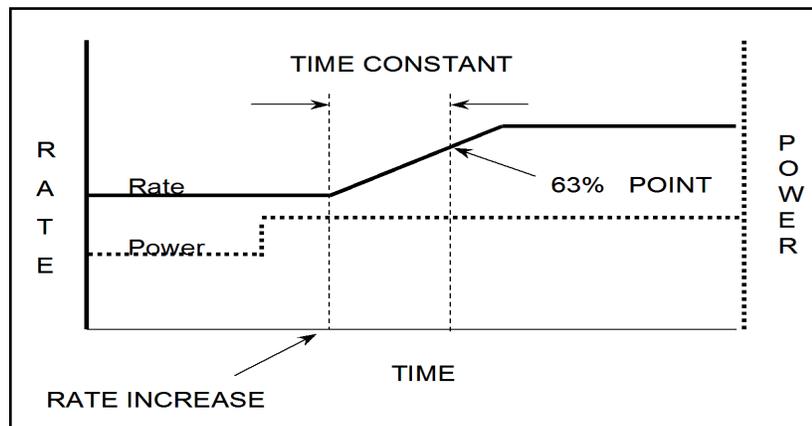
PROCESS GAIN 0.010 to 999.990 Å/s/% pwr

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. Process Gain is calculated by dividing the change in rate caused by the corresponding change in power. The default value is 10.00.

TIME CONSTANT 0.010 to 9999.99 s

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. This parameter is disabled if the CONTROL LOOP option parameter is set to 0 (NonPID).

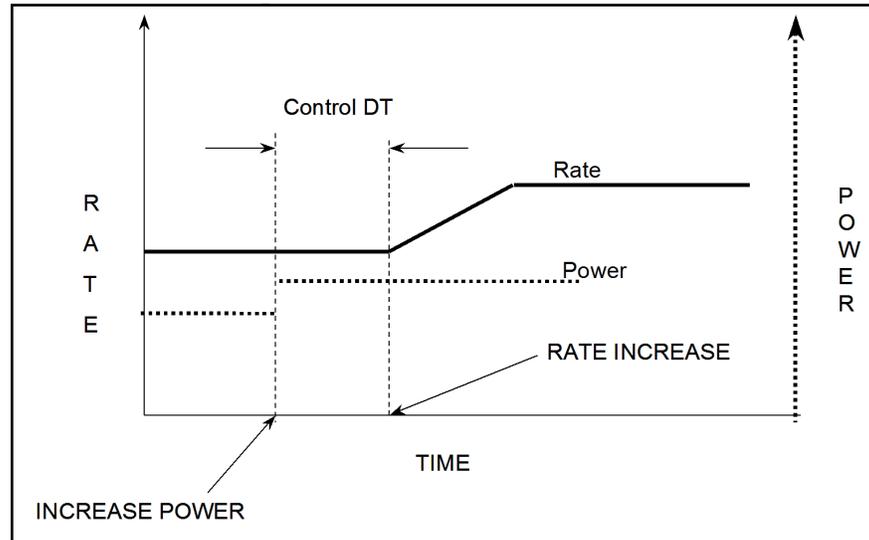
Figure 5-4 Time constant



DEAD TIME 0.010 to 9999.99 s

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 1.0. This parameter is disabled if the CONTROL LOOP option parameter is set to 0 (NonPID).

Figure 5-5 Control dead time



SOURCE 1,2,3,4,5,6

This parameter determines which of the six sources, defined in the Source Set-Up display, is to be used for the material being defined. The default is 1. This parameter cannot be changed while a process is running.

MAXIMUM POWER 0.01 to 99.99%

This parameter is used to set the maximum permissible % power level. The control voltage output will not exceed this limit. The default value is 90.00%.

MAX POWER OPTION Continue (0), Post-Dep (1), Stop Proc (2), Suspend Mat (3)

This parameter provides a safety feature.

0 = Continue. Allows the layer to continue in its current state.

1 = PostDeposit. The layer will proceed to the programmed post deposit state(s).

2 = Stop. Process will stop. Source control voltages for all layers are set to zero.

3 = Suspend. Source control voltage for the layer is set to zero.

The default setting is Stop Proc (2).

MINIMUM POWER 0.00 to 99.98%

This parameter is used to set the minimum permissible % power level. The control voltage output will not exceed this limit. The default value is 0.00%.

RECORDER OUTPUT 0 to 12

There are twelve (six standard, six optional) DAC outputs available which may be divided among source control voltage outputs, individual sensor rate/thickness recorder outputs, aggregate rate/thickness or power level recorder outputs. A value of zero indicates there is not a recorder output chosen for that function. Values 1 through 6 correspond to the six DAC BNC outputs on the back of IC6 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card. The default value is zero for the Rate filtered for the Rate Filter Time, see [section 5.1.7 on page 5-16](#).

RECORDER FUNCTION (Filtered) Rate (0), Thick(ness) (1), RateDev(iation)(2), Power (3). Default is Zero.

RECORDER RANGE 0 to 99999

Selects the full scale value in the appropriate units, Å/s for Rate and Å for Thickness. Default value is 100. Full scale values are fixed at +/- 50 Å/s for Rate Deviation, depending on what was selected on the Operate screen and 100% for Power.

5.1.4 Material Screen Sensor Parameters Page

MATERIAL NUMBER 1 to 32

Change the number to edit or create a different material.

MULTIPOINT No (0), Yes (1)

Enables averaging of multiple sensors if set to Yes (1). Default is No (0). Up to eight sensors may be used to control an “aggregate” rate. The aggregate rate is determined from averaged rate information at each sensor scaled by the sensor tooling and sensor weight parameters. The standard IC6 includes sensor channels 1 and 2. IC6 will support six additional sensor channels with the addition of optional measurement cards.

When Multipoint is set to No (0)

The following parameters are displayed only when the Multipoint parameter is set to the default value of No (0).

SENSOR 1 to 8

Select the sensor to use for this material. This parameter only appears if Multipoint has been set to No.

BACKUP SENSOR 0 to 8

Select the sensor to use if the primary sensor fails. This parameter only appears if Multipoint has been set to No. Default is 0, which disables the function. This parameter cannot be changed when a material is running.

BACKUP TOOLING 1.0 to 999.9%

Sets the Tooling factor for the backup sensor if one has been selected. Visible only if Multipoint is set to No. Default value is 100%.

When Multipoint is set to Yes (1)

AGGREGATE MULTIPLY . No (0), Yes (1)

Default setting is No. For multiple sensor deposition control applications the parameter AGGREGATE MULTIPLY (Yes/No) determines whether a multiplier is calculated for a crystal's rate information if a crystal fail occurs during deposition. This multiplier is used only during the layer in which the crystal failure occurs. After this layer is finished, the multiplier is cleared. Use of AGGREGATE MULTIPLY affects calculation of the aggregate rate as shown in Table 5-1. (Assume all Sensor Weights are the same.)

Table 5-1 Aggregate multiplier effect

Condition of the deposition	Sensor #1 Rate (Å)	Sensor #2 Rate (Å)	Sensor #3 Rate (Å)	Sensor #4 Rate (Å)	Aggregate Rate (Å)	Aggregate Multiplier
Beginning	10	10	10	10	10	1
Later in the Deposition	16	10	10	4	10	1
If #1 fails, notice what happens to the aggregate rate if the aggregate multiplier is not calculated.	Xtal Fail	10	10	4	8	1
An AGGREGATE MULTIPLIER is calculated as the ratio of the aggregate rate before the sensor failure (using an average rate for the failed sensor prior to failure) divided by the aggregate rate after the sensor failure (without the failed sensor's rate information).	With: 10 Without: 8 Ratio 1.25					

Table 5-1 Aggregate multiplier effect (continued)

Condition of the deposition	Sensor #1 Rate (Å)	Sensor #2 Rate (Å)	Sensor #3 Rate (Å)	Sensor #4 Rate (Å)	Aggregate Rate (Å)	Aggregate Multiplier
Applying the multiplier to all future aggregate rate results:	Xtal Fail	10	10	4	10	1.25
If during the deposition the use of the aggregate multiplier is turned off, the aggregate rate reverts back to:	Xtal Fail	10	10	4	8	not used

If the layer has not finished, the use of AGGREGATE MULTIPLY may be turned back on and the previously calculated multiplier (in this case 1.25) will continue to be used.

AGGREGATE RATE CALCULATION EXAMPLE

Table 5-2 Aggregate rate example data

Sensor	1	2	3	4	Unit
APPLIED RATE	2	4	2.667	1	Å/s
MASTER TOOLING	200				%
SENSOR TOOLING	100	50	75	200	%
DISPLAYED RATE	4	4	4	4	Å/s
SENSOR WEIGHT	50	100	75	25	%
Σ WEIGHTS	250				%
RELATIVE WEIGHT	0.2	0.4	0.3	0.1	N/A
CONTRIBUTION RATE	0.8	1.6	1.2	0.4	Å/s
AGGREGATE RATE	4				Å/s

Displayed Rate = Applied Rate * Master Tooling * Sensor Tooling

Relative Weight = Sensor Weight / Σ Weights

Contribution Rate = Displayed Rate * Relative Weight

Aggregate Rate = Σ Contribution Rates. This is the rate that will be displayed on the Operate screen.

The Displayed Rate is the rate for each sensor displayed on the Sensor Information screen. It reflects the effects of Master Tooling and Sensor Tooling and is not affected by the Weight parameter.

Regardless of which sensor fails, the aggregate rate will remain the same.

The following parameters expand from using one sensor when Multipoint is OFF to using up to eight sensors when Multipoint is turned ON.

(SENSOR) FAILURE ACTION . . Unused (0), PostDp (1), Stop (2),
Suspnd (3), TimePw (4)

Desired process change when the sensor fails. PostDp (1) continues into post-deposit states. In Stop (2), all source control voltages will be set to zero. In Suspend (3), only the associated layer will enter the suspend state. It's source control voltage will be set to zero. TimePw (4) continues to Final Thickness using stored average power and rate. This cannot be updated when a transfer or backup sensor is running. The default setting is Unused (0) except for Sensor 1 which is Stop (2) if it is a single sensor.

All sensors except those designated Unused are averaged and weighted together to calculate the layer rate and thickness.

NOTE: When using either the double-start (that is, pressing the START key twice) or the codeposition feature, a sensor may not be used by two layers each in Deposit at the same time. If this is attempted, a sensor conflict error will occur and IC6 will enter the STOP state. If one layer is in either a pre-Deposit or post-Deposit state, and the other layer in Deposit, the layer in Deposit has use of the sensor. Once both layers are started, a sensor cannot be enabled if it is used by the other material.

(SENSOR) FAILURE TRIGGER OnFail (0), Last (1)

Determines when the Failure Action is initiated. Select OnFail (0) to initiate Failure Action when this sensor fails. Select Last (1) to initiate Failure Action only if this sensor is the last one to fail. This cannot be updated when a transfer or backup sensor is running. Default is Last (1).

(SENSOR) WEIGHT 1.0 to 400.0%

The Sensor Weight parameter is used to gauge the relative importance of each sensor's measured rate in calculating a weighted average aggregate rate. The default value is 100%.

If the WEIGHT parameter for a sensor is changed, the new WEIGHT for this sensor will be used for subsequent calculations of the aggregate rate, if the sensor's Failure Action is not "Unused." Field will be inaccessible if unused (0) failure action.

NOTE: This parameter affects the aggregate rate calculation. The aggregate thickness accumulated thus far is not re-scaled based on the change to the weighting factor.

(SENSOR) TOOLING 1.0 to 999.9%

The Sensor Tooling factor is used to account for the geometric tooling factor of each sensor. The default value is 100%.

If the TOOLING parameter for a sensor is changed, the new TOOLING value is used for subsequent calculations of the sensor rate, and therefore the aggregate rate, if the sensor's Failure Action is not "Unused." Field will be inaccessible if unused (0) failure action.

NOTE: This parameter affects the aggregate rate calculation. The aggregate thickness accumulated thus far is not re-scaled based on the change to the TOOLING of a sensor. The individual sensor's accumulated thickness is also not re-scaled.

XTALTWO TOOLING 1.0 to 999.9%

This parameter applies only if the sensor type is XtalTwo (CrystalTwo). Sets the Tooling factor when a dual sensor or two single sensors are connected to the same sensor channel using a CrystalTwo switch. Default value is 100%.

If the sensor type is XtalSix (CrystalSix) or Xtal12 (Crystal12)

XTAL POSITION FIRST . . . 0 to 6 (12 for Xtal12)

XTAL POSITION LAST . . . 0 to 6 (12 for Xtal12)

If all available positions are to be used for this material, set both values to 0. Otherwise, enter values to select the set of positions to use for this material. Permissible values for a CrystalSix are 0 to 6, 0 to 12 for a Crystal12. Default is 0.

NOTE: If an out-of-range position condition results when a sensor type is changed, the position values will be defaulted to 0.

MASTER TOOLING 1.0 to 999.9%

If Multipoint has been set to Yes, this affects all sensors. Tooling is a correction factor used for correlating the (aggregate) 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 MASTER TOOLING factor is calculated using equation [1].

$$\text{TOOLING} = \text{TF}_i \times (\text{T}_m / \text{T}_x) \quad [1]$$

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

The default value is 100%.

If the TOOLING is changed, the new TOOLING value is used for subsequent calculation of the individual as well as aggregate rate and thickness. Also, the aggregate thickness and each sensor's thickness accumulated thus far will be re-scaled based on the change to the TOOLING.

When Multipoint has been set to Yes for multiple sensor applications, the sensor tooling factors should first be adjusted so all sensors read the same rate. Next, adjust this TOOLING to get agreement between the thickness measured by IC6 and the thickness measured at the substrates.

CAL THICKNESS 0 to 999.8, 999.9 = UNCAL

Calibration Thickness values are only used in co-deposition applications and do not pertain to single layer sequential deposition. These thickness values are used to compensate for the cross talk (or interference) from each source onto sensors used to control the other source's flux. The values range from 0.000 to 999.8 kÅ or UNCAL. The default entry of 999.9 is interpreted as UNCAL. UNCAL indicates the sensor has not been calibrated. Values may be entered by the user or may be entered automatically using the cross talk calibration feature of IC6. See section 12.5 on page 12-5 for a discussion of cross talk calibration.

QUALITY PERCENT 0 to 99% and > 0.5 Å/s

Quality Percent selects the permissible rate deviation in percent of the measured rate relative to the desired rate. The default value is 0% which disables the function.

QUALITY COUNTS 0 to 99

This sets the number of measurements that must be outside the allowed Quality Percent before the crystal is declared failed. If the rate deviation relative to the 2.5 second average rate is greater than the programmed Quality Percent limit, the Counts value is incremented. If the rate deviation is less than the programmed Quality Percent, the Counts value is decremented. Counts are not allowed to have negative values. If Counts exceeds the value programmed, IC6 will automatically crystal switch, complete the process on TIME-POWER, POST DEP, SUSPEND or STOP the process. The rate deviation is computed on each individual rate measurement during the deposit phase, that is, every 100 ms. Upon entering Deposit, the Quality Count is delayed by five seconds. The Q Count on the Sensor Information screen will show DLY (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 can be cleared by installing a new crystal or pressing the F3 key to Clear S & Q counts on the Sensor Information screen. This action must be repeated for each sensor used by cursoring to the appropriate sensor number.

STABILITY 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 that will cause a crystal fail. The default value is 0 Hz which disables the function.

STABILITY 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 that will cause a crystal fail. 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 can be cleared by installing a new crystal or pressing the F3 key to Clear S & Q counts on the Sensor Information screen. This action must be repeated for each sensor used by cursoring to the appropriate sensor number.

5.1.5 Pre/Post Screen Deposit Page Parameters

MATERIAL NUMBER 1 to 32

Change the number to edit or create a different material

NOTE: The first power ramp consisting of Pre-Cond Rise and Pre-Cond Soak is skipped if the previous layer had the same source, same crucible and its Idle power is nonzero.

PRECON SOAK POWER 0.00 to 99.99%

This parameter is usually set to the power level at which the source material just begins to glow. IC6 ramps the power level from zero to Pre-Cond Soak Power linearly over the time period Pre-Cond Rise Time. The default value is 0.

PRECON RISE TIME 00:00 to 99:59 min:s

This parameter provides the time period over which the source power is ramped from 0 to Pre-Cond Soak Power. The default values is 00:00.

PRECON SOAK TIME 00:00 to 99:59 min:s

This parameter provides the time period for which IC6 holds at Precon Soak Power. The default value is 00:00.

SOAK POWER 1 0.00 to 99.99%

This parameter is usually set to the power level at which the source material just begins to melt. IC6 ramps the power level from zero or Precon Soak level if programmed to Soak Power 1 linearly over the time period Rise Time 1. The default value is 0. See [section 3.6.6.1](#) for information on determining appropriate Soak Power using the optional Handheld Controller (IPN 755-262-G1).

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 or from Precon Soak Power if programmed to Soak Power 1. The default values is 00:00.

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

This parameter provides the time period for which IC6 holds at Soak Power 1. The default value is 00:00.

SOAK POWER 2 0.00 to 99.99%

This parameter sets the power level at which the rate from the source very nearly matches the desired deposition Rate. IC6 can ramp the power level if programmed from zero, from idle power, from Soak Power 1 linearly to the Soak Power 2 level over the time period RISE TIME 2. The default value is 0%.

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

This parameter sets the time period in which IC6 linearly ramps the power level from Soak Power 1 to Soak Power 2. The default value is 00:00.

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

This parameter sets the time period for which IC6 holds the power level at Soak Power 2. The default value is 00:00.

AUTO SOAK 2 Yes (1), No (0)

The Auto Soak 2 option, when enabled by selecting Yes (1), calculates an average power setting over the last few seconds of the DEPOSIT state. This average power replaces the value programmed in Soak Power 2 so the next time this material is executed, the Soak Power 2 level is the Auto Soak 2 value. In this manner the Soak Power 2 value closely matches the power level required to achieve the desired deposition rate. The power is averaged over the last 2.5 seconds of the deposition. The default value is No (0).

DEP AFTER PRE-DEP Yes (1), No (0)

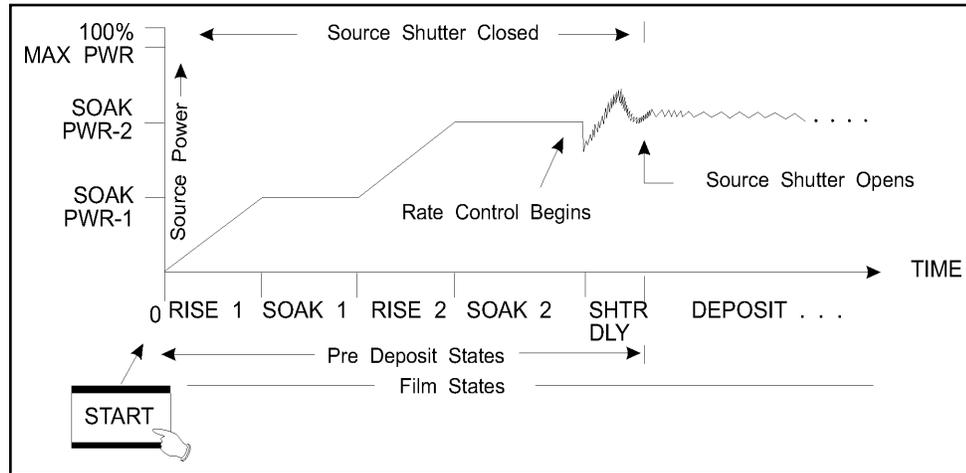
Selects the state to follow the last Soak. Standard processing will continue with Deposit. In special cases, No (0) or Non-deposit control may be appropriate. In this state, the rate is controlled but thickness is not incremented and the source shutter relay is not active. Default is Yes(1) for Deposit.



CAUTION

The Sensor must be positioned so the rate can be monitored with the source shutter closed when going to the non-deposit control state.

Figure 5-6 Source power level profile



DELAY OPTION None (0), Shutter (1), Control (2), Both (3).
The default value is None (0).

Shutter (1): The source shutter relay remains in its normal state and the crystal shutter relay is active. The transfer sensor, which must be positioned to sample the source flux with the source shutter closed, provides closed loop rate control. The rate control must be within the specified Shutter Delay Accuracy or 0.5 Å/s of the desired deposition rate for 5 seconds before IC6 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 60 seconds, the process will STOP.

Control (2): Control delay suspends DEPOSIT control loop action on the source control power for the time interval programmed in Control Delay Time. During Control Delay, the source and sensor shutters are activated.

Both (3): IC6 will first enter a shutter delay state followed by the control delay interval.

CONTROL DELAY TIME 00:00 to 99:59

This is the time interval for IC6 to be held in the Control Delay state. The parameter is displayed only if the Delay Option chosen is Control or Both. The default value is 00:00.

SHUTTER DELAY ACCURACY . . . 1 to 99 %

Specifies how close the rate value must be to the setpoint value for 5 seconds before opening the source shutter. The parameter is displayed only if the Delay Option chosen is Shutter or Both. The default value is 5.

TRANSFER SENSOR 0 to 8

This parameter is only enabled when the Delay option Shutter or Both has been enabled. In addition, a second sensor must be available to use this feature. IC6 will use the transfer sensor for rate control during the shutter delay time and revert back to the primary sensor after the shutter delay time has expired. Default is 0 which will use any sensors that are currently active in the layer.

TRANSFER TOOLING 1.0 to 999.9%

The tooling factor for the transfer sensor. Default value is 100.0%. This parameter is only enabled when the Transfer Sensor is enabled.

5.1.6 Post Deposit Parameters

Feed Ramp State

The next three parameters define a feed ramp provided to maintain power levels during a wire feed. After reaching Final Thickness, IC6 will enter the Feed Ramp state for the specified time. Control voltage is ramped from the power level at the end of the DEPOSIT state to the Feed Power level. Feed Power is held constant until the end of Feed Time. At the end of Feed Time, IC6 will proceed to the Idle ramp state. Source and sensor shutter are inactive.

FEED POWER 0.0 to 99.99%

This is one of three parameters used to affect a Feed Ramp. This value establishes the control voltage power level at which the source is maintained during wire feed. The default value is 0.

FEED RAMP TIME 00:00 to 99:59 min:s

This is the time interval for the source power to ramp linearly from the power level at the end of Deposit to Feed Power level. The Feed state is active during Feed Ramp Time. The default value is 00:00.

FEED TIME 00:00 to 99:59 min:s

This is the time interval for which the source power is maintained at Feed Power. The Feed state is active during Feed Time. The default value is 00:00.

Idle Ramp State

The next two parameters define an idle ramp provided to establish the source power level after the Deposit or Feed state. Control voltage is ramped from the power level at the end of the Deposit state (or Feed Power, if one is set) to the Idle

Power level. The control voltage is maintained at the Idle Power level until IC6 enters the STOP state or until the next layer, using the specified source, is started, or the turret source is rotated.

IDLE POWER 0.0 to 99.99%

This value is the power level at which the source is maintained after the DEPOSIT state (or after Feed state if one is set up). Idle Power is usually the same as Soak Power 1. The default value is 0%. The power level will be set to zero before a crucible switch is done.

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 (or Feed state if one is set) to Idle Power. The default value is 00:00.

5.1.7 Deposit Page Parameters

MATERIAL NUMBER 1 to 32

Change the number to edit or create a different material

RATE 0.000 to 999.9 Å/s (default = 0.000)

NOTE: Rate = 0.000 will skip the Deposit state and take a layer to the post-Deposit state.

This specifies the rate at which the deposition is to be controlled during the DEPOSIT and NON-DEPOSIT CONTROL states. The Rate is calculated based on:

- ♦ The rate information acquired by the sensor(s) in use, based on the density and Z-Ratio values entered for this material.
- ♦ The tooling factors that correct for any relative difference in flux distribution reaching the sensor(s) used for this material.

TIME LIMIT 00:00 to 99:59 min:s

This is the deposition time at which the Time Limit is triggered. This time begins to accumulate at the start of the Deposit state. The Time Limit, once triggered, remains active until the start of the IDLE state. The default value is 00:00.

RATE FILTER TIME One Tenth (0), Four Tenths (1), One (2), Four (3), Ten (4), Twenty (5), Thirty (6) seconds

This parameter is used to apply a boxcar filter to the measured raw rate which is used to produce the Source Recorder Rate DAC output voltage, see Recorder Output on page 5-6 under [section 5.1.3](#). This filter does not apply to the Sensor Rate recorder output programmed at [section 4.1.2, Sensor Parameters](#), on page 4-2.

The Rate Filter Time may be used for enhanced resolution. If a source has a long time constant, rate may be taken as constant over longer intervals. Averaging provides an opportunity to reduce rate noise. Depending on the source of the noise, averaging can improve rate resolution:

- ◆ If the noise is crystal frequency resolution limited—the thickness change over one second provides ten times the thickness change vs. the thickness change measured over a tenth of a second. A one second averaging interval will improve rate resolution by 10 times.
- ◆ If the sensor noise is random, then RMS reduction of rate noise is provided by the square root of the number of points averaged (example a 10 point average provides a factor of 3.1 noise reduction).

The selection of the appropriate Rate Filter Time value will be dependent on the characteristics of the source. The default value is One Tenth.

NOTE: To obtain rate display resolution of 0.001 Å/s for the range of 0.000 to 9.999 Å/s, set the Rate Filter Time to 10 s or greater.

TIME POWER AVERAGING TIME . 0 to 30 min (default = 0)

This parameter value determines the amount of time used in calculating the average rate and average power for use in Time Power and Non-Deposit Hold states if a crystal fails. It also determines the duration of the RateWatcher Sample period (see [RateWatcher™ Sample and Hold Feature](#) on page 5-19).

When the Averaging Time parameter value is 0, then a 2.5 second average, ignoring the most recent 0.5 second, is the averaging interval.

The status message ABBR(EVIATED) AVERAGE is generated if the averaging interval has not been reached, but there was at least a complete whole minute of data to average.

The status message NO or NEG AVERAGE is generated if a crystal fail occurred within the first minute of control with Averaging Time set >0. This error also occurs if there is a crystal fail during the first 2.5 seconds of control with the Averaging Time = 0. (There are also remote communication commands to get and set the average rate and average power values.)

ION ASSIST DEPOSIT No (0), Yes (1).

Sets the logic condition to True if Yes (1) is selected and the Deposit state is entered. Default is No (0).

ON FINAL THICKNESS. Continue (0), Post-Dep (1), NonDepCont (2).

Selects the state to enter after reaching Final Thickness. Standard processing will continue with Post-Deposit (1), the default setting. In special cases, Non-Dep(osit)Cont(rol) (2) may be appropriate. In this state, the rate is controlled but thickness is not incremented and the source shutter relay is not active. Continue (0) ignores reaching Final Thickness but the logic condition is set to True.



CAUTION

The Sensor must be positioned so the rate can be monitored with the source shutter closed when going to the non-deposit control state.

RAMP 1 RATE 0.000 to 999.9 Å/s

Rate Ramp 1 is provided to effect an aggregate rate change while depositing a Layer. The aggregate rate is ramped linearly from the original rate setpoint to the New Rate 1 value over the time interval Ramp 1 Time. It is allowed to ramp to a higher or a lower rate. The default value is 0.0.

START RAMP 1 0.000 to 999.9 kÅ

This value sets the thickness at which to start the Rate Ramp. This thickness value must be less than the Start Ramp 2 thickness value if the value of Start Ramp 2 is non-zero. A value of zero disables the feature. The default value is 0.

RAMP 1 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 New Rate 1. The default value is 00:00.

RAMP 2 RATE 0.000 to 999.9 Å/s

Ramp 2 Rate is provided to effect an aggregate rate change while depositing a Layer. The aggregate rate is ramped linearly from the original Ramp 1 Rate setpoint to the New Rate 2 value over the time interval Ramp 2 Time. It is allowed to ramp to a higher or a lower rate. The default value is 0.0.

START RAMP 2 0.000 to 999.9 kÅ

This value determines the thickness at which to begin Ramp 2 Rate. A value of zero disables this feature. Start Ramp 2 thickness must be greater than Start Ramp 1 thickness. Also, Ramp 2 Rate can not be started until the completion of Ramp 1 Rate. If the thickness of Start Ramp 2 is exceeded while in Ramp 1 Rate, Ramp 2 Rate will begin immediately after Ramp 1 Rate. The default value is 0.

RAMP 2 TIME 00:00 to 99:59 min:s

This value is the time interval over which the aggregate rate is ramped linearly from New Rate 1 to New Rate 2. The default value is 00:00.

RateWatcher Sample and Hold Feature

Two parameters, Ratewatcher Time and Ratewatcher Accuracy, define the Sample and Hold feature. When enabled by selecting RateWatcher Option = Yes, this feature periodically samples the deposition rate by automatically opening the sensor shutter and exposing the sensor to the deposition source. The power is adjusted so the actual rate is set to the desired rate. The sensor shutter is then automatically closed and power is held constant at the adjusted level. A five second time delay for thermal stabilization occurs between opening the shutter and taking measurements. During this time, DELAY is displayed in IC6 message area.

The RateWatcher Sample phase uses the measured deposition rate to control the source power. When the deposition rate meets the requirements of the RateWatcher Accuracy parameter, the RateWatcher Acceptance Window Time is started. If the rate falls out of the RateWatcher Accuracy requirement, the RateWatcher Acceptance Time Interval is reset to zero.

If the deposition rate meets the RateWatcher Accuracy requirement for the duration of the Acceptance Window Time, the sensor shutter is closed and RateWatcher enters Hold phase for the RateWatcher Time duration.

Finally, after the Hold Time has elapsed, RateWatcher will enter a 5 second Delay phase. During the Delay phase, the crystal is exposed to the deposition, but the accumulated rate and sustained power are that from the previous Hold phase. This Delay phase allows the crystal to thermally stabilize to the deposition before re-entering the RateWatcher Sample phase.

The RateWatcher Sample Acceptance Window Time (that is, the length of time that the rate must be within the accuracy range before going into hold) will be calculated as follows:

Time Power Avg Time	Rate Filter Time	RateWatcher Sample Acceptance Window Time	Rate and Power Averages Used
0 min	< 10 s	5 s	2.5 minus 0.5 second averages
0 min	10 s	10 s	2.5 minus 0.5 second averages
1 min	anything	60 s	2.5 minus 0.5 second averages
> 1 min	anything	Average Time * 60 seconds	Average of minute averages (as with Time Power) of Average Time - 1 minute

RateWatcher OPTION No (0), Yes (1)

Default is No (0) which disables the function and greys out the Time and Accuracy parameters.

RateWatcher TIME 00:00 to 99:59 min:s

Ratewatcher Time determines the time interval between sample periods. The crystal shutter relay is in its normal state during this time. Values range from 00:00 to 99:59 minutes:seconds. 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.

RateWatcher ACCURACY 1 to 99%

During the rate sampling period, the deposition rate is measured by the crystal; source power control is active. When the 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 0.1 Å/s, whichever is greater. Values range from 1 to 99%. The default value is 5%

Chapter 6

Process Setup

6.1 Process Setup Introduction

IC6 is capable of storing the descriptions and parameters for up to fifty processes. Processes can consist of up to 200 sequential layers of materials. If more layers are required, another process can be started automatically. A layer or sequence of layers may be copied up to 199 times, provided the maximum number of layers is not exceeded.

Process layer definition includes the specification of a previously defined material (refer to [Chapter 5, Material Setup](#)), Final Thickness, Thickness Limit, and Crucible Number. The co-deposition capability of IC6 allows establishing material ratio and cross-sensitivity relationships.

Processes are defined by sequencing layers. Layers must be defined sequentially starting with Layer 1. Defined layers may be inserted, deleted or copied using the layer editing feature. Layers may be copied to other processes.

Process Setup is initiated by moving the cursor to the Process heading on the Main Menu and pressing MENU. This will invoke the Process screen (see [Figure 6-1](#)). Return to the Main Menu display by pressing MENU again.

6.2 Overview Page

Figure 6-1 Process screen overview page

0.00 $\text{\AA}/\text{s}$		0.000 $\text{k}\text{\AA}$		0.00%		READY	
Overview	1 >	Process 1	18	Process 18	35	Process 35	
	2	Process 2	19	Process 19	36	Process 36	
	3	Process 3	20	Process 20	37	Process 37	
Curr Proc	4	Process 4	21	Process 21	38	Process 38	
	5	Process 5	22	Process 22	39	Process 39	
1 - 10	6	Process 6	23	Process 23	40	Process 40	
	7	Process 7	24	Process 24	41	Process 41	
	8	Process 8	25	Process 25	42	Process 42	
	9	Process 9	26	Process 26	43	Process 43	
	10	Process 10	27	Process 27	44	Process 44	
	11	Process 11	28	Process 28	45	Process 45	
	12	Process 12	29	Process 29	46	Process 46	
	13	Process 13	30	Process 30	47	Process 47	
	14	Process 14	31	Process 31	48	Process 48	
	15	Process 15	32	Process 32	49	Process 49	
	16	Process 16	33	Process 33	50	Process 50	
	17	Process 17	34	Process 34			
Process 1							
Active Process 1							
04/12/2010 09:29							
Select Process		Set Active Process				Default Process	

Processes that have at least one layer programmed are identified by a "greater than" character (>) beside the process number. Only processes with layers can be made active. The active process is shown in the status area. When Start is initiated, the layer sequence in that process will be executed. At end-of-process, to activate another process move the cursor to the process number and press F2 Set Active Process. To edit or create a process, move the cursor to that process number and press F1 Select Process.

6.3 Curr(ent) Proc(ess) Page

The Current Process page, see Figure 6-2, shows the layer sequence for the process.

NAME 15 characters max

The default will be Process #. The default name is returned as a blank entry when queried via communications. The Name can be edited using the keys in cell-phone fashion

Figure 6-2 Current process page

-0.00 μ /s 0.001 k μ 0.00 % READY	
Overview Curr Proc 1 - 10	Process Number 1 Name TWO LAYERS Layers Defined 2 PROCESS 1: Ag, A1
TWO LAYERS Active Process 1 04/12/2010 09:49	
Set Active Process	

6.4 Process Layers 1 - 10 etc.

Layers are shown in groups of 10. Moving the cursor down to one of the layer groups labeled 1 - 10 etc. in the left display pane, shows the layer parameters.

Use the cursor keys to move among and through the layers. Parameters are entered with the numeric keypad.

Figure 6-3 Layer definitions

-0.01 Å/s 0.001 kÅ 0.00%										
READY										
Overview		Process Number 1 Name TWO LAYERS				Layers Defined 2				
Curr Proc		Material		Final	Thick	Cruc	CoDep	Ratio	Cal	Cross
1 - 10		Layer #	Name	Thick	Limit			Cntrl	Stat	Talk
		1	1 Ag	0.100	0.000	1	No	0.0		
		2	2 Al	0.100	0.000	1	No	0.0		
		3								
		TWO LAYERS								
		Active Process 1								
		04/12/2010 12:17								
		Tag Layer		Insert Layer		Delete Layer		UnTag Layer		

6.4.1 Layer Parameters

6.4.1.1 Layer Parameter Editing

On the Process Layer Detail page the user will be allowed to insert or delete one or more layers into or from an existing or a new process.

Place the cursor on any parameter in the layer to be copied or deleted. Pressing F1 Tag Layer will set a tag marker. Tag markers are used to indicate the start and end layers to be copied or deleted. The Layers' font color will change to green when the layer is tagged. The message One Layer Tagged will appear in the status message area.

Moving the cursor to different layers will include those layers in the tag. Pressing F1 Tag Layer a second time will set the end tag marker. The tag will then include the layers between the first tag marker and the second tag marker. A Layers Tagged message will then replace the previous message. When the first tag is set, another parameter, # Times To Copy, will display with a value of one. If the user wants to copy the tagged layers more than once, the user can use the arrow keys from the layer number column to this parameter. The user can change the value to any number between 1 and 200.

To insert, first move the cursor to the layer in which to place the tagged layers. This can be in the current process or any other process. Then, press F2 Insert Layer and the tagged layers will be inserted into the process. The insert will be done the number of times (#) entered into the # Times To Be Copy parameter. Layers that exist will be moved to make room for the new layer(s) as necessary. If the cursor is on the last layer, then the new layer(s) will be added. If there are not enough empty layers to insert the tagged layers the number of times to be copied, the insert will fail, no layers will move and an error message Not Enough Layers will be displayed. Layers may be copied to other processes.

F3 Delete Layer will remove the tagged layer(s) from the process. Any layers in the process after those deleted will be shifted to fill in where the deleted layers were. If a delete removes all layers from the active process, the process will fail. If the updated process has fewer layers than the Layer to start parameter's value, the Layer to start parameter's value will default to 1.

While the layers are tagged, pressing F4 UnTag Layer will remove the tag markers and redisplay the layer(s) in standard font color. Returning to the Main Menu will also remove the tag marker(s). When a tag is removed the # Times To Be Copy parameter will reset to a value of one, and the parameter will no longer be visible. Tags can only be set within a single process. Tags are not allowed between processes.

6.4.1.2 Layer Parameters

MATERIAL # 0 to 32

Specify which Material to use for this layer. If the Material has not yet been defined, its default parameters will be used. Entering 0 deletes the layer. This value cannot be changed on the active process while it is running.

FINAL THICK(ness) 0 to 999.99 kÅ

This is the thickness setting that triggers the end of the DEPOSIT state. A value of 0.000 kÅ will trigger Final Thickness immediately on entering Deposit and continue according to the On Final Thickness parameter setting, [see page 5-17](#). The Source Shutter and Sensor Shutter relays return to their normal states and the Layer enters the Idle Ramp or the Feed Ramp state. The default value is 0.000 kÅ.

THICK(NESS) LIMIT 0.0 to 999.99 kÅ

This sets the thickness at which the Thickness Limit logic state is set True. This thickness begins to accumulate after entering the Deposit state. The state remains active after reaching Thickness Limit until the beginning of the IDLE state. The default value is 0.000 kÅ.

CRUC(IBLE) 1 to 64

The Crucible parameter is used in conjunction with the Number of Crucibles selected in Source Setup. The value entered sets the state of the Crucible relays. Values range from 1 to the number of Crucibles chosen, up to a maximum of 64. This parameter is set to 1 if the Crucible function is not chosen in configuring the Sources. The default value is 1.

CODEP(OSITION) Yes (1), No (0)

Values in brackets are for use with the remote communication commands. This feature allows two Layers to be run concurrently with the pertinent sources controlled independently. The Layers to be co-deposited must be sequential in the Process. This parameter cannot be changed while running a Process. To specify co-deposition, use the TOGL key to enter Yes in the co-deposition parameter for the first layer. The default value is No.

When the first Layer reaches Final Thickness prior to the second Layer, the second layer will terminate. When the second layer reaches Final Thickness prior to the first Layer, the first Layer will continue in DEPOSIT until reaching its own Final Thickness.

RATIO C(O)NTR(O)L 0.0 to 999.9%

This parameter is used with the co-deposition feature. It establishes a Master/Slave relationship between the two sources being co-deposited. The first layer is always the Master, with the second layer's rate being controlled at the specified ratio of the master's setpoint rate. Default value is 0%.

The following two items are relevant only for co-deposited layers and indicate sensor status.

CAL(IBRATION) STAT(US)

Identifies whether CAL thickness values are UNCALibrated, were entered manually on the Sensor page of the Material screen by the user or were AUTOMATICALLY calculated using the automatic calibration feature on the Cross Talk page of the Maintenance screen.

CROSS TALK

Displays computed cross talk values based on cal thickness values for each sensor used in each material in a codeposition process. Cross talk values for both materials must be less than 100% to be able to START the process.

6.5 Special Layer Parameter Features

6.5.1 Skip Deposit

If the Final Thickness is set to 0.000 kÅ, IC6 will skip the DEPOSIT State. State processing will go directly to the post-Deposit parameter state from the last pre-Deposit state.

Chapter 7

General Parameters

7.1 General Setup Overview

IC6 provides the capability to modify a series of top level parameters that define the controller’s method of handling system level activities. Some of the parameters are automatically incremented by IC6.

General Setup is initiated by moving the cursor to the General heading on the Main Menu and pressing MENU. This will invoke the General display (see Figure 7-1). You may return to the Main Menu display by pressing MENU again.

7.2 General Screen Process Page

Figure 7-1 General/Process display

1.29_{Å/s} 0.062_{kÅ} 0.00%				READY
Process				
DACs	Active Process	2		
Comm	Layer To Start	1	Active Layer Output	0
Message	Source DAC Required	Yes	Run Number	19
Date/Time	Auto Start Next	No	Thickness Eq 1	0
Test	Max Concurrent Layer	6	Thickness Eq 2	0
Lock	Layers Displayed	Auto	Thickness Eq 3	0
Audio/Visual				
General				
08/11/2010 08:07 Test				

Select a parameter for entry by positioning the box cursor at the desired value following the parameter description. New values are input from the front panel followed by pressing the Enter key input. Values are cleared by pressing the Clear key.

ACTIVE PROCESS 1 to 50

This parameter selects which sequence of Layers, as defined in Process Setup, is to be executed. Values are 1 to 50. The default value is 1. This parameter cannot be changed while executing a process.

LAYER TO START 1 to 200

This selects the starting Layer from the sequence of Layers defined in the Active Process. The upper limit to the range of values is determined by the number of Layers defined for a given Process. This value cannot be changed while executing a process. Default value is 1.

SOURCE DAC REQUIRED Yes (1), No (0)

The value in parentheses is used for the remote communications commands. Default is Yes for normal deposition processes and enables error checking. When a Start is initiated with DAC Output 0 assigned to an active source, an error message will be displayed.

AUTO START NEXT Yes (1), No (0)

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. Default is No.

NOTE: If Auto Start Next is Yes, the following logic statements will be triggered **only** at the end of the process (**not at the end of each layer**):

- ◆ Idle
- ◆ Layer End
- ◆ Material End
- ◆ Post Deposit, if there are no states between Deposit and Idle.

MAX CONCURRENT LAYER 1 to 6

Prevents accidental double Starts which may cause the process to stop. Default is 2.

LAYERS DISPLAYED Auto (0), 4 (1), 6 (2)

Parameter is not accessible if Max Concurrent Layer is set to 1 or 2. Default is Auto. Determines the number of layers shown simultaneously on the Operate display.

ACTIVE LAYER OUTPUT 0, 1 to 31

Specifies the first of eight consecutive outputs that indicate the active layer's number. The outputs will change to indicate the layer number in binary mode. For example, if a process is started with layer 1 as the Layer To Start, the outputs will be 00000001. In the case of a 20 layer process, when the last layer is started and when it goes into the Idle mode, the outputs will be 00010100. If more than one layer is active, the outputs will indicate the lowest numbered layer. The default value is 0 which disables the function.

RUN NUMBER 1 to 9999

This is a counter which increments by one at each start of a Process. Any arbitrary value may be entered as a starting point. The default value is 1.

THICKNESS EQUATION 1, 2, 3 . . . 0 to 654321

Each of the three thickness equations can be set up to sum the thickness of the specified sources. Each source can only be used once in an equation and can be used in all three equations. For example, 12 means sum the thickness of sources 1 and 2, 1234 sums the first four sources. Thickness equations are designed to be used in logic statements. Equation(s) will be displayed when the general parameter "layers displayed" is set to four or six. The default value is 0.

7.3 DACs Page Parameters

Polarity and full scale voltages can be set up for all DACs, see Figure 7-2. Move the cursor key to the DAC. Use the TOGL key to select + or - for the polarity. Use the numeric keys to enter the full scale voltage in the range of 0.1 to 10.0 volts. These parameters cannot be updated while a process is running. Default is -10.0.

Figure 7-2 General screen DACs page

- 0 . 00 $\text{\AA}/\text{s}$		- 0 . 000 $\text{k}\text{\AA}$		0 . 00 %		READY	
Process	DAC 1 + 10.0			DAC 7 + 10.0			
DACs	DAC 2 + 10.0			DAC 8 + 10.0			
Comm	DAC 3 + 10.0			DAC 9 + 10.0			
Message	DAC 4 + 10.0			DAC 10 + 10.0			
Date/Time	DAC 5 + 10.0			DAC 11 + 10.0			
Test	DAC 6 + 10.0			DAC 12 + 10.0			
Lock							
Audio/Visual							
General							
04/12/2010 12:23							

7.4 COMM Page Parameters

Figure 7-3 General comm display

1.29_{Å/s} 0.102_{kÅ} 0.00_% READY	
Process DACs Comm Message Date/Time Test Lock Audio/Visual	Datalog Xtal Info No RS-232 Baud Rate 115.2k Protocol Standard Ethernet IP Address 10.211.72.107 Net Mask 255.255.0.0
General	
08/11/2010 09:45 Test	
Test RS-232	

Test RS-232

Once the cursor is in the parameter area, the Test RS-232 function can be performed. Plug the loop-back connector 760-406-P1 supplied in the IC6 ship kit into the RS-232 connector on the rear panel and press F1. Message RS-232 Test Failed or RS-232 Test Passed will appear. If the loop-back connector is not available, jumper pins 2 and 3 to perform the test. Contact INFICON Service if the RS-232 Test Failed message appears.

DATALOG XTAL INFO. Yes (1), No (0)

This parameter selects whether to output the crystal use history in addition to the standard set of datalog information. Default is No.

RS-232

BAUD RATE. 9,600 (0), 19,200 (1), 38,400 (2), 57,600 (3), 115,200 (4)

Default is 115,200. Use the TOGL key to select the desired rate.

PROTOCOL Standard (0), Dlog Page (1), Dlog Comma (2)

Standard enables receiving communication commands from an external host and sending the expected responses. Dlog Comma and Dlog Page allow only one-way transmission of information from IC6 to the external device. The Dlog Comma format allows importation of the Data Log string into a spreadsheet program. Dlog Page format is designed for use as text only. A carriage return (d13, h0D) and line feed (d10, h0A) are inserted at the end of each line of data. The Dlog information is transmitted when the source shutter closes at the end of Deposit or following a Stop or a Suspend while in Deposit. The default is Standard (0).

If the Ethernet option is installed, the following parameters will be shown

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 10.211.72.203.

NOTE: This setting is not cleared on pressing **CLEAR** when the instrument is turned on.

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

NOTE: This setting is not cleared on pressing **CLEAR** when the instrument is turned on.

NOTE: After making changes to either the IP Address or the Net mask, you must wait for the prompt: "Ethernet values have changed. Changes take effect on power-up." before cycling power to the instrument. This prompt will occur within ten seconds of the last change. Failure to wait for this prompt will prevent the complete change from being properly written.

7.5 MESSAGE Page Setup

Ten 19 character messages can be created by the user from the front panel or via communications. ASCII characters allowed include all the characters starting with the space character h20 through the character h7E. These messages are turned on and off under control of logic statements. Up to four messages can be displayed in the message area. Newer messages will displace older ones. IC6 status messages have priority and will also displace user messages.

Move the cursor key to one of the 10 message lines. Then use the alphanumeric keys in cell-phone fashion to enter characters. Use 0 for a space, A second press on 0 enters numeric 0. To edit a message, move the cursor to the message and press any numeric key.

Figure 7-4 General screen message page

-0.01 $\text{\AA}/\text{s}$		-0.000 $\text{k}\text{\AA}$		0.00%		READY	
Process							
DACs	1	METALIZATION LAYER		6	_____		
Comm	2	_____		7	_____		
Message	3	_____		8	_____		
Date/Time	4	_____		9	_____		
Test	5	_____		10	_____		
Lock							
Audio/Visual							
General							
04/12/2010 12:28							

7.6 DATE / TIME Set Up

Figure 7-5 General screen date/time page

0.00 Å/s -0.000 kÅ 0.00%		READY
Process DACs Comm Message Date/Time Test Lock Audio/Visual	Date Format MM/DD/YYYY Calendar Day 12 Month 4 Year 2010 System Time 12:30	
General		
04/12/2010 12:30		

DATE FORMAT MM/DD/YYYY, DD/MM/YYYY

Default is MM/DD/YYYY. Use the TOGL key to select DD/MM/YYYY.

CALENDAR

DAY 1 to 31

MONTH 1 to 12

YEAR 2000 TO 2099

SYSTEM TIME HH:MM

7.8 LOCK Page Code Setup

Figure 7-7 General screen lock code page

-0.01 Å/s -0.000 kÅ 0.00 % READY	
Process DACs Comm Message Date/Time Test Lock Audio/Visual	Program Lock Code XXXX File Access Code XXXX
General	
04/12/2010 12:34	

PROGRAM LOCK CODE 1 to 9999

The lock code is set by moving to Program Lock Code and entering the desired code of up to 4 digits. If no lock code is desired, no entry needs to be made. The lock code will be in effect after turning the unit off and an again. L LOCK will be displayed when Program Lock is set. Default value is 0.

NOTE: If a lock code was previously programmed, that code must subsequently be entered on the Main Menu screen, with the cursor positioned on XXXX at the Lock Code XXXX at the lower right corner of the Main Menu options area. After entering the lock code on that screen, the lock code can be cleared by entering 0 for the Program Lock Code on the General >> Lock page. The lock code can also be cleared by pressing CLEAR on power-up, however, if no lock code has been programmed, this will reset all parameters to their default values.

NOTE: Program lock codes are not stored on and retrieved from the USB port.

FILE ACCESS CODE 1 to 9999

The File Access Code allows configuration file retrieval from the USB port when the Program Lock Code is locked. This allows a process recipe to be entered into IC6 from a USB storage device without unlocking the Program Lock Code. If the File Access Code has not been enabled, USB port retrieval is not allowed when a Program Lock Code is present. This parameter has no effect if there are no lock codes or the access code is set to zero. Default value is 0.

When pressing CLEAR on power-up, the File Access Code is cleared when the parameters are cleared, not when the lock codes are cleared. The File Access Code is not stored on nor retrieved from the USB port.

7.9 AUDIO / VISUAL Page Set Up

Figure 7-8 General screen audio visual page

0.00 $\text{\AA}/\text{s}$ -0.000 $\text{k}\text{\AA}$ 0.00 % READY	
Process DACs Comm Message Date/Time Test Lock Audio/Visual	Audio Feedback No LCD Dimmer Time 0 min
General	
04/12/2010 12:35	

AUDIO FEEDBACK Yes (1), No (0)

Default is No. Yes Activates Audio Feedback, signifying keyboard interaction.

LCD DIMMER TIME 0 to 99 min

Determines the time before the backlight is turned off to conserve display life. Default is 0 minutes which disables the dimmer function.

NOTE: The backlight is ON when a process is running. It is only OFF when time elapsed since last key press and in READY or IDLE and end-of-process exceeds the LCD Dimmer Time setting.

Chapter 8

Digital I/O

8.1 Digital I/O Screen

The Digital I/O screen is selected by moving the cursor on the Main Menu screen to Digital I/O and pressing Menu. The I/O Map display for board 1 is shown in Figure 8-3. Upon entry the cursor will be placed at the last referenced output or input number.

8.2 All Input Page

Figure 8-1 All input page

-0.01 Å/s -0.002 kÅ 0.00 % READY		
	Board 1 Input	Board 2 Input
All Input	1 DP_IS_ON	15 DEPO_PR_OK
	2 HECH_P_ON	16 EVAC_CHM
All Output	3 FORE_PR_OK	17 VENT_CHM
	4 FORE_VA_CL	18 AUTO
I/O Bd 1	5 RUGH_VA_CL	19 CHM_AT_ATM
	6 HI_VAC_CL	20 ALARM_ANSW
I/O Bd 2	7 CROS_PR_OK	21 CONNECTORS
	8 GAUGES	22 ABORT
I/O Bd 3	9 _____	23 _____
	10 _____	24 _____
	11 _____	25 _____
	12 _____	26 _____
	13 _____	27 _____
	14 _____	28 _____
Inputs		
10/05/2010 13:12		

All input names assigned by IC6 or by the user are shown to facilitate system diagnosis. Darker font color designates inputs that are currently active.

8.3 All Output Page

Figure 8-2 All output page

1.29 μ /s 0.013 $k\mu$ 26.77 % DEPOSIT				
	Board 1 Relay Output	Board 2 Relay Output	Board 3 Relay Output	Board 3 TTL Output
All Input	1 SRC SHTR 1	9 _____	17 _____	25 _____
	2 SRC SHTR 2	10 _____	18 _____	26 _____
All Output	3 SRC SHTR 3	11 _____	19 _____	27 _____
	4 SRC SHTR 4	12 _____	20 _____	28 _____
I/O Bd 1	5 XTL SHTR 1	13 _____	21 _____	29 _____
	6 XTL SHTR 2	14 _____	22 _____	30 _____
I/O Bd 2	7 XTL SHTR 3	15 _____	23 _____	31 _____
	8 XTL SHTR 4	16 _____	24 _____	32 _____
I/O Bd 3				33 _____
				34 _____
				35 _____
				36 _____
				37 _____
				38 _____
Outputs		Control Delay 1		
10/05/2010 11:17 Test				

All output names assigned by IC6 or by the user are shown to facilitate system diagnosis. Darker font color designates inputs that are currently active.

8.4 I/O Board Page

Figure 8-3 I/O map board 1 page

- 0.00 \dot{A}/s - 0.000 $k\dot{A}$ 0.00%			READY
	Name	Relay Output Type	TTL Input
All Input	1 Xt1 Switching	2 NO	1 TURRET 1
	2 XTL SHTR	3 NO	2 MECH_P_ON
All Output	3 Xt1 Switching	4 NO	3 FORE_PR_OK
	4 Xt1 Switching	5 NO	4 FORE_VA_CL
I/O Bd 1	5 Xt1 Switching	6 NO	5 RUGH_VA_CL
	6 HI_V_INTER	NO	6 HI_VAC_CL
I/O Bd 2	7 FILAMENT	NO	7 CROS_PR_OK
	8 FIL_INTER	NO	8 GAUGES
I/O Bd 3			9 _____
			10 _____
			11 _____
			12 _____
			13 _____
			14 _____
I/O Board 1			
04/12/2010 12:38			

Names, up to 15 characters in length, can be entered by the user for any input or output unless IC6 has automatically assigned a name. Names created by IC6 cannot be edited. To enter or edit a user name, move the cursor onto the appropriate input or output and use the keyboard in cell phone fashion to create or edit the name.

8.4.1 Output Type

Output Types may be defined as normally open (NO) or normally closed (NC). Relay and TTL output types are changed by positioning the cursor on an output type and pressing the TOGL key followed by the ENTER key.

Chapter 9

Logic Statement Setup

9.1 Logic Statement Overview

IC6 programmable logic capabilities allow it to respond to digital external inputs to control the execution of a process or series of processes without operator intervention. You can tailor these capabilities by programming the logic statements.

A logic statement consists of an IF part and a THEN part. The IF part consists of one or more conditional events selected from a table. These IF events can be based on external inputs or internal process states or a combination of both. The THEN part similarly consists of one or more actions selected from another table. When the event string is determined to be true, the associated actions are executed in left to right order. The state of the Logic statement is indicated on the Logic Overview display and on logic statement group pages. The color of the logic statement number will turn green to indicate the IF portion of the statement is true. Also, three stars (***) will be present. The expressions are evaluated in numerical sequence starting with logic statement 1.

- ◆ Programming is accessed by moving the cursor to the Logic heading of the main menu and pressing MENU.
- ◆ Single or multiple actions may be triggered by inputs or the fulfillment of a user specified logical condition.
- ◆ Inputs are only processed when they or the statement they are used in undergo a transition and on IC6 power-up.
- ◆ Single or multiple complex defined conditions are used to define an event.
- ◆ The Logical operators; AND, OR, and NOT (negate) as well as grouping operators (parentheses) are available to define very precise conditionality. An additional operator, ON, specifically ties certain events together.
- ◆ It is possible to execute an action immediately or delay it for a definable period of time through use of a timer or a counter.
- ◆ Each Logic statement is evaluated every measurement cycle of 100 ms, but evaluation is suspended while a configuration file is being loaded.
- ◆ Layer, process, or material entries for each logic statement can be made exclusive or inclusive.
- ◆ The components of the Logic statements may be the transition between or entry of a specific state, specific programmable time limits, programmable thickness limits or various error conditions.
- ◆ There are user defined messages which may be displayed.

- Inputs and outputs may be named on an I/O map display. Additionally on this display, the outputs may be defined as normally open (NO) or normally closed (NC).
- Logic statements may be chained together using the Statement ### Event.

These features, combined with layer based process sequencing, allow moderately complex vacuum processing plants to be controlled without the addition of any other intelligent machines. It is possible that a user may program certain layers within the process definition whose only purpose is to trigger certain other internal sequencing and/or external control events. These “dummy” layers execute very rapidly if the pre and post deposit state times, rate, and final thickness values are all set to zero.

Fourteen TTL inputs and eight relay outputs are standard. An additional fourteen inputs and eight relay outputs are available with an optional I/O card. With a second optional I/O card, eight more relays and fourteen open collector outputs are available.

IC6 has the capacity for 100 logic statements.

9.2 Editing the Logic Statements

Logic Setup is initiated by moving the cursor to the Logic heading on the Main Menu and pressing MENU. This will invoke the Logic display (see Figure 9-1). You may return to the Main Menu display by pressing MENU again. Upon entry to the Logic display, the cursor will be placed at the last referenced Logic statement.

There will be an indication for each statement programmed, (the > symbol next to the statement number) and an indication that the statement is True (green color change and three stars *** will be present).

Figure 9-1 Logic overview page

		-0.01 $\text{\AA}/\text{s}$	-0.006 $\text{k}\text{\AA}$	0.00%	READY	
Overview	1 >	18	35	52	69	86
	2 > ***	19	36	53	70	87
	3	20	37	54	71	88
Logic 1-4	4	21	38	55	72	89
Logic 5-8	5	22	39	56	73	90
	6	23	40	57	74	91
Logic 9-12	7	24	41	58	75	92
Logic 13-16	8	25	42	59	76	93
	9	26	43	60	77	94
Logic 17-20	10	27	44	61	78	95
Logic 21-24	11	28	45	62	79	96
	12	29	46	63	80	97
Logic 25-28	13	30	47	64	81	98
	14	31	48	65	82	99
Logic 29-32	15	32	49	66	83	100
	16	33	50	67	84	
Logic 33-36	17	34	51	68	85	
Logic						
10/05/2010 13:55						
Select						

Logic statements that are "true" are indicated in green and with *** asteriks.

9.2.1 Logic Statement Groups

To view logic statements in groups of four, move the cursor in the left pane down to that group. Individual statements in that group can then be edited by moving the cursor to the statement number and pressing F1 Edit, see Figure 9-3.

Figure 9-2 Logic 1 - 4 page

<p>-0.03 \ddot{A}/s -0.007 $k\ddot{A}$ 0.00 % READY</p>	
<p>Overview</p> <p>Logic 1-4</p> <p>Logic 5-8</p> <p>Logic 9-12</p> <p>Logic 13-16</p> <p>Logic 17-20</p> <p>Logic 21-24</p> <p>Logic 25-28</p> <p>Logic 29-32</p> <p>Logic 33-36</p>	<p>1 IF CONNECTORS and MECH_P_ON and AUTO and GAUGES</p> <p> THEN Start Timer 1</p> <p>2 IF DP_IS_ON</p> <p>***</p> <p> THEN Message On 1</p> <p>3 IF</p> <p> THEN</p> <p>4 IF</p> <p> THEN</p>
<p>Logic</p>	
<p>DIFF PUMP IS ON</p>	
<p>10/05/2010 14:40</p> <p style="text-align: center;">Edit</p>	

From the Logic Overview display, a logic statement can also be selected for editing by positioning the cursor at the desired statement number and pressing F1 Select. See Figure 9-2.

9.2.2 Logic Statement Editing

Figure 9-3 Logic event IF selection

IF Thick Sum 3 0.500				
THEN Go to Non-Dep 6				
----- Events -----				
Pre-Deposit	Deposit	Process	Statement	External Input
In Deposit	Rate Ramp 1	Layer	Computer Cntrl	
Post-Deposit	Rate Ramp 2	Material	Test	Ion Assist Dep
Non-Deposit	Time Power	Source	Autotune	
	Non-Dep Control	Sensor	Stop	
Ready	Non-Dep Hold		Suspend	BkupSnsr In Use
Crucible Switch	Feed Ramp	Process End	Xtal Fail	
	Feed	Layer End	Xtal Switching	XferSnsr In Use
Pre-Cond Rise	Idle Ramp	Material End		
Pre-Cond Soak	Idle		Max Power	Rate < 0.1
Rise 1		Last Layer	Min Power	Rate Dev Err
Soak 1	Thick Limit	Timer HH:MM	Manual	Xtal Life >
Rise 2	Final Thick	Timer Seconds	Auto-Z Fail	Xtal Activity <
Soak 2	Thick Sum	Count Limit	Cruc Swch Fail	
Shutter Delay	Time Limit		Shtrr Dly Error	Parenthesis
Logic Statement 1				
06/25/2010 14:59 Test				
Event/ Action	Delete Element	Cancel Changes	Save & Exit	

Figure 9-4 Logic action Then selection

IF Thick Limit				
THEN Message On 1				
----- Actions -----				
Extern Out On	Switch Xtal	Clear Counter	Message On	Xtl F1 Inhb On
Extern Out Off	Zero Thickness	Increment Count	Message Off	Xtl F1 Inhb Off
	Zero Dep Time			
Select Process	Trig Fnl Thick	Start Timer	PreCond S/H On	RWS Inhibit On
		Cancel Timer	PreCond S/H Off	RWS Inhibit Off
Start	Start Deposit		Soak 1 Hold On	
Stop	Continue Dep	Clock Hold On	Soak 1 Hold Off	RWS Initiate On
Suspend		Clock Hold Off	Soak 2 Hold On	RWS Init Off
Reset	Go to Non-Dep		Soak 2 Hold Off	
	Go to Post-Dep	Start Inhb On		
		Start Inhb Off		
Logic Statement 2				
04/12/2010 12:54				
Event/ Action	Delete Element	Cancel Changes	Save & Exit	

While in logic-edit, the select menu area will be cleared from the screen. This allows the whole screen to be used for statement editing. A single statement is displayed to edit. The lower portion of the screen will be used to display either the event or the action list. Events are displayed if the cursor is on the IF portion of the statement and Actions are displayed if the cursor is on the THEN portion of the statement. Cursor begins on the first IF item.

The following function keys are active when the cursor is on the upper half of the page.

- ◆ **Event/Action** key will move the cursor to the event or action list on the lower half of the screen to select an event or an action. The cursor will jump to whichever event or action in the list that the cursor had been on in the upper half. The event or action in the statement will be highlighted to indicate which element is being worked in.
- ◆ **Delete Element** key will remove the element the cursor is on from the statement.
- ◆ **Cancel Changes** key returns the statement to the way it was before editing was started.
- ◆ **Save & Exit** key will save the statement and re-display the four-statement screen with the select menu.

When the cursor is on the lower half (event or action list) of the page the following function keys are active:

- ◆ **If/Then** (F1) key will return the cursor to the IF/THEN statement, with the cursor returning to the highlighted element in the logic statement.
- ◆ **Replace** (F2) key will write over the highlighted element with the selected Action/Event. The highlight moves to the next element in the statement.
- ◆ **Insert** (F3) key will insert the selected action or event into the highlighted element and moves the elements programmed to the right. The highlight remains on the inserted element in the statement. If the statement is full then a full statement error message will appear.
- ◆ **Negate** (F4) key will negate the highlighted event element in the statement. Actions cannot be negated.

To add or delete parenthesis use the cursor in the Event list to select the event Parenthesis. Pressing Insert or Replace, see [Figure 9-5](#), will add a parenthesis before or after the highlighted event in the statement. If a parenthesis is already there, Insert will act as a toggle, removing the parenthesis.

Figure 9-5 Function keys IF/THEN, REPLACE, INSERT

IF DP_IS_ON				
THEN Message On 1				
----- Actions -----				
Extern Out On	Switch Xtal	Clear Counter	Message On	Xt1 F1 Inhb On
Extern Out Off	Zero Thickness	Increment Count	Message Off	Xt1 F1 Inhb Off
Select Process	Zero Dep Time			
	Trig Fn1 Thick	Start Timer	PreCond S/H On	RWS Inhibit On
Start		Cancel Timer	PreCond S/H Off	RWS Inhibit Off
Stop	Start Deposit		Soak 1 Hold On	
Suspend	Continue Dep	Clock Hold On	Soak 1 Hold Off	RWS Initiate On
Reset	Go to Non-Dep	Clock Hold Off	Soak 2 Hold On	RWS Init Off
	Go to Post-Dep	Start Inhb On	Soak 2 Hold Off	
		Start Inhb Off		
Logic Statement 2		DIFF PUMP IS ON		
10/05/2010 14:52				
If/Then	Replace	Insert		

With the cursor in the lower half of the Event page, the F4 key will carry the Negate function in addition to the first three shown above.

When moving the cursor from an event or action, the next element is a numeric field, if required.

A connector field is required between events. The Toggle key is used to select the connector in the statement.

9.2.3 AND/OR and ON Logic Connectors

If the cursor is on a connector designated by ccc, pressing TOGL will toggle the ccc between a logical AND and a logical OR.

For those Events which are layer, material or source specific an additional operator can be selected. This is the ON operator and pressing the TOGL key will now toggle between AND, OR, and ON.

9.2.3.1 ON Operator

The ON operator is designed for use in multi-layer applications to link an event to a particular layer, material or source.

The only Events allowed following the ON connector are Layer ###, Material ### and Source ###. Only the events that can be associated with one of these entities can precede the ON operator. This includes all States, Pre-Deposit, Deposit, Post-Deposit, Non-Deposit, Final Thickness, Thick Limit, Time Limit, Layer,

Material, Sensor, Source, Layer End, Material End, Crystal Fail, Crystal Switching, Max Power, Min Power, Backup Sensor In Use, Crucible Switch Fail, Rate < 0.1, Transfer Sensor In Use, Auto-Z Fail, Ion-Assist, and Rate Deviation Error.

There cannot be two consecutive ONs in a statement. A ON B ON C is not allowed. A ON B and C ON D is acceptable.

Neither the event preceding nor the event following the ON can have a NOT function or a parenthesis. For example $\sim A$ ON B or A ON $\sim B$ is not allowed. Neither is A ON (B and C) or (A and B) ON C.

The ON connector always takes precedence over the AND and OR operators no matter where it appears in the statement. For example, A AND B ON C will be evaluated as A AND (B ON C) not as (A AND B) ON C.

9.3 IF Event Definitions

If two or more layers are active simultaneously, an Event condition is considered TRUE if it is true for any layers (for example, if the first layer is in DEPOSIT and the second layer is in PRE-DEPOSIT, both the DEPOSIT and the PRE-DEPOSIT Events would be TRUE).

The presence (or absence) of an input's leading edge detection on the transition from high to low (or low to high) is used to evaluate the event condition. Inputs are not re-evaluated if held level at either the high or low state.

IF events can be connected using logic connectors, refer to [section 9.2.3, AND/OR and ON Logic Connectors](#), on page 9-6. IF events can be negated.

ACTIVITY < # ###

Sets the logic condition to be true whenever the Activity value ### on sensor # is less than the value entered for ### for at least 5 seconds. The condition remains true until the Activity value is greater than ### for at least 5 seconds. The Activity value ### can be 1 to 999. Numeric inputs for sensor # range from 0 through 8 (0 for any sensor).

AUTO-Z FAIL #

Sets the logic condition to be true whenever an Auto-Z fail condition occurs on sensor #. The condition remains true until the Auto-Z Fail condition is cleared. Numeric inputs for sensor # range from 0 through 8 (0 for any sensor).

AUTO TUNE

Sets the logic condition to be true when AutoTune is started. The condition remains true until AutoTune is completed, exited, or until an AutoTune Fail condition occurs.

BKUP SENS IN USE

Sets the logic condition to be true while a backup sensor is in use. The condition remains true until a backup sensor is no longer active.

COMPUTER CNTRL

Sets the logic condition to be true when a Set Logic Statement vvv (1 to 100) command is received from the remote communications port. The logic condition remains true until a Clear Logic Statement vvv command is received from the remote communications port. See Remote Commands RG5 and RG6 (see section 10.4.33, Remote General Action, on page 10-55).

COUNT LIMIT XX yyy (xx can be 1 to 20 and yyy can be 0 to 999)

Sets the logic condition to be true when the specified counter XX (1 to 20) has reached the count number set by yyy (1 to 999). The condition remains true until the specified counter is cleared using Clear Counter XX.

CRUC SW FAIL

Sets the logic condition to be true if a Turret Feedback input is specified and is not received within the allocated time span. The condition remains true until the input arrives or a Reset is done.

CRUC SWITCH

Sets the logic condition to be true while switching crucibles. The condition remains true until the turret delay time has expired or the turret input arrives or a Reset is done.

DEPOSIT

Sets the logic condition to be true at the beginning of the Deposit state. The condition remains true until the end of the DEPOSIT state, or when a STOP/RESET or STOP/START sequence is executed. Rate Ramps, Time Power and Manual are considered part of the Deposit state.

EXTERNAL INPUT ## (## can be 1 to 28)

Designates a hardware input which, when it changes state, can be used to trigger an Action. Inputs can be given names up to 15 characters long. Inputs are activated by pulling the specific input's terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 mA (1 low power TTL load).

FEED

Sets the logic condition to be true at the start of Feed Time. The condition remains true until the end of Feed Time. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

FEED RAMP

Sets the logic condition to be true at the start of Feed Ramp. The condition remains true until the end of Feed Ramp. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

FINAL THICK

Sets the logic condition to be true once the Final Thickness is achieved while in Deposit or Manual or when the Final Thickness Trigger action is activated. The condition remains true until the Layer which has achieved Final Thickness enters the IDLE state, or until a Zero Thickness or a STOP/RESET sequence is executed.

IDLE

Sets the logic condition to be true at the beginning of the Idle state. The condition remains true until the end of Idle. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

NOTE: If Auto Start Next is enabled, this logic event is only triggered at the End of Process and not between each subsequent layer.

IN DEPOSIT

Sets the logic condition to be true at the beginning of the Deposit state and **includes** Time-Power and Rate Ramps. It is also true while in Manual **and** the Source/Substrate shutter output is active. The condition is cleared when entering the post-deposit state, or when a STOP/RESET or a STOP/START sequence is executed.

IDLE RAMP

Sets the logic condition to be true at the start of Idle Ramp. The condition remains true until the end of Idle Ramp. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

ION ASSIST DEP

Sets the logic condition to be true at the start of Deposit if Ion Assist Deposit has been enabled for this material. The condition remains true until the end of Deposit. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

LAST LAYER

Sets the logic condition to be true at the beginning of the Last Layer defined for the active process. The condition remains true until the last Layer enters the IDLE state.

LAYER ###

Sets the logic condition to be true at the beginning of Layer ### (when Layer ### is in the READY state at the beginning of a Process or when STARTed during a Process). The condition remains true until the layer is no longer active. Numeric inputs range from 1 to 200 or the maximum number of defined layers.

LAYER END ###

Sets the logic condition to be true when the specified Layer enters the IDLE state. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to 200, or the maximum number of defined layers, with 0 indicating any layer.

NOTE: If Auto Start Next is enabled, this logic event is only triggered at the End of Process and not between each subsequent layer.

LIFE > # ##

Sets the logic condition to be true whenever the Life value ## on sensor # is greater than the value entered for ##, which can be 1 to 99, for at least 5 seconds. The condition remains true until the Life value is less than ## for at least 5 seconds. Numeric inputs for sensor # range from 0 through 8 (0 for any sensor).

MANUAL

Sets the logic condition to be true when the Manual state is entered. The condition remains true until leaving the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

MATERIAL ##

Sets the logic condition to be true whenever a Layer containing Material ## is in the READY state at the beginning of a Process or when it is STARTed during a Process. The condition remains true until the material is no longer active and can stay true across layers if the same material is used in 2 or more consecutive layers. Values for ## range from 1 to 32 or the maximum number of defined materials.

MATERIAL END ##

Sets the logic condition to be true when the layer for the specified Material ## enters the IDLE state. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to 32 or the maximum number of defined materials, with 0 indicating any material.

NOTE: If Auto Start Next is enabled, this logic event is only triggered at the End of Process and not between each subsequent layer.

MAX POWER

Sets the logic condition to be true as long as any source is at Maximum Power. The condition remains true until every source is less than Maximum Power.

MIN POWER

Sets the logic condition to be true as long as any source is at Minimum Power. The condition remains true until every source is greater than Minimum Power.

NON-DEP CONTROL

This Event is evaluated true if a layer is in the Non-Deposit Control state, that is, there is rate control with the source/substrate shutter closed. The condition remains true until the end of the Non-Deposit Control state.

NON-DEP HOLD

This function is similar to Time Power except the source/substrate shutter is closed and there is no determinant end point. The condition remains true until the state is exited, for example when a Stop command is given.

POST-DEPOSIT

Sets the logic condition to be true at the beginning of the Feed state or the beginning of the Idle Ramp state. The condition remains true until a START command is received or until a STOP/RESET sequence is executed.

NOTE: If Auto Start Next is enabled and there are no states (Feed, Feed Ramp, Idle Ramp) between Deposit and Idle, this logic event is only triggered at the End of Process and not between each subsequent layer.

PRE-COND RISE

Sets the logic condition to be true at the beginning of the Pre-Cond Rise state. The condition remains true until the Pre-Cond Soak or a subsequent non-zero state is entered, or until a STOP/RESET sequence is executed.

NOTE: This state, PRE-COND SOAK, RISE 1 and SOAK 1 are skipped if the same material was used in a previous layer and has a non-zero Idle power. The next layer using this material will immediately proceed to the Rise 2 state.

PRECOND SOAK

Sets the logic condition to be true at the beginning of the Precond Soak state. The condition remains true until the Rise 1 or a subsequent non-zero state is entered, or until a STOP/RESET sequence is executed.

NOTE: This state, PRECOND RISE, RISE 1 and SOAK 1 are skipped if the same material was used in a previous layer and has a non-zero Idle power. The next layer using this material will immediately proceed to the Rise 2 state.

PRE-DEPOSIT

Sets the logic condition to be true at the beginning of the Ready, Source Switch, Shutter Delay, PreCond, Rise 1, Rise 2, Soak 1, or Soak 2 state. The condition remains true until the Deposit, Manual, or any Post-Deposit state is entered.

PROCESS ##

Sets the logic condition to be true when Process ## is designated as the Active Process. The condition remains true until the Process number is changed. Values for ## range from 1 to 50.

PROCESS END ##

Sets the logic condition to be true at the end of the specified process when Idle is entered. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to 50, with 1 through 50 indicating the respective active process and 0 indicating any process.

RATE <0.1

This condition will evaluate true when the actual deposition rate is less than 0.1 Å/s for more than 5 seconds while in Deposit or Manual. The condition remains true until the actual deposition rate is greater than 0.1 Å/s for 5 seconds or more, when the layer reaches Idle or on Stop/Reset.

RATE DEVIATION ERROR

This condition will evaluate true when the actual deposition rate differs from the rate setpoint by the larger of 5% or 0.1 Å/s for more than 60 seconds or 20 times the control loop time constant while in Deposit. The condition remains true until the layer leaves deposit.

RATE RAMP 1

Sets the logic condition to be true at the beginning of Rate Ramp 1. The condition remains true until the end of Rate Ramp 1. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

RATE RAMP 2

Sets the logic condition to be true at the beginning of Rate Ramp 2. The condition remains true until the end of Rate Ramp 2. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

READY

Sets the logic condition to be true as long as IC6 is in the READY state. The condition remains true until a START command is received or when entering Manual State.

RISE 1

Sets the logic condition to be true at the start of Rise Time 1. The condition remains true until the end of the Rise Time 1. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

NOTE: This state, PRECOND RISE, PRE-COND SOAK, and SOAK 1 are skipped if the same material was used in a previous layer and has a non-zero Idle power. The next layer using this material will immediately proceed to the Rise 2 state.

RISE 2

Sets the logic condition to be true at the start of Rise Time 2. The condition remains true until the end of Rise Time 2. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

SENSOR #

Sets the logic condition to be true whenever a Layer containing the Sensor # is in the READY state, or when it is STARTed. The condition remains true until a layer containing a material that does not use this Sensor #, is STARTed or placed in the READY state, or until a Crystal Switch on a dual sensor head is done. Numeric inputs range from 1 through 8.

SHUTTER DELAY

Sets the logic condition to be true at the start of Shutter Delay. The condition remains true until the end of Shutter Delay. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

SHTR DLY ERROR

Sets the logic condition to be true when a Shutter Delay Error condition occurs. The condition remains true until a START or a RESET command is received.

SOAK 1

Sets the logic condition to be true at the start of Soak Time 1. The condition remains true until the end of Soak Time 1. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

SOAK 2

Sets the logic condition to be true at the start of Soak Time 2. The condition remains true until the end of Soak Time 2. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed.

SOURCE #

Sets the logic condition to be true whenever a Layer containing Source # is in the READY state, or when it is STARTed. The condition remains true until a Layer containing a Material with a different Source # is STARTed or placed in the READY state. Numeric inputs range from 1 through 6.

STATEMENT ###

This Event can be used to test a logic statement transition and the appropriate Action is taken when the statement designated becomes true. A true statement is indicated by three small asterisks below the statement number. Numeric inputs range from 1 through 100.

STOP

Sets the logic condition to be true as long as IC6 is in STOP. The condition remains true until a RESET or a START command is received.

SUSPEND

Sets the logic condition to be true as long as IC6 is in SUSPEND. The condition remains true until a START command is received.

TEST

Sets the condition to be true when IC6 is in TEST.

THICK LIMIT

Sets the logic condition to be true once the Thickness Limit is achieved while in Deposit. The condition remains true until entering the IDLE state for that Layer or until a Zero Thickness or a STOP/RESET sequence is executed.

THICK SUM # ###

Sets the logic condition to be true when the sum of thickness indicated by the designated Thickness Equation #, 1 to 3, reaches the thickness value ### (0-999.9) μm .

TIME LIMIT

Sets the logic condition to be true once the Time Limit is achieved. The condition remains true until the Layer which has achieved Time Limit enters the IDLE state or until a STOP/RESET sequence is executed.

TIME POWER

Sets the logic condition to be true upon entering a Time Power state. The condition remains true until the end of the DEPOSIT state.

TIMER MINUTES # HH:MM

Sets the logic condition to be true when the designated timer # (1 to 20) reaches the specified number of hours and minutes HH:MM, 00:00 to 99:59.

TIMER SECONDS # ###

Sets the logic condition to be true when the designated Timer # (1 to 20) reaches the specified time expressed in seconds, sss.s, 0 to 999.9.

XFER SENS IN USE

Sets the logic condition to be true while a transfer sensor is in use. The condition remains true until a transfer sensor is no longer active.

XTAL FAIL #

Sets the logic condition to be true as long as there is a Crystal Fail on sensor #. In the case of a multi-position sensor, a Crystal Fail occurs when the last available crystal fails and no backup sensor is available. The logic condition remains false if the XTL FL INHB Action is active (ON). The condition remains true until a working crystal is input to the appropriate sensor. Numeric inputs for sensor # range from 0 through 8 (0 for any sensor).

XTAL SWITCHING #

Sets the logic condition to be true while a crystal switch is taking place on sensor #. The condition remains true until the crystal switch is completed. Numeric inputs for sensor # range from 0 through 8 (0 for any sensor).

9.4 THEN Action Definitions

NOTE: The following are level outputs that once turned on will remain active until turned off. This is true even if the Logic string is cleared.

START INHBT (ON/OFF)	XTL FL INHB (ON/OFF)
RWS INHIBIT (ON/OFF)	RWS INITIATE (ON/OFF)
SOAK 1 HOLD (ON/OFF) ##	SOAK 2 HOLD (ON/OFF) ##
EXTERN OUT (ON/OFF) ##	MESSAGE (ON/OFF) ##
CLOCK HOLD (ON/OFF)	PRE COND S/H (ON/OFF)

CANCEL TIMER ## 1 to 20

Deactivates the designated timer ## and resets it to zero.

CLEAR COUNTER ## 1 to 20

Clears the designated counter ##.

CLOCK HOLD ON/OFF

This feature holds the state timer during any non-rate control state. These states include the pre-deposit states — Ready, Crucible Switch, PreCond Rise, PreCond Soak, Rise 1, Soak 1, Rise 2, Soak 2 — and the post-deposit state Idle Ramp.

For the feature to be activated the state's timer must be non-zero. If IC6 is in the Ready state and a Start command is executed while CLOCK HOLD is active, IC6 will progress to the first pre-deposit state with a non-zero state time. If IC6 is in the Crucible Switch state, waiting for Turret Feedback Input, and CLOCK HOLD is activated, when the turret positioned input is activated, IC6 will progress to the next pre-deposit state having a non-zero state time. IC6 is prevented from continuing state processing until the CLOCK HOLD action is turned OFF.

CONTINUE DEP ## 0 (any material) to 32

Maintains the designated Material ## in the Deposit state but does not zero the thickness. This action cannot be done from a Ready, Idle, Stop, Suspend Crystal Switching, or Crucible Switch state. If the crystal is failed, this action will put the associated source into the Time Power state if the previous state was Non-Deposit Hold, otherwise it is not allowed.

EXTERN OUT (ON/OFF) ## 1 to 38

Designates a hardware output ## and places it into its ON or OFF state. Outputs can be given names up to 15 characters long. Outputs are named in the I/O Map display.

GO TO NONDEP ## 0 (any material) to 32

Places the layer that uses the designated Material ## into the Non-Deposit Control state. Thickness is not incremental. This cannot be done from the Ready, Idle, Stop, Suspend, or Crucible Switch states. If the crystal is failed, this action will place the Channel into the Non-Deposit Hold state if the previous state was Time Power, otherwise it is not allowed.

GO TO POST DEP ## 0 (any material) to 32

This action places the designated Material ## into the Idle Ramp state. This action cannot be done if in Crucible Switch.

INCREMENT COUNT ## 1 to 20

Increases the count by one in the designated counter ##.

MESSAGE (ON/OFF) ## 1 to 10

Designates the user-defined message ## and displays the message on the screen (or removes it from being displayed). The message is displayed in the message section of the display. Messages are defined in the General/ Message page.

PRE COND SOAK HOLD (ON/OFF) ## 0 (any material) to 32

If active (ON), the designated Material ## will pause execution and maintain PreCondition power until Pre Cond Soak Hold is turned OFF. Commands from Remote Comm and Logic will be independent.

RESET

This action is identical to pressing the RESET button on the front panel.

RWS INHIBIT (ON/OFF) ## 0 (Any Material) to 32

When active (ON), this will prevent the designated Material ## from exiting the RateWatcher Hold state. If Sample is already active, remains in Sample until Accuracy requirement is met. When OFF, RateWatcher Sample will be enabled. Commands from Remote Comm and Logic will be independent.

RWS INITIATE (ON/OFF) ## 0 (any material) to 32

When active (ON), this will start the RateWatcher sampling interval for the designated Material ##. When OFF, RateWatcher sampling will take place at the programmed interval based on the RateWatcher time unless RWS INHIBIT is on. Commands from Remote Comm and Logic will be independent.

SELECT PROCESS # 1 to 50

This action selects which Process # is to be the Active Process. The value entered must correspond to a defined Process. If IC6 is already executing a Process, that is, not in Ready or Idle of last layer in process when this Action is activated, the Action is ignored.

SOAK 1 HOLD (ON/OFF) ## 0 (any material) to 32

If active (ON), the designated Material ## will pause execution and maintain Soak Power 1 until Soak Hold 1 is turned OFF. Commands from Remote Comm and Logic will be independent.

SOAK 2 HOLD (ON/OFF) ## 0 (any material) to 32

If active (ON), the designated Material ## will pause execution and maintain Soak Power 2 until Soak Hold 2 is turned OFF. Commands from Remote Comm and Logic will be independent.

START

This action is identical to pressing the START button on the front panel.

START DEPOSIT ## 0 (any material) to 32

This function is used to place the layer that uses the designated Material ## into Deposit from the NONDEP CNTL state and zero the thickness. If the crystal is failed, this command will make the Material go into Time Power if the previous state was Non-Deposit Hold, otherwise the action is not allowed. Cannot be done from Ready, Idle, Stop, Crystal Switch Suspend, or Crucible Switch. When in Ready or Stop, use the Start action.

START INHIBIT ON/OFF

This feature, when active, prohibits the START of a layer. It does not inhibit the START DEPOSIT function. Once Start Inhibit is ON, a layer cannot be started until the START INHIBIT is deactivated (set to OFF). Commands from Remote Comm and Logic will be independent. START INHIBIT will carry through a power cycle

START TIMER ## 1 to 20

Starts the designated timer ##.

STOP

This action is identical to pressing the STOP button on the front panel. The condition remains true until a RESET or START command is received.

SUSPEND ## 0 (any material) to 32

Sets source power for the designated Material ## to zero and freezes its rate and thickness values until a Start is received.

SWITCH XTAL # 1 to 8

This action activates the Crystal Switch output for the sensor number # indicated. It indexes to the next crystal position listed when using a multi-position sensor. This function is available only if a multi-position sensor type is chosen in Sensor Set Up.

TRIG FNL THICK ## 0 (any material) to 32

This action triggers Final Thickness for the designated Material ## and the layer proceeds to the Feed Ramp or Idle Ramp state. This action is ignored if not in the Deposit state.

XTL FL INHB # ON/OFF 0 (any sensor) to 8

When set to On, this action prohibits the Crystal Fail logic event from becoming active for the designated sensor number, but has no effect on crystal switching or sensor failure action. This is useful when changing crystals. Commands from Remote Comm and Logic will be independent.

ZERO DEPOSIT TIME ## 0 (any material) to 32

This action will zero the Layer Deposit time for the designated Material ## being deposited. If two or more materials are in deposit simultaneously, the time will zero for all materials. If an output is triggered on a Time Limit, the output will remain triggered even after resetting the Layer Time

ZERO THICK ## 0 (any material) to 32

This action is identical to selecting the ZERO THICKNESS panel function key in the OPERATE display. The Action will zero the thickness accumulated on the display for the designated Material ## being deposited, and will also zero each of the sensor thicknesses in use for this layer.

9.5 Logic Statement Example

The logic statement capability of IC6 allows for automation of a thin film process. For example, it is possible to start a process without manually pressing START. One way to accomplish this is:

IF: $\overline{\text{PROCESS END ANY AND LAYER END ANY}}$

THEN: START

The $\overline{\text{STOP}}$ can be added to assure that the process does not start again if it was stopped.

To enter this statement follow this procedure:

- 1** On the MAIN MENU screen, make sure the state is READY. If it is not, press STOP, then press RESET.
- 2** Move the cursor to Logic, then press the MENU key.
- 3** Using the down arrow, move to one of the Logic x-y pages.
- 4** From the Logic x -y page, press the right arrow key to move to the statements.
- 5** Place the cursor on any blank logic statement, using the up and down cursor keys.
- 6** Press F1 EDIT.
- 7** Press F1 EVENT/ACTION.
- 8** Cursor to LAYER END. Press F3 INSERT. In the upper left of the screen, LAYER END ### will appear after IF.
- 9** Cursor to PROCESS END. Press F3 INSERT. PROCESS END ### ccc LAYER END ### will appear after IF.
- 10** Press F1 IF/THEN.
- 11** Cursor down to THEN. Press F1 EVENT/ACTION.
- 12** Cursor down to START. Press F3 INSERT. Press F1 IF/THEN.
- 13** Cursor to PROCESS END. Press F1 EVENT/ACTION. Press F4 NEGATE. A bar will appear above PROCESS END.
- 14** Press F1 IF/THEN.
- 15** Cursor to ###. Press 0, Enter. ### will be replaced by ANY.
- 16** The cursor should now be on ccc. Press TOGL once to change the ccc to AND. Press Enter.
- 17** Cursor to ###. Press 0, Enter. The ### will be replaced by ANY.
- 18** Press F4 SAVE & EXIT to return to the Logic page. At this point the Logic Statement is entered into memory.

19 To return to the OPERATE display, press Menu.

To run the multilayer process, press START once. As each layer ends, IC6 will automatically issue another START, until the LAST LAYER has completed.

Chapter 10

Remote Communications

10.1 Remote Communication Configuration Overview

This IC6 can be remotely controlled, programmed or interrogated through remote communications and the use of a remote command set. IC6 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.

HINT: To reduce communications overhead, multiple commands may be combined into one command string as described at [Command Packet \(Host to IC6 Message\)](#) on page 10-6

A host/server relationship is established in remote communications. IC6, as server, responds to the remote host's commands.

10.2 Physical Connections

You may choose to use one of two types of data communications hardware ports.

- ◆ Standard equipment includes a bit serial RS-232C port.
- ◆ Optionally, a TCP/IP port may be added.

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

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.

10.2.1 RS-232C Serial Port

RS-232C serial communications are accomplished through an industry standard 9-pin female connector found on the rear panel of IC6. A mating male connector is required for attachment of a host interface. The host and IC6 can be separated by up to fifty feet using multiconductor shielded data cable.

IC6 is configured as DCE (Data Communication Equipment).

NOTE: Unpredictable RS-232 hardware/software combinations may occasionally cause a command to not be recognized by IC6. Consequently, all communications should include an automatic retry procedure. If a command sent via RS-232 does not produce a response from IC6 within three seconds, it should be sent again.

10.2.2 TCP/IP Ethernet Port

The optional TCP/IP interface supports only the Standard Ethernet TCP/IP protocol. IC6 will communicate via TCP/IP on TCP port number 2101. The interface supports static addressing, DHCP is not supported. Ethernet parameters allowed to be set are the IP address and the net mask.

10.2.2.1 Network Connection

If IC6 is connected through a network or hub connection, a standard “straight” Ethernet cable is required.

10.2.2.2 How to Set Up the Network Protocol on the PC

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

To communicate directly with IC6, the Internet protocol (IP) on the PC must be configured manually and an Ethernet crossover cable (for example, IPN 600-1211-P5) must be connected between the PC and IC6. Some PCs will auto-configure and work with either straight or crossover cable. Instructions are provided here for manually configuring the Internet protocol.

NOTE: If the PC only has one Ethernet port (that is, 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.

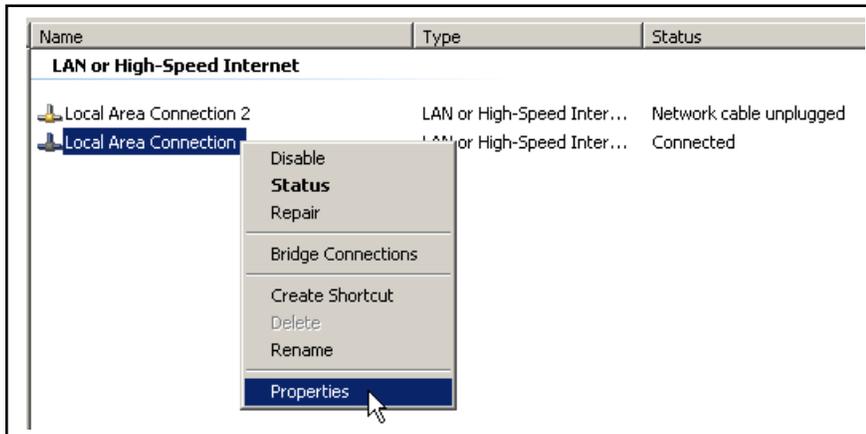
To access the Network Connection on the PC, select **Network Connections** from the Windows® **Start** menu or from the **Control Panel**. See Figure 10-1.

Figure 10-1 Accessing network connections



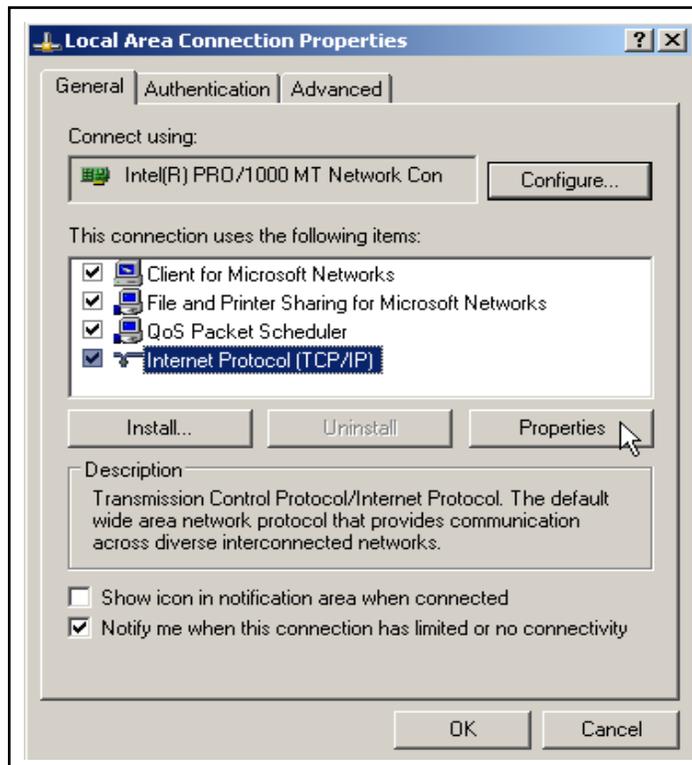
Select the **Local Area Connection** to be changed, right-click and select **Properties**. See Figure 10-2.

Figure 10-2 Local area connection properties



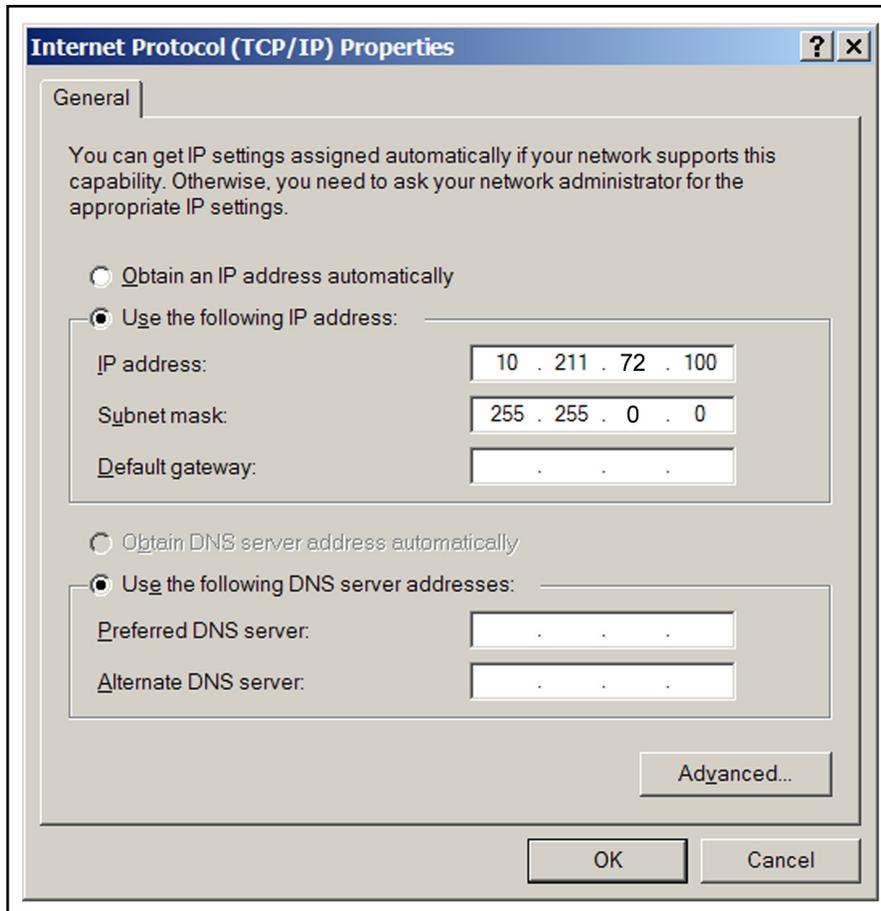
On the **General** tab, select **Internet Protocol (TCP/IP)** and press the **Properties** button. See Figure 10-3.

Figure 10-3 Internet protocol (TCP/IP) properties



Select the button for **Use the following IP address**, enter the **IP address** and **Subnet mask** shown in Figure 10-4, and press **OK**. With this selection, the PC is assigned an IP address to use when communicating with IC6. IC6 is shipped from INFICON with a pre-assigned address of 10.211.72.203. To communicate directly with IC6 from a PC, the PC must also be assigned an address that starts with 10.211.72 but *cannot* be set to 10.211.72.203. The example in Figure 10-4 uses the address 10.211.72.100 for the PC.

Figure 10-4 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.

10.3 Message Format

The Standard 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. IC6 supports the following RS-232 protocols: Standard, Dlog Comma and Dlog Page. The Dlog protocols only provide for one-way transmission of layer data from IC6.

Hardware handshaking is not supported.

Remote Communications parameters are set up in the General screen Comm page.

NOTE: Communication returns "can not do now", Response Error "F", 0x46, when Source Maintenance, Cross Talk Calibrate and Auto Tune modes are enabled.

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

10.3.1 Protocol

Key:

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

() Optional Element

I. Or

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

10.3.1.1 Command Packet (Host to IC6 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>)

Checksum 1 byte, sum, modulo 256, of all bytes, not including length. Modulo 256 is the numeric value from 0 to 255 representing the modulo 256 remainder of the sum of the values of the ASCII codes that comprise the response.

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

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

- 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.

Command Sub-groups for command Q and U:

- C. Source
- G General
- I Input Name.
- K. Process Name
- L Logic
- M Material
- N. Material Name
- O Output Name
- P. Process
- S. Sensor
- T. Type of Output
- V. User Message

Command Sub-groups for command R and S:

- G General
- L Layer
- S. Sensor

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 = see , Format Code REAL_

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

String = Null terminated series of ASCII characters

10.3.1.2 Response Packet (IC6 to Host Message)

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

Length Number of bytes including CCB, Timer, and Response Message. Length bytes and Checksum are not included in Length Count. Numeric value from 0 to 65,500 (two bytes) representing the number of characters in the response. Two byte values, high and low order, are required to represent this number. In order of transmission, the low byte will precede the high byte.

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

Timer 1 byte binary, number between 0 and 255, increments every tenth 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, indicating a command packet error, the response message will be a single packet response error.

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

Checksum 1 byte, sum, modulo 256, of all bytes, including CCB, Timer, and Response Message but not including length. Modulo 256 is the numeric value from 0 to 255 representing the modulo 256 remainder of the sum of the values of the ASCII codes that comprise the response.

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>)

Response Error Code = 1 byte ASCII

- A. illegal command
- B. Illegal parameter value
- D. illegal ID
- E. data not available
- F. cannot do now (some commands require IC6 to be in Ready/Stop).
- L. length Error, must be greater than 0 and equal to or less than 65,500 bytes.
- 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 (The command could not be processed because a byte in the command packet did not fit the recognized format)
- I. invalid message (Unrecognized command in the packet)
- M. too many commands (Only 100 allowed)
- O. response length is larger than response buffer

10.3.1.3 Timeouts

If more than 3 seconds pass between characters of a command packet, IC6 will time out. No response packet is sent, IC6 will clear its buffers and assume any future characters are the beginning of a new packet.

10.3.2 Data Type Codes

All parameters are stored internally as four byte words. The data type codes indicate how individual parameters are represented in the four bytes (and how they need to be passed via remote communications).

Table 10-1 Format code

Format Code	Displays the value as
REAL_3F20	X.XX or XX.X or XXX
REAL_3X1	XX.X
REAL_4F21	XX.XX or XXX.X
REAL_4F31	X.XXX or XX.XX or XXX.X
REAL_4X1	XXX.X
REAL_4X2	XX.XX
REAL_4X3	X.XXX
REAL_5F32	XX.XXX or XXX.XX
REAL_5X2	XXX.XX
REAL_5X3	XX.XXX
REAL_6F32	XXX.XXX or XXXX.XX
TIME	MM:SS (Minutes:Seconds)
ENCODE	Displays text from a Toggle list
INTEGER	Whole number (no decimal point)
LOCKCODE	XXXX

10.3.2.1 REAL_xXx and REAL_xFx

- ◆ Real numbers contain a decimal point.
- ◆ The resolution (or decimal precision) of the real number displayed depends on the format code.
- ◆ The stored value is a floating-point number.

10.3.2.2 TIME

- ◆ Time format is used for times with minutes and seconds.
- ◆ Time parameters are displayed as MM:SS.
- ◆ They are stored in memory as integer seconds.

10.3.2.3 ENCODE

- ◆ Encode parameters have a defined list of acceptable values.

- ◆ Usually two to five values are allowed.
- ◆ As the user toggles through the list the encoded text is displayed on the screen.
- ◆ The value stored is an integer.

10.3.2.4 INTEGER

- ◆ Integers are 32-bit words.
- ◆ Although they are stored as signed integers, all our current parameters have a lower limit greater than or equal to 0.

10.3.2.5 LOCKCODE

- ◆ The lock code parameter is displayed as “XXXX.”
- ◆ The value is stored as an integer.
- ◆ Unlock code is 0.

10.4 Communication Commands

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 section 10.3.1, Protocol, on page 10-6 for their definition.)

General definitions

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

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

<String> = variable length, null terminated ASCII characters.

10.4.1 Query and Update Commands

Query commands are used to request established parameter values. There is a specific query command for each parameter group. Depending on the actual hardware configuration, the response to some Query commands may be an E error code indicating there is no data available. Each command has one to three arguments.

Update commands are used to change a specified parameter to a new value or condition. Some parameters are order dependent in that they cannot be updated prior to certain other parameters. There is a specific update command for each parameter group.

The command variations include:

Table 10-2 QUERY and UPDATE commands

QUERY command	Parameter	UPDATE Command
QC	Source Parameters	UC
QG	General Parameters	UG
QI	Input Name	UI
QK	Process Name	UK
QL	Logic Statements	UL
QM	Material Parameters	UM
QN	Material Name	UN
QO	Output Name	UO
QP	Process Layer Parameters	UP
QS	Process Sensor Parameters	US
QT	Output Type	UT
QV	User Message	UV

10.4.2 Status Commands

Status commands return pertinent information based on a specific request made. Commands are provided to determine global information which is system level, layer or sensor information. A status code is required for each command. See [Status General on page 10-47](#) to [Status Sensor on page 10-52](#).

The command variations include:

Table 10-3 Status commands

Status command	Parameter
SG	General System Level
SL	Layer Information
SS	Sensor Information

Remote commands perform an action based on the specific command given. Commands are provided to affect global features which are system level oriented (RG commands, see [Remote General Action on page 10-55](#)) or layer oriented (RL commands see [Remote Layer Action on page 10-59](#)). Every command requires a remote code and may require a value.

Command variations include:

RG = Affects system or IC6 level conditions.

RL = Affects conditions for a specified layer.

10.4.3 HELLO Command

H <Command ID> given in hex format

Hex form example for H1 including length and checksum: 0200480149,

Response:

Table 10-4 Hello command response

Command ID	Meaning	Response
(0x01)	ASCII name and version	<String> = IC6 Version x.xx
(0x02)	Version numbers Structure Version Compatibility Version, Range Version	<Integer><Integer><Integer>
(0x03)	Firmware version number	<Float>

10.4.4 Query Source Parameter

Command = QC <Command ID> <Source number>

Command ID = <Byte> See Table 10-5

Source Number = <Byte> Source number 1 - 6

Response = <Integer> | <Float> See Data Type column in Table 10-5.

10.4.5 Update Source Parameter

Command = UC <Command ID> <Source number> <Parameter Value>

Command ID = <Byte> See Table 10-5.

Source Number = <Byte> Source number 1 - 6

Parameter Value = <Integer> | <Float>

Type of value depends on command ID, see Data Type column in Table 10-5.

Response = None (Just header and trailer).

Table 10-5 Source parameters

QC UC Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
1 (0x01)	DAC Output	0/ 12/ #	Integer	0 = not defined. Default for source 1 is 1, source 2 is 2, etc.	Update not allowed if source is running. Not allowed to set if the DAC is set as a recorder output.
2 (0x02)	(Source) Shutter Output	0/ 38/ 0	Integer	0 = not defined. Update not allowed if source is running. The same output can be used for multiple shutters. If multiple shutters have the same output, the name will list on the I/O all source numbers assigned to that output.	
3 (0x03)	Number of Crucibles	0/ 5/ 0	Encode	0 = 1 1 = 4 2 = 8 3 = 16 4 = 32 5 = 64	Update not allowed if source is running.
4 (0x04)	Crucible Output	0/ 38 /0	Integer	0 = not defined Gray font if Number of Crucibles = 0	
5 (0x05)	Turret Feedback	0/ 1/ 0	Encode	0 = No 1 = Yes Gray font if Number of Crucibles = 0	
6 (0x06)	Turret Input	0/ 28/ 0	Integer	0 = not defined Gray font if Turret Feedback = No or if Number of Crucibles = 1	
7 (0x07)	Turret Delay (Seconds)	2/ 180/ 5	Integer	Time out interval with feedback. Delay interval without feedback. Gray font if Number of Crucibles = 0 or if Number of Crucibles = 1	

10.4.6 Query General Parameter

Command = QG <Command ID>

Command ID = <Byte> See Cmnd ID in Table 10-6

Response = <Integer> | <Float>

Description = Type of response depends on command ID, see Data Type column in Table 10-6.

10.4.7 Update General Parameter

Command = UG <Command ID> <Parameter Value>

Command ID = <Byte> See Table 10-6

Parameter Value = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 10-6.

Response = None (Just header and trailer)

General Parameters:

Table 10-6 General parameters

QG UG Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
1 (0x01)	Active Process	1/ 50/ 1	Integer		Update not allowed if process is running.
2 (0x02)	Layer To Start	1/ 200/ 1	Integer	Cannot be greater than number of layers in active process. If process change causes this conflict, then value will be changed to 1.	
3 (0x03)	Run Number	1/ 9999/ 1	Integer		
4 (0x04)	Auto Start Next	0/ 1/ 0	Encode	0 = No 1 = Yes	
5 (0x05)	Max Concurrent Layers	1/ 6/ 2	Integer	Number of layers allowed running simultaneously	
6 (0x06)	Layers Displayed	0/ 2/ 0	Encode	0 = Auto 1 = 4 Layers 2 = 6 Layers	Gray Font if Max Concurrent Layer is < 3

Table 10-6 General parameters (continued)

QG UG Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
7 (0x07)	Not Used				
8 (0x08)	Active Layer Output	0/ 31/ 0	Integer	0 = Off 1 -31 = First of 8 consecutive binary encoded outputs	Update not allowed if layer is running or if this or any of the next 7 outputs in use by other hardware.
9 (0x09)	Thickness Eq 1	0/ 654321/ 0	Integer	Values are the sources whose thicknesses are summed	No duplicate numbers allowed
10 (0x0a)	Thickness Eq 2				
11 (0x0b)	Thickness Eq 3				
12 (0x0c)	Test	0/ 1/ 0	Encode	0 = Off 1 = On	
13 (0x0d)	Time Compressed (10x time acceleration)	0/ 1/ 0	Encode	0 = No 1 = Yes	Gray font when Test = Off
14 (0x0e)	Advanced Test (Crystal Fails active)	0/ 1/ 0	Encode	0 = Off 1 = On	
15 (0x0f)	Audio Feedback	0/ 1/ 0	Encode	0 = No 1 = Yes	
16 (0x10)	LCD Dimmer Time (Minutes)	0/ 99/ 0	Integer	0 = Always On Non 0 = Minutes till off	
17 (0x11)	Date Format	0/ 1/ 0	Encode	0 = mm/dd/yyyy 1 = dd/mm/yyyy	
18 (0x12)	USB Datalog Format	0/ 2/ 0	Encode	0 = Log Off 1 = Page 2 = Comma	
19 (0x13)	Datalog Xtal Info	0/ 1/ 0	Encode	0 = No 1 = Yes	

Table 10-6 General parameters (continued)

QG UG Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
20 (0x14)	Graph Scale	0/ 2/ 2	Encode	0 = Power 1 = +/-10Å/s 2 = +/-20Å/s	
21 (0x15)	Graph Scan Rate	0/ 3/ 0	Encode	0 = Auto 1 = Slow 2 = Med 3 = Fast	
22 (0x16)	RS-232 Baud Rate	0/ 4/ 4	Encode	0 = 9600 1 = 19200 2 = 38400 3 = 57600 4 = 115200	Cannot update via RS-232 communications
23 (0x17)	RS-232 Protocol	0/ 2/ 0	Encode	0 = Standard 2 = Dlog Page 1 = Dlog Comma	

Table 10-6 General parameters (continued)

QG UG Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
24 (0x18)	DAC 1 Scale	0.1/ 10.0/ 10.0	REAL_3X1		Update not allowed if process is running.
25 (0x19)	DAC 2 Scale				
26 (0x1a)	DAC 3 Scale				
27 (0x1b)	DAC 4 Scale				
28 (0x1c)	DAC 5 Scale				
29 (0x1d)	DAC 6 Scale				
30 (0x1e)	DAC 7 Scale				
31 (0x1f)	DAC 8 Scale				
32 (0x20)	DAC 9 Scale				
33 (0x21)	DAC 10 Scale				
34 (0x22)	DAC 11 Scale				
35 (0x23)	DAC 12 Scale				

Table 10-6 *General parameters (continued)*

QG UG Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
36 (0x24)	DAC 1 Polarity	0/ 1/ 1	Encode	0 = Negative 1 = Positive	Update not allowed if process is running.
37 (0x25)	DAC 2 Polarity				
38 (0x26)	DAC 3 Polarity				
39 (0x27)	DAC 4 Polarity				
40 (0x28)	DAC 5 Polarity				
41 (0x29)	DAC 6 Polarity				
42 (0x2a)	DAC 7 Polarity				
43 (0x2b)	DAC 8 Polarity				
44 (0x2c)	DAC 9 Polarity				
45 (0x2d)	DAC 10 Polarity				
46 (0x2e)	DAC 11 Polarity				
47 (0x2f)	DAC 12 Polarity				
48 (0x30)	Source DAC Required	0/ 1/ 1	Encode	1 = Yes 0= No	

10.4.8 Query Input Name

Command = QI <Input Number>

Input Number = <Byte> 1 - 28

Response = <Input Name>

Input Name = <String> Up to 15 characters, null terminated

10.4.9 Update Input Name

Command = UI <Input Number> <Input Name>

Input Number = <Byte> 1 - 28

Input Name = <String> Up to 15 characters, null terminated

Response = None (Just header and trailer)

Input Names may only be updated if IC6 is in Ready or Stop.

NOTE: UI changes are not allowed while a process is running. The UI command will not allow updating a name set by hardware designation, unless it is identical to the defined hardware name.

10.4.10 Query Process Name

Command = QK < Process Number>

Process Number = <Byte> 1 - 50

Response = < Process Name>

Process Name = <String> Up to 15 characters, null terminated. The string returned will be a blank if the default Process # name has not been changed.

10.4.11 Update Process Name

Command = UK <Process Number> <Process Name>

Process Number = <Byte> 1 - 50

Process Name = <String> Up to 15 characters, null terminated

Response = None (Just header and trailer)

10.4.12 Query Logic Statement

Command = QL <Statement Number>

Statement Number = <Byte> 1 - 100

Response = <Length of logic elements> <Set of elements>

NOTE: This length is NOT the same as the length of the packet. It tells how many bytes follow in the "event/action" <set of elements>.

Response can be made up of the following elements. All elements except Numeric 2 are one byte. Numeric 2 is a 4-byte integer.

AND connector 0x26
 Or connector 0x7C
 Left parenthesis 0x28
 Right Parenthesis 0x29
 On connector 0x40
 Event code <byte> (See note 1)
 Negated Event code <byte> (See note 1)
 Numeric 1 <byte> (See note 2)
 Numeric 2 <integer> (See note 3)
 Space 0x20 separates "if" and "then"
 Action code <byte> (See note 1)
 Action Numeric <byte> (See note 4)
 Terminator (ETX) 0x03 Indicates end of "then"

Note 1: For definition of event and action codes see [section 10.4.14 on page 10-22](#) for the Event list and [section 10.4.15 on page 10-26](#) for the Action list. The codes sent via communications would be the number listed there. If the event is to be negated, the event code will be negated as well. For example, the code for external input is 0x41. To indicate not external input (that is, input not set) the code is 0xBF. Action codes may not be negated.

Note 2: Numeric 1 is present if the event code requires a numeric. The range is dependent on the specific code.

Note 3: Numeric 2 is present if the event code requires a second numeric. It is a 4-byte integer. The range is dependent on the specific code.

Note 4: The Action Numeric is present if the action code requires a numeric. The range is dependent on the specific code.

The ordering of the logic elements is as follows: (The term Event Code includes Negated Event Code)

Event Terms

- 1** First element of term can be (, a space, or an Event code.
- 2** If space, there are no events, go straight to Action Terms (see below).
- 3** if (, next element must be event code.
- 4** If event code, if numerals are required for specific code, they must be next.
- 5** After event code, with its numerals, there may or may not be a).
- 6** Next must be either a connector or a space.
- 7** If a space, move on to Action Terms.
- 8** If connector, start next event (go to point 3. above).

NOTE: The last term cannot have a connector

Action Terms

Up to five action codes make up the action terms. Each code will be followed by a numeric if it is required. There are no connectors passed with the actions, as all actions are anded together.

The logic statement ends with a 0x03 (ETX).

10.4.13 Update Logic Statement

Command = UL<Statement Number><Length of logic elements> <Set of elements>

Statement Number = <Byte> 1 - 100

Length of logic elements = <Byte> number of bytes of the Logic element for each statement, including the 0x03 (ETX) terminator.

Set of elements = See description in QL above.

Example: IF External Input 21 and External Input 2 and External Input 18 and External Input 8

THEN Start Timer 1 and Extern Out On 10

Hex code for above including length and checksum:

1500554C01114115264102264112264108205101410A031A

Response = None (Just header and trailer)

Logic changes are not allowed while a process is running or if IC6 is in a stop.

10.4.14 IC6 Event List

Events used in the Logic Statement IF section. Logic codes are used in the remote communication query and update commands. The Logic codes start at 0x41 because there are formatting codes (for connectors, parentheses, etc.) used in the logic statements that are ASCII codes below 0x41. See [Table 10-7](#).

Table 10-7 Event list

Events	1st numeric (1 Byte) (XXX)	Min	Max	2nd numeric (Integer) (YYY)	Min	Max	Logic Code	Logic Code Negated
Parenthesis								
External Input	Input #	1	28				0x41	0xBF
Pre-Deposit							0x42	0xBE
In Deposit							0x43	0xBD
Post-Deposit							0x44	0xBC
Non Deposit							0x45	0xBB
Ready							0x46	0xBA
Crucible Switch							0x47	0xB9
PreCond Rise							0x48	0xB8
PreCond Soak							0x49	0xB7

Table 10-7 Event list (continued)

Events	1st numeric (1 Byte) (XXX)	Min	Max	2nd numeric (Integer) (YYY)	Min	Max	Logic Code	Logic Code Negated
Rise 1							0x4A	0xB6
Soak 1							0x4B	0xB5
Rise 2							0x4C	0xB4
Soak 2							0x4D	0xB3
Shutter Delay							0x4E	0xB2
Deposit							0x4F	0xB1
Rate Ramp 1							0x50	0xB0
Rate Ramp 2							0x51	0xAF
Manual							0x52	0xAE
Time Power							0x53	0xAD
Non-Dep Control							0x54	0xAC
Non-Dep Hold							0x55	0xAB
Feed Ramp							0x56	0xAA
Feed							0x57	0xA9
Idle Ramp							0x58	0xA8
Idle							0x59	0xA7
Suspend							0x5A	0xA6
Stop							0x5B	0xA5
Final Thick							0x5C	0xA4
Thick Limit							0x5D	0xA3
Thick Sum XXX See Note 4	Equation #	1	3	Thickness xxx.xxx	0	999.9	0x5E	0xA2
Time Limit							0x5F	0xA1
Process XXX	Process #	1	50				0x60	0xA0
Layer XXX	Layer #	1	200				0x61	0x9F
Material XXX	Material #	1	32				0x62	0x9E
Sensor XXX	Sensor #	1	8				0x63	0x9D

Table 10-7 Event list (continued)

Events	1st numeric (1 Byte) (XXX)	Min	Max	2nd numeric (Integer) (YYY)	Min	Max	Logic Code	Logic Code Negated
Source XXX	Source #	1	6				0x64	0x9C
Layer End XXX	Layer # 0 = Any	0	200				0x65	0x9B
Material End XXX	Material # 0 = Any	0	32				0x66	0x9A
Process End XXX	Process # 0 = Any	0	50				0x67	0x99
Last Layer							0x68	0x98
Timer Minutes (See Notes 2 & 3)	Timer #	1	20	Number of minutes	00:00	99:59	0x69	0x97
Timer Seconds (See Note 1)	Timer #	1	20	Time in Tenths of Seconds	0	999.9	0x6A	0x96
Count limit	Counter #	1	20	Counter value	0	999	0x6B	0x95
Statement	Logic Statement #	1	100				0x6C	0x94
Xtal Fail	Sensor # 0 = any	0	8				0x6D	0x93
Xtal Switching	Sensor # 0 = any	0	8				0x6E	0x92
Max Power							0x6F	0x91
Min Power							0x70	0x90
Not Used							0x71	0x8F
BkupSens In Use							0x72	0x8E
Ion Assist Dep							0x73	0x8D
Auto-Z Fail	Sensor # 0 = any	0	8				0x74	0x8C

Table 10-7 Event list (continued)

Events	1st numeric (1 Byte) (XXX)	Min	Max	2nd numeric (Integer) (YYY)	Min	Max	Logic Code	Logic Code Negated
Cruc Sw Fail							0x75	0x8B
Rate < 0.1							0x76	0x8A
Shutter Dly Error							0x77	0x89
Not Used							0x78	0x88
XferSnsr In Use							0x79	0x87
Xtal Life > xxx	Sensor # % Life 0 = any	0	8	% Life	1	99	0x7A	0x86
Xtal Activity < xxx	Sensor # Activity 0 = any	0	8	Activity	1	999	0x7B	0x85
Computer Cntrl							0x7C	0x84
Test							0x7D	0x83
AutoTune							0x7E	0x82
Rate Dev(iation) Err(or)							0x7F	0x81

Note 1: Seconds are entered via remote communications as tenths of seconds. Seconds are entered by keyboard as whole numbers.

Note 2: The time is entered via remote communications as whole minutes. 99 hours = 5940 minutes, so 99 hours + 59 minutes = 5999 minutes maximum. The time entered by keyboard is in hours and minutes.

Note 3: Maximum number of minutes is 59. The entry of 00:65 is invalid. That time can be entered as 01:05.

Note 4: Thick Sum will be sent as an integer Angstroms (the number multiplied by 1000).

10.4.15 IC6 Action List

Actions are triggered in the Logic Statement THEN section. Logic codes are used in the remote communication query and update commands. Some actions that require a numeric may act on all items by entering a zero, as noted in Table 10-8.

Table 10-8 Action list

Actions	Numeric (Byte)	Min	Max	Logic Code
Extern Out On XXX	Output #	1	38	0x41
Extern Out Off XXX	Output #	1	38	0x42
Select Process XXX	Process #	1	50	0x43
Stop				0x44
Start				0x45
Reset				0x46
Suspend XXX	Material #	0	32	0x47
Zero Deposit Time XXX				0x48
Zero Thick XXX				0x49
Trig Fnl Thick XXX				0x4A
Continue Dep XXX				0x4B
Start Deposit XXX				0x4C
Go to NonDep XXX				0x4D
Go to PostDep XXX				0x4E
Increment Count XXX				Counter #
Clear Counter XXX	0x50			
Start Timer XXX	Timer #	1	20	0x51
Cancel Timer XXX				0x52
Switch Xtal XXX	Sensor #	1	8	0x53
* PreCond S/H Off XXX	Material #	0	32	0x54
* PreCond S/H On XXX				0x55

Table 10-8 Action list (continued)

Actions	Numeric (Byte)	Min	Max	Logic Code
* Soak 1 Hold Off XXX	Material #	0	32	0x56
* Soak 1 Hold On XXX				0x57
* Soak 2 Hold Off XXX				0x58
* Soak 2 Hold On XXX				0x59
* Clock Hold Off				0x5A
* Clock Hold On				0x5B
* Start Inhbt Off **				0x5C
* Start Inhbt On **				0x5D
* Xtl FI Inhbt Off	Sensor #	0	8	0x5E
* Xtl FI Inhibit On				0x5F
* RWS Inhibit Off XXX (RWS = RateWatcher Sample)	Material #	0	32	0x60
* RWS Inhibit On XXX				0x61
* RWS Init(iate) Off XXX				0x62
* RWS Initiate On XXX				0x63
Message On XXX See Note 1	Message #	1	10	0x64
Message Off XXX See Note 1				0x65
<p>Note: There are ten User Messages available for the user to construct. These messages can be displayed and cleared via logic actions. User Messages are constructed on the General page Message screen.</p>				
<p>Note: * = Remote Comm and Logic will be independent. Methods used to set action must be used to clear action. ** = Start Inhibit will carry through a power cycle</p>				

10.4.16 Query Material Parameter

Command = QM <Command ID> <Material Number>

Command ID = <Byte> See Table 10-9

Material Number = <Byte> 1- 32

Response = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 10-9.

10.4.17 Update Material Parameter

Command = UM <Command ID> <Material Number> <Parameter Value>

Command ID = <Byte> See Table 10-9.

Material Number = <Byte> 1- 32

Parameter Value = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 10-9.

Response = None (Just header and trailer)

Table 10-9 Material parameters

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
1 (0x01)	Density (g/cc)	0.1/ 99.999/ 1.0	REAL_5X3		
2 (0x02)	Z-Ratio	0.1/ 15.0/ 1.0			
3 (0x03)	Master Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1		
4 (0x04)	Control Loop	0/ 2/ 0	Encode	0 = NonPID 1 = PI 2 = PID	
5 (0x05)	Process Gain (Å/s/%)	0.01/ 999.99/ 10.0	REAL_ 5F32		
6 (0x06)	Time Constant (seconds)	0.01/ 9999.99/ 1.0	REAL_ 6F32	Gray font if Control Loop = NonPID	

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
7 (0x07)	Dead Time (seconds)	0.01/ 9999.99/ 1.0	REAL_ 6F32	Gray font if Control Loop = NonPID	
8 (0x08)	Source	1/ 6/ 1	Integer		Update not allowed if material is running.
9 (0x09)	Maximum Power (%)	0.01/ 99.99/ 90.0	REAL_4X2		
10 (0x0a)	Minimum Power (%)	0.00/ 99.98/ 0.0	REAL_4X2		
11 (0x0b)	Max Power Option	0/ 3/ 2	Encode	0 = Continue 1 = Post-Dep 2 = Stop Proc 3 = Suspend Mat	
12 (0x0c)	PreCond Soak Power (%)	0.0/ 99.99/ 0.0	REAL_4X2		
13 (0x0d)	PreCond Rise Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	Time Note: Times are displayed as mm:ss. Times are stored as seconds. The maximum number of seconds is 5999. This would be displayed as 99:59.	
14 (0x0e)	PreCond Soak Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time		
15 (0x0f)	Soak Power 1 %	0.0/ 99.99/ 0.0	REAL_4X2		
16 (0x10)	Rise Time 1 (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
17 (0x11)	Soak Time 1 (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
18 (0x12)	Soak Power 2 %	0.0/ 99.99/ 0.0	REAL_4X2		
19 (0x13)	Rise Time 2 (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
20 (0x14)	Soak Time 2 (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time		
21 (0x15)	Auto Soak 2	0/ 1/ 0	Encode	0 = No 1 = Yes	
22 (0x16)	Dep After Pre-Dep	0/ 1/ 1	Encode	0 = No 1 = Yes	
23 (0x17)	Delay Option	0/ 3/ 0	Encode	0 = None, 1 = Shutter 2 = Control, 3 = Both	
24 (0x18)	Control Delay Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	Gray font unless Delay option is set to control or both.
25 (0x19)	Shutter Delay Accur (%)	1/ 99/ 5	Integer		Gray font unless Delay option is set to shutter or both.
26 (0x1a)	Transfer Sensor	0/ 8/ 0	Integer	0 = No transfer sensor. Gray font unless delay option is set to shutter or both and transfer service is not set to 0. Update not allowed if material is running.	
27 (0x1b)	Transfer Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1		
28 (0x1c)	Feed Power (%)	0.0/ 99.99/ 0.0	REAL_4X2		
29 (0x1d)	Feed Ramp Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
30 (0x1e)	Feed Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
31 (0x1f)	Idle Power (%)	0.0/ 99.99/ 0.0	REAL_4X2		
32 (0x20)	Idle Ramp Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
33 (0x21)	Rate (Å/s)	0/ 999.9/ 0	REAL_ 4F31		
34 (0x22)	Time Limit (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
35 (0x23)	Rate Filter Time (seconds)	0/ 6/ 0	Encode	0 = 0.1 1 = 0.4 2 = 1.0 3 = 4.0 4 = 10.0 5 = 20.0 6 = 30.0	
36 (0x24)	Time Power Avg Time (Minutes)	0/ 30/ 0	Integer		
37 (0x25)	Ion Assist Deposit	0/ 1/ 0	Encode	0 = No, 1 = Yes	Update not allowed if material is running
38 (0x26)	On Final Thickness	0/ 2/ 1	Encode	0 = Continue, 1 = Post-Dep 2 = NonDepCont	
39 (0x27)	Ramp 1 Rate (Å/s)	0/ 999.9/ 0	REAL_ 4F31		
40 (0x28)	Start Ramp 1 (KÅ)	0/999.999/ 0	REAL_ 4F31	Value must be less than Start Ramp 2 thickness value if Start Ramp 2 thickness value is non-zero	
41 (0x29)	Ramp 1 Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
42 (0x2a)	Ramp 2 Rate (Å/s)	0/ 999.9/ 0	REAL_ 4F31		

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
43 (0x2b)	Start Ramp 2 (KÅ)	0/999.999/ 0	REAL_ 4F31	Value must be greater than Start Ramp 1 thickness value	
44 (0x2c)	Ramp 2 Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	
45 (0x2d)	RateWatcher Option	0/ 1/ 0	Encode	0 = No, 1 = Yes	
46 (0x2e)	RateWatcher Time (seconds) (mm:ss)	0/ 5999/ 0 0/ 99:59/ 0	Time	See Time Note	Grey font unless RateWatcher option set to Yes
47 (0x2f)	RateWatcher Accuracy (%)	1/ 99/ 5	Integer		
48 (0x30)	Multipoint	0/ 1/ 0	Encode	0 = No, 1 = Yes	Update not allowed if material is running
49 (0x31)	Aggregate Multiplier	0/ 1/ 0	Encode	0 = No, 1 = Yes	Visible only if Multipoint is set to Yes

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
50 (0x32)	Sensor 1 Failure Action	0/ 4/ 2	Encode	0 = Unused 1 = PostDp 2 = Stop 3 = Suspnd 4 = TimePw	Visible only if Multipoint is set to Yes At least one must be non-zero (when multipoint set to "Yes") Update not allowed when transfer or backup sensor is running
51 (0x33)	Sensor 2 Failure Action	0/ 4/ 0			
52 (0x34)	Sensor 3 Failure Action				
53 (0x35)	Sensor 4 Failure Action				
54 (0x36)	Sensor 5 Failure Action				
55 (0x37)	Sensor 6 Failure Action				
56 (0x38)	Sensor 7 Failure Action				
57 (0x39)	Sensor 8 Failure Action				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
58 (0x3a)	Sensor 1 Failure Trigger	0/ 1/ 1	Encode	0 = OnFail 1 = Last	Visible only if Multipoint is set to Yes Gray font if Failure Action= 0 (Not Used) Update not allowed when transfer or backup sensor is running
59 (0x3b)	Sensor 2 Failure Trigger				
60 (0x3c)	Sensor 3 Failure Trigger				
61 (0x3d)	Sensor 4 Failure Trigger				
62 (0x3e)	Sensor 5 Failure Trigger				
63 (0x3f)	Sensor 6 Failure Trigger				
64 (0x40)	Sensor 7 Failure Trigger				
65 (0x41)	Sensor 8 Failure Trigger				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
66 (0x42)	Sensor 1 Weight (%)	1/ 400.0/ 100.0	REAL_4X1		Visible only if Multipoint is set to Yes Gray font is Failure Action = 0 (not used)
67 (0x43)	Sensor 2 Weight (%)				
68 (0x44)	Sensor 3 Weight (%)				
69 (0x45)	Sensor 4 Weight (%)				
70 (0x46)	Sensor 5 Weight (%)				
71 (0x47)	Sensor 6 Weight (%)				
72 (0x48)	Sensor 7 Weight (%)				
73 (0x49)	Sensor 8 Weight (%)				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
74 (0x4a)	Sensor 1 Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1		Visible only if Multipoint is set to Yes Gray font is Failure Action = 0 (not used)
75 (0x4b)	Sensor 2 Tooling (%)				
76 (0x4c)	Sensor 3 Tooling (%)				
77 (0x4d)	Sensor 4 Tooling (%)				
78 (0x4e)	Sensor 5 Tooling (%)				
79 (0x4f)	Sensor 6 Tooling (%)				
80 (0x50)	Sensor 7 Tooling (%)				
81 (0x51)	Sensor 8 Tooling (%)				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
82 (0x52)	Sensor 1 CrystalTwo Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1		Visible only if Multipoint is set to Yes Gray if crystal type not Crystal2
83 (0x53)	Sensor 2 CrystalTwo Tooling (%)				
84 (0x54)	Sensor 3 CrystalTwo Tooling (%)				
85 (0x55)	Sensor 4 CrystalTwo Tooling (%)				
86 (0x56)	Sensor 5 CrystalTwo Tooling (%)				
87 (0x57)	Sensor 6 CrystalTwo Tooling (%)				
88 (0x58)	Sensor 7 CrystalTwo Tooling (%)				
89 (0x59)	Sensor 8 CrystalTwo Tooling (%)				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
90 (0x5a)	Sensor 1 Cal Thickness (KÅ)	0/ 999.8/ 999.9	REAL_ 4F31	Value of 999.9 kÅ is considered "Un-Calibrated"	
91 (0x5b)	Sensor 2 Cal Thickness (KÅ)				
92 (0x5c)	Sensor 3 Cal Thickness (KÅ)				
93 (0x5d)	Sensor 4 Cal Thickness (KÅ)				
94 (0x5e)	Sensor 5 Cal Thickness (KÅ)				
95 (0x5f)	Sensor 6 Cal Thickness (KÅ)				
96 (0x60)	Sensor 7 Cal Thickness (KÅ)				
97 (0x61)	Sensor 8 Cal Thickness (KÅ)				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
98 (0x62)	Sensor 1 Xtal Position First	0/ 12/ 0	Integer		Visible only if Multipoint is set to Yes Gray font if Sensor Type is Single, CrystalTwo, or Generic
99 (0x63)	Sensor 2 Xtal Position First				
100 (0x64)	Sensor 3 Xtal Position First				
101 (0x65)	Sensor 4 Xtal Position First				
102 (0x66)	Sensor 5 Xtal Position First				
103 (0x67)	Sensor 6 Xtal Position First				
104 (0x68)	Sensor 7 Xtal Position First				
105 (0x69)	Sensor 8 Xtal Position First				

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
106 (0x6a)	Sensor 1 Xtal Position Last	0/ 12/ 0	Integer		Visible only if Multipoint is set to Yes Gray font if Sensor Type is Single, CrystalTwo, or Generic
107 (0x6b)	Sensor 2 Xtal Position Last				
108 (0x6c)	Sensor 3 Xtal Position Last				
109 (0x6d)	Sensor 4 Xtal Position Last				
110 (0x6e)	Sensor 5 Xtal Position Last				
111 (0x6f)	Sensor 6 Xtal Position Last				
112 (0x70)	Sensor 7 Xtal Position Last				
113 (0x71)	Sensor 8 Xtal Position Last				
114 (0x72)	Sensor	1/ 8/ 1	Integer		Visible only if Multipoint is set to No. Update not allowed if material is running
115 (0x73)	Failure Action	1/ 4/ 2	Encode	1 = PostDp 2 = Stop 3 = Suspnd 4 = TimePw	Visible only if Multipoint is set to No. Update not allowed when transfer sensor or backup sensor is running
116 (0x74)	CrystalTwo Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1		Visible only if Multipoint is set to No. Gray font if Sensor Type is not CrystalTwo
117 (0x75)	Xtal Position First	0/ 12/ 0	Integer		Visible only if Multipoint is set to No. Gray font if Sensor Type is Single, CrystalTwo or Generic

Table 10-9 Material parameters (continued)

QM UM Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
118 (0x76)	Xtal Position Last	0/ 12/ 0	Integer	Visible only if Multipoint is set to No. Gray font if Sensor Type is Single, CrystalTwo, or Generic	
119 (0x77)	Backup Sensor	0/ 8/ 0	Integer	0 = No backup sensor. Visible only if multipoint is set to No.	Backup sensor cannot be equal to the sensor parameter. Update not allowed if material is running.
120 (0x78)	Backup Tooling (%)	1.0/ 999.9/ 100.0	REAL_4X1	Visible only if Multipoint is set to No. Gray font if Backup Sensor is set to 0.	
121 (0x79)	Quality Percent (%)	0/ 99/ 0	Integer		
122 (0x7a)	Quality Counts	0/ 99/ 0	Integer		
123 (0x7b)	Stability Single (Hz)	0/ 9999/ 0	Integer		1-24 are excluded
124 (0x7c)	Stability Total (Hz)	0/ 9999/ 0	Integer		1-24 are excluded
125 (0x7d)	Recorder Output	0/ 12/ 0	Integer	0 = No recorder	Not allowed to be the same as a source DAC
126 (0x7e)	Recorder Function	0/ 3/ 0	Encode	0 = Filtered Rate 1 = Thick 2 = RateDev 3 = Power	Gray font if recorder output set to 0
127 (0x7f)	Recorder Range	0/ 99999/ 100	Integer	Gray font if recorder output is set to 0 or Recorder Function is Power or Rate Deviation	

Time Note: Times are displayed as mm:ss. Times are stored as seconds.
The maximum number of seconds is 5999. This would be displayed as 99:59.

10.4.18 Query Material Name

Command = QN <Material Number>

Material Number = <Byte> 1-32

Response = <Material Name>

Material Name = <String> Up to 15 characters, null terminated. The string returned will be a blank if the default Material # name has not been changed.

10.4.19 Update Material Name

Command = UN <Material Number> <Material Name>

Material Number = <Byte> 1 - 32

Material Name = <String> Up to 15 characters, null terminated

Response = None (Just header and trailer)

10.4.20 Query Output Name

Command = QO <Output Number>

Output Number = <Byte> 1 - 38

Response = <Output Name>

Output Name = <String> Up to 15 characters, null terminated

10.4.21 Update Output Name

Command = UO <Output Number> <Output Name>

Output Number = <Byte> 1 - 38

Output Name = <String> Up to 15 characters, null terminated

Response = None (Just header and trailer)

Output Names may only be updated if IC6 is in Ready or Stop.

NOTE: UO changes are not allowed while a process is running. The UO command will not allow updating a name set by hardware designation, unless it is identical to the defined hardware name.

10.4.22 Query Process Layer Parameter

Command: QP <Command ID> <Process Number><Layer Number>

Command ID = <Byte> See Table 10-10.

Process Number = <Byte> 1 - 50

Layer Number = <Byte> 1 - 200

Response = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 10-10.

10.4.23 Update Process Layer Parameter

Command = UP <Command ID> <Process Number><Layer Number>
<Parameter Value>

Command ID = <Byte> See Table 10-10.

Process Number = <Byte> 1 - 50

Layer Number = <Byte> 1 to 200

Parameter Value = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 10-10.

Response = None (Just header and trailer)

Table 10-10 Process layer parameters

QP UP Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
1 (0x01)	Material	0/ 32/ 0	Integer	0 = Layer is not defined	Update not allowed if active process is running
2 (0x02)	(Final Thickness) Final Thick (KÅ)	0.0/ 999.999/ 0.0	REAL_5F3 2		
3 (0x03)	(Thickness Limit) Thick Limit (KÅ)	0.0/ 999.999/ 0.0	REAL_5F3 2		

Table 10-10 Process layer parameters (continued)

QP UP Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
4 (0x04)	(Crucible) Cruc	1/ 64/ 1	Integer		Update not allowed if active process is running
5 (0x05)	(Co-Deposition) CoDep	0/ 1/ 0	Encode	0 = No 1 = Yes When this layer is set to yes the next layer will not display.Gray font if next layer is empty OR next layer is set to Yes OR this layer is the last layer.	Update not allowed if active process is running No update if the last programmed layer OR if the next layer's Co-Dep parameter is set to Yes
6 (0x06)	(Ratio Control) Ratio Cntrl (%)	0/ 999.9/ 0	REAL_4X1	Gray Font when Co-deposition is No	

10.4.24 Query Sensor Parameter

Command = QS <Command ID> <Sensor Number>

Command ID = <Byte> See Table 10-11.

Sensor Number = <Byte> Sensor number 1 - 8

Response = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 10-11.

10.4.25 Update Sensor Parameter

Command: = US <Command ID> <Sensor Number> <Parameter Value>

Command ID = <Byte> See Table 10-11

Sensor Number = <Byte> Sensor number 1 - 8

Parameter Value = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 10-11.

Response = None (Just header and trailer)

Table 10-11 Sensor parameters

QS US Cmd ID	Name (Units)	Range: Low Limit/ High Limit/ Default	Data Type	Notes	Update Restrictions and Display Notes
1 (0x01)	(Sensor) Shutter Out(put)	0/ 38/ 0	Integer	0 = not defined Update not allowed if the sensor is running. Not accepted if output in use by other hardware	
2 (0x02)	Sensor Type	0/ 4/ 0	Encode	0 = Single 1 = XtalTwo 2 = XtalSix 3 = Xtal12 4 = Generic	Update not allowed if the sensor is running.
3 (0x03)	(Sensor) Switch Out(put)	0/ 38/ 0	Integer	0 = not defined Gray font if Sensor Type = Single	Update not allowed if the sensor is running. Not accepted if output in use by other hardware.
4 (0x04)	Auto-Z	0/ 1/ 0	Encode	0 = No, 1 = Yes	
5 (0x05)	# of Positions	1/ 12/ 1	Integer	Visible only when Sensor Type = 4	Update not allowed if the sensor is running.
6 (0x06)	# of Pulses	1/ 10/ 1	Integer		
7 (0x07)	Pulse On (Time) (Seconds)	0.1/ 9.9 /1	REAL_3X1		
8 (0x08)	Pulse Off (Time) (Seconds)	0.1/ 9.9 /1	REAL_3X1		
9 (0x09)	Recorder Output	0/ 12/ 0	Integer	0 = not defined	Not allowed to be the same as a source DAC
10 (0x0a)	Recorder Function	0/ 2/ 0	Encode	0 = Rate 1 = Thick 2 = RateDev	Note: Rate Filter Time has no effect
11 (0x0b)	Recorder Range	0/ 99999/ 100	Integer		Gray font when Recorder Function = Rate Deviation

10.4.26 Query Output Type

Command = QT <Output Number>

Output Number = <Byte> 1 - 38

Response = <Output Type>

Output Type = <Byte> 0 or 1 (0 = NO, 1 = NC)

10.4.27 Update Output Type

Command = UT <Output Number> <Output Type>

Output Number = <Byte> 1 - 38

Output Type = <Byte> 0 or 1 (0 = NO, 1 = NC)

Response: None (Just header and trailer)

NOTE: UT changes are not allowed while a process is running.

10.4.28 Query User Message

Command = QV <User Message Number>

User Message Number = <Byte> 1 - 10

Response = < User Message>

User Message = <String> Up to 19 characters, null terminated

10.4.29 Update User Message

Command = UV < User Message Number> < User Message Name>

User Message Number = <Byte> 1 - 10

User Message # Name = <String> Up to 19 characters, null terminated

Response = None (Just header and trailer)

NOTE: A user message that is currently displayed will not be changed on the screen until the message area is refreshed.

10.4.30 Status General

Command = SG <Command ID><Option>

Command ID = <Byte> See Description in Table 10-12.

Option = <Byte> | < Integer > | <32 Bit Word> | <48 Bit Word>

Response = <Byte>... <Byte> | <Integer>...<Integer>

Table 10-12 Status general commands

SG Comm and ID	Description	Option	Number of bytes in the response	Data Returned	Notes
0 (0x00)	N/A				
1 (0x01)	Active process		4	<Integer>	
2 (0x02)	Active layer(s)		1 to 7	<Byte>[<Byte>] [<Byte>]...[<Byte>]	First byte is number of active layers. The following bytes are which layer(s) is (are) active
3 (0x03)	Output status		5	<Byte><Byte><Byte> <Byte><Byte> Each bit represents an output, bit set means output active.	MSB of first byte is output 1. MSB of the fifth byte is output 33.
4 (0x04)	Input status		4	<Byte><Byte><Byte> <Byte> Each bit represents an input. Bit set means input active.	MSB of first byte is input 1. MSB of the fourth byte is input 25.
5 (0x05)	Logic statement status		13	<Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte> Each bit represents a logic statement, bit set means logic statement is true.	MSB of first byte is logic statement 1. MSB of the thirteenth byte is logic statement 97.

Table 10-12 Status general commands (continued)

SG Comm and ID	Description	Option	Number of bytes in the response	Data Returned	Notes
6 (0x06)	Status Messages		8	<Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	See encodes in section 15.1 on page 15-1 . One bit is set for each error. Multiple bits may be set.
7 (0x07)	Status Message Designators	<Status Message Word> 8 bytes	1-13 (Can have 12 DAC recorders)	<Byte> <Byte>...<Byte>	Status Message Word corresponding to one of the status messages, as encoded in the SG 6 command.
This indicates which status message designators are to be returned. Note that only one bit may be set, that is, only the designators for one error can be requested per command. Returns a string of bytes. First byte is the number of bytes following. The following bytes indicate the designators for the requested status message. If there are no designators, the first byte returned will be zero.					
8 (0x08)	Cause of Stop		1	<Byte>	See encodes in section 15.4 on page 15-7 . If not currently in Stop, will return "Data Not Available" error.
9 (0x09)	Transient Messages		1	<Byte>	See encodes in section 15.5 on page 15-9 .
10 (0x0a)	Sensor Status		8	<Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	One byte for each sensor Range between 0 and 5.
0 = Good Crystal and active. 1 = Failed Crystal and active. 2 = Invalid Measurement on Crystal and active. 3 = Good Crystal and inactive. 4 = Failed Crystal and inactive. 5 = Invalid Measurement on Crystal and inactive.					
11 (0x0b)	Timer Status	Timer Number <Integer> 1 - 20	1	<Byte>	Response: 0 = Timer inactive 1 = Timer active
12 (0x0c)	Timer Value	Timer Number <Integer> 1 - 20	4	<Integer>	Response is in tenths of seconds. Max Time = 99:59:59.0 (3599990 tenths of seconds)

Table 10-12 Status general commands (continued)

SG Comm and ID	Description	Option	Number of bytes in the response	Data Returned	Notes
13 (0x0d)	Counter Value	Counter Number <Integer> 1 - 20	4	<Integer>	
14 (0x0e)	Thickness Sum	Equation number <Integer> 0 - 3	4 or 12	<Float> or <Float><Float> <Float>	0 = All thickness equations 1 - 3 = the number of the equation to return.
15 (0x0f)	Get date		12	<Integer><Integer> <Integer>	Integers for month, day, year or day, month year, depending on date format general parameter.
16 (0x10)	Get time		12	<Integer><Integer> <Integer>	Integers for the hour, minute and the seconds.
17 (0x11)	System Configuration (What boards are present.)		2	<Byte><Byte>	Bit
	0x0001 = Measurement Bd 1 0x0002 = Measurement Bd 2 0x0004 = Measurement Bd 3, 0x0008 = Measurement Bd 4, 0x0010 = I/O Board 1, 0x0020 = I/O Board 2, 0x0040 = I/O Board 3, 0x0080 = Optional DAC Board, 0x0100 = Temperature Control Board 1, 0x0200 = Temperature Control Board 2, 0x0400 = Ethernet Board, 0x0800 = {Reserved}, 0x1000 = {Reserved}, 0x2000 = {Reserved}, 0x4000 = {Reserved}, 0x8000 = {Reserved}				
18 (0x12)	Number of Layers in Process	Process Number <Integer> 1-50	4	<Integer>	

10.4.31 Status Layer

Command = SL <Command ID><Layer>

Command ID = <Byte> See Description in Table 10-13.

Layer = <Byte>Layer number (0 – 200 or 255 (0xFF))

- ♦ Layer = 0 will return the status of six layers. The response will include all active layers. If there is less than six active layers the data for the inactive layers will be filled with zeros.
- ♦ Layer = 255 (0xFF) will return the status for the active layer, if there is only one. If more than one layer is active, an error will be returned.
- ♦ Layer = 1-200 will return the status for the requested active layer. If the requested layer is inactive, an error will be returned.

Response = See Data Returned in Table 10-13.

Table 10-13 Status layer

SL Command ID	Description	Number of bytes in the response	Data Returned	Notes
0 (0x00)	N/A			
1 (0x01)	Filtered Rate	4 or 24	<Float>	Å/S
2 (0x02)	Displayed Rate	4 or 24	<Float>	Å/S Averaged over one second
3 (0x03)	Source Power Output	4 or 24	<Float>	%
4 (0x04)	Thickness	4 or 24	<Float>	KÅ
5 (0x05)	State	1 or 6	<Byte>	See encodes in section 3.5 on page 3-32
6 (0x06)	State Time	4 or 24	<Integer>	Seconds in the current state
7 (0x07)	Active Sensors	1 or 6	<Byte>	Active Sensors Byte is an eight-bit word where each bit represents a sensor
Any bit set indicates a sensor is active for the requested layer. Bit 0 = Sensor 1, bit 1 = Sensor 2, thru bit 7 = Sensor 8.				

Table 10-13 Status layer (continued)

SL Command ID	Description	Number of bytes in the response	Data Returned	Notes
8 (0x08)	Power Source Number	1 or 6	<Byte>	Source number for the requested layer.
9 (0x09)	Accumulated Layer Time	4 or 24	<Integer>	Seconds since "Ready"
10 (0x0a)	Deposit Average Rate	4 or 24	<Float>	KÅ Based on Averaging Time parameter. Only available when in a control state.
11 (0x0b)	Deposit Average Power	4 or 24	<Float>	% Based on Averaging Time parameter. Only available when in a control state.
12 (0x0c)	Raw Rate	4 or 24	<Float>	Å/S
13 (0x0d)	One Minute Averages for Rate and Power	8 or 48	<Float><Float>	Returns a 'No Data Error' if not enough data to do a one minute average of the rate or the power
14 (0x0e)	Rate Deviation / power output trend	Varies with # of data points	<Integer><Float>... <Float>	Number of bytes in the response. Average values from the operate screen graph. Format of each data point.
15 (0x0f)	State before Suspend	1 or 6	<Byte>	See encodes in section 3.5 on page 3-32 . If not currently in Suspend, will return "No Data Error"
16 (0x10)	Data Log	76 or 456	Multiple pieces of information	See section 3.6.10 on page 3-43 for order of data.
17 (0x11)	Data Log with Xtal History	3,148 or 18,888	<Data Log + Crystal data for 12 crystals in 8 sensors>.	See section 3.6.10 on page 3-43 for order of data. Length of response = 76 bytes Data Log + 3072 bytes Xtal History Xtal History = 32 bytes per crystal, 12 crystals in 8 sensors = 33*12*8=3072 bytes

10.4.32 Status Sensor

Command = SS <Command ID><Sensor>

Command ID = <Byte> See Description in Table 10-14.

Sensor = <Byte> Sensor number (0 - 8)

If the sensor number is zero the response will give the value for all eight sensors.

Response = See Data Returned in Table 10-14.

Table 10-14 Status sensor

SS Command ID	Description	Number of bytes in the response	Data Returned	Notes																																	
0 (0x00)	Crystal Life	1 or 8	<Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	One byte for each sensor. Range will be 0 - 100																																	
1 (0x01)	Crystals Remaining	1 or 8	<Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	One byte for each sensor. Range between 0 and 12. Number of good crystals on a CrystalTwo, Crystal6 or Crystal12 Sensor. Returns either a 0 (current crystal failed) or a 1 (current crystal good) for a Singlesensor. The command is not intended to be used for Generic sensor - returns NO_DATA .																																	
2 (0x02)	Crystal Position	1 or 8	<Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	One byte for each sensor. Range between 1 and 12. The current crystal position on a CrystalTwo, Crystal6 or Crystal12.																																	
3 (0x03)	Sensor Status	1 or 8	<Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte>	One byte for each sensor. <table border="0"> <tr> <td>Bit1</td> <td>Bit 0</td> <td></td> </tr> <tr> <td>0</td> <td>0</td> <td>Good Crystal</td> </tr> <tr> <td>0</td> <td>1</td> <td>Failed Crystal</td> </tr> <tr> <td>1</td> <td>0</td> <td>Invalid Measurement</td> </tr> <tr> <td colspan="3">on Crystal</td> </tr> <tr> <td>1</td> <td>1</td> <td>Undefined</td> </tr> <tr> <td>Bit 7</td> <td>Bit 6</td> <td></td> </tr> <tr> <td>0</td> <td>0</td> <td>Auto-Z-Ratio</td> </tr> <tr> <td>0</td> <td>1</td> <td>Sensor Z-Ratio</td> </tr> <tr> <td>1</td> <td>0</td> <td>Material Z-Ratio</td> </tr> <tr> <td>1</td> <td>1</td> <td>Undefined</td> </tr> </table>	Bit1	Bit 0		0	0	Good Crystal	0	1	Failed Crystal	1	0	Invalid Measurement	on Crystal			1	1	Undefined	Bit 7	Bit 6		0	0	Auto-Z-Ratio	0	1	Sensor Z-Ratio	1	0	Material Z-Ratio	1	1	Undefined
Bit1	Bit 0																																				
0	0	Good Crystal																																			
0	1	Failed Crystal																																			
1	0	Invalid Measurement																																			
on Crystal																																					
1	1	Undefined																																			
Bit 7	Bit 6																																				
0	0	Auto-Z-Ratio																																			
0	1	Sensor Z-Ratio																																			
1	0	Material Z-Ratio																																			
1	1	Undefined																																			

Table 10-14 Status sensor (continued)

SS Command ID	Description	Number of bytes in the response	Data Returned	Notes
4 (0x04)	Fundamental Frequency	8 or 64	<Long> or <Long><Long><Long> <Long><Long><Long> <Long><Long>	One long integer for each sensor. Unconverted. To convert to Hz, multiply by 0.000873114913702011
5 (0x05)	Fundamental Activity	4 or 32	<Integer> or <Integer><Integer> <Integer><Integer> <Integer><Integer> <Integer>Integer	One integer for each sensor Range 0 - 999
6 (0x06)	Current Z-Ratio	4 or 32	<Float> or <Float><Float><Float> <Float><Float><Float> <Float><Float>	Z-Ratio currently in use.
7 (0x07)	Anharmonic Frequency	8 or 64	<Long> or <Long><Long><Long> <Long><Long><Long> <Long><Long>	One long integer for each sensor. Unconverted, to convert to Hz, multiply by 0.000873114913702011
8 (0x08)	Anharmonic Activity	4 or 32	<Integer> or <Integer><Integer> <Integer><Integer> <Integer><Integer> <Integer>Integer	One Integer for each sensor Range 0 - 999
9 (0x09)	New crystal Frequency	16 or 128	<Long><Long> or < Long>x16	Returns the Fundamental and Anharmonic "NEW" crystal frequencies
10 (0x1a)	LCQ value	4 or 32	<Float> or <Float><Float><Float> <Float><Float><Float> <Float><Float>	Returns the LCQ running value (for factory diagnostic use only)

Table 10-14 Status sensor (continued)

SS Command ID	Description	Number of bytes in the response	Data Returned	Notes
11 (0x0b)	N/A			
12 (0x0c)	Sensor Thickness	4 or 32	<Float> or <Float><Float><Float> <Float><Float><Float> <Float><Float>	kÅ Returns sensor thickness
13 (0x0d)	Sensor Raw Rate	4 or 32	<Float> or <Float><Float><Float> <Float><Float><Float> <Float><Float>	Å/s Returns sensor raw rate. If sensor is not in use, response will be 0 Å/s

10.4.33 Remote General Action

Command = RG <Command ID> (<Action Value>)

Command ID = <Byte> See Table 10-15.

Action Value = <Byte>... <Byte> | <Integer>...<Integer>|<Float>...<Float>

See Table 10-15 for commands that require an action value.

Response = None (Just header and trailer)

Table 10-15 Remote general

RG Command ID	Meaning	Action Value	Notes
0 (0x00)	Start		Duplicates the equivalent front panel action
1 (0x01)	Stop		Duplicates the equivalent front panel action
2 (0x02)	Reset		Duplicates the equivalent front panel action
3 (0x03)	Remote Lock On		No parameters can be updated from the front panel "R Lock" displayed
4 (0x04)	Remote Lock Off		Cancel RG 3 command
5 (0x05)	Set Logic Statement <Statement Number> to True	<Byte>	Range is 1-100. Only does something if logic statement event "Computer Control" set. Otherwise, ignored.
6 (0x06)	Clear Logic Statement <Statement Number> to False.	<Byte>	Range is 1-100. Only does something if logic statement event "Computer Control" set. Otherwise, ignored.
7 (0x07)	Crystal Fail Inhibit On	<Byte>	Range is 0-8 (0 = All) "Crystal Fail" output always set to FALSE, even during crystal fail
8 (0x08)	Crystal Fail Inhibit Off	<Byte>	Range is 0-8 (0 = All) "Crystal Fail" output has normal meaning
9 (0x09)	Set date (Month, Day, Year) or (Day, Month, Year) Depending on General parameter 17 (Date Format).	<Integer> <Integer> <Integer>	Range as follows:Month = 1 to 12 Day = 1 to 31 Year = 2000 to 2099
10 (0x0a)	Set time (Hour, Minute, Second)	<Integer> <Integer> <Integer>	Range as follows Hour = 0 to 23 Minute = 0 to 59 Second = 0 to 59

Table 10-15 Remote general (continued)

RG Command ID	Meaning	Action Value	Notes
11 (0x0b)	Zero Counter <Counter>	<Byte>	Counter Range is 0-20 0 = All
12 (0x0c)	Zero Timer <Timer>	<Byte>	Timer Range is 0-20 0 = All
13 (0x0d)	Start Timer <Timer>	<Byte>	Timer Range is 1-20
14 (0x0e)	Cancel Timer <Timer>	<Byte>	Timer Range is 0-20 0 = All
15 (0x0f)	Clock Hold On <Material>	<Byte>	Stops timer in Pre-Deposit or Post-Deposit. Keeps in current state at current power setting. Material Range 0-32 (0 = all materials)
16 (0x10)	Clock Hold Off <Material>	<Byte>	Restarts timer in Pre-Deposit or Post-Deposit Material Range 0-32 (0 = all materials)
17 (0x11)	User message on <Message #>	<Byte>	Message Range is 1-10
18 (0x12)	User message off <Message #>	<Byte>	Message Range is 1-10
19 (0x13)	Soak Hold 1 on <Material>	<Byte>	Material Range is 0-32 (0 = all materials)
20 (0x14)	Soak Hold 1 off <Material>	<Byte>	Material Range is 0-32 (0 = all materials)
21 (0x15)	Soak Hold 2 on <Material>	<Byte>	Material Range is 0-32 (0 = all materials)
22 (0x16)	Soak Hold 2 off <Material>	<Byte>	Material Range is 0-32 (0 = all materials)
23 (0x17)	Switch Sensor<Sensor #> to <Crystal #>	<Byte><Byte>	Sensor Range = 1 - 8 Crystal Range = 0 to maximum allowed crystals for the requested sensor. If Crystal # = 0, will switch to the "next" crystal. If the sensor is not used in a layer currently running, the next crystal will be the next one in the sequence. If the sensor is used in a layer that is running, the next crystal will be the next one from the XL Position parameters sequence. If a sensor is used in a layer that is running, the value of "Crystal #" must be zero, otherwise, an error will occur.

Table 10-15 Remote general (continued)

RG Command ID	Meaning	Action Value	Notes
24 (0x18)	Clear Failed Crystals X	<Byte>	Clears all failed crystals except the current crystal for the requested sensor. X = Sensor
25 (0x19)			Reserved for future use.
26 (0x1a)	Rotate head X	<Byte>	If the requested sensor is a multi crystal sensor and IC6 is in Ready, Stop or all active layers are in Idle or Suspend, the sensor head will rotate. X = Sensor
27 (0x1b)	Default all Parameters		Sets all parameters except the communication parameters to default values.
28 (0x1c)	Default Process <Process#>	<Byte>	# Range is 1 to 50 Removes all layers of the specified process.
29 (0x1d)	Soak Hold Pre Con on <Material >	<Byte>	Material Range is 0 - 32 (0 = All Materials)
30 (0x1e)	Soak Hold Pre Con off <Material >	<Byte>	
31 (0x1f)	Start Inhibit On		Disallows a Start command to be executed.
32 (0x20)	Start Inhibit Off		Allows a Start command to be executed.
33 (0x21)	RateWatcher Sampling Inhibit On <Material >	<Byte>	Will immediately cause the Deposit state to leave sampling and not return until turned off.
34 (0x22)	RateWatcher Sampling Inhibit Off <Material >	<Byte>	Allows the Deposit state to go into the RateWatcher algorithm.
35 (0x23)	RateWatcher Sample Initiate On <Material >	<Byte>	Allows the Deposit state to enter RateWatcher sampling

Table 10-15 Remote general (continued)

RG Command ID	Meaning	Action Value	Notes
36 (0x24)	RateWatcher Sample Initiate Off <Material >	<Byte>	Turns RateWatcher sampling off.
37 (0x25)	Clear Q and S counts for sensor X	<Byte>	Clear Q and S counts for specified sensor X
38 (0x26)	Name Material <Material><Library Entry>	<Byte><Byte>	Give material number <Material> (1-32) the name corresponding to material entry <Library Entry> (0-254). Library entries range from 0 (Ag) to 254 (ZrO ₂), with numbers corresponding to the alphabetical listing in the library. The density and Z-Ratio will be changed accordingly.

10.4.34 Remote Layer Action

Command = RL <Command ID> <Layer Number> (<Action Value>)

Command ID = <Byte>.

Layer Number = <Byte> 0 - 200

If Zero is given as the layer number then the remote action will be for the active layer. If more than one layer an error will be returned.

Action Value = <Byte> | <Integer> | <Float>

See Table 10-16 for commands that require an action value.

Response = None (Just header and trailer)

Table 10-16 Remote layer

RL Command ID	Meaning	Action Value	Notes
0 (0x00)	Suspend		Cannot be done from Idle
1 (0x01)	Zero Thickness		Cannot be done from Suspend
2 (0x02)	Start Deposit		Will always zero thickness on entry. This cannot be done from Ready, Idle, Stop, Suspend, Crystal Switching or Crucible Switch. When there is no good crystal, this command will go to "Time Power" if the previous state was Non-Deposit Hold, otherwise, is not allowed
3 (0x03)	Go to Non-Deposit Control		This cannot be done from Ready, Stop, Suspend or Crucible Switch. When there is no good crystal, this command will go to Non-Deposit Hold if the previous state was Time Power, otherwise, is not allowed
4 (0x04)	Go to Post-Deposit (Feed Ramp)		Cannot be done if in Crucible Switch
5 (0x05)	Continue Deposit		Go to Deposit, but don't zero thickness. This cannot be done from Ready, Idle, Stop, Suspend, Crystal Switching or Crucible Switch. When there is no good crystal, this command will go to Time Power if the previous state was Non-Deposit Hold, otherwise, is not allowed
6 (0x06)	Go to Manual.		(Source shutter does not change position) Cannot be done if in STOP, Suspend or Crucible Switch, or there is not a good crystal.
7 (0x07)	Set Power Level	<Float>	Range is 0-99.99. Only allowed if in Manual, Time Power, or Non-Deposit Hold State. If the value is greater than the Max Power or less than the Min Power, a value error is returned.

Table 10-16 Remote layer (continued)

RL Command ID	Meaning	Action Value	Notes
8 (0x08)	Open Source shutter		Only allowed if in Manual
9 (0x09)	Close Source shutter		Only allowed if in Manual
10 (0x0a)	Set Averaged Rate	<Float>	Range is 0-999.9. Only in Time power or Non Deposit Hold - the estimated rate used.
11 (0x0b)	N/A		

10.4.35 IC6 Communications Examples

10.4.35.1 General Command Packet Format

<Length(low/high, 2 byte)><Message(command)><Checksum(1 byte Hex)>

10.4.35.2 General Response Packet Format

<Length(low/high, 2 byte)><CCB(1 byte, no errors returns 00)><Timer(1 byte binary)><Response Message (Command Response)><Checksum(1 byte Hex)>

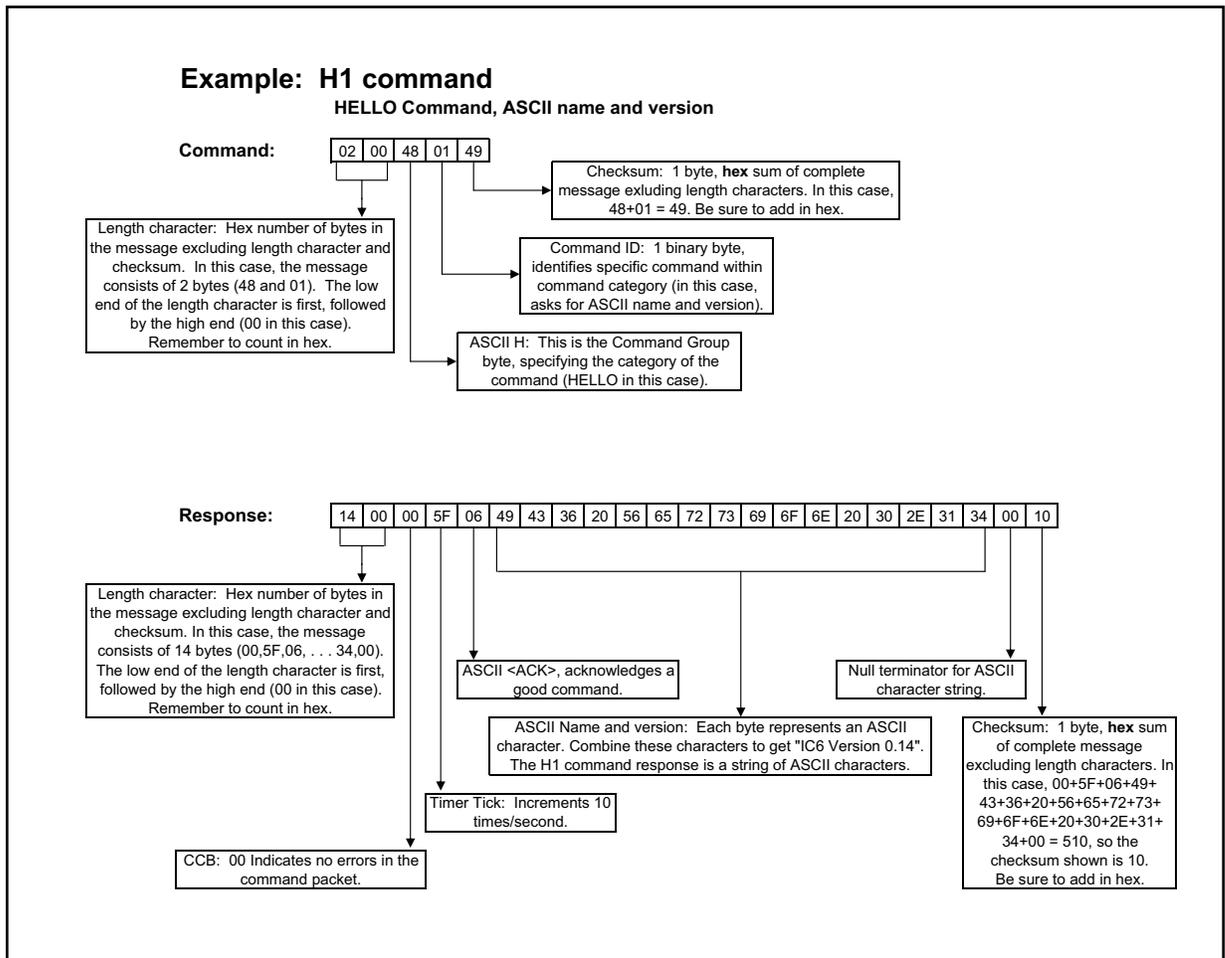
10.4.35.3 HELLO Command, ASCII Name and Version

Command Format: H <Command ID>

H1

Command H1: 0200480149

Response: 140005F064943362056657273696F6E20302E31340010



10.4.35.4 Query General Parameter

Active Process (1)
Command Format: QG <Command ID>
QG1
Command QG1 = 030051470199
Response: 07000019060200000021

10.4.35.5 Update General Parameter

Active Process (1), Make Process 2 active
Command Format: UG <Command ID> <Parameter Value>
UG1 2
Command UG1 2: 0700554701020000009F
Response: 030000C506CB

10.4.35.6 Query Material Parameter

Z-Ratio (2), Material 1
Command Format: QM <Command ID> <Material Number>
QM2 1
Command QM2 1: 0400514D0201A1
Response: 070000F10648E1BA3E18

10.4.35.7 Update Material Parameter

Control Loop (4), Material 1, PID (2)
Command Format: UM <Command ID> <Material Number> <Parameter Value>
UM4 1 2
Command UM4 1 2: 0800554D040102000000A9
Response: 0300000D0613

10.4.35.8 Query Sensor Parameter

Shutter Output (1), Sensor 1
Command Format: QS <Command ID> <Sensor Number>
QS1 1
Command QS1 1: 040051530101A6
Response: 0700008706000000008D

10.4.35.9 Update Sensor Parameter

Sensor Type (2), Sensor 1, CrystalTwo (1)

Command Format: US <Command ID> <Sensor Number> <Parameter Value>

US2 1 1

Command US2 1: 08005553020101000000AC

Response: 0300002F0635

10.4.35.10 Query Source Parameter

Shutter Output (2), Source 1

Command Format: QC <Command ID> <Source Number>

QC2 1

Command QC2 1: 04005143020197

Response: 0700003F060000000045

10.4.35.11 Update Source Parameter

Number of crucibles (3), Source 1, 4 crucibles (1)

Command Format: UC <Command ID> <Source Number> <Parameter Value>

UC3 1 1

Command UC3 1 1: 080055430301010000009D

Response: 03000054065A

10.4.35.12 Query Process Layer Parameter

Process 1, Layer 1

Command Format: QP <Command ID> <Process Number> <Layer Number>

QP1 1 1

Command QP1 1 1: 05005150010101A4

Response: 0700002A060300000033

10.4.35.13 Update Process Layer Parameter

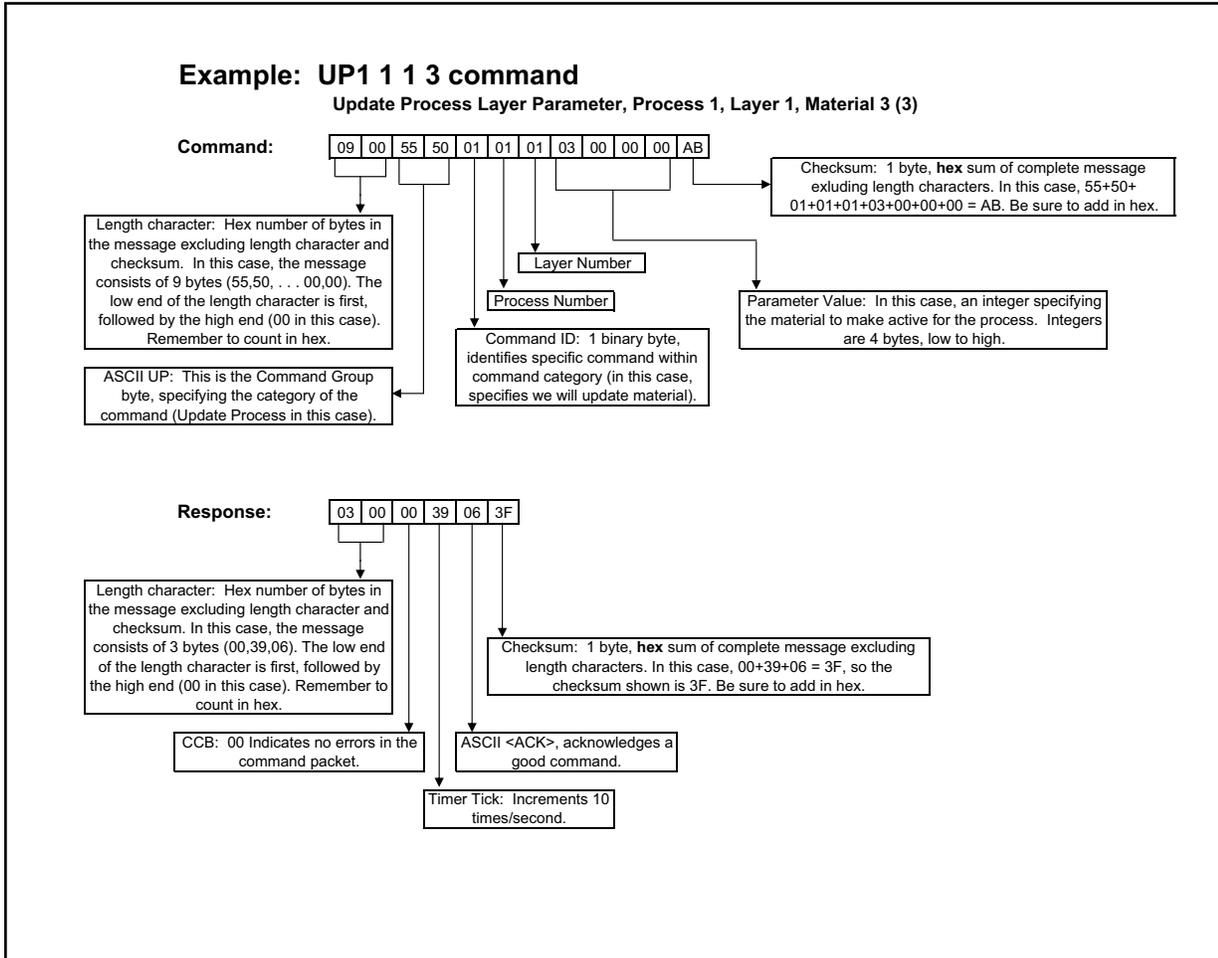
Process 1, Layer 1, Material 3 (3)

Command Format: UP <Command ID><Process Number><Layer Number><Parameter Value>

UP1 1 1 3

Command UP1 1 1 3: 0900555001010103000000AB

Response: 0300039063F



10.4.35.14 Query Material Name

Material 1

Command Format: QN <Material Number>

QN 1

Command QN 1: 0300514E01A0

Response: 0A0000470653494C5645520022

10.4.35.15 Update Material Name

Material 1, "SILVER"

Command Format: UN <Material Number> <Material Name>

UN 1 SILVER

Command UN 1 SILVER: 0A00554E0153494C5645520079

Response: 030000E806EE

10.4.35.16 Query Process Name

Process 1

Command Format: QK <Process Number>

QK 1

Command QK 1: 0300514B019D

Response: 080000C906474F4C4400F5

10.4.35.17 Update Process Name

Process 1, "GOLD"

Command Format: UK <Process Number> <Process Name>

UK 1 GOLD

Command UK 1 GOLD: 0800554B01474F4C4400C7

Response: 0300007D0683

10.4.35.18 Query Input Name

Input 1

Command Format: QI <Input Number>

QI 1

Command QI 1: 03005149019B

Response: 060000BB0650310042

10.4.35.19 Update Input Name

Input 1, "P1"

Command Format: UI <Input Number> <Input Name>

UI 1 P1

Command: 060055490150310020

Response: 030000A306A9

10.4.35.20 Query Output Name

Output 1

Command Format: QO <Output Number>

QO 1

Command QO 1: 0300514F01A1

Response: 0B0000E206534855545445520017

10.4.35.21 Update Output Name

Output 1, "SHUTTER"

Command Format: UO <Output Number> <Output Name>

UO 1 SHUTTER

Command UO 1: 0B00554F015348555454455200D4

Response: 030000E306E9

10.4.35.22 Query Output Type

Output 1

Command Format: QT <Output Number>

QT 1

Command QT 1: 0300515401A6

Response: 040000BF0600C5

10.4.35.23 Update Output Type

Output 1, Normally Closed (1)

Command Format: UT <Output Number> <Output Type>

UT 1 1

Command UT 1 1: 040055540101AB

Response: 030000FA0600

10.4.35.24 Query User Message

Message 1

Command Format: QV <User Message Number>

QV 1

Command QV 1: 0300515601A8

Response: 0A0000C80648454C4C4F210063

10.4.35.25 Update User Message

Message 1, "HELLO!"

Command Format: UV <User Message Number> <User Message Name>

UV 1 HELLO!

Command UV 1 HELLO!: 0A0055560148454C4C4F210041

Response: 030000CD06D3

10.4.35.26 Query Logic Statement

Statement 1

Command Format: QL <Statement Number>

QL 1

Command QL 1: 0300514C019E

Response: 090000B00605410120450365

10.4.35.27 Update Logic Statement

Statement 1, "IF External Input 1 THEN Start"

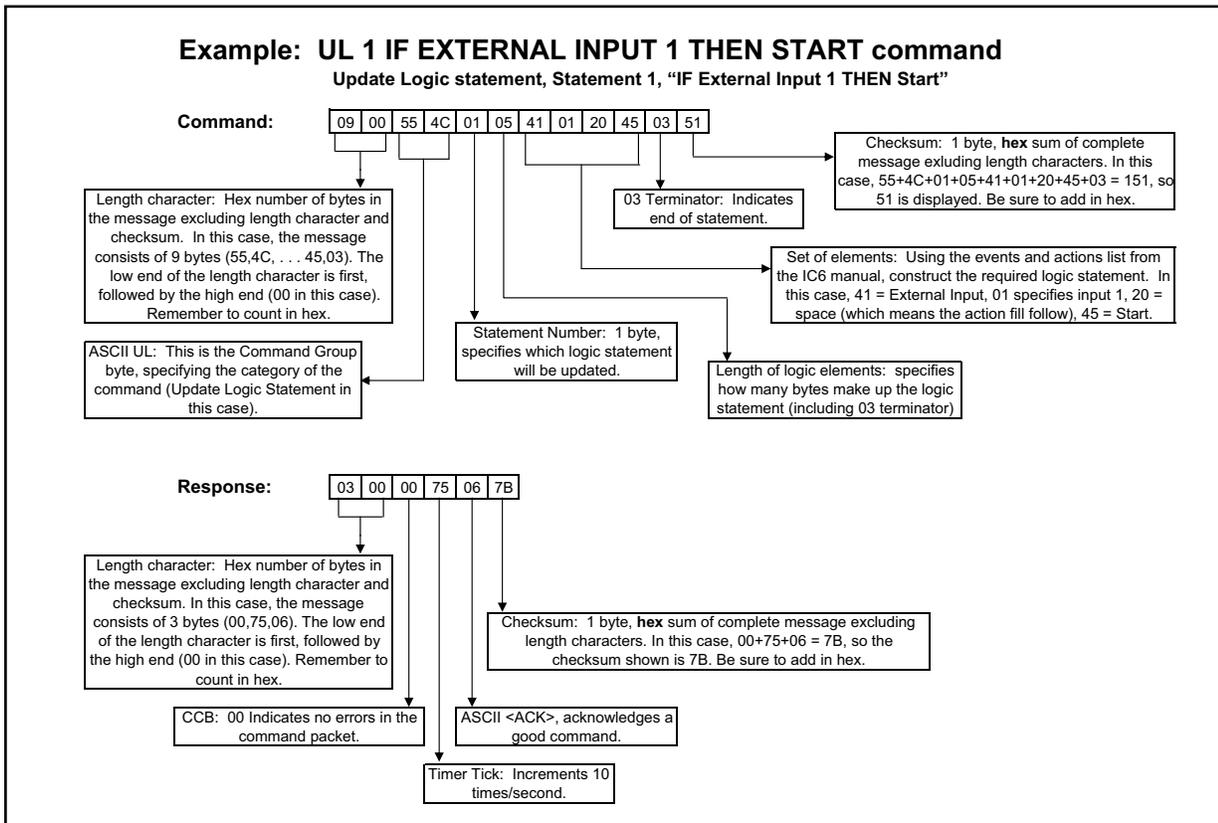
Command Format: UL <Statement Number> <Length of logic elements> <set of elements>

UL 1 IF EXTERNAL INPUT 1 THEN START

Command UL 1 IF EXTERNAL INPUT 1 THEN START:

0900554C0105410120450351

Response: 03000075067B



10.4.35.28 Status General

Active Process (1)

Command Format: SG <Command ID> <Option>

SG1

Command SG1: 03005347019B

Response: 0700009D0602000000A5

10.4.35.29 Status Layer

Thickness (4), Layer 1

Command Format: SL <Command ID> <Layer>

SL4 1

Command SL4 1: 0400534C0401A4

Response: 070000980689418C4236

10.4.35.30 Status Sensor

Crystal Life (0), Sensor 1

Command Format: SS <Command ID> <Sensor>

SS0 1

Command SS0 1: 040053530001A7

Response: 040000C10600C7

10.4.35.31 Remote General Action

Start (0)

Command Format: RG <Command ID> (<Action Value>)

RG0

Command RG0: 030052470099

Response: 030000D706DD

10.4.35.32 Remote Layer Action

Open Source Shutter (8)

Command Format: RL <Command ID> <Layer Number> (<Action Value>)

RL8

Command RL8: 0400524C0801A7

Response: 0300004B0651

10.4.35.33 Example for Interpreting Float Responses

Command used: SS 6 1, Status Sensor, Z-Ratio, Sensor 1

NOTE: Data is shown in Hex format for convenience. Actual data transmission is in binary. Commas have been inserted for clarity.

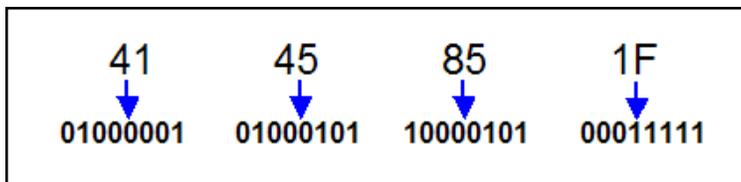
Sent to IC6: 04,00,53,53,06,01,AD

Response from IC6: 07,00,00,AA,06,1F,85,45,41,DA

Float portion of response from IC6 (low to high): 1F,85,45,41

Reverse the float response, so it is now high to low: 41,45,85,1F

Convert each byte to its binary equivalent (you can do this using a scientific calculator) to produce the 32 bit float response:



Rearrange the 32 bits making up the float response into packets of 1, 8, and 23 bits, representing the Sign, Exponent, and Mantissa, respectively:

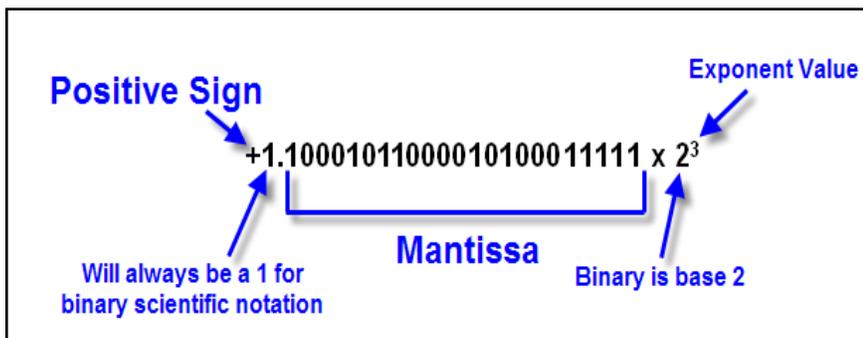


Rewrite the current value in binary scientific notation.

The Sign "0" means that the sign of the decimal number is positive.

Using a scientific calculator, convert the Exponent value to decimal. In this case, the decimal value will be 130. Now, subtract 127 from 130 and you get 3, the actual exponent value (You must always subtract 127 from the exponent decimal value).

Insert the Mantissa to the right of the decimal point.



Rewrite each individual "1" in the value above in exponent form:

$$1.10001011000010100011111 \times 2^3$$

$$= (2^0 + 2^{-1} + 2^{-5} + 2^{-7} + 2^{-8} + 2^{-13} + 2^{-15} + 2^{-19} + 2^{-20} + 2^{-21} + 2^{-22} + 2^{-23}) \times 2^3$$

Distribute the 2^3 (Add the exponents, so for example, $2^{-2} \times 2^3 = 2^1$ etc) :

$$= 2^3 + 2^2 + 2^{-2} + 2^{-4} + 2^{-5} + 2^{-10} + 2^{-12} + 2^{-16} + 2^{-17} + 2^{-18} + 2^{-19} + 2^{-20}$$

Expand the exponents in their decimal form:

$$= 8 + 4 + 0.25 + 0.0625 + 0.03125 + 0.0009765625$$

$$+ 0.000244140625 + 0.0000152587890625 + 0.00000762939453125$$

$$+ 0.000003814697265625 + 0.0000019073486328125$$

$$+ 0.00000095367431640625$$

Compute the sum and round appropriately.

In this case, this is the Z-Ratio of sensor 1.

$$= 12.34500026702880859375$$

$$= 12.345$$

Chapter 11

Applications

11.1 Multiple Sensor Deposition Control

The conventional method of controlling thin film depositions is to use one crystal sensor for each material source. In addition to this conventional method, IC6 can make use of multiple sensors for control of each material source.

To use multiple sensor deposition control, elect the appropriate Sensor Option for as many sensors as desired (up to 8). For conventional deposition control (one sensor per material source) select one sensor.

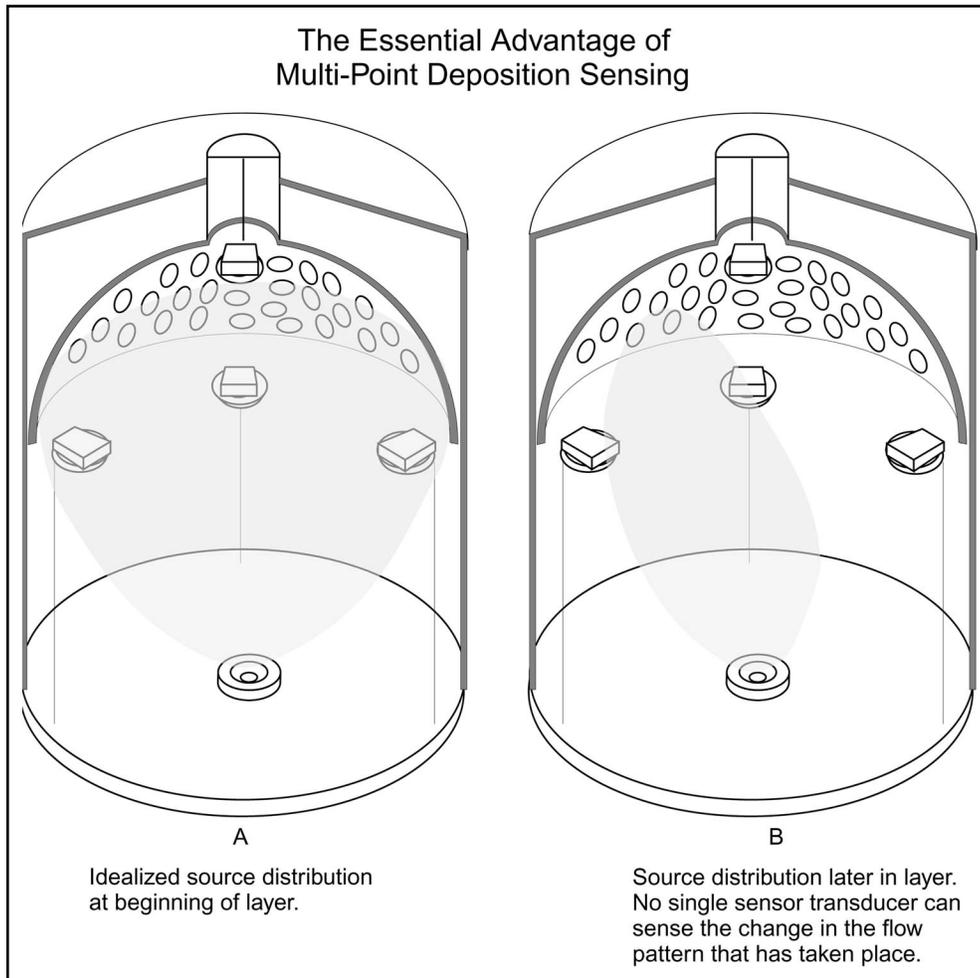
The multiple sensor deposition control feature is designed to monitor a source's flux distribution using many sensors. Multiple point sensing improves thickness reproducibility by controlling an aggregate (averaged) deposition rate. Two important elements of a deposition process contribute to layer-to-layer thickness variances and cannot be addressed by a single point controller. First, a deposition source never has the idealized (cosine) flux distribution. Second, the flux distribution is dynamic, changing as the deposition progresses.

IC6, when using more than one sensor for each material, calculates an aggregate rate and uses it for rate control and thickness termination. This aggregate rate is comprised of rate information from up to 8 sensors, each sensor having its own weighting and tooling factors.

As the source distribution changes, any individual sensor may detect more (or less) of the source flux. However, the aggregate rate is held constant. Each substrate, contained in a rotating planetary substrate holder, is then exposed to the constant aggregate rate, eliminating thickness variations due to a change in the source's flux distribution.

This concept is illustrated in [Figure 11-1](#), which also shows the preferred placement of the sensors relative to the deposition source and substrates.

Figure 11-1 The essential advantage of multi-point deposition sensing



11.1.1 IC6 Parameters and Corrections for Multiple Sensor Operation

Figure 11-2 Multi-point display

0.00 Å/s		-0.000 kÅ		0.00%		READY			
Overview	Material Number	3			Quality Percent	0 %			
	Multipoint	Yes			Quality Counts	0			
Source	Aggregate Multiply	No			Stability Single	0 Hz			
	Master Tooling	100.0 %			Stability Total	0 Hz			
Sensor									
Pre/Post	Sensor	1	2	3	4	5	6	7	8
	Sensor Thickness	0.450	0.448	0.448	0.448				
Deposit	Failure Action	STOP	PostDp	Suspnd	TimePw	Unused	Unused	Unused	Unused
	Failure Trigger	Last	OnFail	Last	Last	OnFail	OnFail	OnFail	OnFail
Lib A-Hf	Weight	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Tooling	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lib Hf-Sc	Cal Thickness	0.100	0.100	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL	UNCAL
	CrystalTwo Tooling	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lib Sc-Z	Xtal Position First	0	0	0	0	0	0	0	0
	Xtal Position Last	0	0	0	0	0	0	0	0
Au									
04/12/2010 13:00									

AGGREGATE RATE

The Aggregate Rate calculation is based on:

- ◆ The rate information acquired by each sensor in use.
- ◆ A weighting factor that reflects the relative importance of each sensor's information.
- ◆ A sensor tooling factor that corrects for any relative difference in flux distribution reaching the sensors.

The aggregate rate is calculated from a combination of the above information into a weighted average.

If a sensor fails during deposition, a sudden change in the aggregate rate may occur due to this sensor's rate information being lost. An aggregate multiplier is calculated to correct for this sudden change. The aggregate multiplier is based on the average deposition prior to sensor failure. An average aggregate rate is calculated both with and without the newly failed sensor. The ratio of the two is used as a multiplier for the rest of this layer's deposition. This removes any sudden jump in the aggregate rate at the time of sensor failure. After this layer finishes, the aggregate multiplier is removed.

AGGREGATE MULTIPLIER

The parameter AGGREGATE MULTIPLY (Yes/No) determines whether an aggregate multiplier is calculated for this crystal's rate information if a crystal fails occurs during deposition. This parameter appears on the Material/Sensor display if Multipoint is set to Yes. This multiplier is used only during the layer in which the crystal failure occurs. After this layer is finished, the multiplier is cleared. Default is NO.

(SENSOR) WEIGHT 1.0 to 400.0 %

The Sensor Weight parameter is used to gauge the relative importance of an individual sensor's is measured rate in calculating the weighted average, "aggregate" rate. See see page 5-9. Default is 100%.

**(SENSOR) FAILURE ACTION
and FAILURE TRIGGER See see page 5-9**

TOOLING: MASTER & SENSOR

The tooling factor is comprised of two parts. The MASTER TOOLING parameter located in the upper block of the Material/Sensor Set-Up display is used to scale the aggregate rate and thickness to the substrate. When Multipoint is set to Yes, additional parameters, including the SENSOR TOOLING parameter appear in the Sensor Setup display area as shown in Figure 11-2 on page 11-3.

MASTER TOOLING 10.0 to 400.0 %

The MASTER TOOLING is used as a global tooling factor. This parameter is used to affect all the sensors' tooling together and calibrate the aggregate rate and thickness to the thickness measured on the substrate. Default is 100%.

(SENSOR) TOOLING 10.0 to 400.0 %

SENSOR TOOLING is used to account for the geometric tooling factor of each sensor. The default value is 100%. The calibration procedure for the MASTER TOOLING can also be applied to the SENSOR TOOLING parameter. Alternatively each SENSORS TOOLING factor can be adjusted relative to a particular sensor. See see page 5-10.

11.2 Trend Analysis

Along with multiple sensor monitoring and control of the deposition process, IC6 allows rate and thickness information from individual quartz crystal sensors to be output to the Digital-to-Analog (DAC) outputs. This enables mapping of an individual sensor's information, which is useful in monitoring the change in source flux distribution during the deposition process.

11.2.1 IC6 Parameters Associated with the Trend Analysis Feature

RECORDER OUTPUT 0 to 12

This parameter designates which of the DAC outputs is to be used as a recorder output. 0 indicates there is not a DAC identified with this particular material. Values 1 through 6 correspond to the six DAC BNC outputs on the back of IC6 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card.

SENSOR RECORDER FUNCTION . Rate/Thick/RateDev

This parameter determines the function of the Sensor's recorder output. Default is Rate. Note: Rate Filter Time has no effect.

RECORDER RANGE 0 to 99999

The full scale range value selected corresponds to 10 V at the DAC output. Default value is 100.

NOTE: A recorder output cannot be associated with a DAC that is configured as a Source output. An error message will be displayed if this is attempted.

11.3 IC6 Cygnus Emulation

IC6 has features that allow it to meet the critical requirements of Cygnus applications in OLED manufacturing.

Cygnus emulation features:

- ◆ ability to run up to six layers simultaneously and show rate, thickness, power and state for each layer
- ◆ crosstalk correction between three co-deposited pairs of the six active layers
- ◆ suspend (stop) individual layers. Stop stops all active layers, suspend only acts on an individual layer
- ◆ maintain a layer in rate control but with the source/substrate shutter closed and without incrementing the thickness (NonDepCnt!)
- ◆ 12 DAC outputs providing flexibility to record rate, power, and thickness associated with sensors, sources and materials
- ◆ ability to transition from deposit to non-deposit control using remote communications or logic statements
- ◆ three thickness equations to use in logic statements to allow state sequencing based on the sum of thicknesses of up to six active layers
- ◆ rate averaging interval up to 30 seconds for highest noise reduction for very low rates
- ◆ rate setpoint can be entered to 0.001 Angstroms/second accuracy.

11.4 IC6 Four and Six Layer (Cygnus Emulation) Configuration

NOTE: The same method applies to any smaller set of simultaneous layers.

Instrument: IC6 with 3 measurement boards for six simultaneous layers or 2 measurement boards for four simultaneous layers and optional DAC Outputs card.

Figure 11-3 6 Layer display

1 Layer 1 00:19 Au_1 2.00 Å/s 8.80% 0.003 kÅ DEPOSIT <small>00:01</small>		2 Layer 2 00:18 Au_2 2.07 Å/s 11.95% 0.002 kÅ DEPOSIT <small>00:00</small>	
3 Layer 3 00:17 Material 3 13.33 Å/s 12.00% 0.239 kÅ DEPOSIT <small>00:00</small>		4 Layer 4 00:17 Material 4 10.00 Å/s 12.00% 0.179 kÅ DEPOSIT <small>00:00</small>	
5 Layer 5 00:17 Material 5 8.00 Å/s 10.00% 0.137 kÅ SOAK 2		6 Layer 6 00:17 Material 6 6.67 Å/s 12.00% 0.114 kÅ SOAK 2	
Thick Sum 1 0.378		Thick Sum 2 0.295 00:01	
Thick Sum 3 0.117		00:01	
Process 1 Active Process 1 00:19 Run 0011 06/23/2010 06:24 Test			Crystal Fail 2 3 4 5 6
Zero Thickness		Toggle Manual	
		Show Graph	

Figure 11-4 4 Layer display

1 Layer 1 00:17 Au_1 2.00 Å/s 12.00% 0.038 kÅ DEPOSIT <small>00:00</small>		2 Layer 2 00:17 Au_2 2.07 Å/s 12.00% 0.035 kÅ SOAK 2 <small>00:01</small>	
3 Layer 3 00:16 Material 3 13.33 Å/s 12.00% 0.213 kÅ SOAK 2 <small>00:02</small>		4 Layer 4 00:16 Material 4 10.00 Å/s 12.00% 0.160 kÅ SOAK 2 <small>00:02</small>	
Thick Sum 1 0.251		Thick Sum 2 0.195	
Thick Sum 3 0.038			
Process 1 Active Process 1 00:17 Run 0011 06/23/2010 06:56 Test			Crystal Fail 2 3 4
Zero Thickness		Toggle Manual	
		Show Graph	

11.4.1 Configure Sensors 1 to 6

(See section 4.1, *Sensor Setup Introduction*, on page 4-1.)

Assign a unique DAC output under the Recorder Settings Output parameter to each sensor if the associated layer's Rate, Thickness or Rate Deviation is to be monitored.

11.4.2 Configure Sources 1 to 6

(See section 4.2, *Source Setup Introduction*, on page 4-4.)

Assign a unique DAC output to each source if the associated layer's rate is to be controlled by the control loop's adjustment of the DAC output voltage level or if the Power output for each source will be monitored by an external device.

If the deposition rate from a particular source will not be controlled directly from that source's DAC Power output, assign DAC Output 0 to that source.

11.4.3 Configure Six Materials

(See Chapter 5, *Material Setup*.)

- 1 Assign a unique source (1 to 6) to each of the six materials.
- 2 Assign a unique Recorder Output (requires DAC Option board, and no DAC outputs to be assigned to sources) in each material source page.
- 3 Assign a unique sensor (1 to 6) to each of the six materials. Set the Failure Action for each sensor to Suspend, TimePw, PostDp or Stop. Stop causes all active layers to stop, suspend only stops the associated layer.
- 4 Enter Pre/Post parameters for each material.
- 5 Enter Deposit parameters for each material.
- 6 If the source/substrate shutter is to be closed while continuing to control the source power and the rate and thickness are to be frozen after reaching final thickness, set On Final Thickness to NonDepCntl.

This setting is required to enable individual layers to be toggled between Deposit (remote command RL2 #, Start Nw Deposit or RL5 #, Continue Deposit depending on whether Final Thickness had been reached) and Non-deposit Control (remote command RL3 #) without affecting other layers.

If the source/substrate shutter is to remain open while continuing to control the source power and the rate and thickness are to continue to increment after reaching final thickness, set On Final Thickness to Continue.

11.4.4 Configure the Process

(See Chapter 6, Process Setup.)

Assign a different one of the six unique materials defined in step 3 to layers 1 to 6. If crosstalk correction is required between two sequential layers, set the CoDep parameter for the first of those two layers to Yes and enter values for Sensor Cal Thickness on the material Sensor page or use the Cross Talk procedure in the Maintenance screen. A Start command starts both layers that are linked by co-deposit.

11.4.5 General Parameters

(See Chapter 7, General Parameters.)

- 1 Set Layer to Start to 1.
- 2 Set Source DAC Required to No.
- 3 Set Auto Start Next to No.
- 4 Set Max Concurrent Layer to 6
- 5 Set up Thickness Eq 1, 2 and 3 if desired to use in a logic statement.

11.4.6 Logic Functions Table

Table 11-1 Logic functions table

Cygnus # is Channel number	IC6
IF (Events) (see section 9.3 on page 9-7)	
Rise/Soak n #	Rise/Soak n ON Layer#, Material# or Source#
Ready #	Ready ON Layer#, Material# or Source#
Substr Shtr #	Deposit ON Layer#, Material# or Source#
Deposit #	Deposit ON Layer#, Material# or Source#
IF NOT (Event) #	No direct equivalent, negated events may not be used with the ON connector, but two linked statements may be close. For example, #1 If (Event) THEN (blank) #2 If NOT (Statement #1) THEN (Actions)

Table 11-1 Logic functions table (continued)

Cygnus # is Channel number	IC6
THEN (Actions) (see section 9.4 on page 9-16)	
Start #	Start (starts the first layer in Ready and all layers in Stop or Suspend) or Start Deposit Material# or Continue Deposit Material# (both only from NonDep Cntl)
Stop #,	Suspend Material#, (if not in Idle)
Stop All	Stop
Reset #	
Reset All	Reset

11.4.7 State Descriptions

(See section 3.5 on page 3-32.)

11.4.7.1 NonDepCntl State

Once a layer reaches its Final Thickness and enters the NonDepCntl state,

Remote command (see chapter 10 in IC6 manual)

RL 2 # zeroes the layer's thickness and reenters deposit,

RL 0 # suspends the layer.

RL 4 # places the layer in the programmed PostDeposit state.

Logic statements (see chapter 9) can also be used to zero thickness, continue deposit etc.

11.4.7.2 Suspend

Once a layer is suspended, it can only be restarted with a Start from the front panel, RG 0 command or a logic statement. All suspended layers will be started together.

11.4.7.3 Idle

Once a layer is in Idle, it can only be restarted after all active layers reach Idle and end-of-process.

Chapter 12

Maintenance and Calibration Procedures

12.1 Importance of Density, Tooling and Z-Ratio

The quartz crystal microbalance is capable of precisely measuring the mass added to the face of the oscillating quartz crystal sensor. IC6's knowledge of the density of this added material (specified in the density parameter in Material 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 12.2](#).

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 Material Set-Up. The tooling factor can be experimentally established by following the guidelines in [section 12.3 on page 12-2](#).

In IC6 if the Z-Ratio is not known it could be estimated from the procedures outlined in [section 12.4 on page 12-3](#), or, typically, the Auto-Z function can be used to determine the Z-Ratio.

12.2 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 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 equation [1]:

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

where:

D_1 = Initial density setting

T_x = Thickness reading on IC6

T_m = Measured thickness

- 7 A quick check of the calculated density may be made by programming IC6 with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that IC6'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 $T_x = T_m$.

12.3 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 shown in equation [2]:

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

where

T_m = Actual thickness at substrate holder

T_x = Thickness reading in IC6

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 calibrations.

12.4 Laboratory Determination of Z-Ratio

NOTE: On IC6, the Auto-Z function is available to automatically calculate the Z-Ratio. Especially when precise Z-Ratio values are significant, Auto-Z is recommended. See [section 16.1.6 on page 16-9](#) for a description of Auto-Z theory.

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:

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

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

where:

d_f = density (g/cm³) of deposited film

μ_f = shear modulus (dynes/cm²) of deposited film

d_q = density of quartz (crystal) (2.649 g/cm³)

μ_q = shear modulus of quartz (crystal) (3.32 x 10¹¹ dynes/cm²)

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 12.2 on page 12-1](#).
- 2** Install a new crystal and record its starting frequency F_{co} . It will be necessary to send the SS 4 n command to get this information (refer to [section 10.4.32, Status Sensor, on page 10-52](#)).
- 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 SS 4 n 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.

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

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)

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

- ♦ If the thickness of layer 1 is large compared to layer 2, use material 1 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.

12.5 AutoTuning

The AutoTune feature of IC6 is used to automatically characterize the response of a system. AutoTune examines the rate change response after executing step changes in power. Control parameters are calculated for algorithms designed for either slow-responding systems or fast-responding systems, with PID parameters determined for slow systems and a process gain coefficient determined for fast sources.

There are two subsets of AutoTune. A shortened version, called Quick Tune, calculates the required values from a fixed change in source power. The Complete Tune process first incorporates the Quick Tune procedure and then refines the parameter values by operating at a set of rates established about the desired operating point.

12.5.1 AutoTune Preparation Instructions

The following procedure should be followed to perform an AutoTune:

1 Determine the Correct System Setup

In order to ensure good AutoTune results and good source control, careful consideration should be given to eliminating system noise, thermal shorting, and any other factors that result in rate instabilities.

2 Verify that the Material Source parameters are correct and that at least one sensor has been assigned to the Material to be autotuned. Choose the source's voltage range that best suits the material and evaporation technique. Generally, low melting point materials can use smaller ranges, while high melting point materials may use the full range.

In a high gain system, where a small change in source control voltage results in a large change in rate, it may be necessary to reduce the DAC output range to avoid exceeding the Maximum Rate on the Bump power step.

3 Determine the Correct AutoTune Parameters

Material Number Choose the index number of the desired material.

Desired Rate Choose the rate at which to control the deposition. This parameter is used only for a Complete Tune.

Maximum Rate Choose the maximum rate the system can handle safely (i.e., source doesn't spit, equipment is not damaged).

Tune Type Choose either Quick Tune or Complete Tune.

- 4 Press F1 START AUTOTUNE and increase the power level with the Hand-Held Controller until the rate is approximately one half the desired rate.
- 5 Allow the source to come to an equilibrium by leaving the power level constant for approximately three minutes.
- 6 When the source has reached equilibrium, press the F1 START TUNING and observe the instrument as it goes through the "tuning" portion of AUTOTUNE.
- 7 When AutoTune is completed, the instrument will automatically return to the AutoTune Parameters display and the newly calculated values will be displayed next to the old values. The user then has the option to F3 ACCEPT or F4 REJECT the new control loop values. Accepting the changes replaces the old parameters with the new values, while rejecting the changes leaves the old values in place.
- 8 An AUTOTUNE failure means IC6 was unable to consistently measure the system's response characteristics.

NOTE: To ensure a successful AutoTune, there are a few items to be considered:

- ◆ A well-conditioned source is imperative. Be certain the source will be able to withstand the automatic power increments without spitting or other damage occurring to the system.
- ◆ A "quiet" crystal is essential. Rate noise and gun arcs will cause AutoTune Failures.
- ◆ Use the Maximum Rate and Maximum Power limits to protect your equipment.
- ◆ Do not set the Maximum Rate at exactly twice the Desired Rate. Allow for overshoot.

See [Table 15-3](#) on [page 15-6](#) for messages that may be displayed during the Auto Tune process.

The Auto Tune feature of IC6 is accessed via the Main Menu Maintenance display.

Figure 12-1 AutoTune overview

0.00 Å/s 0.000 kÅ 0.00%		READY
Auto Tune	Auto Tune Disabled	
Cross Talk	Material Number 1 Name Material 1	
Source Maint	Desired Rate 10.00 Å/s Maximum Rate 100.0 Å/s	
Sys Status	Tune Type Quick Control Loop NonPID Process Gain 10.000 Å/s/% Time Constant 1.000 s Dead Time 1.000 s	
Maintenance		
08/24/2010 09:18		
Start Accept Reject Auto Tune		

The default condition is Auto Tune Disabled.

To enable Auto Tune, move the cursor onto the Disabled box and press **TOGL**, then **ENTER**.

The parameter value should now show Enabled. To return to the Main Menu display, disable the Auto Tune function by setting it back to Disabled.

Figure 12-2 AutoTune parameters display

0.00 Å/s 0.000 kÅ 0.00%		MAINT STOP
Auto Tune	Auto Tune Enabled	
Cross Talk	Material Number 1 Name Material 1	
Source Maint	Desired Rate 10.00 Å/s Maximum Rate 100.0 Å/s	
Sys Status	Tune Type Quick Control Loop NonPID Process Gain 10.000 Å/s/% Time Constant 1.000 s Dead Time 1.000 s	
Maintenance		
08/23/2010 16:15		
Start Accept Reject Auto Tune		

12.5.2 AutoTune Parameters

MATERIAL INDEX 1 to 32

This parameter is used to select the Material that is to be AutoTuned. Values range from 1 to 32. The default value is 1.

DESIRED RATE 0.001 to 999.9 Å/s

For a Complete Tune, this parameter determines the Rate for which the AutoTuned control loop parameters will be calculated. For Quick Tune this parameter is ignored. Values range from 0.001 to 999.9 Å/s. The default value is 10.0 Å/s.

MAXIMUM RATE 0.002 to 999.9 Å/s

This parameter is used to set the maximum deposition Rate allowed during an AutoTune session. The events which occur upon exceeding this value are dependent upon whether a Quick Tune or a Complete Tune is designated. The range of values permitted for this parameter is dependent on the value chosen for the Desired Rate. The maximum allowed value will always be 999.9 Å/s. The minimum allowed value is 2 times the Desired Rate value.

TUNE TYPE Quick/Complete

This parameter is used to choose between a Quick Tune and a Complete Tune described in [section 12.5.5](#). The default value is Quick.

MATERIAL NAME

This is a read-only parameter that identifies the material being deposited.

CONTROL LOOP

This is a read-only parameter that indicates the type of control loop specified during material definition. It has no effect during Auto Tune. The type can be Non-PID, PI or PID.

PROCESS GAIN

This is a read-only parameter that represents the rate of change of % source power for a given rate deviation. It has no effect during Auto Tune.

TIME CONSTANT

This is a read-only parameter that represents the source's time constant. It is valid only for a PI or PID control loop and has no effect during Auto Tune.

DEAD TIME

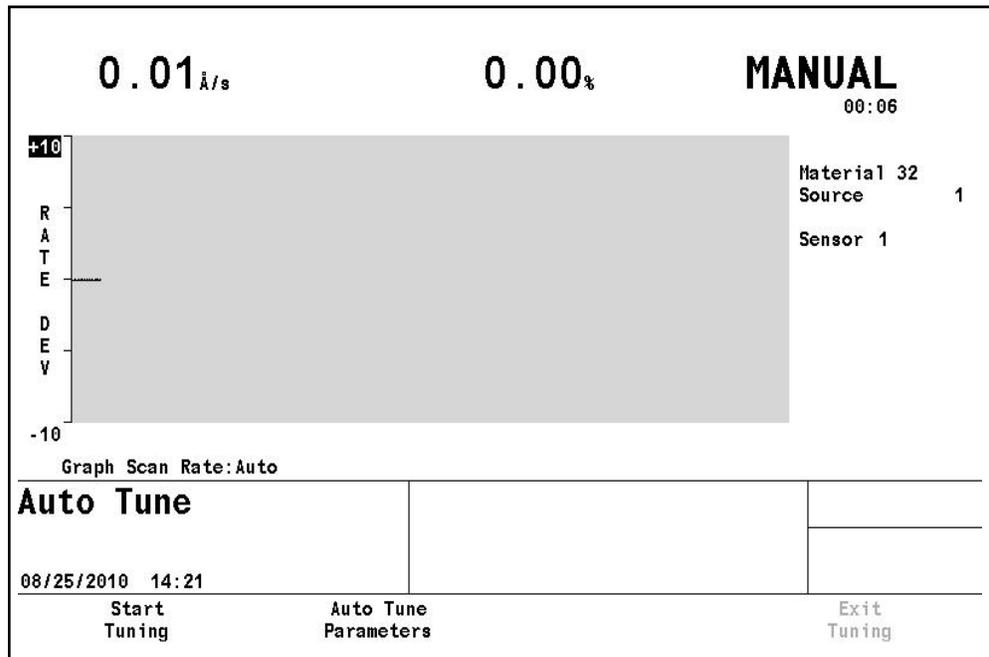
This is a read-only parameter that represents the source's lag time. It is valid only for a PI or PID control loop and has no effect during Auto Tune.

12.5.3 AutoTune Manual Display

The AutoTune Manual display is entered from the AutoTune Maint Stop display by selecting F1 START AUTO TUNE. To return to the AutoTune Parameters display, press F2 AUTO TUNE PARAMETERS.

The AutoTune Manual display is similar to the general Operate display with the exception that Thickness and Process information will be absent. The AutoTune Manual display automatically places the instrument into the MANUAL state. Just like the normal MANUAL state, the power level can be adjusted via the handheld controller and the source shutter relay is active.

Figure 12-3 AutoTune manual display



12.5.4 AutoTune Tuning Display

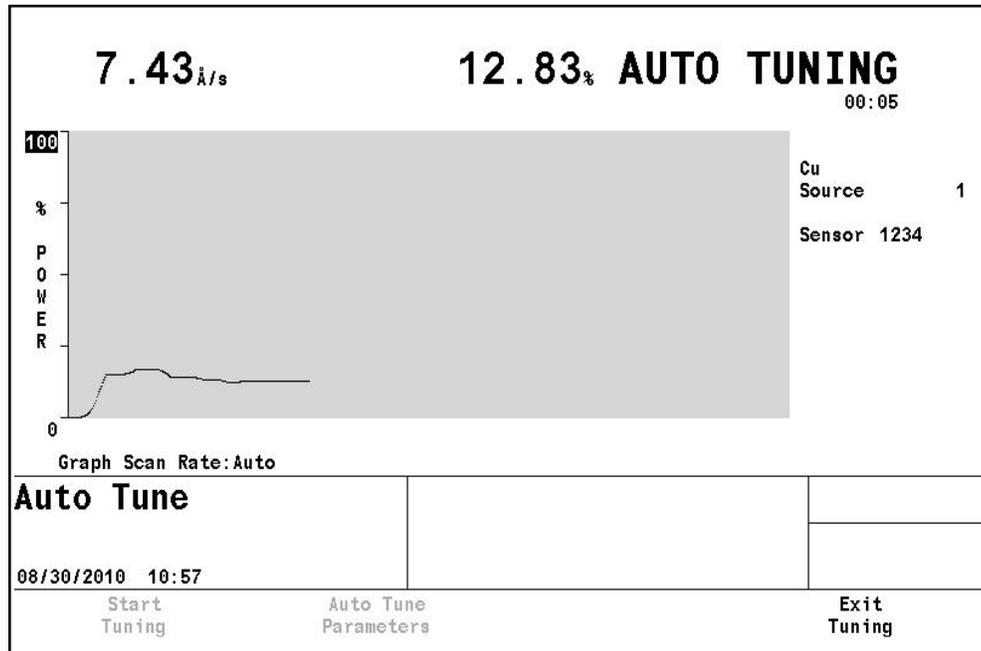
After a stable rate has been achieved in Manual, the AutoTune Tuning display is entered from the AutoTune Manual display by selecting F1 START TUNING.

AutoTune tuning is executed automatically by the instrument.

Operator intervention is not required.

STOP the tuning process by pressing F4 EXIT TUNING.

Figure 12-4 AutoTune tuning display



12.5.5 AutoTune Description

The instrument goes through the following algorithm when AutoTuning:

The first portion of Tuning is the Speed Test. The Speed Test calculates how quickly the system reacts to an instantaneous increase in source power level. The results of the Speed Test determine whether the system is fast or slow. Consequently, this designation of fast or slow determines what action is to follow.

For Quick Tune, the increment in power level is a pre-determined percentage of the power, while for a Complete Tune the increment in power level is calculated to obtain a specific rate increase.

If Quick Tune is chosen, the instrument will begin the AutoTune procedure by first recognizing an initial power setting. This initial power setting is the power level the operator adjusts to while in the Manual state of AutoTune. Next, the instrument will increase the power level to a value 5% greater than the initial level. If the rate of

deposition exceeds the Maximum Rate value during this transition, the power level is returned to the initial power setting and the instrument will increase the power level to a value of 2.5% greater than the initial level.

Again, if the Maximum Rate value is exceeded, the power level is returned to the initial power setting and the instrument will increase the power level to a value of 1.25% greater than the initial level. If the Maximum Rate is exceeded this final time a Quick Tune Failure message will appear and the control loop parameters must be determined manually. If the rate does not exceed the Maximum Rate value during any one of these power increments then the rate transition for this pre-determined power increment is used to calculate the control loop parameters. There is no Rate control feedback during Quick Tune.

If a Complete Tune is chosen, a Quick Tune is done first and will proceed as described above. These Quick Tune values are used as backup parameters in the event a Complete Tune fails. After completing the Quick Tune, the instrument will initially establish rate control to one-half the Desired Rate, then increment the power level to obtain a rate at twice the Desired Rate.

If the Maximum Rate is exceeded, the power level will be adjusted to reestablish rate control at one-half the desired rate and then increased to obtain a rate at the Desired Rate. If the Maximum Rate is again exceeded, the instrument will leave AutoTune and return the values calculated with Quick Tune. If the Maximum Rate is not exceeded, the control loop parameters will be calculated based on the rate transition. There is rate feedback when doing a Complete Tune.

The major difference in the implementation of AutoTune for a fast source (typically an electron beam gun) as opposed to a slow source, is the way in which rate stability is determined. For a fast source there can be many rate instabilities, such as sweep frequency fluctuations and short term thermal shorts; therefore rate noise makes determination of when the rate is stable impractical.

To circumvent this problem with a fast source the power level for both Quick Tune and Complete Tune is increased to the appropriate level and held for approximately 9 seconds. The rate transition over this time period is used to calculate the Process Gain parameter. Having calculated the Process Gain, the power level is returned to the initial power setting (or rate if in Complete Tune) and the procedure is repeated. The Process Gain value is again calculated and the two values compared. If the relative deviation between the two values is less than 40%, AutoTune for a fast source is completed.

This procedure may be repeated up to 4 times to obtain agreement between calculated Process Gain values. If agreement can not be reached after four times, Quick Tune values will be returned. A failure message will be returned if a Quick Tune can not be accomplished. The time for a complete tune of a fast source is typically no more than two minutes. A Quick Tune on a slow system typically takes 10 minutes, while a Complete Tune may take as long as 30 minutes.

Figure 12-5 AutoTune success display

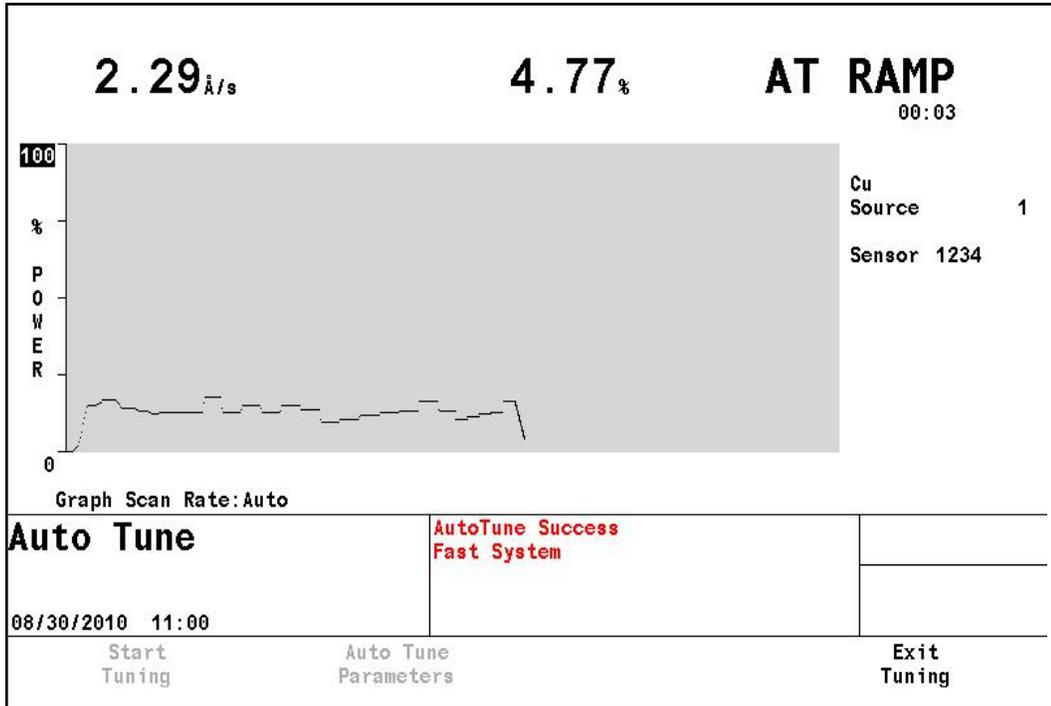
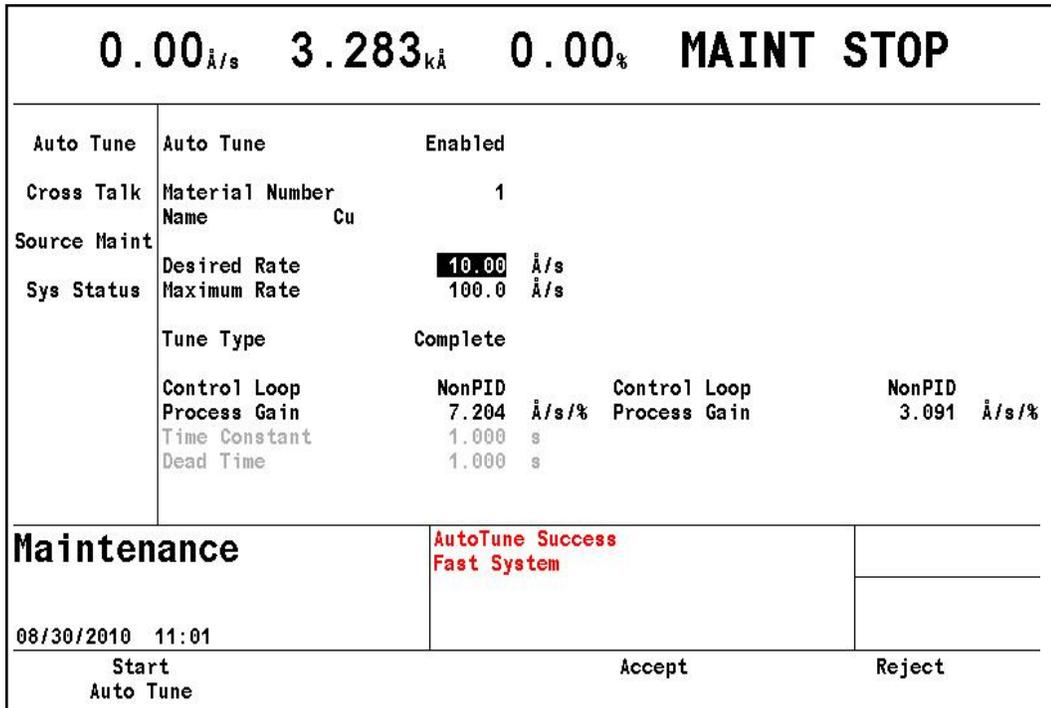


Figure 12-6 AutoTune complete display



When AutoTune is complete, the newly calculated values will be displayed next to the old values. The user then has the option to F3 ACCEPT or F4 REJECT the new control loop values. Accepting the changes replaces the old parameters with the new values, while rejecting the changes leaves the old values in place.

12.6 Determining Cross Talk Calibration For Co-Deposition

The automatic Cross Talk Calibration feature of IC6 is beneficial to applications involving the simultaneous deposition of two materials. When depositing two materials, it is not always possible to isolate each crystal so that it samples material from a single source. The Cross Talk Calibration feature is used to eliminate interference from the second source's material being deposited onto sensors intended to control the deposition rate from the first source.

Calibration Thickness (CalThickness) values must be determined for each sensor, and for each material used in the co-deposition, otherwise a co-deposition uncalibrated message will be displayed. The Process cannot be STARTed until the Cal Thickness values are entered. These values may be manually entered on the Sensor page of the Material display or may be automatically calculated using the Cross Talk Calibration series of displays. If Automatic Cross Talk Calibration is chosen, the Cal Thickness values calculated will be displayed on the Material Sensor page.

The Cal Thickness values are then used to calculate the percent cross talk (Cross Talk) values shown on the Layer definition display. EVERY sensor used on BOTH materials of a codeposition MUST be calibrated for each material.

The general expression for computation of Cross Talk is by the following:

Example: Materials A and B are to be co-deposited

Material A uses Sensors 1, 2 and 3 which control the aggregate rate for Source 1. Material B uses Sensors 4, 5 and 6 which control the aggregate rate for Source 2.

Enter CAL Thick values for Material A (either automatically or manually):

	Sens 1	Sens 2	Sens 3	Sens 4	Sens 5	Sens 6
CAL Thick	2.500 kA	2.200 kA	0.200 kA	1.000 kA	0.900 kA	0.100 kA

The percent Cross Talk for the Layer having Material A is:

$$\left[\frac{\left(\frac{\text{CAL Thick Sens 4} + \text{CALThick Sens 5} + \text{CALThick Sens 6}}{3} \right)}{\left(\frac{\text{CALThick Sens 1} + \text{CALThick Sens 2} + \text{CALThick Sens 3}}{3} \right)} \right] \times 100\% = 29.6 \quad [6]$$

Enter CAL Thick values for material B (either automatically or manually)

	Sens 1	Sens 2	Sens 3	Sens 4	Sens 5	Sens 6
CAL Thick	0.100 kA	0.150 kA	0.125 kA	2.125 kA	0.125 kA	0.100

The percent Cross Talk for the Layer having Material B is:

$$\left[\frac{\left(\frac{\text{CAL Thick Sens 1} + \text{CALThick Sens 2} + \text{CALThick Sens 3}}{3} \right)}{\left(\frac{\text{CALThick Sens 4} + \text{CALThick Sens 5} + \text{CALThick Sens 6}}{3} \right)} \right] \times 100\% = 16.0 \quad [7]$$

If two Layers to be co-deposited have Cross Talk percentages greater than 100%, the Process will STOP and the error message Cross Talk > 100% will be displayed.

For the above example the calculated Cross Talk percentages are both below 100% and the two co-deposited Layers can be STARTed. If a sensor were to fail during deposition, IC6 will calculate new Cross Talk percentages for the "new" sensor configuration. For example, if Sensor 4 fails, the new Cross Talk percentage is modified for Material A as per the following:

$$\left[\frac{\left(\frac{\text{CAL Thick Sens 5} + \text{CALThick Sens 6}}{2} \right)}{\left(\frac{\text{CALThick Sens 1} + \text{CALThick Sens 2} + \text{CALThick Sens 3}}{3} \right)} \right] \times 100\% \quad [8]$$

For Material A the new Cross Talk value will be 22.4% which is acceptable, however, Material B's new Cross Talk percentage will now be 111.1%. If this occurs the Process will STOP and the error message Cross Talk > 100% will be displayed. This error condition must be rectified before the Process can continue.

12.6.1 Procedure Set-Up

The Cross Talk Calibration feature will automatically calculate the Cal Thickness values that appear on the Material Sensor page. These values in turn are used in co-deposition to determine rates adjusted for the interference of one source with the other. Calibration is done for each Material to be used in a Co-deposition. Note that EVERY sensor used on BOTH Materials of a co-deposition MUST be calibrated for EACH Material calibrated. Each material to be co-deposited is calibrated separately. If a material is used in more than one co-deposition application, for example, materials A and B co-deposited then materials A and C co-deposited, Material A needs to be calibrated only once. This is especially important if using Dual Sensor Heads.

12.6.1.1 Cross Talk Calibration Procedural Notes

- 1 The Calibration thickness values do not include any adjustment for Sensor Tooling (set in the Material Sensor page) This is because the cross sensitivity adjustments are done prior to the sensor tooling being factored into the sensor rate calculation. The Aggregate Rate, used to control the deposition source, DOES include the Sensor Tooling factors.
- 2 During Cross Talk Calibration CALIBRATE, if a Crystal Fail occurs the calibration is aborted and the power ramp is entered. The user can still enter the calibration thickness values of the partially completed calibration if desired, or replace the failed crystal and recalibrate.
- 3 If the MAX POWER option for the Material is set to STOP PROC(ESS), SUSPEND MAT(ERIAL) or POST-DEP(OSIT) and MAX POWER is reached, the calibration will be aborted and the Source Power zeroed. No option of

entering the partially completed results is given. Only the CONTINUE setting on MAX POWER will allow the calibration to continue on reaching MAX POWER.

- When using a Dual Crystal Sensor it is important that the Crystal shutter be removed during calibration so that material will deposit onto both crystals. An alternative to removing the crystal shutter is to perform the calibration procedure allowing only one of the crystals to receive material and then manually entering this Cal Thickness Value for the secondary sensor. This manual entry of the Cal Thickness value ignores the tooling difference between the two crystal positions.

Cross Talk Calibration is accessed via the Main Menu / Maintenance display.

NOTE: In the figures following, only four sensors are used. Sensor 1 and 2 for Material 1 and Sensor 3 and 4 for Material 2.

Figure 12-7 Cross talk overview

-0.08 Å/s		0.00 %		0.00 Å/s		0.00 %			
0.000 kÅ		READY		-0.000 kÅ		READY			
Auto Tune	Cross Talk Calibrate Disabled								
Cross Talk	Material Number	1							
	Name	Material 1							
Source Maint	Desired Rate	10.00 Å/s							
Sys Status	Maximum Power	90.00 %							
	Calibrate	Sens1	Sens2	Sens3	Sens4	Sens5	Sens6	Sens7	Sens8
		No	No	No	No	No	No	No	No
	Rate								
	Cal Thick								
Maintenance									
08/31/2010 09:04									
Toggle Manual		Toggle Calibration		Accept		Reject			

The default condition is Cross Talk Calibrate Disabled.

To enable Cross Talk Calibrate, move the cursor onto the Disabled box and press TOGL, then ENTER. The parameter value should now show Enabled. To return to the Main Menu display, disable the Cross Talk Calibrate function by setting it back to Disabled.

With Cross Talk Calibrate Enabled, the appropriate parameters can be entered by cursoring to them.

Figure 12-8 Cross talk maint stop display

-0.02 Å/s -0.004 kÅ 0.00% MAINT STOP									
Auto Tune	Cross Talk Calibrate Enabled								
Cross Talk	Material Number	1							
Source Maint	Name	Material 1							
Sys Status	Desired Rate	10.00 Å/s							
	Maximum Power	90.00 %							
	Calibrate	Sens1	Sens2	Sens3	Sens4	Sens5	Sens6	Sens7	Sens8
		No	No	No	No	No	No	No	No
	Rate								
	Cal Thick								
Maintenance									
08/31/2010 09:47									
Toggle Manual		Toggle Calibration			Accept			Reject	

12.6.1.2 Cross Talk Calibrate Parameters

MATERIAL NUMBER 1 to 32

This parameter is used to select the Material to be calibrated. Values range from 1 to 32. The default value is 1. The name of the material is displayed below the selection.

DESIRED RATE. 0.001 to 999.9 Å/s

This parameter determines the aggregate rate at which to control the deposition source while a Cross Talk Calibration is being done. This aggregate rate is comprised of the sensors enabled in the Material Sensor page. Values range from 0.001 to 999.9 Å/s. The default value is 10 Å/s. It is recommended this rate be identical to the aggregate rate desired during deposition.

MAXIMUM POWER 0.0 to 99.99 %

This parameter is identical in function to the Maximum Power parameter found in Material Set-Up. The default value is 90.0 %.

CALIBRATE. Yes, No

This entry selects which sensors are to be calibrated.

NOTE: Every Sensor used for both of the co-deposited materials must be turned on (set to Yes) during calibration of each Material in order for the Cross Talk Correction to work properly. The aggregate rate, however, is determined only from those sensors turned on in the Material Sensor page for each Material.

To initiate the Cross Talk Calibrate operation, press F1 TOGGLE MANUAL to start Manual mode as described below.

12.6.2 Cross Talk Calibration MANUAL display

Upon pressing the TOGGLE MANUAL function key while in MAINT STOP, IC6 enters the Manual state, allowing manipulation of the source power level using the Hand-Held Controller. This is used to prepare the source for calibration. Bring the source power level to a point where the deposition rate is stable and approximately the rate at which you wish to calibrate. Upon entering the MANUAL state, Source and Sensor shutters will activate. Rates and Thicknesses for each of the sensors being calibrated will also be displayed. The Aggregate Rate, Thickness, and % Power are also displayed.

Figure 12-9 Crosstalk manual display

0.00 Å/s 0.000 kÅ 0.10%		MANUAL							
Auto Tune	Cross Talk Calibrate Enabled								
Cross Talk	Material Number	1							
	Name	Cu							
Source Maint	Desired Rate	10.00 Å/s							
Sys Status	Maximum Power	90.00 %							
	Calibrate	Sens1 Yes	Sens2 Yes	Sens3 Yes	Sens4 Yes	Sens5 No	Sens6 No	Sens7 No	Sens8 No
	Rate	0.01	0.02	-0.01	0.00				
	Cal Thick	4.007	3.811	3.085	3.108				
Maintenance									
08/30/2010 11:06									
Toggle Manual		Toggle Calibration			Accept		Reject		

12.6.2.1 Function Key Selection Choices

Key	Function	Description
F2	TOGGLE CALIBRATION	When the power level and rates are stable press F2 TOGGLE CALIBRATION to enter the automatic calibration portion of Cross Talk Calibration. Press it again to return to the MANUAL state.
F1	TOGGLE MANUAL	Press this key to leave the Cross Talk Calibration Manual display and return to the Cross Talk Calibration Maint Stop display.

12.6.3 Cross Talk Calibration CALIBRATE display

Upon entering this display the thickness values are zeroed and the aggregate rate will be controlled to the desired rate. Thickness will accumulate on each of the sensors set for Calibrate Yes. Calibration will continue until a 300 Hz frequency shift has taken place on the sensors selected in the Material Sensor page (i.e., the sensors used to calculate the Aggregate Rate). The instrument will stay in the automatic calibration mode for a minimum of 1 minute. The estimated time to complete calibration is displayed.

If the desired 300 Hz frequency shift has not taken place within 15 minutes, automatic calibration will time out and a Status error message will be given. When automatic calibration is completed IC6 will enter a CAL RAMP Power Down state in which the source control power is ramped to Zero over the time period designated by this material's Idle Ramp Time.

Figure 12-10 Crosstalk calibrate display

10.24_{Å/s} 0.018_{kÅ} 14.24%									
CALIBRATE									
Auto Tune	Cross Talk Calibrate Enabled								
Cross Talk	Material Number 1								
Source Maint	Name Cu								
Sys Status	Desired Rate 10.00 Å/s								
	Maximum Power 90.00 %								
	Calibrate	Sens1	Sens2	Sens3	Sens4	Sens5	Sens6	Sens7	Sens8
		Yes	Yes	Yes	Yes	No	No	No	No
	Rate	12.67	12.01	9.75	9.77				
	Cal Thick	0.020	0.019	0.016	0.016				
	Estimated Time to completion. 00:59								
Maintenance									
08/30/2010 11:09									
Toggle Manual		Toggle Calibration			Accept			Reject	

12.6.4 Cross Talk Calibration SELECT display

After the RAMP down state IC6 enters the SELECT display, from which the user can accept or reject the calibration thickness values, as desired. If the values are accepted they are stored on the Material's Sensor page.

Figure 12-11 Crosstalk complete display

0.01 Å/s 0.614 kÅ 0.00% MAINT STOP									
Auto Tune	Cross Talk Calibrate Enabled								
Cross Talk	Material Number 1								
Source Maint	Name Cu								
Sys Status	Desired Rate 10.00 Å/s								
	Maximum Power 90.00 %								
	Calibrate	Sens1	Sens2	Sens3	Sens4	Sens5	Sens6	Sens7	Sens8
		Yes	Yes	Yes	Yes	No	No	No	No
	Rate	0.03	-0.00	0.01	0.01				
	Cal Thick	0.688	0.656	0.530	0.529				
	Estimated Time to completion. 00:01								
Maintenance									
08/30/2010 11:11									
Toggle Manual			Toggle Calibration			Accept		Reject	

12.6.4.1 Function Key Selection Choices for Cross Talk Calibration Select

Key	Function	Description
F3	ACCEPT	Press this key to accept the Calibration Thickness values and return to the Cross Talk Calibration SETUP display. The accepted Calibration Thickness values are entered into page 3 of the Material Set-Up display.
F4	REJECT	Press this key to reject the Calibration Thickness values and return to the Cross Talk Calibration SETUP display.

12.7 Source Maintenance

The Source Maintenance page allows toggling source and sensor shutters and rotating the crucible indexer associated with a selected material. Source power may be manually adjusted using the handheld controller.

The unit must be in Ready mode to Enable Source Maintenance and it must be Disabled to exit back to normal operation.

Figure 12-12 Source maintenance page

- 0.00 $\text{\AA}/\text{s}$ 0.000 $\text{k}\text{\AA}$ 0.00%									
MAINT STOP									
Auto Tune	Source Maintenance		Enabled						
Cross Talk	Material Number		1						
Source Maint	Name		Au_1						
Sys Status	Source		1						
	Number of Crucibles		One						
	Current Crucible		1						
	Switch to Crucible		1						
	Source Shutter		Closed						
	Sensor	1	2	3	4	5	6	7	8
	Shutter	Closed	Unused	Unused	Unused	Unused	Unused	Unused	Unused
Maintenance									
06/14/2010 11:41									
Switch Crucible		Toggle Sensors Shutters			Toggle Source Shutter			Start / Stop Manual Power	

12.7.1 Source Maintenance Parameters

SOURCE MAINTENANCE Enabled/Disabled

IC6 must be in Ready to Enable and must be Disabled to return to normal operation. Default is Disabled.

MATERIAL NUMBER 1 to 32

While in Maint Stop, select the material associated with the source or sensor to be checked. Material cannot be changed while in Manual.

12.7.1.1 Crucible Rotation

If IC6 has been configured for a multi-position crucible indexer, pressing the F1 key will advance it to the next position. Setting the Switch to Crucible parameter to one of the positions before pressing F1 will activate the programmed crucible indexer outputs to rotate to the specified position.

The F1 key is greyed out for a single position crucible to indicate it is not active.

12.7.1.2 Toggle Sensor and Source Shutter

Press the F2 key to toggle all sensor shutters associated with this material.

Press the F3 key to toggle the source shutter for this material's source.

12.7.1.3 Start/Stop Manual Power

Press the F4 key to start Manual mode. Once in manual mode, use the optional handheld controller to increase or decrease the power.

12.8 System Status

Figure 12-13 System status display

400.0 $\text{\AA}/\text{s}$ 254.8 $\text{k}\text{\AA}$ 0.00 % READY	
Auto Tune Cross Talk Source Maint Sys Status	MEASUREMENT BOARD 1 is installed Version 0.07 MEASUREMENT BOARD 2 is installed Version 0.07 MEASUREMENT BOARD 3 is not installed MEASUREMENT BOARD 4 is not installed IO BOARD 1 is installed System Firmware Version 0.210 IO BOARD 2 is not installed Line Frequency 60 Hz IO BOARD 3 is installed USB Firmware Version 03.66 VDAPP DAC OPTION BOARD is installed OPTION BOARD 1 is not installed OPTION BOARD 2 is not installed Ethernet Card is installed
Maintenance	
Crystal Fail 2	
06/28/2010 16:42 Test	

The System Status display shows installed option boards and firmware versions. There are no user parameters.

Chapter 13

Counters and Timers

13.1 Introduction

The IC/6 has twenty counters and twenty timers. These counters and timers enable you to customize logic statements. Timers and counters are "up/increasing" value variables. You can increment a counter or start a timer on any event via a logic statement. These counters and timers can then be checked via other logic statements to initiate one or more actions at a given count or when an elapsed amount of time has passed. On the counter/timer screen, see Figure 13-1, you can monitor all the counters and timers and by positioning the cursor on the counter or timer number, manually zero a timer/counter (F1) or start timer (F2) or cancel a timer (F3) using the function keys.

Figure 13-1 Counter/Timer screen

0.06 μ /s		1.344 μ kA		0.00%		READY	
Counters				Timers			
1	000	11	000	1	00:00.0	11	00:00.0
2	000	12	000	2	00:00.0	12	00:00.0
3	000	13	000	3	00:00.0	13	00:00.0
4	000	14	000	4	00:00.0	14	00:00.0
5	000	15	000	5	00:00.0	15	00:00.0
6	000	16	000	6	00:00.0	16	00:00.0
7	000	17	000	7	00:00.0	17	00:00.0
8	000	18	000	8	00:00.0	18	00:00.0
9	000	19	000	9	00:00.0	19	00:00.0
10	000	20	000	10	00:00.0	20	00:00.0
Counter/Timer							
04/14/2010 14:31							
Zero Timer/ Counter		Start Timer		Cancel Timer			

Chapter 14

USB Storage

14.1 File Handling (USB)

File handling is achieved via a USB port. Three types of files are used: configuration files which contain all user programmed parameters, screen capture files, and data log files. Configuration files can be written to and retrieved from the USB port storage device. Data log files and bitmap files of screen captures can only be written to the USB port storage device. To prevent loss of data, no more than 500 data log files should be written to the USB device. IC6 will only display the first 120 files (15 per page) and a message "More Files on the USB." All files will be displayed on a computer.

The USB port is not set up for any other use. USB file handling allows for only eight characters in a file name with an optional three-character extension.

14.1.1 USB Storage Devices

The following USB 2.0 storage devices have been tested for use with IC6:

- ◆ Memorex® TravelDrive 512 MB Flash Drive
- ◆ SanDisk® SDCZ2-1024-A10 1 GB Cruzer Mini Flash Drive
- ◆ Lexar® 1 GB Sport Flash Drive
- ◆ Lexar 4 GB Lightning Flash Drive
- ◆ Kingston® 32 GB DataTraveler 150 Flash Drive

NOTE: The USB storage device is to be plugged directly into the IC6 front panel USB port. Use of USB extension cables is **not** supported.

14.2 Directory Structure

All files will be written to and read from pre-defined directories. Three directories will be defined for the three types of files written by IC6.

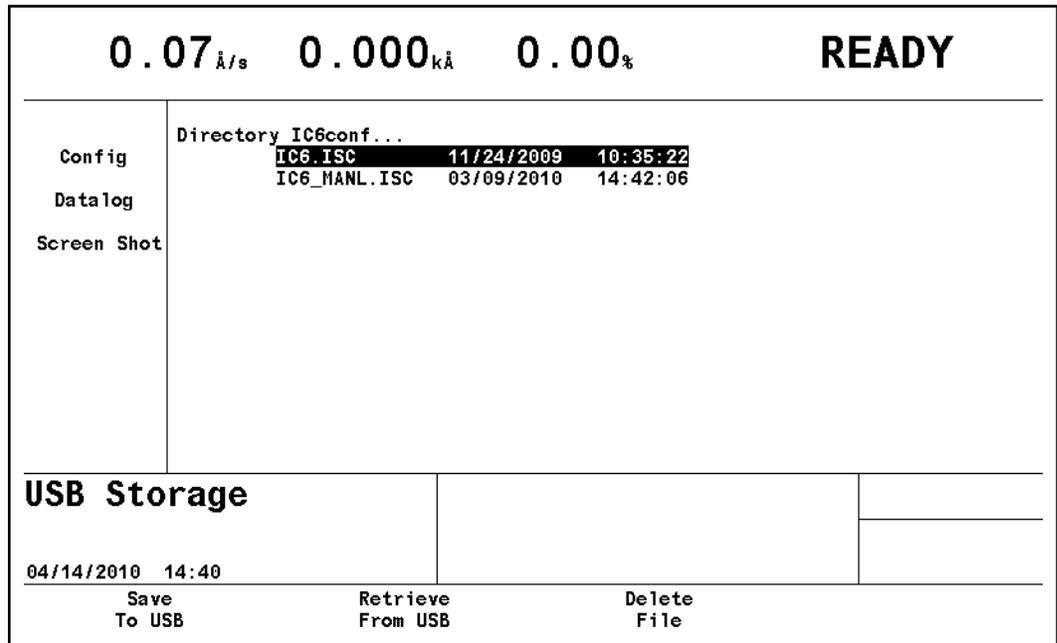
- ◆ IC6CONF will hold configuration files
- ◆ IC6SCRN will hold screen capture files
- ◆ IC6DLOG will hold data log files

If the directories don't exist on the storage device attached to the USB port, IC6 will create them at the first attempt to access the directory.

14.3 Configuration Files

With the instrument in the READY state, the configuration of IC6 may be sent to a storage device attached to the USB port. Configuration files will be written with the default name IC6.ISC. The configuration file can be named within the eight-character limitation that exists in the USB file handling firmware. File names cannot contain the space character. IC6 will use the .ISC extension to identify configuration files. IC6 will ignore or reject IC/5 and Cygnus .ISC configuration files—these files are not compatible with IC6. See Figure 14-1.

Figure 14-1 Configuration files



NOTE: IC6 must be in the READY mode to save a configuration file.

14.4 Data Logs

NOTE: To prevent loss of data, do not allow the number of files on the USB storage device to exceed 500.

Data log files will be sent to the USB port storage device when the USB Datalog Format parameter located on the datalog page of the USB STORAGE screen is set to either Page or Comma by using the TOGL key. Error message "USB Disk Error" appears if datalogging is turned on and a USB flash drive is not present.

The LogOff setting turns off datalogging.

As the layers create the datalog file they will be sent to the IC6DLOG directory on the storage device attached to the USB port. The files will be named PxxRyyy.IDL, where xx is the process number and yyy is the run number. If a file with the same name exists, the new data log information will be appended to the existing file. IC6 will use the .IDL extension to identify Datalog files. See Figure 14-2.

See section 3.6.10, Datalog, on page 3-43 for the details of the data log data.

Figure 14-2 Datalog files

2.00 Å/s 0.073 kÅ 0.00 % IDLE																									
Config Datalog Screen Shot	<table border="1"> <thead> <tr> <th>USB Datalog Format</th> <th>Comma</th> <th>Datalog Xtal Info</th> <th>Yes</th> </tr> </thead> <tbody> <tr> <td>Directory IC6dlog...</td> <td></td> <td></td> <td></td> </tr> <tr> <td>P01R0011.IDL</td> <td>06/28/2010</td> <td>08:10:26</td> <td></td> </tr> <tr> <td>P02R0011.IDL</td> <td>06/28/2010</td> <td>08:10:26</td> <td></td> </tr> <tr> <td>P01R0012.IDL</td> <td>06/28/2010</td> <td>08:11:34</td> <td></td> </tr> <tr> <td>P02R0012.IDL</td> <td>06/28/2010</td> <td>08:12:40</td> <td></td> </tr> </tbody> </table>	USB Datalog Format	Comma	Datalog Xtal Info	Yes	Directory IC6dlog...				P01R0011.IDL	06/28/2010	08:10:26		P02R0011.IDL	06/28/2010	08:10:26		P01R0012.IDL	06/28/2010	08:11:34		P02R0012.IDL	06/28/2010	08:12:40	
USB Datalog Format	Comma	Datalog Xtal Info	Yes																						
Directory IC6dlog...																									
P01R0011.IDL	06/28/2010	08:10:26																							
P02R0011.IDL	06/28/2010	08:10:26																							
P01R0012.IDL	06/28/2010	08:11:34																							
P02R0012.IDL	06/28/2010	08:12:40																							
USB Storage Active Process 2 Run 0012 06/28/2010 08:12 Test	End Of Process Delete File																								

14.5 Screen Captures

A BMP file of the screen can be sent to the USB port storage device. Pressing the Print key will send a BMP file of the screen to the IC6SCRN directory on the storage device attached to the USB port. The Screen captures will be named as either DDMMYYxx.BMP or MMDDYYxx.BMP depending on the date format setting. DD = day of month, MM = month, YY = year, xx is a number that increments from 0 to 99, resetting to 0 every day. IC6 will use the .BMP extension to identify screen capture files. The +++ indicates that additional files exist on the USB device beyond those displayed. Use the Up/Down arrows keys to navigate.

Individual screen shots can be deleted by cursoring to the specific file and selecting the F3 function key.

Figure 14-3 Screen capture files

40.00 Å/s		23.66 kÅ		10.00%		IDLE	
Config	+++	Directory IC6scrn...					
		04121015.BMP	04/12/2010	11:58:20			
		04121016.BMP	04/12/2010	11:59:48			
Datalog		04121017.BMP	04/12/2010	12:07:50			
		04121018.BMP	04/12/2010	12:10:22			
Screen Shot		04121019.BMP	04/12/2010	12:17:12			
		04121020.BMP	04/12/2010	12:23:54			
		04121021.BMP	04/12/2010	12:25:22			
		04121022.BMP	04/12/2010	12:28:38			
		04121023.BMP	04/12/2010	12:30:08			
		04121024.BMP	04/12/2010	12:31:46			
		04121025.BMP	04/12/2010	12:33:10			
		04121026.BMP	04/12/2010	12:34:26			
		04121027.BMP	04/12/2010	12:35:56			
		04121028.BMP	04/12/2010	12:38:30			
		04121029.BMP	04/12/2010	12:40:08		+++	
USB Storage			End Of Process				
Active Process 1							
Run 0001							
04/14/2010 14:57			Test				
						Delete File	

Chapter 15

Troubleshooting, Status and Error Messages

15.1 Status Messages

Some IC6 status messages will have designators to indicate the Material, Source or Sensor the status refers. Table 15-1 indicates designators and to what they refer. If there is a message that has multiple occurrences, it will display on one line with multiple designators after it.

There are a few status messages that have a designated area in the status message area. These messages are noted in Table 15-1.

Table 15-1 Status messages

Status Message	Set	Cleared	Screen	Remote Comm. Encode
Crystal Fail X...X	One or more of the sensors that are called out in currently active layers fails to measure a crystal. X = Sensor	When all sensors in use are good. When any sensor in use is good the sensor number clears from the numeric list	All Designated area	0x8000,0000 0000,0000
Max Power X...X	Whenever the source power reaches the maximum power programmed for an active layer. X = Material number	Whenever the source power is reduced from the maximum power for an active layer	All Note: This message will display in the cause of stop area whenever it is TRUE. Designated area	0x4000,0000 0000,0000
Test	The general parameter Test has been set to Yes	The general parameter Test has been set to No	All. Designated area	0x2000,0000 0000,0000
A TEST	The general parameter Advanced Test has been set to Yes	The general parameter Advanced Test has been set to No	All. Designated area	0x1000,0000 0000,0000
R Lock	A command was received via remote communications to lock IC6. NOTE: R Lock supersede L Lock)	A command was received via remote communications to unlock IC6	All Designated area	0x0800,0000 0000,0000
L Lock	A lock code has been programmed via the keyboard and the lock has been set. NOTE: R Lock supersedes L Lock)	The lock code has been entered via the keyboard to unlock IC6	All Designated area	0x0400,0000 0000,0000

Table 15-1 Status messages (continued)

Status Message	Set	Cleared	Screen	Remote Comm. Encode
Min Power X..X	While in a rate control state, whenever the source power reaches the programmed minimum power. This message doesn't appear if the Minimum power is programmed for 0.0%. X = Material	When the source power is greater then the programmed minimum power or when IC6 leaves rate control	All	0x0200,0000 0000,0000
Crystal Switch(ing) X..X	A multi crystal sensor is switching to a new crystal. X = Sensor	The sensor switching has reached its next position. When replaced with Switcher Error message	All	0x0100,0000 0000,0000
Crystal Sw(itcher) Fail X..X	A crystal position was not reached in the time allotted for a crystal switch. X = Sensor	The sensor switching has reached its next position. When replaced with switcher error message	All	0x0080,0000 0000,0000
Carousel Open X..X	The Crystal12 carousel is not detected as in place. X = Sensor	When the carousel is detected or when the sensor type is set to something other than Crystal12	All	0x0040,0000 0000,0000
Control Delay X..X	When the Delay option is set to Control and a material enters the control delay. X = Material	The control delay is complete.	All	0x0020,0000 0000,0000
Transfer Delay X..X	Sensor Shutter delay for a transfer sensor is active. X= Material	The transfer delay is complete.	All	0x0010,0000 0000,0000
RateWatcher Delay X..X	When RateWatcher is turned on, the active state is displayed. Only one state per material can be active at a time. X= Material	When RateWatcher is inactive or as the RateWatcher state changes	All	0x0008,0000 0000,0000
RateWatcher Hold X..X				0x0004,0000 0000,0000
RateWatcher Sample X..X				0x0002,0000 0000,0000
Soak Hold Pre Con Y.....Y	A Soak Hold condition is active Y = Material	The Soak Hold condition is no longer active	All	0x0001,0000 0000,0000
Soak Hold 1 Y ...Y				0x0000,8000 0000,0000
Soak Hold 2 Y ...Y				0x0000,4000 0000,0000

Table 15-1 Status messages (continued)

Status Message	Set	Cleared	Screen	Remote Comm. Encode
Abbr(eviated) Average X..X	During a rate control state, a crystal failure occurred after more then one minute but before the number of minutes specified in the parameter Time Power Averaging Time. The time to average the rate and power is less then requested. X = Material	When a new layer is started. Stop/Reset	All	0x0000,2000 0000,0000
No or Neg. Average X ... X	Then entering time power of non deposit control and there is not enough data to calculate and average rate or power. X = material	As the layer is unloaded	All	0x0000,1000 0000,0000
Time Pwr (Power) Complete X	Time Power was active when the Material completed. X = Material	Another layer overloads the layer that completed in Time Power	All	0x0000,0800 0000,0000
Clock Hold	A clock hold has been set via a Digital Input, Logic Action or remote communication command	A clock hold has been cleared via a Digital Input, Logic Action or remote communication command	All	0x0000,0400 0000,0000
End Of Process	The last active layer of the process is complete	A new process or the first layer of the active process starts. Stop/Reset	All	0x0000,0200 0000,0000
CoDep Not Calibr(ated) X...X	The co-deposited materials do not have calibrated thickness values entered in the material setup for all active sensors. Therefore, the Cross Talk calibration is un-calibrated. X = Material	Material parameter Cal Thickness values are entered for all active sensors either manually or via automatic calibration. Layer parameter Co-Dep is set to No	All	0x0000,0100 0000,0000
One Layer Tagged	When First tag is set for layer editing	When second tag is set for layer editing. When leaving layer editing pages After UnTag layers function key is pressed	Process	0x0000,0080 0000,0000
Layers Tagged	When second tag is set for layer editing	When leaving layer editing pages After UnTag layers function key is pressed	Process	0x0000,0040 0000,0000
(CoDep) Too Many Layers	When attempting to load two CoDep layers during a reset and only one layer is allowed	After a successful reset	All	0x0000,0020 0000,0000

Table 15-1 Status messages (continued)

Status Message	Set	Cleared	Screen	Remote Comm. Encode
Source Conflict	When attempting to load two Codep layers during a reset and both layers call for the same source	After a successful reset	All	0x0000,0010 0000,0000
Recorder Conflict	A DAC output is set as a Recorder output on two or more loaded materials or sensors	Conflict has been removed	All	0x0000,0008 0000,0000
Unable to Auto-Z X ... X	An active sensor is unable to Auto-Z. X = sensor	A sensor is no longer active or is able to Auto-Z. Sensor Parameter Auto-Z is set to No	All	0x0000,0004 0000,0000
DAC Error X	DAC monitoring has detected an error in a DAC used for a recorder. X = DAC	On Reset	All	0x0000,0002 0000,0000
Testing XIU X	When XIU test begun. X = Sensor Number	When XIU test finished	Sensor Info	0x0000,0001 0000,0000
Backup Sensor X	The backup sensor is loaded. X = Material	The backup sensor is no longer loaded		0x0000,0000 8000,0000
Backup Delay X	When switching to backup sensor,, X = Material	After a 5 second delay, when the backup sensors measurements start to be used		0x0000,0000 4000,0000

15.2 User Messages

Table 15-2 messages are a subgroup of status messages. The user defines these messages. They are displayed and cleared via logic actions. The messages will display in the same screen area as other status messages.

Table 15-2 User messages

Status Message	Set	Cleared	Screen	Remote Comm. Encode
User Message 1	Logic event "Message On 1"	Logic event "Message Off 1"	All	0x0000,0000,0000,0200
User Message 2	Logic event "Message On 2"	Logic event "Message Off 2"	All	0x0000,0000,0000,0100
User Message 3	Logic event "Message On 3"	Logic event "Message Off 3"	All	0x0000,0000,0000,0080
User Message 4	Logic event "Message On 4"	Logic event "Message Off 4"	All	0x0000,0000,0000,0040
User Message 5	Logic event "Message On 5"	Logic event "Message Off 5"	All	0x0000,0000,0000,0020
User Message 6	Logic event "Message On 6"	Logic event "Message Off 6"	All	0x0000,0000,0000,0010
User Message 7	Logic event "Message On 7"	Logic event "Message Off 7"	All	0x0000,0000,0000,0008
User Message 8	Logic event "Message On 8"	Logic event "Message Off 8"	All	0x0000,0000,0000,0004
User Message 9	Logic event "Message On 9"	Logic event "Message Off 9"	All	0x0000,0000,0000,0002
User Message 10	Logic event "Message On 10"	Logic event "Message Off 10"	All	0x0000,0000,0000,0001

15.3 AutoTune and Calibration Messages

Table 15-3 is a subgroup of the Status messages. They will appear only on the calibration screens. Only one line is necessary for the display of these messages.

Table 15-3 AutoTune and calibration messages

AutoTune and Cal Message	Set	Cleared	Screen	Remote Comm Encode
Speed test	Indicates the first step of the AutoTune is in process.	When the speed of the system is determined.	AutoTune	Remote communications are not permitted while in AutoTune.
Fast System	AutoTune has detected the response of IC6 to be fast Result of speed test.	Exit AutoTune Restart AutoTune	AutoTune	
Slow System	AutoTune has detected the response of IC6 to be slow. Result of speed test.	Exit AutoTune Restart AutoTune	AutoTune	
Quick Bump #	Indicates which power increment is active. Displays when speed test is started.	The quick AutoTune is complete. If complete tune is required, when Half Rate message is displayed.	AutoTune	
Half Rate	When a complete tune is required this is displayed after the quick bump is finished.	When the next message is put up.	AutoTune	
Complete Bump #	AutoTune displays the change in the power supply setting.	Test is complete and results are displayed.	AutoTune	
AutoTune Failure	AutoTune is unable to calculate control loop parameters when doing a quick tune.	Exit AutoTune Restart AutoTune	AutoTune	
AutoTune Success	AutoTune has successfully established control loop parameters.	Exit AutoTune Restart AutoTune	AutoTune	
AutoTune Timeout	AutoTune is unable to maintain a stable deposition or complete the measurement of a deposition transition.	Exit AutoTune Restart AutoTune	AutoTune	
AutoTune Max Pwr (Power)	When the maximum power is reached during an AutoTune	Exit AutoTune Restart AutoTune	AutoTune	
Rate above max	Rate has increased above maximum allowed.	When next bump is started.	AutoTune	
Ramp	At end of AutoTune, when power is ramped to zero	When ramp is complete	AutoTune	
Calibr(ation) Timeout	While in Cross Talk calibration a 300 Hz minimum frequency shift has not taken place within 15 minutes.	Exit Cross Talk cal. Restart another Cross Talk cal.	Cross Talk Cal	

15.4 STOP messages

When IC6 goes into STOP, a cause of stop message appears on the line below STOP. Some of these messages will have designators to indicate the Material, Source or Sensor that caused the Stop. Table 15-4 indicates which messages have designators and what the designator indicates.

Table 15-4 Stop messages

Cause of STOP Message	Set	Clear	Screen	Remote Comm. Encodes
Max Power X	Maximum power was reached and held there for more then 5 seconds and the material parameter Max Power Option is set to Stop on Max Power. X = Material	A RESET command received from the keyboard, digital input, remote communications or a Logic action. A Start, if the condition causing the stop has been cleared and the process can resume.	All	1
Crystal Fail X	There was a crystal failure and the material parameter Failure Action is set to stop on fail. X = Sensor.			2
Hand Controller	STOP command was received from the handheld controller.			3
Front Panel	Keyboard STOP key was pressed.			4
Communication	A STOP command was received from remote communications.			5
Crucible Fail X	IC6 failed to detect a good crucible in the time allowed. X = Source			6
Switcher Fail X	A crystal switch failed. X = Sensor			7
Logic Eqn #N	A STOP command was received from logic statement number #.			8
No Source DAC	A layer tried to start without a source DAC programmed.			9
Power Loss	IC6 lost power.			10
Source Conflict	A layer is attempting to start with a source that is already in use.			11
Sensor Conflict X	The process is trying to enter the Deposit state with two layers using the same sensor. X = Sensor.			12
Shutter Fail X	The desired Rate Accuracy has not been achieved in the allotted time in Shutter Delay. X = Material.			13

Table 15-4 Stop messages (continued)

Cause of STOP Message	Set	Clear	Screen	Remote Comm. Encodes
CrossTalk > 100%	One or both of the co-deposited layers has a Cross Talk percentage $\geq 100\%$. When starting a co-dep layer the Cross Talk % is checked. If the calculated Cross Talk % is $\geq 100\%$ then there must be a problem with the cal thickness values the user entered and the layer stops with this message as the cause of stop. If a layer is running and the cal thickness values are changed to cause the calculated Cross Talk % $\geq 100\%$ then the layer stops with this message as the cause of stop	A RESET command received from the keyboard, digital input, remote communications or a Logic action. A Start, if the condition causing the stop has been cleared and the process can resume.	All	14
DAC Failure	Monitoring of the DAC output via an ADC determined that the output voltage is incorrect.		All	15
Half Rate Fail	AutoTune is unable to vary the source power to obtain half the desired deposition rate.		AutoTune	16
Low Rate	Auto tuning is terminated when the deposition rate at the start of tuning is below 0.1 Å/s.		AutoTune	17
AutoTune Fail	The complete tune portion of AutoTune did not determine reliable system response results.		AutoTune	18
Quick Tune Fail	The Quick tune portion of AutoTune did not get repeatable system response results.		AutoTune	19
Bad Co-Dep Load	The loading of co deposition layers is bad		All	20
Uncalibrated	The co-deposition layers are uncalibrated.		All	21
Bad Layer Load	There was a problem loading a layer.		All	22

15.5 Transient Messages

Transient messages, see [Table 15-5](#), are displayed as the condition happens. The messages are removed from the screen on any key press or if another transient message appears. Only one transient message will be displayed at a time. These messages will appear on all screens. A single line is assigned in the message box.

Table 15-5 Transient messages

Transient Message	Set	Clear	Screen	Remote Comm. Encodes
Locks Cleared	Local Lock, Remote lock cleared on power up.	The message is removed from the screen on any key press or if another transient message appears	All	1
Already Switching	Crystal is already switching when a request to switch the crystal is received.			2
Process Running	Can't do some activities if a process is running. These activities include: Layer editing, used in the active process, copying/defaulting a material, entering source maintenance, running an RS232 test, running an XIU test and reading in a configuration file.			3
Parameter Default	All parameters were set to their default values on power up.			4
Process Variables Default	All process variables were set to their default values on power up. Process variables include current rates, thicknesses, processes, layers, crystals, states and other information needed to continue a process after a power loss.			5
Manual Not Allowed	Cannot enter manual state while in idle, stop or suspend states, or while crystal failed.			6
Empty Process	Cannot set a process to active if it is empty		Process General	7
No Good Xtal to switch	There are no good crystals left in the crystal list. Only when trying to switch while the sensor is in use on an active layer.		All	8
No Switch Output	No switch output defined for a crystal switch.		All	9
No Switch Single	Cannot switch a single sensor.		All	10

Table 15-5 Transient messages (continued)

Transient Message	Set	Clear	Screen	Remote Comm. Encodes
Datalog Failure	IC6 is sending the Datalog information faster than the receiving device can accept the data. The data is lost.	The message is removed from the screen on any key press or if another transient message appears	All	11
Ethernet In Use	Ethernet port is active and the Ethernet parameters can't be changed. The command sent to the Ethernet card did not go through or the Ethernet card did not send a valid message indicating the update of values was completed.		General	12
No Rotate: CrystalTwo	Cannot rotate a CrystalTwo.		Sensor Info	13
No Rotate: Layer Running	Cannot rotate a sensor while a layer is running.		Sensor Info	14
Invalid Equation	An attempt was made to save an invalid logic statement. Logic statements must have connectors and any required numeric before exiting Logic editing.		Logic edit	15
Power Not Zero	A source maintenance crucible switch was requested when the source power is not zero.		Maintenance	16
RS232 Test Failed	RS-232 loop back test failed.		General/Comm	17
RS232 Test Passed	RS-232 loop back test passed.		General/Comm	18
XIU Test Failed	XIU test failed		Sensor Info/Type	19
XIU Test Passed	XIU test passed.		Sensor Info/Type	20
No XIU Test: Switching	Cannot test an XIU while a crystal switch is in process.		Maintenance	21
Edit In Process	When an edit is process and the menu key is pressed.		All	22
USB Disk Error	Fault Conditions: No Disk, Folder/File Read Only, Firmware Invalid, Firmware No Upgrade, Exceeded max. file count		Storage	23
USB error: Disk Full	Disk is Full		Storage	24

Table 15-5 Transient messages (continued)

Transient Message	Set	Clear	Screen	Remote Comm. Encodes
USB (File Check Sum) Error: Data Corrupt		The message is removed from the screen on any key press or if another transient message appears	Storage	25
USB error: Bad Conf. File			Storage	26
USB DataLog Fast Out Error				27
USB Error (generic)	USB Interface system error		All	28
(USB: Conf. file:) Structure Version Change	Structure version updated because of the new configuration.		Storage	29
(USB:) Parameter Value Changed	Parameter value has been adjusted during the Range Check verification procedure.		Storage	30
USB Busy	Any key is pressed while the USB is busy.		All	31
(USB:) No Such File (Available)	Attempt to access non- existing or folder non-specific file.		Storage	32
(USB: Too many files) Archive Old Files	Too many files in a directory		All	33
No Start: Too Many Layers	Start key was pressed when the allowed number of layers are already running.		All	40
All Tags Set	Both tags are already set when the tag key was pressed.		Process	41
No Tags Across Processes	An attempt was made to set the two tags in two different processes.		Process	42
Material Running	The material was running when the Paste material or the default material functions keys were pressed.		Material	43
Material Copied	After the copy material function is successful		Material	44
Material Pasted	After the paste material function is successful.		Material	45
No Material Copied	Paste Material function key was pressed with no material pasted.		Material	46
Material Defaulted	After Default Material function is successful.		Material	47
Not Enough Layers	An attempt was made to insert more layers then the process can hold.	Process	48	

Table 15-5 Transient messages (continued)

Transient Message	Set	Clear	Screen	Remote Comm. Encodes
Can't Delete: Co-Dep	An attempt was made to delete one layer of a co-dep pair of layers.	The message is removed from the screen on any key press or if another transient message appears	Process	49
Can't Insert: Co-Dep	An attempt was made to insert layers between a co-dep pair of layers or to insert only one layer of a co-dep pair.		Process	50
Can't Empty Active Process	An attempt was made to empty or default the Active process.		Process	51
Layers Copied	After Insert Layers is successful.		Process	52
Logic Edit In Progress	Key press (STOP,RESET,START, MENU) while in logic edit mode:		Logic Edit	53
No Paren on Empty Term	Parentheses are not allowed on an empty term.		Logic Edit	54
No Left Paren on Last Term.	Cannot insert Left (opening) parenthesis on the last term.		Logic Edit	55
Select an Event to Edit	Attempt to edit a non-event assigned label.		Logic Edit	56
Select an Action to Edit	Attempt to edit a non-action assigned label.		Logic Edit	57
Select an Event to Delete	Attempt to delete a non-event assigned label.		Logic Edit	58
Select an Action to Delete	Attempt to delete a non-action assigned label.		Logic Edit	59
Max Terms: Cannot Insert	An attempt was made to enter an equation with more then the allowed event or action terms.		Logic Edit	60
Cannot Negate Empty Term	Attempt to negate an empty term.		Logic Edit	61
Meas. Board Comm Error	Bad communications with the measurement card.		All	62
No Switch: No XIU	No XIU attached, cannot do a switch.		All	63
In Crucible Switch	An attempt was made to navigate or change a parameter in the Source Maintenance screen while a crucible switch was in process.	Source Maintenance	* Not available	
Maintenance Enabled	An attempt was made to leave a Maintenance screen while Auto Tune, Cross Talk Calibrate or Source Maintenance was enabled	Source Maintenance	Not available from Remote Comm	

Table 15-5 Transient messages (continued)

Transient Message	Set	Clear	Screen	Remote Comm. Encodes
Crucible Switch Fail	Crucible switch fail while in Source Maintenance.	The message is removed from the screen on any key press or if another transient message appears	Source Maintenance	Not available from Remote Comm
Invalid Calibration Value	Cross Talk Calibration value is out of range.		Cross Talk Calibration	* Not Available
Xtal Fail in Calibration	Crystal failure in Calibration		Cross Talk Calibration	Not Available from Remote Comm
Start Inhibited	A Start is issued while Start Inhibit is active.		All	69
* Remote communications are not permitted while in source Maintenance.				

15.6 Input Error Messages

Keyboard Input Error Messages come up on the entry of invalid parameters. These messages will appear on the transient error message line in the message box. The font color of the parameter value being updated will change to a different color to denote an input error has been made. They will clear when the clear key is pressed. The original stored value will then be re-displayed. See Table 15-6.

Table 15-6 Input error messages

Input Error Message	Set	Cleared	Screen
Value Too High	The value entered is larger than the maximum value allowed.	Each input error message is taken down by pressing the clear key.	Any Parameter edit
Value Too Low	The value entered is lower than the minimum value allowed.		Any Parameter edit
Duplicate Source	Can use each source number only once for thickness sum.		General
Duplicate Sensor	The single or one of the multipoint sensors for the material cannot also be set as the backup sensor.		Material
Empty Process	Can't select an empty process as process to run.		General
Invalid Mask	An attempt was made to enter an incorrect Ethernet net mask.		General
Incorrect Time	An attempt was made to enter more then 59 seconds or 99 minutes into a time parameter.		Material
Must use one sensor	In multi-point mode, at least one sensor for each defined material must have its option parameter non-zero.		Material
Ramp 1 > Ramp 2	Invalid material parameter 'Ramp', values were entered. Start Ramp 1 thickness value must be less then Start Ramp 2 value when the Start Ramp 2 value is non-zero.		Material
Ramp 2 < Ramp 1	Invalid material parameter 'Ramp', values were entered. Start Ramp 2 thickness value must be greater then Start Ramp 1 value.		Material
Sensor in use	An attempt is being made to turn on a sensor that is already in use for the other material of a co-deposited material.		Material
Bad Crystal and Running	An attempt is being made to turn on a sensor that is bad and the Material is running.		Material
Co-Dep Uncalibrated	An attempt is being made to turn on a sensor that is not calibrated for Co-Dep.		Material

Table 15-6 Input error messages (continued)

Input Error Message	Set	Cleared	Screen
Co-Dep Crosstalk Error	An attempt is being made to turn on a sensor that will cause a Crosstalk error.	Each input error message is taken down by pressing the clear key.	Material
DAC Used Material ## Or DAC Used Sensor ##	The DAC number has been previously defined as a recorder output in the material or the sensor set up.		Source parameter
DAC Used Source XX	The DAC number has been previously defined as a source DAC output in one of the source set ups		Material, Sensor and Source parameter
Input in use	An attempt was made to enter an input that is already reserved for use in source setup or one of the logic statements.		Source parameter
Output in use	An attempt was made to enter an output that is already reserved for use. The output is already reserved for use in Sensor or Source set up or in one of the logic statements.		Sensor, Source parameter and Logic Edit
Invalid Lock Code	An incorrect lock code was used to attempt to unlock IC6.		Menu
Can't Empty Active Process	Can't empty a process if it is set as the active process.		Process Layer detail
Can't Delete Co-Dep	An attempt was made to delete a layer set for co-deposition.		Process Layer detail
Can't Insert Co-Dep	A layer cannot be inserted between two layers set for co-deposition.		Process Layer detail
Output Used In Logic Equ #	An attempt was made to use an Output that is programmed in Logic Statement #.		Source Sensor General
Reset Required First	An attempt was made to enable Source Maintenance while not in Ready.		Source Maintenance

15.7 Troubleshooting Guide

If IC6 fails to work, or appears to have diminished performance, the following Symptom/Cause/Remedy charts may be helpful.



CAUTION

There are no user serviceable components within the IC6 case.

Potentially lethal voltages are present when the line cord, Inputs or Outputs are connected.

Refer all maintenance to qualified personnel.

This IC6 contains delicate circuitry which is susceptible to transients. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.

15.7.1 Troubleshooting IC6

Table 15-7 Troubleshooting IC6

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 IC6	b. Reconnect power cord
	c. Incorrect line voltage	c. Have qualified personnel verify line voltage, verify IC6 is configured for the correct voltage
2. IC6 "locks" up	a. Cover or back panels not attached to IC6	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 IC6), 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 IC6 grounding
3. IC6 does not retain parameters on power down (loss of parameters on power up)	a. Faulty static RAM	a. SRAM battery has a normal life expectancy of ten years, contact INFICON service department
	b. Power supply problem	b. Contact INFICON service department
4. Some keys on front panel function while others do not	a. Faulty keypad or faulty keypad ribbon cable	a. Contact INFICON service department
5. All keys on the front panel fail to function	a. IC6 is "locked" up	a. Turn power to OFF or to STBY, then to ON, see item 2 above

Table 15-7 Troubleshooting IC6 (continued)

SYMPTOM	CAUSE	REMEDY
6. Control voltage output does not function properly	a. DAC board damaged from applying voltage to the control voltage output	a. Ensure cable connection to the DAC board does not have a potential across the contacts, contact INFICON service department
	b. Reversed polarity of control voltage relative to that accepted by the source power supply	b. Verify source output polarity of the DAC and the required input polarity of the source power supply, refer to the instruction manual to reconfigure IC6 if necessary
	c. Improper control cable fabrication	c. Check for correct cable wiring in the appropriate section of the manual
7. LCD display dull or blank	a. Brightness/contrast adjustment required	a. Refer to manual for location of adjustment potentiometer, adjust as desired
	b. LCD or power supply problem	b. Contact INFICON service department
8. Poor rate control	a. Control loop parameters improperly selected	a. Refer to the instruction manual section on tuning control loop parameters
	b. Electron beam sweep frequency "beating" with IC6's measurement frequency	b. Adjust the sweep frequency so it is not a multiple of IC6's measurement frequency

Table 15-7 Troubleshooting IC6 (continued)

SYMPTOM	CAUSE	REMEDY
9 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 service department
	c. Defective cable from feedthrough to XIU/oscillator or from IC6 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. S & Q values exceed programmed values	h. Clear S & Q via Remote Comm or Function Key F3 on Sensor Information page.

15.7.2 Troubleshooting Transducers/Sensors

NOTE: 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 center pin to ground. If the reading is less than 1-2 megohms, the source of the leakage should be found and corrected. Likewise, with the vacuum system open check for center conductor continuity, a reading of more than 1 ohm from the feedthrough to the transducer contact indicates a problem. Cleaning contacts or replacing the in-vacuum cable may be required.

A somewhat more thorough diagnosis may be performed with the optional Crystal Sensor Emulator, 760-601-G1. See [section 15.9 on page 15-33](#) for a discussion of its use and diagnostic capabilities.

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

Table 15-8 Troubleshooting Transducers/Sensors

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

Table 15-8 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
2. Crystal ceases to oscillate during deposition before it reaches the end its normal life	a. Crystal struck by particulate or spatter from molten source	a. Thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	b. Material on crystal holder partially masking crystal cover aperture	b. Clean crystal holder
	c. Existence of electrical short or open condition	c. Using an ohm meter or DVM, check for electrical continuity in the sensor cable, connector, contact springs, connecting wire inside sensor, and feedthroughs
	d. Check for thermally induced electrical short or open condition	d. See C above
NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition.		
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 approx. 45°
	c. RF interference from sputtering power supply	c. Verify earth ground, use ground strap adequate for RF ground, change location of IC6 and oscillator cabling away from RF power lines, connect IC6 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

Table 15-8 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
4. Crystal oscillates in vacuum but stops oscillation after open to air	a. Crystal was near the end of its life; opening to air causes film oxidation which increases film stress	a. Replace crystal
	b. Excessive moisture accumulates on the crystal	b. Turn off cooling water to sensor prior to venting, flow warm water through sensor while chamber is open
5. Thermal instability: large changes in thickness reading during source warm-up (usually causes thickness reading to decrease) and after the termination of deposition (usually causes thickness reading to increase)	a. Inadequate cooling water/cooling water temperature too high	a. Check cooling water flow rate, be certain that cooling water temperature is less than 30°C; refer to appropriate sensor manual
	b. Excessive heat input to the crystal	b. If heat is due to radiation from the evaporation source, move sensor further away from source and use sputtering crystals for better thermal stability; install radiation shield
	c. Crystal not seated properly in holder	c. Clean or polish the crystal seating surface on the crystal holder
	d. Crystal heating caused by high energy electron flux (often found in RF sputtering)	d. Use a sputtering sensor head
	e. Poor thermal transfer from water tube to body (XtalSix 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 15-8 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 IC6's measurement frequency
7. Large drift in thickness (greater than 200 Å for a density of 5.00 g/cc) after termination of sputtering	a. Crystal heating due to poor thermal contact	a. Clean or polish the crystal seating surface on the crystal holder
	b. External magnetic field interfering with the sensor's magnetic field (sputtering sensor)	b. Rotate sensor magnet to proper orientation with external magnetic field, refer to the sputtering sensor manual IPN 074-157
	c. Sensor magnet cracked or demagnetized (sputtering sensor)	c. Check sensor magnetic field strength, the maximum field at the center of the aperture should be 700 gauss or greater

Table 15-8 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
8. XtalSix, Xtal12, or Generic crystal switch problem (does not advance or not centered in aperture)	a. No relay or incorrect relay output programmed	Program relay
	b. Loss of pneumatic supply, or pressure is insufficient for proper operation	b. Ensure air supply is regulated at 80-90 psi
	c. Operation has been impaired as a result of material accumulation on cover	c. Clean material accumulation as needed, refer to XtalSix manual IPN 074-155 for maintenance
	d. Improper alignment	d. Realign as per instructions in XtalSix manual IPN 074-155
	e. 0.0225" diameter orifice not installed on the supply side of solenoid valve assembly	e. Install orifice as shown in the XtalSix manual IPN 074-155

15.7.3 Troubleshooting Computer Communications

Table 15-9 Troubleshooting computer communications

SYMPTOM	CAUSE	REMEDY
1. Communications cannot be established between the host computer and IC6	a. Improper cable connection	a. Verify for correct cable wiring as described in section 2.3.2.5 on page 2-11 .
	b. BAUD rate in host computer not the same as IC6	b. Verify BAUD rate in the host's applications program, verify BAUD rate in IC6
	c. Incompatible protocols being used	c. Verify that IC6 protocol: RS232, DATALOG, matches host

Table 15-9 Troubleshooting computer communications (continued)

SYMPTOM	CAUSE	REMEDY
2. Error code returned	a. A = illegal command	a. The command sent was not valid; verify command syntax as shown in IC6's manual (placement of spaces within the command string is important)
	b. B = illegal value	b. The parameter's value sent is outside the range for the given parameter, verify parameter's range
	c. C = illegal ID	c. The command sent was for a parameter which doesn't exist; verify the correct parameter number
	d. D = illegal command format	d. The command sent is not valid; verify command syntax as shown in IC6 manual (placement of spaces within the command string is important)
	e. E = no data to retrieve	e. Some parameters may not be in use, depending on the value of other parameters

Table 15-9 Troubleshooting computer communications (continued)

SYMPTOM	CAUSE	REMEDY
2. Error code returned (continued)	f. F = Cannot change value now	f. The command sent is for a parameter that cannot be changed while IC6 is executing a Process; place IC6 in the READY state in order to change the value
	g. G = Bad checksum	g. Checksum value does not match the value sent by the host's application program, may be caused by noise on the RS232 cable or the checksum is not calculated properly by the applications program
	h. 0 = Data overrun	h. I/O port unable to keep up with data transfer rate; lower BAUD rate, increase speed of host's applications program by; using a compiled version of the program, stream lining program execution, use a faster CPU

15.8 Replacing the Crystal

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



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.

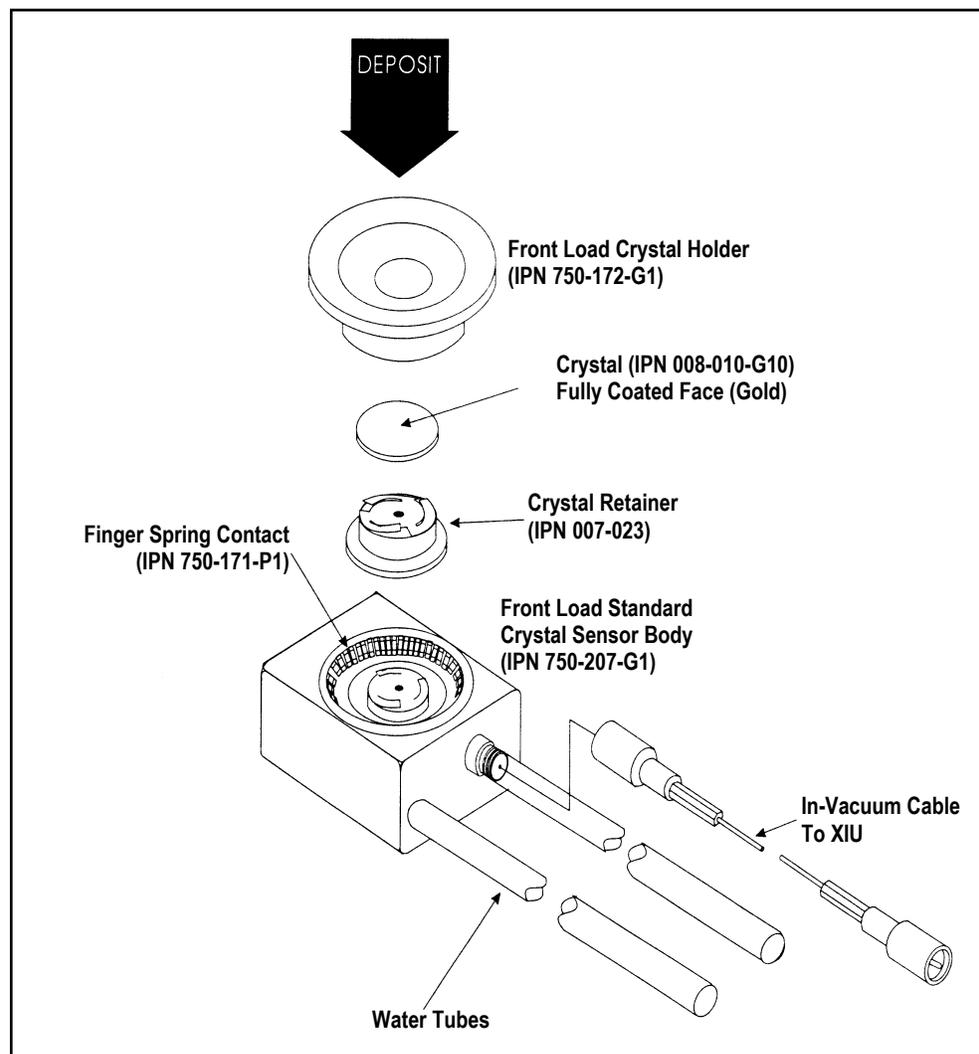
NOTE: Thick deposits of some materials, such as SiO₂, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, replace the crystals.

15.8.1 Front Load

Follow the procedure below to replace the crystal in the Front Load sensor: (See Figure 15-1.)

- 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 15-6 on page 15-32).
- 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 15-1 Front load crystal sensor (exploded)



15.8.2 Cool Drawer

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, as shown in Figure 15-2.
- 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 15-3.
- 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 15-3. Never push down (or pull up) on the contact spring, doing so may permanently damage it.
- 5 Inspect the whole assembly. The retainer should be even and engage the drawer at all four corners.

Figure 15-2 Cool drawer - removing the crystal

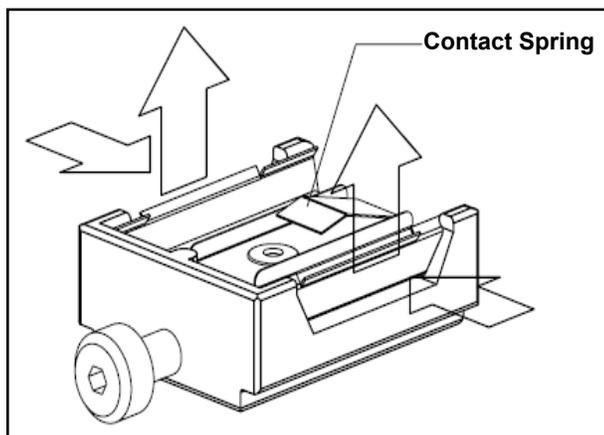
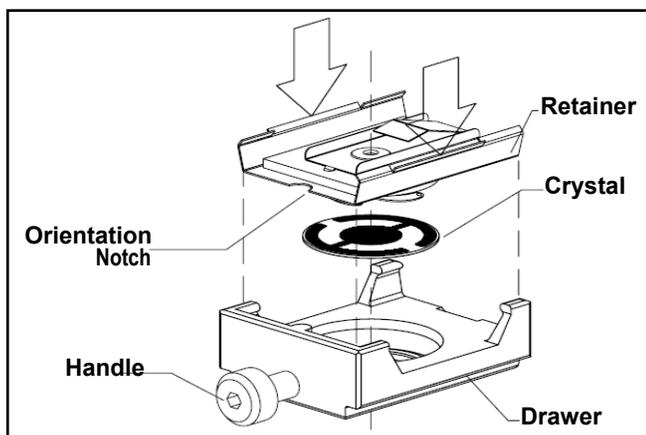


Figure 15-3 Cool drawer - replacing the crystal



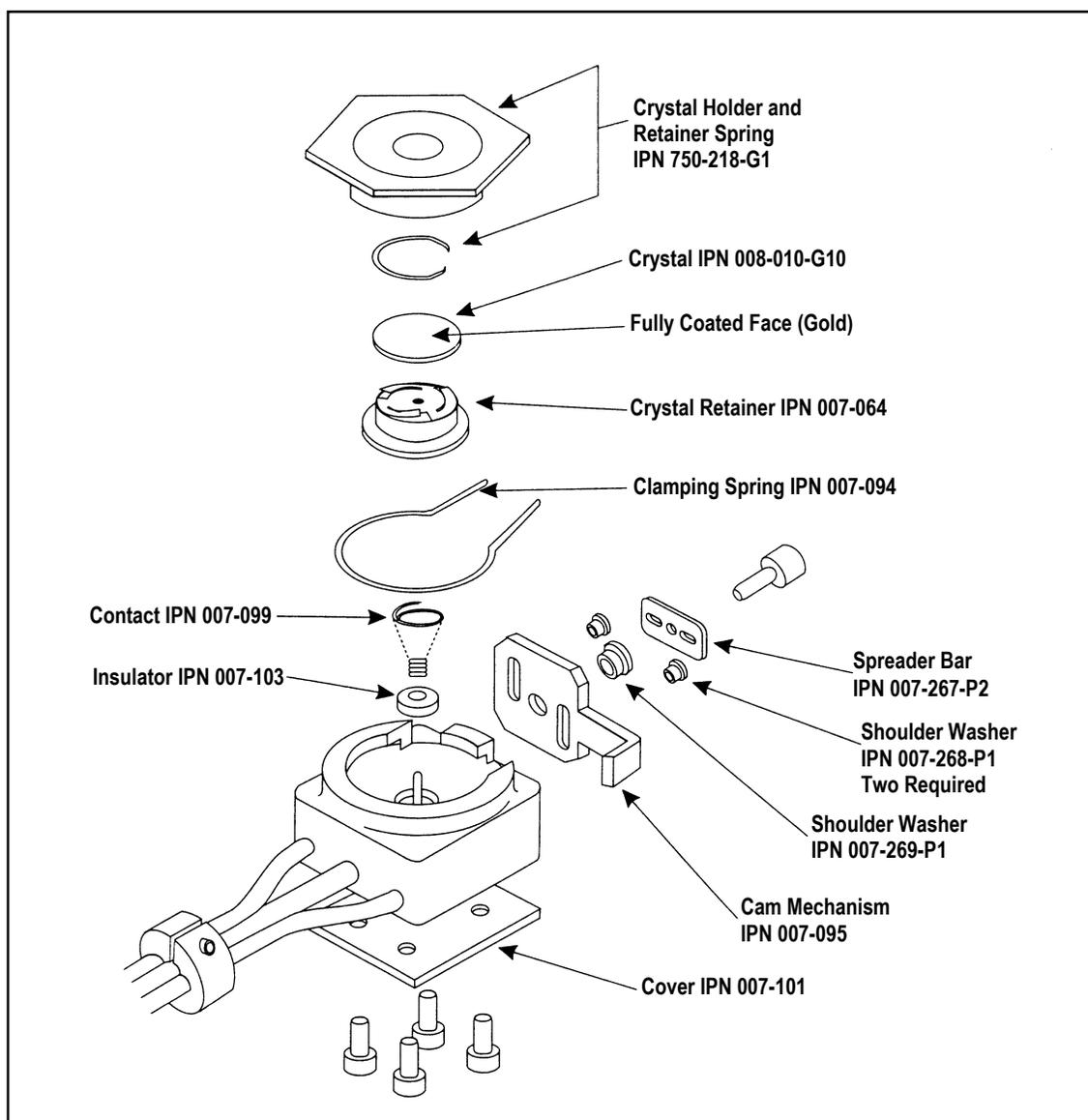
15.8.3 Shuttered and Dual Sensors

There is no difference in the crystal replacement procedure between shuttered and non-shuttered Front Load sensors, since the shutter pivots away from the crystal opening when the shutter is in the relaxed state. This is also the case for Cool Drawer Sensors as the shutter assembly does not obstruct the drawer from being inserted into the sensor body.

15.8.4 Bakeable Sensor

For the Bakeable sensor, the procedure is the same as the Front Load sensor except that you must first unlock the cam assembly by flipping it up. Once the crystal has been replaced, place a flat edge of the holder flush with the cam mechanism and lock it in place with the cam. See Figure 15-4.

Figure 15-4 Bakeable crystal sensor

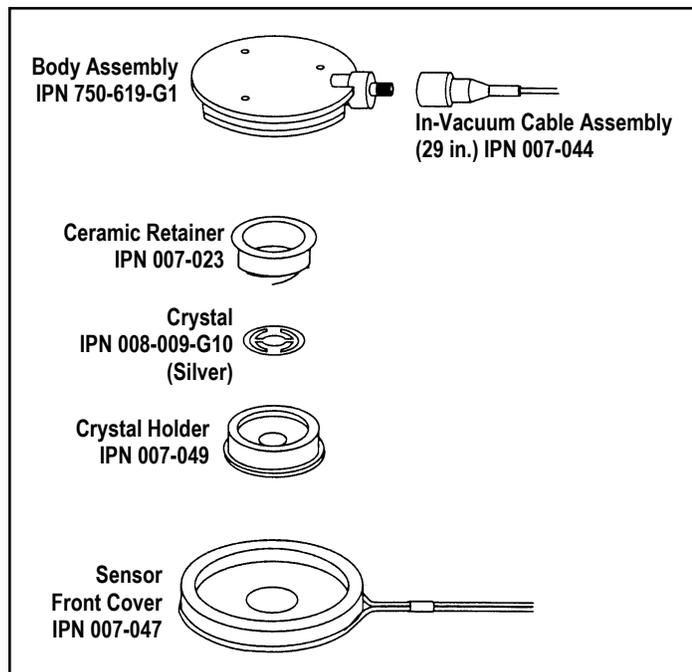


15.8.5 Sputtering Sensor

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 cover. (You may have to disconnect the sensor cable in order to separate the parts.) See [Figure 15-5](#).
- 2 Pull the crystal holder straight out from the front of the body assembly.
- 3 Remove the ceramic retainer from the crystal holder by pulling it straight out with the crystal snatcher (see [section 15.8.6 on page 15-32](#)).
- 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.
- 6 Put the ceramic retainer back into the crystal holder and put the holder into the body assembly of the sensor.
- 7 Align the position of the body assembly so that the connector matches with the notch on the front cover of the sensor. Snap the two parts together. Reconnect the sensor cable if it has been disconnected.

Figure 15-5 Sputtering crystal sensor

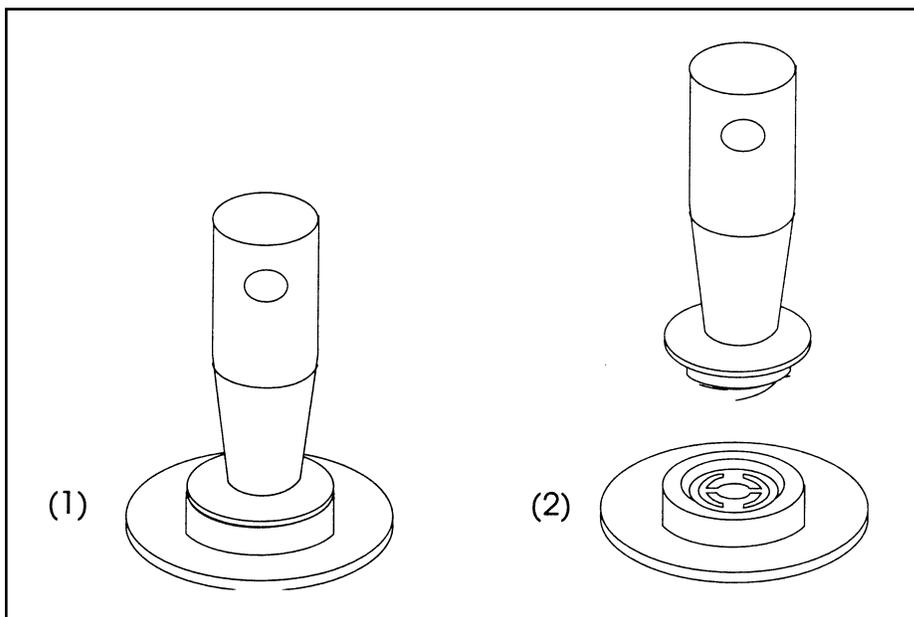


15.8.6 Crystal Snatcher

Use the crystal snatcher, supplied with the sensor, 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). See Figure 15-6.
- 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 15-6 Use of the crystal snatcher



15.8.7 CrystalSix (XtalSix)

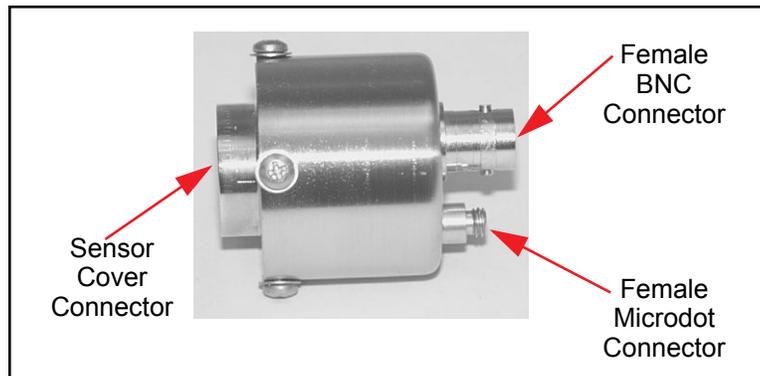
Refer to the Crystal Six Operating Manual (IPN 074-155) for specific instructions for this device.

15.9 Crystal Sensor Emulator IPN 760-601-G1 or 760-601-G2

NOTE: Crystal Sensor Emulator 760-601-G1 (obsolete) is not compatible for use with an IC6, IC5 and IC4. 760-601-G2 is fully compatible with all Thin Film Deposition Controllers.

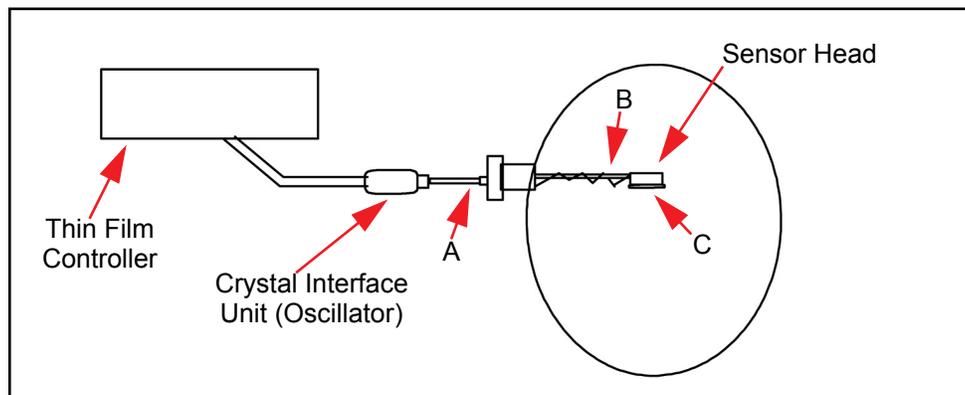
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See Figure 15-7.

Figure 15-7 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 15-8.

Figure 15-8 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.

15.9.1 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.

NOTE: The Unable To Auto-Z message will be displayed if the Crystal Sensor Emulator is attached to a deposition controller and you are attempting to use the Auto-Z feature. This is to be expected and is normal.

15.9.1.1 Measurement System Diagnostic Procedure

- 1 Refer to [Figure 15-8](#) on page 15-33. Remove the six-inch BNC cable from the feedthrough at point A.
 - 2 Connect the Crystal Sensor Emulator to the 6 inch BNC cable at Point A.
 - ♦ If the Crystal Fail message disappears after approximately five seconds, the measurement system is working properly. Re-install the six-inch BNC cable to the feedthrough. Go to [section 15.9.1.2](#).
 - ♦ If the Crystal Fail message remains, continue at step 3.
 - 3 Disconnect the six-inch BNC cable from the Oscillator and from the Emulator.
 - 4 Visually inspect the six-inch BNC cable to verify that the center pins are seated properly.
 - 5 Use an Ohm meter to verify the electrical connections on the six-inch BNC cable.
 - ♦ There must be continuity (<0.2 ohms after accounting for resistance of ohmmeter leads) between the center pins.
 - ♦ There must be isolation (>10 megohms) between the center pins and the connector shield.
 - ♦ There must be continuity between the connector shields.
- Replace the six-inch BNC cable if it is found to be defective and repeat Step 2 of this procedure.
- 6 If the six-inch BNC cable is not defective, re-connect the six-inch cable to the oscillator and to the Crystal Sensor Emulator. If the Crystal Fail message remains, contact INFICON.

15.9.1.2 Feedthrough Or In-Vacuum Cable Diagnostic Procedure

- 1 Refer to [Figure 15-8 on page 15-33](#). 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 Crystal Fail message disappears after approximately five seconds, the feedthrough and in-vacuum Cable are working properly. Re-install the in-vacuum cable to the Sensor Head. Go to [section 15.9.1.3 on page 15-36](#).
 - ♦ If the Crystal Fail message remains, continue at step 3.
- 3 Disconnect the in-vacuum cable from the feedthrough and the Emulator. Disconnect the six-inch BNC cable from the feedthrough.
- 4 Using an Ohm Meter, verify electrical continuity from the BNC center pin on the feedthrough to the Microdot center pin on the feedthrough. A typical value would be less than 0.2 ohms.
- 5 Verify electrical isolation of the center pin on the feedthrough from the electrical ground (feedthrough body). A typical value would be in excess of 10 megohms.

If the feedthrough is found to be defective, replace the feedthrough, 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 feedthrough.
- 9 Verify electrical continuity from the center pin on the BNC connector of the feedthrough 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 (feedthrough body).

If the feedthrough/in-vacuum cable system is found to be defective, look for defective electrical contacts at the feedthrough to in-vacuum cable connection. Repair or replace the feedthrough 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 six-inch BNC cable to the feedthrough and disconnect it from the Crystal Interface Unit (or Oscillator)

- 12** Verify electrical continuity from the center pin of the Microdot connector on the feedthrough to the un-terminated end of the six-inch BNC cable.
- 13** Verify electrical isolation from the center pin to electrical ground (feedthrough body).

If the feedthrough/six-inch BNC cable system is found to be defective, look for defective contacts at the feedthrough to BNC cable connection. Repair or replace the feedthrough 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.

15.9.1.3 Sensor Head Or Monitor Crystal Diagnostic Procedure

NOTE: The procedure is for use with front load style sensor heads.

- 1** Remove the Crystal Cover from the Sensor Head.
- 2** Refer to [Figure 15-7 on page 15-33](#). Connect the Crystal Sensor Emulator to the Sensor Head at Point C.
 - ◆ If the Crystal Fail message disappears after approximately 5 seconds the Sensor Head is operating properly. Remove the Crystal Sensor Emulator and re-insert the Crystal Cover into the Sensor Head.
 - ◆ If the Crystal Fail message remains, continue at step 3.
- 3** Disconnect the in-vacuum cable from the Sensor Head and the feedthrough. 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 leaf spring contact in the Sensor Head. Take care not to apply too much pressure on the center pin of the microdot connector as it may become damaged.
 - ◆ 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.

- 5 Connect the in-vacuum Cable to the Sensor Head.
 - ◆ Verify there is continuity (<0.2 ohm) from the leaf 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 megohm) between the leaf 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 feedthrough 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° and 45° from flat, respectively.

15.9.1.4 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 Holder for build-up of material. Clean or replace the Crystal Holder 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 new 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.

15.9.2 % 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 30% for IC6 deposition controllers which allow a 1.5 MHz frequency shift.

15.9.3 Sensor Cover Connection

The Crystal Sensor Emulator can be used to verify the measurement system for INFICON Thin Film Deposition Controllers and Monitors.

NOTE: The Crystal Sensor Emulator 760-601-G1 is not compatible for use with an IC6. Use 760-601-G2 for all thin film deposition controllers.

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.

15.9.3.1 Compatible Sensor Heads

The Sensor Cover Connection will fit the sensor heads shown in [Table 15-10](#).

Table 15-10 Compatible sensor heads

Sensor Head	Part Number
Front Load Single Sensor Head	SL-XXXXX
Front Load Dual Sensor Head	DL-AEXX

15.9.3.2 Incompatible Sensor Heads

The Sensor Heads for which the Crystal Sensor Emulator's Sensor Cover Connector will not fit are shown in [Table 15-11](#).

Table 15-11 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.

15.9.4 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

760-601-G1: 5.5 MHz \pm 30 ppm at room temperature
760-601-G2: 5.5 MHz \pm 1 ppm at room temperature

Materials

304 Stainless Steel, Nylon, Teflon, brass. Some internal components contain zinc, tin, and lead.

Chapter 16

Measurement and Control Theory

16.1 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 are reduced. This change in frequency is very repeatable and is precisely understood for specific oscillating modes of quartz. This heuristically easy to understand phenomenon is the basis of an indispensable measurement and process control tool that can easily detect the addition of less than an atomic layer of an adhered foreign material.

In the late 1950's it was noted by Sauerbrey^{1,2} and Lostis³ 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:

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

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:

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

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 ($= 2.649 \text{ g/cm}^3$) is the density of single crystal quartz and N_{at} ($= 166100 \text{ Hz cm}$) is the frequency constant of AT cut quartz. A crystal with a starting frequency of 6.0 MHz will display a reduction of its frequency by 2.27 Hz when 1 angstrom of Aluminum (density of 2.77 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

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

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

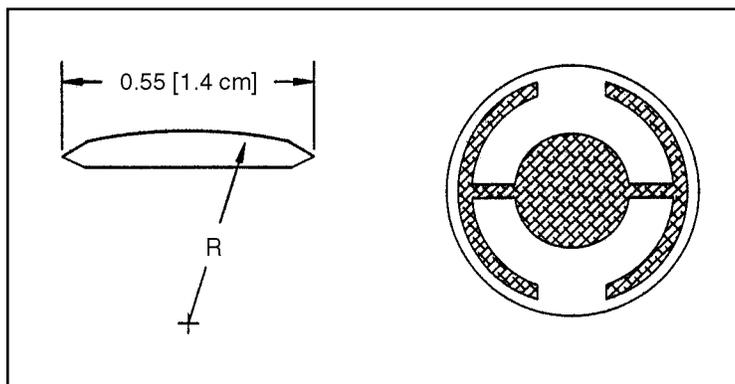
3.P. Lostis, Rev. Opt. 38,1 (1959)

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.

16.1.1 Monitor Crystals

No matter how sophisticated the electronics surrounding it, the essential device of the deposition monitor is the quartz crystal. The quartz crystal shown in Figure 16-1 has a frequency response spectrum that is schematically shown in Figure 16-2. The ordinate represents the magnitude of response, or current flow of the crystal, at the specified frequency.

Figure 16-1 Quartz resonator

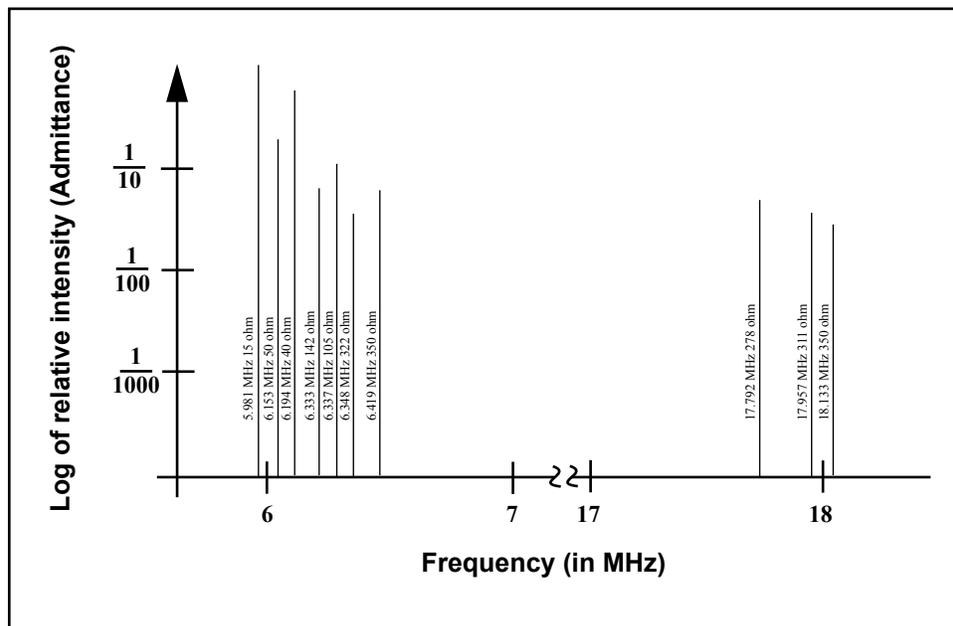


The lowest frequency response is primarily a “thickness shear” mode that is called the fundamental. The characteristic movement of the thickness shear mode is for displacement to take place parallel to the major monitor crystal faces. In other words, the faces are displacement antinodes as shown in Figure 16-3. 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 are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

The monitor crystal design depicted in Figure 16-1 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.

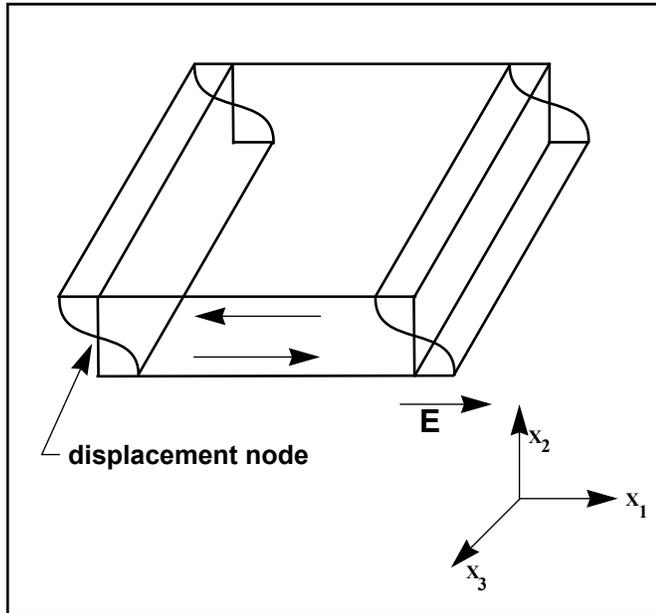
Figure 16-2 Frequency response spectrum



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 16-3 Thickness shear displacement



16.1.2 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 DF less than $0.02 F_q$. In 1961 it was recognized by Behrndt⁴ that:

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

where T_c and T_q are the periods of oscillation of the crystal with film (composite) and the bare crystal respectively. The period measurement technique was the outgrowth of two factors; 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. Since the frequency of the reference is stable and known, the time to accumulate the m counts is known to an accuracy equal to $\pm 2/F_r$ where F_r is the reference oscillator's frequency. The

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

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.

16.1.3 Z-match Technique

After learning of fundamental work by Miller and Bolef⁵, which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis⁶ 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].

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

where $Z = (d_q u_q / d_f u_f)^{1/2}$ is the acoustic impedance ratio and u_q and u_f are the shear moduli of the quartz and film, respectively. Finally, there was a fundamental understanding of the frequency-to-thickness conversion that could yield theoretically correct results in a time frame that was practical for process control. To achieve this new level of accuracy requires only that the user enter an additional material parameter, Z , for the film being deposited. This equation has been tested

5. J. G. Miller and D. I. Bolef, J. Appl. Phys. **39**, 5815, 4589 (1968)

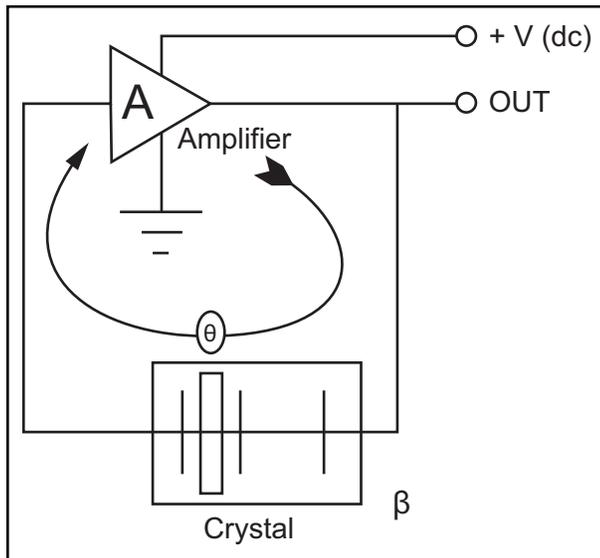
6. C. Lu and O. Lewis, J Appl. Phys. **43**, 4385 (1972)

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 $\sim 0.05F_q$.

16.1.4 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 16-4. 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 16-5 on page 16-7.

Figure 16-4 Active oscillator circuit



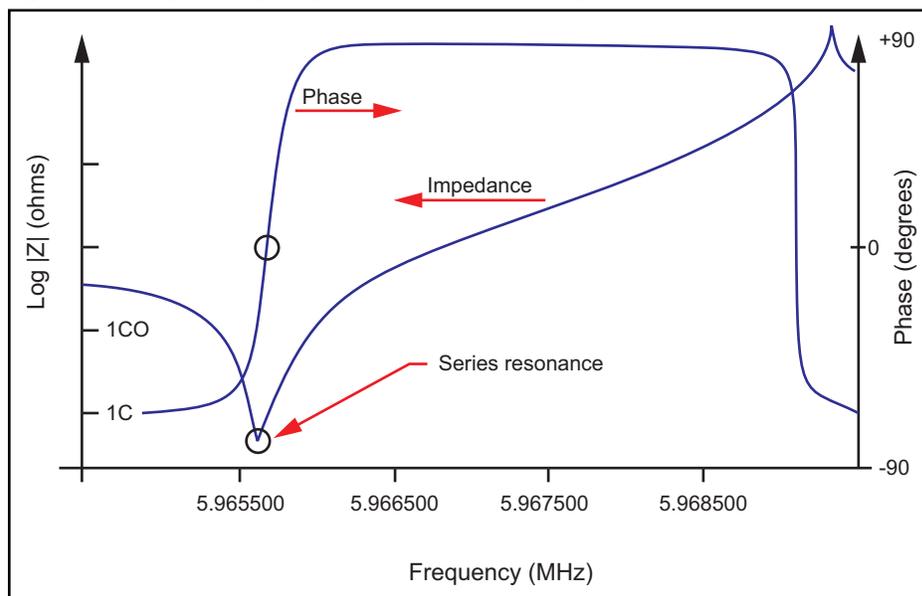
The active oscillator circuit is designed so the crystal is required to produce a phase shift of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain 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 16-6 on page 16-8 is the same plot as Figure 16-5 overlaid with the response of a heavily loaded crystal. The crystal has lost the steep slope displayed in Figure 16-5. 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 16-5 Crystal frequency near series resonance point

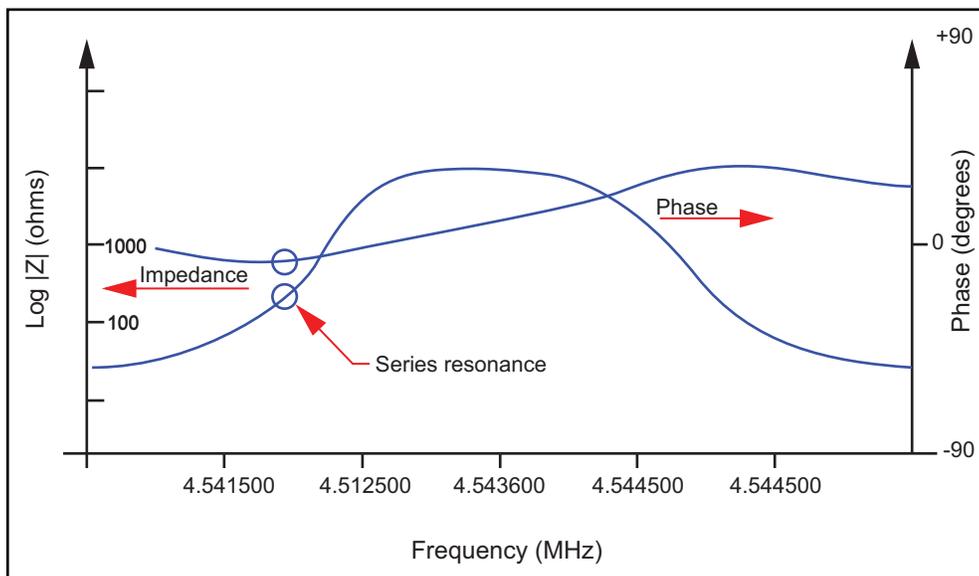


16.1.5 ModeLock Oscillator

INFICON 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 0.005 Hz at a rate of 10 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 16-6 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. The technique also allows the implementation of a sophisticated feature that cannot even be contemplated using the active oscillator approach. The same capability that allows the new technology to sweep and identify the fundamental can be used to identify other oscillation modes, such as the anharmonics and the quasiharmonic. Not only can the instrument track the

fundamental mode continuously, but also it can be implemented to alternate between one or more other modes. This interrogation of multiple modes can be performed as fast as 10 Hz for two modes of the same crystal.

16.1.6 Auto-Z Theory

The one drawback in using equation [4] on page 16-5 is that the acoustic impedance must be known. There are several cases where accuracy has to be compromised because of incomplete or limited knowledge of the material constants of the deposited materials.

- ♦ Often the Z-Ratio for the bulk material is different from that of the deposited thin film. Thin films are especially sensitive to process parameters, particularly in a sputtering environment. Consequently, the values available for bulk materials may not be pertinent.
- ♦ For many exotic materials, including alloys, the Z-Ratio is not known nor easily available.
- ♦ There has always been a need to accurately measure layer thickness of multiple material films using the same crystal sensor. This is particularly true for multi-layer optical coatings and high-temperature superconductor fabrication. The effective Z-Ratio of the composite of multi-material layers is not known.

In such cases, the only recourse is to assume the Z-Ratio to be unity (that is, ignoring the reality of wave propagation in composite media). This false premise introduces error in the thickness and rate predictions. The magnitude of this error depends upon the film thickness and the amount of departure of the true Z-Ratio from unity.

In 1989, A. Wajid became aware of the ModeLock oscillator⁷. He speculated there might be a relationship between the fundamental and one of the anharmonics similar to the relationship noted by Benes⁸ between the fundamental and the third quasiharmonic. The frequencies of the fundamental and the anharmonics are very similar, solving the problem of capacitance of long cables. He found the ideas needed for establishing the required connections in papers published by Wilson⁹ in 1974 and Tiersten and Smythe¹⁰ in 1979.

Contouring a crystal, that is, giving one face a spherical shape, has the effect of separating the various modes further apart and preventing the transfer of energy from one mode to another. For the sake of identification it is common to assign mode [100] to the fundamental, [102] to the lowest frequency anharmonic and [120] to the next lowest frequency anharmonic. The three indices of the mode

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

8.E. Benes, J. Appl. Phys. 56(3), 608-626 (1984)

9.C. J. Wilson, J. Phys. d7,2449 (1974)

10.H. F. Tiersten and R.C. Smythe, J. Acoust. Soc. Am., 65(6), 1455 (1979).

assignment refer to the number of phase reversals in the wave motion along the three axes of the crystal. The above-referenced papers by Wilson and Tiersten & Smythe are examinations of modal properties, relating the various properties of the radius of curvature to the placement of the anharmonics relative to the fundamental.

As material is deposited upon one face of a crystal, the entire spectrum of resonances shifts to lower frequencies. The three above mentioned modes are observed to have slightly different mass sensitivity and hence undergo slightly different frequency shifts. It is this difference that is used to estimate the Z-Ratio of the material. Using the modal equations and the observed frequencies of the modes [100] and [102], one can calculate the ratio of two elastic constants C_{66} and C_{55} . Both of these elastic constants relate to shear motion. The essential element of Wajid's theory is the following equation:

$$\frac{(C_{55}/C_{66})_{\text{coated}}}{(C_{55}/C_{66})_{\text{uncoated}}} \sim \frac{1}{(1 + MZ)} \quad [5]$$

where M is the aerial mass density (film mass to quartz mass ratio per unit area) and Z is the Z-Ratio. It is a fortunate coincidence that the combination MZ also appears in the Lu-Lewis equation [4], which can be used to extract an estimate of the effective Z-Ratio from the equations below:

$$\tan\left(MZ\pi\frac{F_c}{F_q}\right) + Z \tan\left(\pi\frac{F_c}{F_q}\right) = 0 \quad [6]$$

or

$$Z = -\frac{\tan\left(MZ\pi\frac{F_c}{F_q}\right)}{\tan\left(\pi\frac{F_c}{F_q}\right)} \quad [7]$$

Where, F_q and F_c denote uncoated and coated crystal frequencies in the fundamental mode (mode [100]). Due to the multi-valued nature of the mathematical functions involved, the value of Z-Ratio extracted in this manner is not always a positive definite quantity. This is hardly of any consequence however, because M is uniquely determined with the estimated Z and the measured frequency shift. Thus, thickness and rate of deposition are subsequently calculated from the knowledge of M.¹¹

One must be aware of the limitations of this technique. Since the estimate for Z-Ratio is dependent on the frequency shifts of the two modes, any spurious shift due to excessive mechanical or thermal stress on the crystal will lead to errors.

11.U.S. Patent No. 5,112,642 (May 12, 1992) International Patents Pending.

Needless to say, similar errors occur with the Z-match™ technique under similar circumstances. However, the automatic Z-Ratio estimate is somewhat more prone to error, because the amplitude distribution of the mode [102] is asymmetric, whereas that of the mode [100] is symmetric over the active area of the crystal.

In our experience, film-induced stress on the crystal has the most deleterious effect. This effect is most pronounced whenever there is a presence of gas in the environment, for example, in reactive evaporation or sputtering processes. In such cases, if the bulk Z-Ratio is already well known, it is better to use the bulk value instead of the automatically determined Auto-Z-Ratio. In cases of co-deposition and sequential layers, automatic Z-Ratio estimation is significantly superior.

16.1.7 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.

It is quite laborious and frustrating to tune a controller for an evaporation source that takes several minutes to stabilize. It may take several hours to obtain satisfactory results. Often the parameters chosen for a specific rate will not be satisfactory for another. Ideally, it would be nice if a machine could optimize itself. The IC6 can do this. In an operator initiated mode that is used during initial setup IC6 will measure the source characteristics. Slow sources are characterized by having significant dead time, whereas fast sources have no dead time.

For a slow source, IC6 will use a PID model to calculate optimum source control parameters. For a fast source, IC6 will use an integrating control loop model to calculate optimum source control parameters

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.

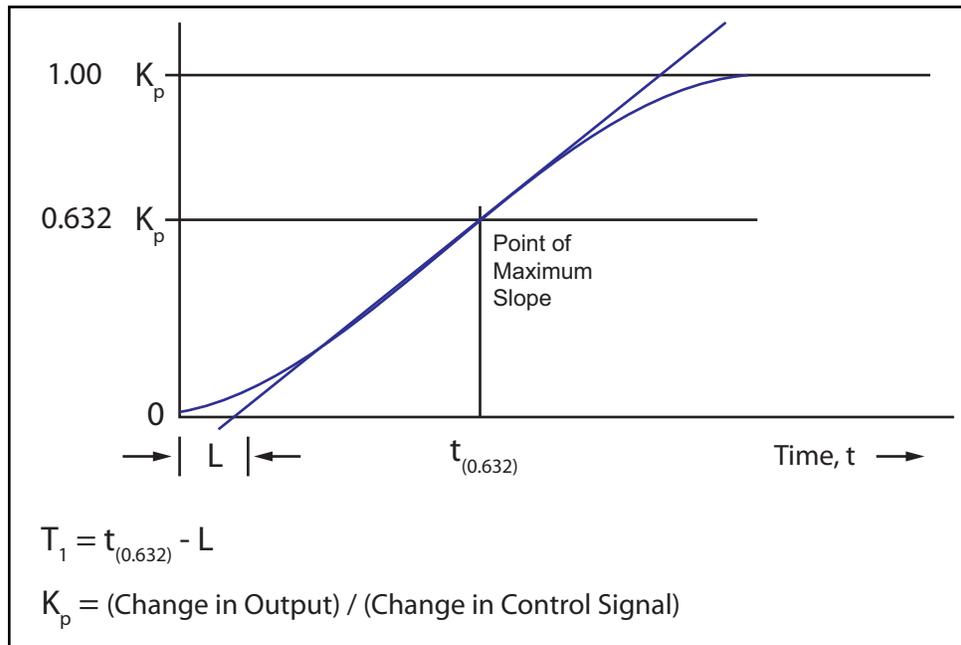
INFICON Auto-Control-Tune characterizes a process from its step response attributes. After Auto-Control-Tune executes a step change of power, the resulting rate changes are smoothed and stored. The important response characteristics are determined as shown in [Figure 16-7](#).

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:

$$\frac{\text{Output}}{\text{Input}} = \frac{K_p \exp(-Ls)}{T_1 s + 1} \quad [8]$$

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 16-7](#). 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 16-7 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 [9].

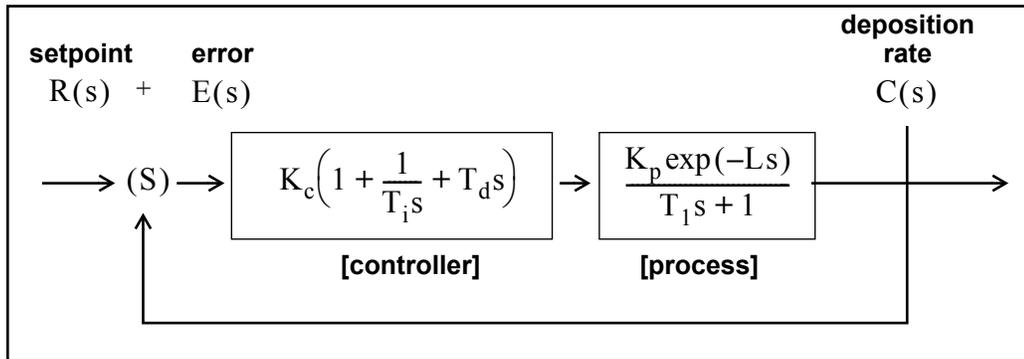
$$M(s) = K_c \left(1 + \frac{1}{T_i s} + T_d s \right) E s \quad [9]$$

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 16-8 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 16-8 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:

$$ISE = \int e^2(t)dt \tag{10}$$

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:

$$IAE = \int |e(t)|dt \tag{11}$$

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

Graham and Lathrop¹² introduced the Integral of Time multiplied by the Absolute Error (ITAE) as an alternate criterion of performance:

$$ITAE = \int t|e(t)|dt \tag{12}$$

12.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.

Auto-Control-Tune is based on an open loop measurement of the system's response. From a step change in the control signal, the response characteristics of the system are calculated. The experimental determination of response characteristics is accomplished through two types of 2-point curve fits. They are determined either quickly, but less accurately (that is, Quick Tune) at an arbitrary deposition rate, or less quickly, but more accurately (that is, Complete Tune) near the desired rate setpoint. Since the process response characteristics depend on the position of the system (that is, deposition rate for this discussion), the process response is best measured at the desired operating point of the system. This measured process information (that is, process gain, K_p , time constant, T_1 , and dead time, L) is used to generate the best fitting PID control loop parameters for the specific system.

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

$$K_c = (1.36/K_p)(L/T_1)^{-0.947} \quad [13]$$

$$T_i = (1.19T_1)(L/T_1)^{0.738} \quad [14]$$

$$T_d = (0.381T_1)(L/T_1)^{0.995} \quad [15]$$

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. Auto-Control-Tune detects the characteristics of these fast response systems during measurement of the step response. This information is used to calculate the controller gain coefficient for the non-PID control algorithm.

Appendix A

Material Table

A.1 Introduction

The following Table A-1 represents the content of IC6's material library. The list is alphabetical by chemical formula.



CAUTION

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

Remote Communications Responses and Commands use the code value to represent a specific material. 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

Code	Formula	Density	Z-Ratio	Material Name
0	Ag	10.500	0.529	silver
1	AgBr	6.470	1.180	silver bromide
2	AgCl	5.560	1.320	silver chloride
3	Al	2.700	1.080	aluminum
4	Al ₂ O ₃	3.970	0.336	aluminum oxide
5	Al ₄ C ₃	2.360	*1.000	aluminum carbide
6	AlF ₃	3.070	*1.000	aluminum fluoride
7	AlN	3.260	*1.000	aluminum nitride
8	AlSb	4.360	0.743	aluminum antimonide
9	As	5.730	0.966	arsenic
10	As ₂ Se ₃	4.750	*1.000	arsenic selenide
11	Au	19.300	0.381	gold
12	B	2.370	0.389	boron
13	B ₂ O ₃	1.820	*1.000	boron oxide
14	B ₄ C	2.370	*1.000	boron carbide
15	BN	1.860	*1.000	boron nitride
16	Ba	3.500	2.100	barium

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
17	BaF ₂	4.886	0.793	barium fluoride
18	BaN ₂ O ₆	3.244	1.261	barium nitrate
19	BaO	5.720	*1.000	barium oxide
20	BaTiO ₃	5.999	0.464	barium titanate (tetr)
21	BaTiO ₃	6.035	0.412	barium titanate (cubic)
22	Be	1.850	0.543	beryllium
23	BeF ₂	1.990	*1.000	beryllium fluoride
24	BeO	3.010	*1.000	beryllium oxide
25	Bi	9.800	0.790	bismuth
26	Bi ₂ O ₃	8.900	*1.000	bismuth oxide
27	Bi ₂ S ₃	7.390	*1.000	bismuth trisulfide
28	Bi ₂ Se ₃	6.820	*1.000	bismuth selenide
29	Bi ₂ Te ₃	7.700	*1.000	bismuth telluride
30	BiF ₃	5.320	*1.000	bismuth fluoride
31	C	2.250	3.260	carbon (graphite)
32	C	3.520	0.220	carbon (diamond)
33	C ₈ H ₈	1.100	*1.000	parlyene (union carbide)
34	Ca	1.550	2.620	calcium
35	CaF ₂	3.180	0.775	calcium fluoride
36	CaO	3.350	*1.000	calcium oxide
37	CaO-SiO ₂	2.900	*1.000	calcium silicate (3)
38	CaSO ₄	2.962	0.955	calcium sulfat
39	CaTiO ₃	4.100	*1.000	calcium titanate
40	CaWO ₄	6.060	*1.000	calcium tungstate
41	Cd	8.640	0.682	cadmium
42	CdF ₂	6.640	*1.000	cadmium fluoride
43	CdO	8.150	*1.000	cadmium oxide
44	CdS	4.830	1.020	cadmium sulfide
45	CdSe	5.810	*1.000	cadmium selenide
46	CdTe	6.200	0.980	cadmium telluride
47	Ce	6.780	*1.000	cerium
48	CeF ₃	6.160	*1.000	cerium (III) fluoride
49	CeO ₂	7.130	*1.000	cerium (IV) dioxide

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
50	Co	8.900	0.343	cobalt
51	CoO	6.440	0.412	cobalt oxide
52	Cr	7.200	0.305	chromium
53	Cr ₂ O ₃	5.210	*1.000	chromium (III) oxide
54	Cr ₃ C ₂	6.680	*1.000	chromium carbide
55	CrB	6.170	*1.000	chromium boride
56	Cs	1.870	*1.000	cesium
57	Cs ₂ SO ₄	4.243	1.212	cesium sulfate
58	CsBr	4.456	1.410	cesium bromide
59	CsCl	3.988	1.399	cesium chloride
60	CsI	4.516	1.542	cesium iodide
61	Cu	8.930	0.437	copper
62	Cu ₂ O	6.000	*1.000	copper oxide
63	Cu ₂ S	5.600	0.690	copper (I) sulfide (alpha)
64	Cu ₂ S	5.800	0.670	copper (I) sulfide (beta)
65	CuS	4.600	0.820	copper (II) sulfide
66	Dy	8.550	0.600	dysprosium
67	DY ₂ O ₃	7.810	*1.000	dysprosium oxide
68	Er	9.050	0.740	erbium
69	Er ₂ O ₃	8.640	*1.000	erbium oxide
70	Eu	5.260	*1.000	europium
71	EuF ₂	6.500	*1.000	europium fluoride
72	Fe	7.860	0.349	iron
73	Fe ₂ O ₃	5.240	*1.000	iron oxide
74	FeO	5.700	*1.000	iron oxide
75	FeS	4.840	*1.000	iron sulfide
76	Ga	5.930	0.593	gallium
77	Ga ₂ O ₃	5.880	*1.000	gallium oxide (B)
78	GaAs	5.310	1.590	gallium arsenide
79	GaN	6.100	*1.000	gallium nitride
80	GaP	4.100	*1.000	gallium phosphide
81	GaSb	5.600	*1.000	gallium antimonide
82	Gd	7.890	0.670	gadolinium

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
83	Gd ₂ O ₃	7.410	*1.000	gadolinium oxide
84	Ge	5.350	0.516	germanium
85	Ge ₃ N ₂	5.200	*1.000	germanium nitride
86	GeO ₂	6.240	*1.000	germanium oxide
87	GeTe	6.200	*1.000	germanium telluride
88	Hf	13.090	0.360	hafnium
89	HfB ₂	10.500	*1.000	hafnium boride
90	HfC	12.200	*1.000	hafnium carbide
91	HfN	13.800	*1.000	hafnium nitride
92	HfO ₂	9.680	*1.000	hafnium oxide
93	HfSi ₂	7.200	*1.000	hafnium silicide
94	Hg	13.460	0.740	mercury
95	Ho	8.800	0.580	holmium
96	Ho ₂ O ₃	8.410	*1.000	holmium oxide
97	In	7.300	0.841	indium
98	In ₂ O ₃	7.180	*1.000	indium sesquioxide,
99	In ₂ Se ₃	5.700	*1.000	indium selenide
100	In ₂ Te ₃	5.800	*1.000	indium telluride
101	InAs	5.700	*1.000	indium arsenide
102	InP	4.800	*1.000	indium phosphide
103	InSb	5.760	0.769	indium antimonide
104	Ir	22.400	0.129	iridium
105	K	0.860	10.189	potassium
106	KBr	2.750	1.893	potassium bromide
107	KCl	1.980	2.050	potassium chloride
108	KF	2.480	*1.000	potassium fluoride
109	KI	3.128	2.077	potassium iodide
110	La	6.170	0.920	lanthanum
111	La ₂ O ₃	6.510	*1.000	lanthanum oxide
112	LaB ₆	2.610	*1.000	lanthanum boride
113	LaF ₃	5.940	*1.000	lanthanum fluoride
114	Li	0.530	5.900	lithium
115	LiBr	3.470	1.230	lithium bromide

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
116	LiF	2.638	0.778	lithium fluoride
117	LiNbO ₃	4.700	0.463	lithium niobate
118	Lu	9.840	*1.000	lutetium
119	Mg	1.740	1.610	magnesium
120	MgAl ₂ O ₄	3.600	*1.000	magnesium aluminate
121	MgAl ₂ O ₆	8.000	*1.000	spinel
122	MgF ₂	3.180	0.637	magnesium fluoride
123	MgO	3.580	0.411	magnesium oxide
124	Mn	7.200	0.377	manganese
125	MnO	5.390	0.467	manganese oxide
126	MnS	3.990	0.940	manganese (II) sulfide
127	Mo	10.200	0.257	molybdenum
128	Mo ₂ C	9.180	*1.000	molybdenum carbide
129	MoB ₂	7.120	*1.000	molybdenum boride
130	MoO ₃	4.700	*1.000	molybdenum trioxide
131	MoS ₂	4.800	*1.000	molybdenum disulfide
132	Na	0.970	4.800	sodium
133	Na ₃ AlF ₆	2.900	*1.000	cryolite
134	Na ₅ Al ₃ F ₁₄	2.900	*1.000	chiolite
135	NaBr	3.200	*1.000	sodium bromide
136	NaCl	2.170	1.570	sodium chloride
137	NaClO ₃	2.164	1.565	sodium chlorate
138	NaF	2.558	1.645	sodium fluoride
139	NaNO ₃	2.270	1.194	sodium nitrate
140	Nb	8.578	0.492	niobium (columbium)
141	Nb ₂ O ₃	7.500	*1.000	niobium trioxide
142	Nb ₂ O ₅	4.470	*1.000	niobium (v) oxide
143	NbB ₂	6.970	*1.000	niobium boride
144	NbC	7.820	*1.000	niobium carbide
145	NbN	8.400	*1.000	niobium nitride
146	Nd	7.000	*1.000	neodymium
147	Nd ₂ O ₃	7.240	*1.000	neodymium oxide
148	NdF ₃	6.506	*1.000	neodymium fluoride

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
149	Ni	8.910	0.331	nickel
150	NiCr	8.500	*1.000	nichrome
151	NiCrFe	8.500	*1.000	Inconel
152	NiFe	8.700	*1.000	permalloy
153	NiFeMo	8.900	*1.000	supermalloy
154	NiO	7.450	*1.000	nickel oxide
155	P ₃ N ₅	2.510	*1.000	phosphorus nitride
156	Pb	11.300	1.130	lead
157	PbCl ₂	5.850	*1.000	lead chloride
158	PbF ₂	8.240	0.661	lead fluoride
159	PbO	9.530	*1.000	lead oxide
160	PbS	7.500	0.566	lead sulfide
161	PbSe	8.100	*1.000	lead selenide
162	PbSnO ₃	8.100	*1.000	lead stannate
163	PbTe	8.160	0.651	lead telluride
164	Pd	12.038	0.357	palladium
165	PdO	8.310	*1.000	palladium oxide
166	Po	9.400	*1.000	polonium
167	Pr	6.780	*1.000	praseodymium
168	Pr ₂ O ₃	6.880	*1.000	praseodymium oxide
169	Pt	21.400	0.245	platinum
170	PtO ₂	10.200	*1.000	platinum oxide
171	Ra	5.000	*1.000	radium
172	Rb	1.530	2.540	rubidium
173	RbI	3.550	*1.000	rubidium iodide
174	Re	21.040	0.150	rhenium
175	Rh	12.410	0.210	rhodium
176	Ru	12.362	0.182	ruthenium
177	S ₈	2.070	2.290	sulfur
178	Sb	6.620	0.768	antimony
179	Sb ₂ O ₃	5.200	*1.000	antimony trioxide
180	Sb ₂ S ₃	4.640	*1.000	antimony trisulfide
181	Sc	3.000	0.910	scandium

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
182	Sc ₂ O ₃	3.860	*1.000	scandium oxide
183	Se	4.810	0.864	selenium
184	Si	2.320	0.712	silicon
185	Si ₃ N ₄	3.440	*1.000	silicon nitride
186	SiC	3.220	*1.000	silicon carbide
187	SiO	2.130	0.870	silicon (ii) oxide
188	SiO ₂	2.648	1.000	silicon dioxide
189	Sm	7.540	0.890	samarium
190	Sm ₂ O ₃	7.430	*1.000	samarium oxide
191	Sn	7.300	0.724	tin
192	SnO ₂	6.950	*1.000	tin oxide
193	SnS	5.080	*1.000	tin sulfide
194	SnSe	6.180	*1.000	tin selenide
195	SnTe	6.440	*1.000	tin telluride
196	Sr	2.600	*1.000	strontium
197	SrF ₂	4.277	0.727	strontium fluoride
198	SrO	4.990	0.517	strontium oxide
199	Ta	16.600	0.262	tantalum
200	Ta ₂ O ₅	8.200	0.300	tantalum (V) oxide
201	TaB ₂	11.150	*1.000	tantalum boride
202	TaC	13.900	*1.000	tantalum carbide
203	TaN	16.300	*1.000	tantalum nitride
204	Tb	8.270	0.660	terbium
205	Tc	11.500	*1.000	technetium
206	Te	6.250	0.900	tellurium
207	TeO ₂	5.990	0.862	tellurium oxide
208	Th	11.694	0.484	thorium
209	ThF ₄	6.320	*1.000	thorium (IV) fluoride
210	ThO ₂	9.860	0.284	thorium dioxide
211	ThOF ₂	9.100	*1.000	thorium oxyfluoride
212	Ti	4.500	0.628	titanium
213	Ti ₂ O ₃	4.600	*1.000	titanium sesquioxide
214	TiB ₂	4.500	*1.000	titanium boride

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
215	TiC	4.930	*1.000	titanium carbide
216	TiN	5.430	*1.000	titanium nitride
217	TiO	4.900	*1.000	titanium oxide
218	TiO ₂	4.260	0.400	titanium (IV) oxide
219	Tl	11.850	1.550	thallium
220	TlBr	7.560	*1.000	thallium bromide
221	TlCl	7.000	*1.000	thallium chloride
222	TlI	7.090	*1.000	thallium iodide (B)
223	U	19.050	0.238	uranium
224	U ₃ O ₈	8.300	*1.000	tri uranium octoxide
225	U ₄ O ₉	10.969	0.348	uranium oxide
226	UO ₂	10.970	0.286	uranium dioxide
227	V	5.960	0.530	vanadium
228	V ₂ O ₅	3.360	*1.000	vanadium pentoxide
229	VB ₂	5.100	*1.000	vanadium boride
230	VC	5.770	*1.000	vanadium carbide
231	VN	6.130	*1.000	vanadium nitride
232	VO ₂	4.340	*1.000	vanadium dioxide
233	W	19.300	0.163	tungsten
234	WB ₂	10.770	*1.000	tungsten boride
235	WC	15.600	0.151	tungsten carbide
236	WO ₃	7.160	*1.000	tungsten trioxide
237	WS ₂	7.500	*1.000	tungsten disulfide
238	WSi ₂	9.400	*1.000	tungsten silicide
239	Y	4.340	0.835	yttrium
240	Y ₂ O ₃	5.010	*1.000	yttrium oxide
241	Yb	6.980	1.130	ytterbium
242	Yb ₂ O ₃	9.170	*1.000	ytterbium oxide
243	Zn	7.040	0.514	zinc
244	Zn ₃ Sb ₂	6.300	*1.000	zinc antimonide
245	ZnF ₂	4.950	*1.000	zinc fluoride
246	ZnO	5.610	0.556	zinc oxide
247	ZnS	4.090	0.775	zinc sulfide

Table A-1 Material table (continued)

Code	Formula	Density	Z-Ratio	Material Name
248	ZnSe	5.260	0.722	zinc selenide
249	ZnTe	6.340	0.770	zinc telluride
250	Zr	6.490	0.600	zirconium
251	ZrB ₂	6.080	*1.000	zirconium boride
252	ZrC	6.730	0.264	zirconium carbide
253	ZrN	7.090	*1.000	zirconium nitride
254	ZrO ₂	5.600	*1.000	zirconium oxide

