

Oxford Instruments NanoScience

Mercury iTC cryogenic environment controller

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Handbook

Mercury iTC

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Contents

Section		Page
PREFACE.....		11
Use of this manual		11
Customer support.....		11
Health and safety information		12
Intended users		12
Statement of intended use of the Mercury iTC		12
Typographical conventions		13
Disclaimers.....		13
Copyright notice		13
Acknowledgements		14
Acronyms, abbreviations and special terms.....		14
Revision history.....		14
Certification compliance statements		15
1 HEALTH AND SAFETY		17
1.1 Warnings		17
1.1.1 Protective ground		17
1.1.2 High voltage hazard		17
1.1.3 Maintenance and adjustment		18
1.1.4 Restrictions on use		18
1.2 Cautions		18
1.2.1 Electrostatic caution		18
1.2.2 Cooling caution		19
1.3 Solid waste		19
2 GETTING STARTED		21
2.1 Checking the electrical supply		21
2.2 Mounting the equipment		21
2.3 Connecting electrical power		22
2.3.1 Connecting the heaters and sensors		22
2.3.2 Connecting the data interfaces		22
2.3.2.1 Connecting the ethernet interface (if required).....		22
2.3.2.2 Connecting the RS232 serial interface (if required)		22
2.3.2.3 Connecting ISOBUS (if required)		22
2.3.2.4 Connecting the GPIB (if required)		23
2.3.3 Connecting the auxiliary port (if required)		23
2.3.4 Connecting the level-meter (if required)		23
2.4 Powering up the unit for the first time		24
2.4.1 Setting the date and time		24
2.4.2 General settings		24
2.4.3 Updating firmware		24
2.5 Configuring the Mercury iTC		25
2.5.1 Configuring the inputs		25
2.5.1.1 Configuring the sensor details.....		25
2.5.1.2 Using a generic calibration-file		26
2.5.2 Configuring a heater		27
2.5.3 Configuring the heater control loop		27
2.5.3.1 Configuring manual heater control		27
2.5.3.2 Configuring automatic heater control		28



Contents (continued)

Section		Page
2.5.4	Configuring a gas valve	28
2.5.4.1	Configuring manual control of the gas valve	29
2.5.4.2	Configuring automatic control of the gas valve.....	29
2.6	Testing the inputs and outputs	30
2.6.1	Testing the temperature sensor inputs	30
2.6.2	Testing the heater output	30
2.6.3	Configuring remote interfaces	30
2.7	Engineering mode	30
2.7.1	Entering engineering mode.	30
2.7.2	2 Exiting engineering mode	30
3	OVERVIEW OF THE ITC	31
3.1	System description	32
3.1.1	Temperature sensor circuits	33
3.1.2	Heater circuits	33
3.1.3	Optional cooling circuit	33
3.1.4	Remote interfaces	33
3.1.5	Display and touch-screen	33
3.1.6	Electrical power supply	34
4	USER INTERFACE	35
4.1	Front and rear panel controls	35
4.2	LCD display and GUI	35
4.2.1	Using the touch screen	35
4.2.1.1	Initiating actions.....	35
4.2.1.2	Drop-down menus	35
4.2.1.3	Scrolling	36
4.2.1.4	Soft keypads	37
4.2.1.5	Using arrows to adjust integer values	39
4.2.1.6	Button labels	39
4.2.2	Common screen features	40
4.2.2.1	Home and Apply buttons	40
4.2.3	Home page	41
4.2.3.1	Channel summary panel	42
4.2.4	Channel display configuration page	43
4.2.5	Device pair configuration page	44
4.2.6	Sensor details pages	45
4.2.6.1	Temperature Sensor Details page.....	45
4.2.6.2	Generic Sensor Adjustment page.....	46
4.2.6.3	Level Meter Sensor Details page.....	47
4.2.7	Plot Configuration page	49
4.2.8	Plot page	50
4.2.9	Control Loop Configuration page	50
4.2.10	Gas Flow Configuration page	52
4.2.11	PID Table Editor page	54
4.2.12	General Settings tab	56
4.2.12.1	Display Settings tab.....	57
4.2.12.2	Card settings tab	58
4.2.12.3	RS232 Settings tab	59

Contents (continued)

Section		Page
4.2.12.4	Ethernet Settings tab	60
4.2.12.5	ISOBus Settings tab	61
4.2.12.6	GPIB Settings tab	61
4.2.12.7	Clock Settings tab	62
4.2.12.8	Cal Update settings tab	63
4.2.12.9	F/W Update settings tab	64
4.2.12.10	EngMode tab	65
4.2.12.11	Factory Settings tab	66
4.2.13	Alarm Logs page	67
4.2.14	Heater configuration page	68
4.2.15	Sweep Table page	69
4.2.16	Save File pages	70
4.2.17	Load File pages	71
5	FUNCTIONAL DESCRIPTION	73
5.1	Main components	73
5.1.1	User interface	74
5.1.2	Motherboard	74
5.2	iTC connections	74
5.2.1	Electrical power connection	74
5.2.2	Temperature sensor inputs	74
5.2.3	Outputs	75
5.2.4	Heater and sensor connections	75
5.2.4.1	Connecting thermocouples.....	75
5.2.5	Communications interfaces	76
5.2.5.1	Serial RS232 interface	76
5.2.5.2	Oxford Instruments NanoScience ISOBUS	77
5.2.5.3	USB interface	77
5.2.5.4	Ethernet interface	77
5.3	Daughter boards	78
5.3.1	Expansion slots	78
5.3.2	Positioning daughter boards	79
5.3.2.1	Interconnecting heater and temperature-sensor boards	79
5.4	Overview of temperature measurement	80
5.4.1	Measurement principles	80
5.5	Types of temperature sensor	80
5.5.1	Thermocouples	82
5.5.2	Resistance and diode sensors	82
5.5.3	Calibration for different sensors	82
6	BASIC OPERATING INSTRUCTIONS	83
6.1	Configuring the LCD	83
6.2	Changing a setpoint	83
6.2.1	Changing a heater setpoint	83
6.2.2	Changing a gas-flow setpoint	83
6.3	Using the sweep function	83
6.3.1	The purpose of the sweep function	83
6.3.2	Programming a sweep	84
6.3.3	Loading a sweep	84



Contents (continued)

Section		Page
6.3.4	Starting a sweep	84
6.3.5	Stopping a sweep	85
6.4	Using the plot function	85
6.4.1	Configuring a plot	85
6.4.2	To remove a trace from the plot	86
6.4.3	To adjust the plot scaling	86
6.4.4	To exit the plot	87
6.5	Configuring external interfaces	87
6.5.1	Configuring the ethernet interface (if required)	87
6.5.2	Configuring the RS232 serial interface (if required)	88
6.5.3	Configuring the GPIB (if required)	88
6.5.4	Configuring the USB interface (if required)	88
6.5.5	Enabling remote control of the iTC	88
6.5.6	Enabling local control of the iTC	88
6.6	Re-configuring sensors and heaters	89
6.6.1	To clear a panel configuration	89
6.6.2	Re-configuring a sensor	89
6.6.3	Re-configuring a heater	89
6.6.4	Re-configuring a control loop	89
6.7	Changing control-loop parameters	89
6.7.1	Entering PID parameters manually	89
6.7.2	Creating a PID table	89
6.8	Updating the firmware	90
6.8.1	Updating the application	90
6.8.2	Updating the firmware on a board	91
6.9	Saving and restoring configurations	91
6.9.1	Saving a configuration	91
6.9.2	Restoring a configuration	91
7	REMOTE OPERATION	93
7.1	Notes on instrument addresses	93
7.2	Communication protocols for RS232 and GPIB	93
7.2.1	Commands and responses	94
7.2.2	Numeric parameters	94
7.3	Control via ISOBUS	94
7.4	GPIB interface	95
7.4.1	Switching between RS232 and GPIB operation	95
7.4.2	Sending commands via the GPIB	95
7.4.3	Accepting responses via the GPIB.	96
7.4.4	Status byte and use of a serial poll	96
7.4.4.1	RQS bit	96
7.4.4.2	BAV bit.....	96
7.4.4.3	MAV bit	96
7.4.4.4	Status byte update rate.....	97
7.4.5	Use of the service request line	97
7.4.6	Use of the device clear function	97
7.4.7	Use of the interface clear function	97
7.4.8	Non-implemented features of the GPIB	97
7.4.9	Compatibility with IEEE-488.2	97

Contents (continued)

Section		Page
7.4.10	Writing a reliable GPIB control program	98
7.4.10.1	Timeouts.....	98
8	PREVENTIVE MAINTENANCE	99
8.1	Six-monthly maintenance	99
8.1.1	Cleaning the touch-screen	99
8.1.2	Calibrating the temperature-sensor circuits	99
8.1.3	Unscheduled maintenance	99
9	TROUBLESHOOTING	101
9.1	Fault-finding features of the iTC	101
9.1.1	The alarm-logs	101
9.2	Troubleshooting information	101
10	COMMAND REFERENCE GUIDE	103
10.1	Nomenclature used in this section	103
10.2	SCPI and legacy command sets	103
10.3	SCPI command messages	103
10.3.1	SCPI protocol conventions	103
10.3.2	Reading the overall instrument configuration	104
10.3.3	Basic SCPI command structure	104
10.3.4	Verbs	104
10.3.5	Nouns	105
10.3.5.1	System commands	106
10.3.5.2	Addressing a temperature sensor	107
10.3.5.3	Addressing a heater controller	109
10.3.5.4	Addressing a level meter sensor	109
10.3.5.5	Addressing an auxiliary I/O daughter board	111
10.3.5.6	Addressing a control loop	112
10.3.6	Invalid responses	112
10.4	Legacy command messages	113
10.4.1	Legacy monitor commands	113
10.4.1.1	Cn command - Set Control	113
10.4.1.2	Rn command - Read Parameter	114
10.4.1.3	V command - Read Version	114
10.4.1.4	X command - Examine Status	114
10.4.2	Legacy control commands	116
10.4.2.1	An command - Auto/Manual	116
10.4.2.2	Dnnn, Innn and Pnnn commands - Set PID Control Terms	116
10.4.2.3	Gnnn command - Set Gas Flow	116
10.4.2.4	Hn command - Set Heater Sensor	116
10.4.2.5	Mnnn command - Set Maximum Heater Volts Limit	116
10.4.2.6	Onnn command - Set Output Volts	116
10.4.2.7	Tnnn command - Set Desired Temperature	117
10.4.3	Legacy system commands	117
10.4.3.1	! command - Set ISOBUS Address	117



Contents (continued)

Section		Page
11	TECHNICAL SPECIFICATIONS	119
11.1	Physical specification	119
11.2	Electrical power supply	119
11.3	Sensor inputs	119
11.4	Heater outputs	120
11.5	PC interfaces	120
11.6	Electrical isolation	121
11.7	Environmental specifications	121
12	THEORY OF CONTROL LOOPS	123
12.1	General information on control loops	123
12.2	General information on temperature control loops	123
12.2.1	Open loop operation	124
12.2.2	On-Off control	124
12.2.3	Proportional control	125
12.2.4	Proportional control with integral action	126
12.2.5	Proportional control with integral and derivative action	127
12.2.6	North American terminology	127
12.2.7	PID tables	128
12.2.7.1	PID table operation	128
12.2.7.2	Entering a PID table	128
12.3	Theory of gas-flow control	129
12.3.1	Overview of gas control	129
12.3.2	Manual control of the gas flow	129
12.3.3	Automatic control of the gas flow	129
12.3.3.1	Heater target tables	130
12.3.3.2	Syphon algorithm	130
13	TEMPERATURE SENSOR DAUGHTER BOARD	131
13.1	Overview of the temperature sensor board	131
13.2	Installing a temperature sensor board	131
13.2.1	Fitting the board	131
13.2.2	Connecting the sensor	132
13.2.3	Configuring the temperature sensor board	132
13.3	Circuit description of the temperature sensor board	133
13.3.1	Description of voltage measurement mode	133
13.3.2	Description of constant current measurement mode	134
13.3.3	Description of constant voltage measurement mode	135
13.3.4	Calibrating the temperature measurement circuit	137
14	HEATER DAUGHTER BOARD	139
14.1	Overview of the heater board	139
14.2	Installing a heater board	139
14.2.1	Fitting the board	139
14.2.2	Connecting the heater	140
14.2.3	Configuring the heater board	140
14.2.4	Configuring the control loop	140
14.3	Circuit description of the heater board	141
14.3.1	Description of the heater circuit	141



Contents (continued)

Section		Page
14.3.2	Calibrating the heater circuit	142
15	AUXILIARY I/O DAUGHTER BOARD	143
15.1	Description of the auxiliary I/O board	143
15.1.1	Auxiliary I/O board functions	143
15.1.2	Gas-flow control using a motorised needle-valve	143
15.2	Installing an auxiliary I/O board	144
15.2.1	Fitting the board	144
15.2.2	Connecting to the auxiliary I/O board	145
15.2.3	Configuring an input on the auxiliary I/O board	145
15.2.4	Configuring an output on the auxiliary I/O board	146
16	LEVEL-METER DAUGHTER BOARD	147
16.1	Description of the level-meter board	147
16.1.1	Principles of operation	147
16.1.1.1	Operation of the board with a helium-level probe.....	147
16.1.1.2	Operation of the board with a nitrogen-level probe	148
16.1.1.3	Explanation why different methods are used for the two liquids	148
16.1.1.4	Refill control.....	148
16.2	Installing the level-meter board	148
16.2.1	Fitting the board	148
16.2.2	Connecting the sensor	149
16.3	Configuring the level-meter board	150
16.3.1	Configuring a liquid-helium sensor	150
16.3.2	Configuring a liquid-nitrogen sensor	151
16.4	Specification of the level-meter board	152
17	GPIB DAUGHTER BOARD	155
17.1	Description of the GPIB daughter board	155
17.2	Installing a GPIB board	155
17.2.1	Fitting the board	155
17.2.2	Connecting to a GPIB board	156
GLOSSARY		157
Acronyms and abbreviations		157



Handbook

Mercury iTC

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PREFACE

Welcome to the Operator's Handbook for the Oxford Instruments NanoScience **Mercury** iTC cryogenic environment controller unit. The **Mercury** iTC is a high performance laboratory temperature controller, with a number of features specifically intended for use in cryogenic applications.

This Operator's Handbook provides all the information necessary for the safe and proper installation and operation of the **Mercury** iTC.

Use of this manual

This manual provides operating and service information for the Oxford Instruments NanoScience **Mercury** iTC cryogenic environment controller.

[Chapter 1](#) to [Chapter 5](#) provide essential information that must be read and understood before operating the **Mercury** iTC for the first time.

Customer support

Oxford Instruments NanoScience has global customer support facilities that provide a coordinated response to customer's queries. All queries are recorded on our support database and are dealt with as quickly as possible. If we are not able to answer the query immediately, we will contact you promptly.

Before contacting a customer support facility, please ensure that you have referred to the appropriate section of this manual.

Please direct all queries through your nearest support facility (see below) and have the following details available:

System type **Mercury** iTC

Serial number

Contact information Your name, the name of your company, and how we can contact you.

Details of your query The nature of your problem, part numbers of spares required, etc.

You can contact us at the telephone numbers and email addresses listed on the last page of this handbook.



Mercury iTC

Health and safety information

The iTC contains hazardous areas. Before working with the **Mercury iTC**, all personnel must read and become thoroughly familiar with the information given in [Chapter 1](#). In particular, users must read, understand and strictly observe all:

- Warning notices
- Caution notices
- Safety labels and markings on the equipment

For ease of reference and rapid response in an emergency, this handbook must be safely kept in close proximity to the **Mercury iTC**.

Intended users

Users of the **Mercury iTC** must have received adequate training on its safe and effective use before attempting to work with the equipment. Please contact Oxford Instruments NanoScience for information on training requirements and training courses that are available.

Training requirements vary from country to country. Users must ensure that training is given in accordance with all applicable local laws and regulations.

If any user of the equipment has not been directly trained by Oxford Instruments NanoScience, ensure that they understand the safety issues associated with the equipment, and that they consult relevant personnel for guidance when operating the equipment.

Statement of intended use of the Mercury iTC

The **Mercury iTC** has been designed for environmental control in a laboratory environment. The equipment has been designed to operate within the process parameter limits that are outlined in this manual.

The **Mercury iTC** is intended to be installed, used and operated only for the purpose for which the **Mercury iTC** was designed, and only in accordance with the instructions given in this manual and other accompanying documents. Nothing stated in this manual reduces the responsibilities of users to exercise sound judgement and best practice.

It is the user's responsibility to ensure the system is operated in a safe manner. Consideration must be made for all aspects of the system's life-cycle, including, handling, installation, normal operation, maintenance, dismantling, decontamination and disposal. It is the user's responsibility to complete suitable risk assessments, to determine the magnitude of hazards.

The installation, use and operation of the **Mercury iTC** are subject to laws in the jurisdictions in which the equipment is installed and in use. Users must install, use and operate the equipment only in such ways that do not conflict with said applicable laws and regulations.

If the equipment is not installed, used, maintained, refurbished, modified and upgraded as specified by the manufacturer, then the protection it provides could be impaired. Any resultant non-compliance, damage, or personal injury would be the fault of the owner or user.

Use of the equipment for purposes other than those intended and expressly stated by Oxford Instruments NanoScience, as well as incorrect use or operation of the equipment, may relieve Oxford Instruments NanoScience or its agent of the responsibility for any resultant non-compliance, damage or injury. The system must only be used with all external panels fitted.

Typographical conventions

For clarity and ease of explanation, the following typographical conventions are used in this manual:

- Modes of operation are expressed in upper case, italic letters. Thus:
AUTO, MANUAL, SERVICE.
- On-screen objects in the graphical user interface (GUI) are expressed in bold letters. Thus:
manual button, **Position** panel, **Forward** field.
- The names of on-screen windows and panels in the GUI are expressed with upper-case initial letters. Thus:
AMU Service Util panel.
- The names of physical controls are expressed in bold letters enclosed in arrow symbols. Thus:
<Alt> key (on the PC keyboard), **<ON>** button.
- Keys to be pressed in sequence are expressed thus:
<Ctrl> <S>.
- Keys to be pressed simultaneously are expressed thus:
<Ctrl> + <S>.
- Directory paths are expressed thus:
C:\name\name\name.

Disclaimers

Oxford Instruments NanoScience assumes no liability for use of this document if any unauthorised changes to the content or format have been made.

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Acknowledgements

All tradenames and trademarks that appear in this manual are hereby acknowledged.

Acronyms, abbreviations and special terms

A [GLOSSARY](#) of acronyms, abbreviations and special terms is given at the end of this manual.

Revision history

This is issue 02 of the **Mercury** iTC Handbook, as shown in the footer at the bottom of each page.

The changes made to this document and a summary of previous issues are listed in the table below.

Always use the latest issue of the manual.

Revision	Affected page(s)	Summary of changes
01	All pages.	First edition of the Mercury iTC Handbook.
02	All pages	Changes to several GUI pages.

Certification compliance statements

The **Mercury iTC** cryogenic environment controller complies with the following standards and certifications:

- EN61010.1: Safety requirements for electrical equipment for measurement, control and laboratory use.
- EN61326: Electrical equipment for measurement, control and laboratory use: EMC requirements.
- CE
- UL
- CSA
- China Restriction of Hazardous Substances 

Signed: 

Jim Hutchins
Managing Director
Oxford Instruments NanoScience Limited



Mercury iTC

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1 HEALTH AND SAFETY

This chapter describes all health and safety considerations relating to the Oxford Instruments NanoScience **Mercury iTC** cryogenic environment controller.

The following safety precautions must be observed during the operation, service and repair of this instrument.

1.1 Warnings

Before you attempt to install or operate this equipment for the first time, please make sure that you are aware of the precautions that you must take to ensure your own safety.

1.1.1 Protective ground

The equipment must be connected to an electrical ground. The ground wire (green/yellow) in the equipment power cable must be connected to the electrical ground system of the installation.

Only use extension cords that have a protective ground conductor.

Do not disconnect the protective ground connection inside or outside the equipment.

Do not connect external electrical circuits to the equipment if its protective ground is disconnected.

There is a ground pillar on the rear panel, identified by a  symbol. Connect the grounds of any external equipment to this pillar.

1.1.2 High voltage hazard



HIGH VOLTAGE

Danger of death or serious injury.

Switch off the external AC electrical supply and disconnect and remove the external supply cable, before maintaining this equipment or removing any covers.

HAUTE TENSION

Danger de mort ou de blessure grave. Sectionner l'alimentation électrique C.A. externe puis déconnecter et retirer le cordon d'alimentation externe avant d'effectuer toute maintenance de cet équipement ou d'en retirer les capots.

This equipment contains high voltages. Isolate this equipment before removing and covers. To isolate this equipment, switch off the external AC electrical supply, and disconnect and remove the external supply cable.

The AC electrical supply is considered to be the disconnect device for the equipment. Do not restrict access to the AC electrical supply at any time. The AC electrical supply cable must remain accessible for disconnection of the equipment.



Mercury iTC

1.1.3 Maintenance and adjustment

Only qualified and authorised persons must service or repair this equipment.

Under no circumstances must the user adjust or repair this equipment while the electrical power supply is connected.

Ensure that the equipment is disconnected from the AC electrical power supply before the covers are removed or fuses are removed or fitted. It is NOT sufficient to switch off the <1 0> switch on the rear panel or the <On/Off> button on the front panel.

The equipment contains capacitors that may remain charged after AC electrical power is removed. Discharge all capacitors before starting work.

1.1.4 Restrictions on use

The equipment is not suitable for use in explosive, flammable or hazardous environments.

The equipment does not provide protection against the ingress of water. The equipment must be positioned so that it will not be exposed to water ingress.

1.2 Cautions

1.2.1 Electrostatic caution



ELECTROSTATIC SENSITIVE EQUIPMENT

This equipment contains electrostatic sensitive devices (ESSD). Use approved ESSD procedures when installing or maintaining this product.

ÉQUIPEMENT SENSIBLE AUX DÉCHARGES ÉLECTROSTATIQUE

Cet équipement contient des dispositifs qui sont sensibles aux décharges électrostatiques (ESSD). Utiliser des procédures ESSD homologuées lors de l'installation ou de la maintenance de ce produit.

This equipment contains electrostatic sensitive devices (ESSD). Use ESSD protective procedures in accordance with BS CECC00015 Part 1 and American National Standard EIA-541-1998 when installing or maintaining this product.

1.2.2 Cooling caution

Internal components in this equipment are air-cooled. Ensure that the side and rear ventilation spaces are not obstructed.



EQUIPMENT VENTILATION

If the Mercury unit is to be rack mounted, to ensure an adequate airflow around the unit it is important that the back of the rack is open and the rack is not placed less than 30 cm from a back wall.

Lorsque le Mercury est monté en rack, s'assurer que le rack est ouvert à l'arrière et se trouve au minimum à 30 cm du mur afin de garantir une circulation d'air suffisante.

If the iTC is mounted in a rack, ensure that the rear of the rack is open. Site the rack at least 30 cm from a wall or other obstruction, to ensure adequate airflow around the unit.

1.3 Solid waste

The lithium battery on the motherboard will become solid waste if it has to be replaced. Dispose of this item according to local and national regulations.



Mercury iTC

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2 GETTING STARTED

Ensure that you have read and understood the information in [Chapter 1](#) before installing or operating this equipment.

2.1 Checking the electrical supply



CHECK THE SUPPLY VOLTAGE

Check that the voltage supplied to the equipment is within the specified range. Operating the equipment with an incorrect voltage may cause permanent damage.

CONTRÔLER LA TENSION D'ALIMENTATION

Contrôler que la tension fournie à l'équipement est comprise dans les limites spécifiées. Exploiter l'équipement avec une tension incorrecte peut l'endommager de manière permanente.

The iTC automatically configures itself to match the supplied electrical power supply, if the voltage and frequency are within the specified ranges (see [Section 11.2](#).) No user intervention is required.

2.2 Mounting the equipment

The equipment is housed inside a 19 inch, 2U rack-mountable enclosure. The enclosure can either be placed on a bench or a table, or fitted within a suitable rack enclosure. Ensure there is sufficient access at the rear for the electrical connections.



EQUIPMENT VENTILATION

If the Mercury unit is to be rack mounted, to ensure an adequate airflow around the unit it is important that the back of the rack is open and the rack is not placed less than 30 cm from a back wall.

Lorsque le Mercury est monté en rack, s'assurer que le rack est ouvert à l'arrière et se trouve au minimum à 30 cm du mur afin de garantir une circulation d'air suffisante.

If the iTC is mounted in a rack, ensure that the rear of the rack is open. Site the rack at least 30 cm from a wall or other obstruction, to ensure adequate airflow around the unit.

Mercury iTC

2.3 Connecting electrical power

Connect the equipment to an electrical supply, using an appropriate mains cable.

In the EU, the mains supply cable must be rated for the maximum current rating of the equipment. The cable must meet the requirements of IEC227 or IEC245. Mains cables certified or approved by any recognised nation test house are regarded as meeting this requirement.

In the USA, the mains cable must be a listed mains cable set approved to the standard UL817 for cable sets and power supply cables. The mains plug must be a separable plug without a locking device. If the mains cable is to be a disconnecting device for the equipment, the cable must be shorter than 3 m. The cable set must be suitable for purpose and must have a current rating at least 125% that of the equipment rating.

In Canada, the cable set must be certified by CSA.

Green/yellow covered conductors must only be used for connection to protective ground terminals.

2.3.1 Connecting the heaters and sensors

- 1 Connect all sensors as described in [Section 5.2.4](#).
- 2 Connect all heaters as described in [Section 5.2.4](#).

2.3.2 Connecting the data interfaces

If it is required to connect the iTC to a computer, refer to the relevant section below.

2.3.2.1 Connecting the ethernet interface (if required)

- 1 Connect the ethernet interface to the computer, using a standard ethernet cable.

2.3.2.2 Connecting the RS232 serial interface (if required)

- 1 Connect the RS232 interface to the computer, using a suitable cable (See [Section 5.2.5.1](#)).

2.3.2.3 Connecting ISOBUS (if required)

- 1 Connect the iTC to one of the Slave connectors on the ISOBUS cable.
- 2 Connect the computer to the Master connector on the ISOBUS cable.

2.3.2.4 Connecting the GPIB (if required)



CABLE DISCONNECTION

Do not connect or disconnect GPIB cables while the computer, or any of the instruments, are powered up. Equipment damage can result if this precaution is not observed.

DÉBRANCHEMENT DU CORDON

Ne pas brancher ou débrancher des cordons de bus d'interface général pendant que l'ordinateur, ou n'importe lequel des instruments, est sous tension. Ne pas respecter cette précaution risque d'endommager l'équipement.

- 1 Switch off electrical power to the iTC.
- 2 Switch off electrical power to all instruments and controllers that are connected to the GPIB.
- 3 Connect the iTC to the bus using a standard GPIB cable.

2.3.3 Connecting the auxiliary port (if required)

- 1 Referring to [Section 15.2.2](#), connect any required inputs or outputs to the port on the auxiliary I/O daughter-board.

2.3.4 Connecting the level-meter (if required)

- 1 Referring to [Section 16.2.2](#), connect a level-sensor to the relevant port on the level-meter daughter-board.



Mercury iTC

2.4 Powering up the unit for the first time

2.4.1 Setting the date and time

- 1 Switch the <1 0> switch on the rear panel of the unit so that the 1 is depressed.
- 1 Press the <Power> button on the front of the unit. The button illuminates blue.
- 2 Wait until the Home page appears (see [Figure 2-1](#)).



Figure 2-1 Home page

- 3 Tap **Settings** on the Home page. The General Settings page is displayed (see [Section 4.2.12](#)).
 - 4 Scroll the tabs until the Clock tab is displayed.
 - 5 Tap **Clock**. The Clock Settings tab is displayed (see [Section 4.2.12.7](#)).
 - 6 Check the date and time that are displayed.
 - 7 To change the date or time:
 - a) Select the parameter to be changed (e.g. Hour).
 - b) Enter a positive or negative offset value and tap **Apply** to save the change.
 - c) Repeat steps a to b until the displayed time is correct.
- Example: The currently set time is 11:31. The correct time is 9:27. Enter an offset of minus two hours and four minutes to set the clock correctly.
- 8 If the unit has already been configured for your application, continue from section [Section 2.5.3](#).
 - 9 If the unit has not been configured for your application, continue from [Section 2.5.1](#).

2.4.2 General settings

Refer to [Section 4.2.12](#) for general settings.

2.4.3 Updating firmware

Refer to [Section 6.8](#) for information on updating the firmware.

2.5 Configuring the Mercury iTC

2.5.1 Configuring the inputs

The home page shows six panels and four buttons. If the unit is unconfigured, all six panels will display 0.0000. Additional panels can be displayed by scrolling left or right.

- 1 Tap once on an unconfigured panel. The Channel Display Configuration page is displayed (see [Section 4.2.4](#)).
- 2 Choose a sensor input from the drop-down menu in the **Devices** field.

The sensor names are initially of the form **BoardBN.DTSN**.

Where:

Board= **MB** for Mother Board or **DB** for Daughter Board.

BN= Board Number.

DN= Device Number.

DT= **T** for Temperature sensor, **H** for Heater, **L** for Level Meter, or **G** for Gas-flow Controller.

SN= Signal Number.

- 3 Tap **Signals** and select **Temperature**.
- 4 Tap **Assign** to save the changes and to return to the Home page.
- 5 If required, configure the other panels on the Home page in a similar fashion.

2.5.1.1 Configuring the sensor details

- 1 Tap a configured panel on the Home page. The Temperature Sensor Details page is displayed.
- 2 Tap the **Sensor Type** field and select a sensor type from the drop-down menu.
- 3 Tap the **Calibration** field and select a calibration file from the drop-down menu. If you select the Generic calibration file, you can adjust the calibration to suit a particular sensor (see [Section 2.5.1.2](#)).
- 4 Tap the **Excitation** field and select an excitation mode from the drop-down menu.
- 5 Tap the **Magnitude** field and enter an excitation value:
current in μA for Diode or PTC sensors
voltage in mV for NTC sensors.
- 6 If required, tap the field containing the name of the sensor and enter a new name.
(e.g. Change **DB3.T1** to **Zone 1 Temperature**).
- 7 Tap **Home**. The Home page is displayed. If the sensor has been configured correctly, the selected panel will display a sensor reading.



Mercury iTC

2.5.1.2 Using a generic calibration-file

Overview of using a generic calibration file

Some generic calibration-files are supplied for common sensors having reasonably predictable forms of resistance as a function of temperature, for example sensors that conform to an ITS-90 standard. However the response of an individual sensor may deviate slightly from the standard curve.

If two known temperatures are available it is possible to make small adjustments to the scale and offset of the standard curve to match a particular sensor. The process can be used with either PTC and NTC sensors.

The adjustment is applied to the measured parameter, so for a resistance sensor the adjustment is applied to the measured resistance.

For best results the scaling adjustment should be applied at the high-parameter end and the offset at the low-parameter end. So for a NTC resistance sensor, apply the scaling at the known low-temperature point (ideally near the high-resistance end of the range). If a scale adjustment of more than a few percent is required to correct the temperature reading, investigate the measurement set-up to check there is not some other error present.

Once the scaling adjustment has been made, change to the low-resistance end of the range and make the offset adjustment (for an NTC resistance sensor, this is a high-temperature point). Again this should be a small adjustment. As these adjustments are not independent, re-check the high-resistance point after the offset has been adjusted. A few iterations of these adjustments may be required to achieve the desired accuracy.

Procedure for using a generic calibration file

You need a method of maintaining the temperature sensor at two known temperatures (T1 and T2) to perform this calibration. This procedure calibrates the sensor for temperatures between these two known values.

For this procedure, T1 produces a lower sensor-resistance than T2:

For a PTC sensor, T1<T2.

For an NTC sensor, T1>T2.

- 1 Tap a configured panel on the Home page. The Temperature Sensor Details page is displayed.
- 2 Tap the **Calibration** field and select *Generic* from the drop-down menu.
- 3 Tap **Cal Adj.**
- 4 Place the sensor in a location with temperature T1.
- 5 Adjust the **Offset** value to produce the required **Scaled Parameter** value.
- 6 Place the sensor in a location with temperature T2.
- 7 Adjust the **Scale** value to produce the required **Scaled Parameter** value.
- 8 Repeat steps 4 to 7 until a calibration of the required accuracy has been obtained.
- 9 Tap **Save** to apply the new calibration.

2.5.2 Configuring a heater

- 1 Double-tap a configured panel on the Home page. The Channel Display Configuration page is displayed.
- 2 Tap **Pair**. The Device Pair Configuration page is displayed.
- 3 Tap the name of the required temperature sensor in the **Sensor** column.

The device names are initially of the form **BoardBN.DTSN**.

Where:

Board= **MB** for Mother Board or **DB** for Daughter Board.

BN= Board Number.

DT= **T** for Temperature sensor or **H** for Heater.

SN= Signal Number.

- 4 Tap the relevant cell in the **Heater** column and select a heater from the drop-down menu.
- 5 Tap **Home** to return to the Home page.
- 6 Tap **Heater**. The Heater Configuration page appears (see [Section 4.2.14](#)).
- 7 Locate the heater in the Name column.
- 8 If required, enter an alternative name of the heater in the **Name** field.
- 9 Enter a voltage limit for the heater (in volts) in the **Lim(v)** field.
- 10 Enter the resistance of the heater (in ohms) in the **Res(Ω)** field.
- 11 Tap **Home** to return to the Home page.

2.5.3 Configuring the heater control loop

- 1 Tap **Control**.
- 2 Select the sensor that you want to configure in the **Sensor** field.

NOTE: An error message is displayed if you haven't configured a heater for the selected sensor.

- 3 Tap the **Heat(%)** button to select either *Manual* or *Auto* Control. **Manual** configures the heater for open-loop control. **Auto** configures the heater and associated temperature sensor in a closed control loop (see [Section 12.2.1](#)).

2.5.3.1 Configuring manual heater control

- 1 If you selected *Manual* control, enter the required heater power, as a percentage of the maximum power, in the **Heat (%)** field.
- 2 Tap **Home** to return to the Home page. The requested heater power should be displayed in the relevant panel.



Mercury iTC

2.5.3.2 Configuring automatic heater control

- 1 If you selected **Automatic** control, tap **PID** and select either **Manual** or **Auto** PID operation. Auto PID means that the PID values for the control loop are automatically loaded from a PID table. See [Section 12.2.7](#) for an explanation of PID tables. Manual PID means that the PID values are entered directly on this page.
- 2 If you selected Manual PID operation, enter the PID parameters to be used in the **P**, **I**, and **D** fields.
- 3 If you selected Automatic PID operation, tap **PID Table**. The PID Table Editor page is displayed (see [Section 4.2.11](#)).
- 4 Tap **Load** to load an existing PID table (see [Section 4.2.17](#)).
- 5 Alternatively enter a new PID table on this page (see [Section 12.2.7.2](#)).
- 6 Tap **Control** to return to the Control Loop Configuration page.
- 7 Tap **Home** to return to the Home page.

2.5.4 Configuring a gas valve

- 1 Double tap a configured panel on the Home page.
- 2 Tap **Pair**. The Device Pair Configuration page appears (see [Section 4.2.5](#)).
- 3 Choose a temperature sensor from the drop-down menu in the **Temperature Sensor** field.

The device names are initially of the form **BoardBN.DTSN**.

Where:

Board= **MB** for Mother Board or **DB** for Daughter Board.

BN= Board Number.

DT= **T** for Temperature sensor or **H** for Heater.

SN= Signal Number.

- 4 Tap the relevant cell in the **Flow** column and select a gas controller from the drop-down menu.
- 5 Tap **Assign** to save the configuration.
- 6 Tap **Home** to return to the Home page.
- 7 Tap **Control**. The Control Loop Configuration page opens (see [Section 4.2.9](#)).
- 8 Select the sensor that you want to configure in the **Sensor** field.

NOTE: An error message is displayed if you haven't configured a heater for the selected sensor.

- 9 Tap the **Flow(%)** button to select either **Manual** or **Auto** Control. **Manual** configures the gas controller for open-loop control. **Auto** configures the gas controller and associated temperature sensor in a closed control loop (see [Section 12.2.1](#)).



2.5.4.1 Configuring manual control of the gas valve

- 1 If **Manual** is selected in the **Flow(%)** field, enter the required opening of the gas valve as a percentage of the maximum opening.
- 2 Tap **Gas Cfg**. The Gas Flow Configuration page opens.
- 3 Tap **Valve Gearing** and enter the required value. See [Section 4.2.10](#) for an explanation of Valve Gearing.
- 4 Tap **Home** to return to the Home page. The requested gas valve position should be displayed in the relevant panel.

2.5.4.2 Configuring automatic control of the gas valve

- 1 If **Auto** is selected in the **Flow(%)** field, tap **Gas Cfg**. The Gas Flow Configuration page opens.
- 2 Tap **HTT**.
- 3 Select a Heater Target Table to be used for controlling the valve.
- 4 Tap **Valve Gearing** and enter the required value. See [Section 4.2.10](#) for an explanation of Valve Gearing.
- 5 If required, adjust the **TES** value.
- 6 If required, adjust the **TVES** value.
- 7 If required, adjust the **Min Gas Flow (%)** value to define a minimum opening position for the needle valve.
- 8 Tap **Type** and select either **Syphon** or **VTI**. See [Section 4.2.10](#) for an explanation of these terms.
- 9 Tap **Home** to return to the Home page.

Mercury iTC

2.6 Testing the inputs and outputs

If any of the following tests fails, refer to [Chapter 9](#) for troubleshooting information.

- 1 Switch on the iTC.

2.6.1 Testing the temperature sensor inputs

- 1 Check that the temperature displayed on each of the connected temperature sensors is correct.

2.6.2 Testing the heater output

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Set the **Heat** field to *Auto*.
- 4 Tap **Set (K)**.
- 5 Enter a setpoint that is slightly above the temperature displayed by the sensor.
- 6 Tap **Home** to return to the Home page.
- 7 Check that the heater power displayed in the relevant panel is greater than 0%.
- 8 Check that the temperature displayed in the panel rises to the setpoint value and then stabilises.
- 9 Test the heater at various setpoint values.

2.6.3 Configuring remote interfaces

If it is required to control the iTC from a remote computer, refer to [Section 6.5](#).

2.7 Engineering mode

2.7.1 Entering engineering mode.

- 1 Tap **Settings** on the Home page.
- 2 Scroll right until the EngMode tab is visible.
- 3 Tap **EngMode**. The EngMode page opens.
- 4 Enter the engineering password in the Password field.
- 5 Tap **Enter**. If the correct password was entered, the message *Correct!* appears.

2.7.2 Exiting engineering mode

- 1 Tap **Settings** on the Home page.
- 2 Scroll right until the EngMode tab is visible.
- 3 Tap **EngMode**. The EngMode page opens.
- 4 Tap **LogOff**. The message *Correct!* disappears.

3 OVERVIEW OF THE ITC

The Integrated Temperature Controller (iTC) is a high-performance laboratory temperature-controller designed for use in cryogenic applications. The unit accommodates up to eight optional daughter boards to allow additional features to be added.

Most commonly the unit is used to control the temperature of a sample whose properties are being investigated. The sample contains a sensor monitoring its temperature (see [Section 3.1.1](#)), a method of cooling the sample to cryogenic temperatures, and an optional heater for temperature control (see [Section 3.1.2](#)). The iTC is usually configured to control the application of heat to a cooling medium, as this method provides better control than adjusting the refrigeration process. The unit can also control sample cooling by fitting an auxiliary I/O board, which can control the flow of gas in a continuous-flow cryostat.

The iTC is a microprocessor based instrument and is controlled by an operating program (firmware) contained in flash memory. The firmware version number is indicated by a two-part number (e.g. 1.01). The first digit of this number indicates the major version of the firmware, and the second two digits indicate minor revisions.

The basic iTC includes a single input channel for one temperature sensor. An additional 8 sensor inputs can be added (to a total of 9 inputs). The unit can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground. The heater output is disabled if a faulty sensor is detected.

The basic iTC includes a single 80 W heater output. An additional three 80 W heater outputs can be added (to make a total of 4 outputs, each of 80 W).

An optional port can be added to drive a stepper motor. This is commonly used to control the motorised valve in a continuous-flow cryostat, a variable-temperature insert, or an AutoGFS transfer-syphon.

An optional board can be added to monitor and control the level of cryogen in a reservoir. The additional board has inputs for helium-level and nitrogen-level probes.

The iTC contains non-volatile flash-memory, and it retains its configuration when electrical power is removed.



Mercury iTC

3.1 System description

Figure 3-1 is a block diagram of the iTC.

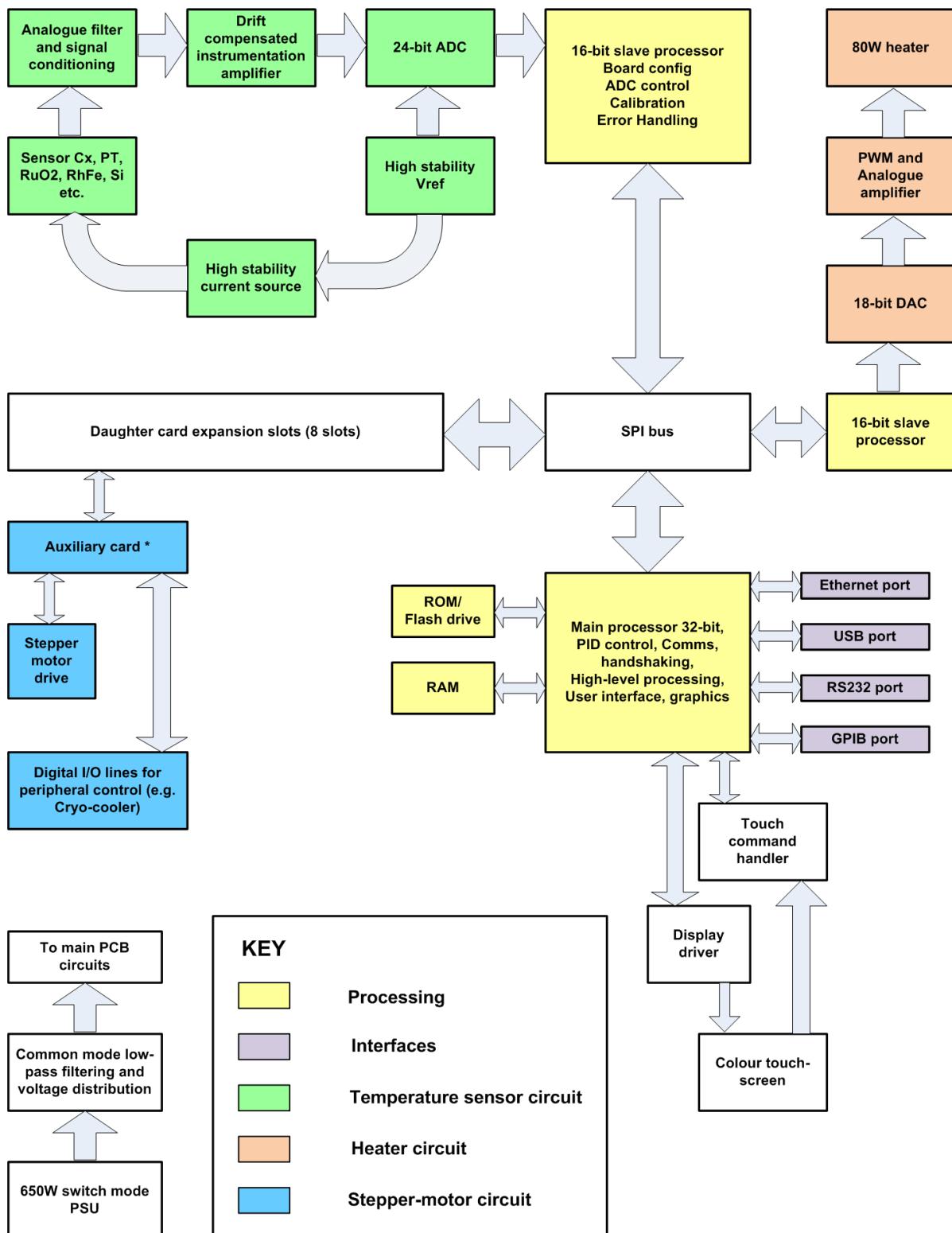


Figure 3-1 Block diagram of the iTC

3.1.1 Temperature sensor circuits

The iTC can interface with a wide variety of temperature sensors. A high-accuracy measurement circuit amplifies, scales and filters the voltage produced by the sensor. This conditioned voltage is then passed to a 24-bit analogue to digital converter (ADC).

Some sensors (e.g. resistance sensors) require excitation. For positive temperature coefficient sensors, this is generated by a high-stability current source. For negative temperature coefficient sensors, this is provided by a true voltage-source.

The basic iTC can monitor one temperature sensor. Additional sensors can be monitored by adding daughter boards.

3.1.2 Heater circuits

The demand voltage for the heater is generated by a 16-bit digital to analogue converter (DAC). This demand is then amplified to a maximum of 80 W output.

The basic iTC can drive one heater. Additional heaters can be driven by adding daughter boards.

3.1.3 Optional cooling circuit

The system can be configured using an open-loop cooling system. Temperature control is then performed using the heater only. Improved stability can be obtained if the flow of cooling fluid is also controlled by the iTC. An optional auxiliary I/O board contains drive circuitry for a stepper motor. This can drive the opening and closing of a needle-valve, which can control the flow of a suitable fluid. This function is referred to as gas-control in the GUI.

3.1.4 Remote interfaces

The iTC contains several interfaces that can be connected to a remote PC:

- RS232 / ISOBUS interface.
- Universal serial bus (USB) interface.
- Ethernet interface.
- Optional general purpose interface bus (GPIB) (IEEE-488) interface.

The remote PC can send data to the iTC and read data from the iTC. Only one interface can be active at a time.

3.1.5 Display and touch-screen

The iTC contains a 4.3 inch full-colour liquid crystal display (LCD) with a touch-screen. The touch screen is the main input device to the iTC.

The unit contains an ambient-light sensor and can be configured to automatically change the display brightness to match ambient light conditions.

Mercury iTC

3.1.6 Electrical power supply

The iTC automatically configures itself to match the supplied electrical power, as long as the voltage and frequency are within the specified ranges. No user intervention is required.

The iTC powers all sensors, heaters, and stepper motors that are connected to it.

4 USER INTERFACE

The iTC is controlled from the front panel (see [Figure 4-1](#)).



Figure 4-1 iTC front panel

4.1 Front and rear panel controls

The <On/Off> button on the front panel switches the unit into *STANDBY* mode. When the switch is OFF, electrical power is still supplied to the switch-mode power-supply inside the unit. The button illuminates blue when the unit is powered up.

The switch marked <1 0> on the rear panel switches electrical power on and off.

4.2 LCD display and GUI

The graphical user interface (GUI) contains several pages that the user can access as required.

4.2.1 Using the touch screen

4.2.1.1 Initiating actions

Each page of the GUI contains a number of buttons. On certain pages, other areas of the screen are also active.

To initiate an action, tap the relevant button or active area once.

Certain system features are accessed by tapping the relevant button or active area twice. These features are clearly indicated in the text of this manual.

The plot page allows the user to zoom in and out by dragging a finger across the screen. This is described in more detail in [Section 4.2.9](#).

4.2.1.2 Drop-down menus

Certain fields require the user to choose an item from a drop-down menu. These fields are indicated by a downwards-pointing arrow to the right of the field.



Figure 4-2 A field linked to a drop-down menu

Mercury iTC

- 1 Tap once, anywhere in the field, to display the drop-down menu. It is not necessary to tap the arrow.
- 2 If necessary drag the scroll bar up or down to reveal more menu items.
- 3 Tap the desired menu item to select it. The menu item is highlighted.
- 4 Tap **OK** to select the item, or **Cancel** to exit without selecting the item.

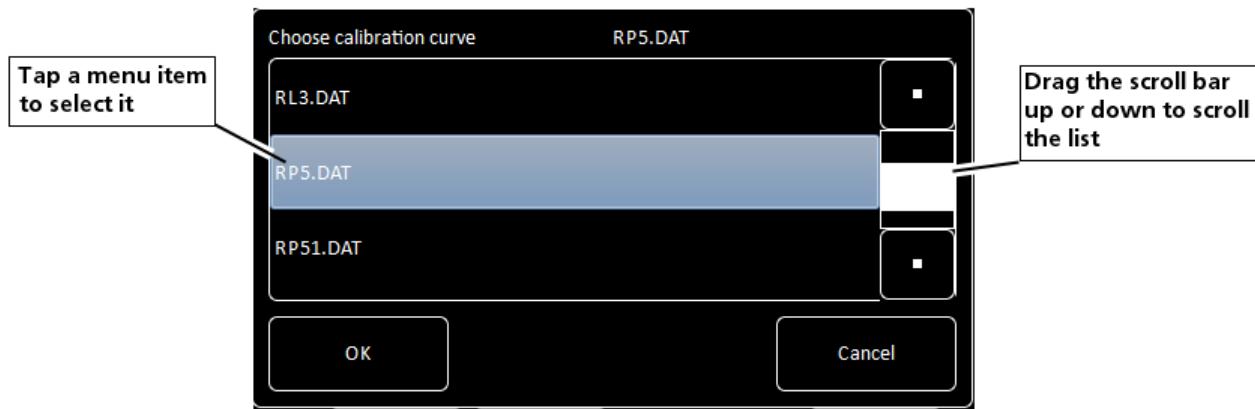


Figure 4-3 A drop-down menu

4.2.1.3 Scrolling

On some pages there is not enough space to display all the keys or information associated with the page. This is indicated by buttons labelled either > or <.

Tap the < button to scroll to the left. Tap the > button to scroll to the right.



Figure 4-4 Scroll buttons

4.2.1.4 Soft keypads

Certain fields in the GUI require the user to enter alpha-numeric characters. Tap the field to display a keypad.

There are two types of keypad that may be displayed. If a field requires numeric data only, a numeric keypad is displayed (see [Figure 4-5](#)).



Figure 4-5 Numeric keypad

The keypad has a field in the top-right corner that displays the number that been entered so far.

This keypad contains the following keys:

- Ten single-digit keys and a decimal-point key.

- **Del**

This button either deletes the character to the left of the cursor, or any highlighted characters. To delete the last character that has been entered, tap **Del** once.

To delete a single character within the text:

- a) Tap anywhere within the entered text to position the cursor.
- b) Tap **Del** to delete the character to the left of the cursor.

To delete several characters within the text:

- a) Touch individual characters, or strings of characters, to highlight them.
- b) Tap **Del** to delete the highlighted characters.

- **Ret**

Tap to save the number that has been entered.

- **Quit**

Tap to close the keypad without saving the number that has been entered.

Mercury iTC

If a field requires alpha-numeric data, an alpha-numeric keypad is displayed (see [Figure 4-6](#)).



Figure 4-6 Alpha-numeric keypad

The keypad has a field in the top-right corner that displays the text that has been entered so far.

This keypad contains the following keys:

- Ten character-entry keys and a decimal-point key.
- **Del**
Tap to delete the last entered character.
- **Ret**
Tap to save the text that has been entered.
- **CAPS**
Tap to enter capital letters. The characters on the keypad change to match the selection.
- **Quit**
Tap to exit the keypad without saving the number that has been entered.

Each character-entry key represents several characters.

- a) Tap a key once to enter the digit displayed on the key.
- b) Tap a key twice to enter the first character displayed on the key.
- c) Tap a key three, four, or five times to enter subsequent characters displayed on the key.

For example:

- a) To enter the digit **2**, tap the **2** key once.
- b) To enter the letter **B**, tap the **2** key three times.
- c) To enter the letter **Z**, tap the **9** key five times.

4.2.1.5 Using arrows to adjust integer values

Some numeric fields use up and down arrows to adjust their value.



Figure 4-7 A numeric field with up and down arrows

- Tap once to decrease the displayed value.
- Numeric display
Tap once to enter a new value using a numeric keypad.
- Tap once to increase the displayed value.

4.2.1.6 Button labels

The labels on some buttons change depending on the configuration that is set. The label on most buttons describes the present state of the unit. For example, the button shown on the left in [Figure 4-8](#) is labelled Auto, indicating that the function is in automatic mode. Tap the button once to select Manual mode.



Figure 4-8 Auto / Manual button

Some buttons operate differently to the method just described. The operation of these buttons is clearly indicated in the text.

Mercury iTC

4.2.2 Common screen features

The following features appear on several pages of the GUI. To avoid repetition, these features are described once in this section.

4.2.2.1 Home and Apply buttons



Figure 4-9 Home and Apply buttons

- **Home**
Tap once to return to the Home page.
- **Apply**
Tap once to save the changes made on the present page.

4.2.3 Home page

When the equipment is powered on, the Home page is displayed.

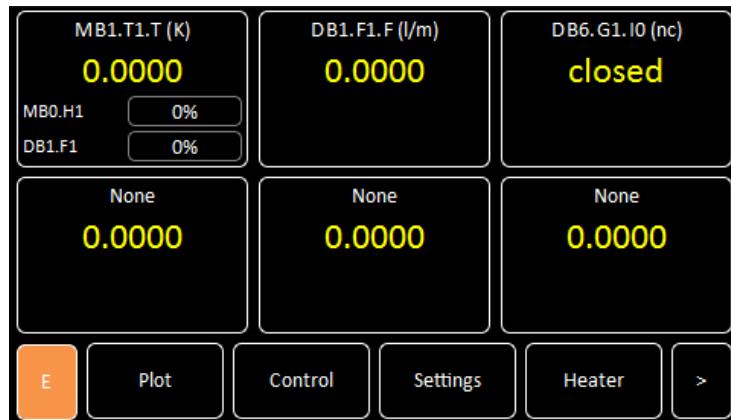


Figure 4-10 GUI home page

The Home page contains the following features:

- Six channel-summary panels. Each displays summary information for a channel that is enabled (see [Section 4.2.3.1](#)).
- Interface connect/disconnect button
The button displays one of the following letters:

- **E** if the ethernet interface is selected.
- **I** if the Isobus interface is selected.
- **U** if the USB interface is selected.
- **G** if the GPIB interface is selected.
- **L** if local control is selected.

The button is orange if the selected interface is connected.

The button is black if the selected interface is not connected.

Tap the button once to connect or disconnect the interface.

- **Plot** button
Tap once to plot information against time (see [Section 4.2.8](#)).
- **Control** button
Tap once to display control-loop information (see [Section 4.2.9](#)).
- **Settings** button
Tap once to display the General Settings tab (see [Section 4.2.12](#)).
- **Heater** button
Tap once to display the Heater Configuration page (see [Section 4.2.14](#)).
- Scroll-buttons to display two more pages of summary panels.

Mercury iTC

4.2.3.1 Channel summary panel

Figure 4-11 shows a typical channel-summary panel on the Home page.



Figure 4-11 Channel-summary panel

The channel-summary panel displays the following information:

- Channel identifier or nickname.
- The main display value for the channel (e.g. measured temperature).
- Identifier of the channel heater (if applicable).
- Output power of the channel heater (if applicable).
- Identifier of the gas-flow controller (if applicable).
- Percentage flow for the gas-flow controller (if applicable).

If the summary panel has not been configured:

the panel displays the name *None* and the value 0.0000.

- 1 Tap the panel once to display the Channel Display Configuration Page (see Figure 4-12).

If the summary panel has been configured:

the panel displays a sensor name and a sensor value.

- 1 Tap the panel once to display the Sensor Details page (see Section 4.2.6).
- 2 Tap the panel twice to display the Channel Display Configuration Page (see Figure 4-12).

4.2.4 Channel display configuration page

This page allows the user to configure inputs and outputs associated with a panel on the Home page. [Figure 4-12](#) shows the page when the panel is unconfigured.

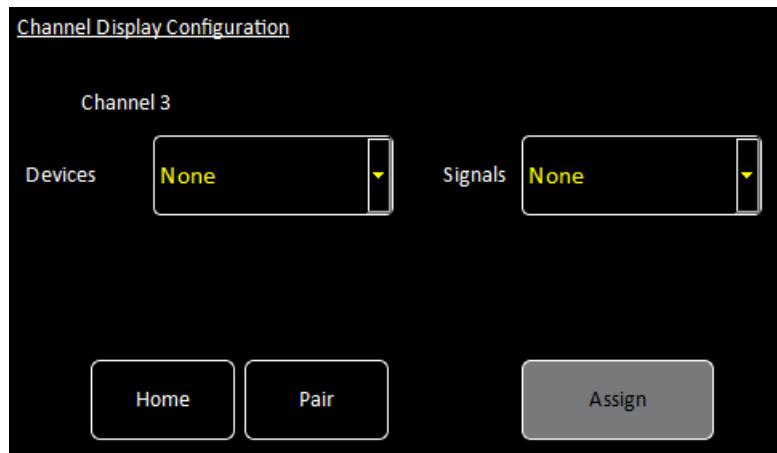


Figure 4-12 Channel Display Configuration page

The page contains the following fields and controls:

- **Devices**
Select a sensor for this panel from a drop-down menu. Select *None* to clear the configuration for this panel.
- **Signals (Devices)**
Select a sensor parameter to display from a drop-down menu.
- **Pair button**
Tap once to display the Device Pair Configuration page (see [Section 4.2.5](#)).
- **Assign button**
Tap once to save any changes made.

Mercury iTC

4.2.5 Device pair configuration page

This page allows the user to pair a temperature sensor with a heater or gas flow controller in a control loop. For example, a temperature sensor can be paired with a heater. [Figure 4-13](#) shows the page when all the pairings are unconfigured.

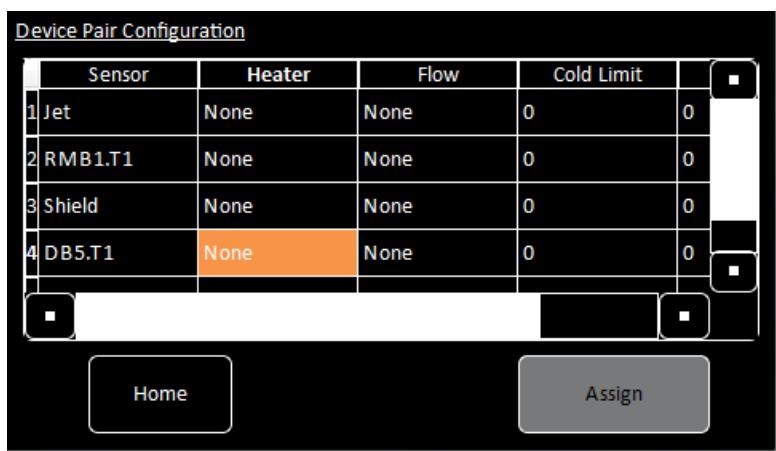


Figure 4-13 Device Pair Configuration Page (unconfigured)

The page contains the following fields:

- **Board number**
The board number is the first column in the table.
- **Sensor**
Displays the nickname of each sensor that is fitted to the unit. Tap this field to change the sensor nickname.
- **Heater**
Displays the heater that is paired with each temperature sensor. Select a heater to assign it to this temperature sensor (if applicable). Select *None* to remove a heater from this configuration.
- **Flow**
Displays the gas flow controller that is paired with each temperature sensor. Select a Gas Controller to assign it to this temperature sensor (if applicable). Select *None* to remove a gas controller from this configuration. The gas controller is mounted on the optional auxiliary I/O daughter board.
- **Cold Limit**
This value can only be changed in *ENGINEERING* mode.
Enter a lower temperature limit. If the sensor temperature falls below this limit, the gas flow is disabled.
- **Hot Limit**
This value can only be changed in *ENGINEERING* mode.
Enter an upper temperature limit. If the sensor temperature rises above this limit, the heater is disabled.

4.2.6 Sensor details pages

There are several alternative sensor details pages. The page that displays depends on which Channel Summary panel was selected.

4.2.6.1 Temperature Sensor Details page

This page displays detailed information about the selected temperature sensor.

Sensor Readings		Sensor Type	Calibration
I (μA)	100.0000	PTC	RP51.DAT
P (μW)	0.0000	Interpolation	Linear
R (Ω)	0.0000	Excitation	Unipolar
S (Ω/K)	0.0000	Magnitude (μA)	100.00
T (K)	53.1000		
V (mV)	0.0000		

Buttons: Home, Cal Adj, Calibrate

Figure 4-14 Temperature Sensor Details Page

The page contains the following fields and controls:

- Sensor name

- **Sensor Readings**

The values shown are:

I(μA) - the sensor excitation current in μA .

P(μW) - the power dissipated in the sensor in μW .

R(Ω) - the resistance of the sensor in Ohms.

S(Ω/K) - the sensitivity of the sensor in ohms per Kelvin.

T(K) - the temperature measured by the sensor in Kelvin.

V (mV) - the sensor output voltage in mV.

- **Sensor Type**

Select a sensor type from a drop-down menu. Available types are:

Thermocouple - a thermocouple.

PTC - positive temperature coefficient sensor.

NTC - negative temperature coefficient sensor.

Diode - a diode sensor.

Refer to [Section 5.5](#) for a detailed explanation of sensor types.

- **Calibration**

Select a calibration file from a drop-down menu. The list of files changes depending on which sensor type is selected.

- **Interpolation**

Select an interpolation method for calculating the calibration curve from the calibration table (see [Section 5.5.3](#)).

- **Excitation**

Select an excitation mode from a drop-down menu (see [Section 5.4.1](#)).



Mercury iTC

- **Excitation Magnitude**
Tap once to display a numeric keypad.
If **Sensor Type** is set to *PTC*, enter an excitation current in μA .
If **Sensor Type** is set to *Diode*, enter an excitation current in μA .
If **Sensor Type** is set to *NTC*, enter an excitation voltage in mV.
If **Sensor Type** is set to *Thermocouple*, this value is ignored.
- **Cal Adj button**
This button is only active if the **Calibration** field is set to *Generic*. Tap once to access the Generic Sensor Adjustment page (see [Section 4.2.6.2](#)). This allows the user to adjust the scale and offset of a generic calibration curve to suit a particular sensor.
- **Calibrate button**
Tap once to calibrate this measurement circuit. This routine takes approximately one minute. An error message is generated if the calibration fails for any reason.

4.2.6.2

Generic Sensor Adjustment page

This page allows the user to adjust the calibration curve of a generic sensor. See [Section 2.5.1.2](#) for a detailed explanation of this process.

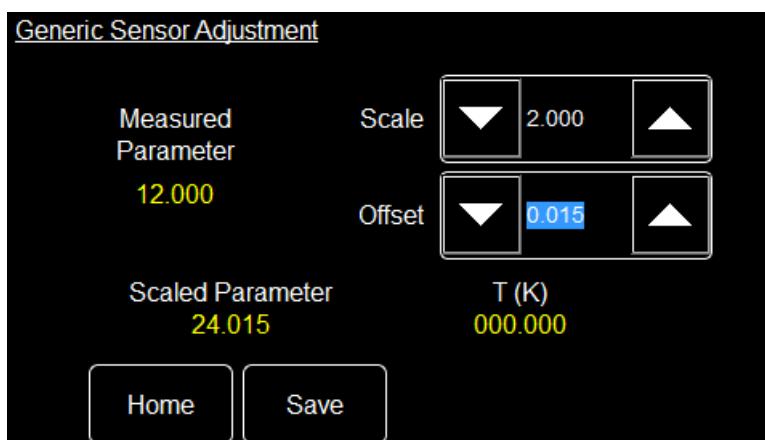


Figure 4-15 Generic Sensor Adjustment page

The page contains the following fields and controls:

- **Measured Parameter**
Displays the measured sensor value (i.e. resistance or voltage).
- **Scaled Parameter**
Displays the measured parameter value after the selected **Scale** and **Offset** have been applied. If **Scale**= 1 and **Offset**= 0, **Measured Parameter** and **Scaled Parameter** are identical.
- **Scale**
Adjust to change the slope of the calibration curve.
- **Offset**
Adjust to change the offset of the calibration curve.
- **Save**
Tap to save the new **Scale** and **Offset** values.

The following expression explains the effect of scale and offset:

$$\text{Scaled Parameter} = (\text{Measured Parameter} * \text{Scale}) + \text{Offset}$$

4.2.6.3 Level Meter Sensor Details page

This page displays detailed information about the selected level sensor.

There are two tabs. Select either the Helium tab (see [Figure 4-16](#)) or the Nitrogen tab (see [Figure 4-17](#)), depending on which type of level sensor is fitted.

Helium tab

Level Meter Sensor Details			
Helium	Nitrogen		
Resistance at 0% (Ω)	25.00	Resistance at 100% (Ω)	0.12
Pre-pulse Amplitude (mA)	150.00	Pre-pulse Duration (s)	0.50
Measure Pulse Amplitude (mA)	100.00	Measure Pulse Duration (s)	2.00
<input type="button" value="Home"/>		<input type="button" value="Slow"/>	

Figure 4-16 Level Meter Sensor Details page - Helium tab

The page contains the following fields and controls:

- **Resistance at 0% (Ω)**
Enter the resistance of the sensor when the level is 0%.
- **Resistance at 100% (Ω)**
Enter the resistance of the sensor when the level is 100%.
- **Pre-pulse Amplitude (mA)**
Enter the pre-pulse amplitude in mA.
- **Pre-pulse Duration (s)**
Enter the duration of the pre-pulse in seconds.
- **Measure Pulse Amplitude (mA)**
Enter the amplitude of the measurement pulse in mA.
- **Measure Pulse Duration (s)**
Enter the duration of the measurement pulse in seconds.
- **Slow/Fast button**
Select *Fast* sampling when filling the reservoir.
Select *Slow* sampling when the reservoir is full, to conserve helium.

Mercury iTC

Nitrogen tab

Level Meter Sensor Details			
Helium		Nitrogen	
Frequency at 0% (Hz)	<input type="text" value="0"/>	Frequency at 100% (Hz)	<input type="text" value="0"/>
Pulse Counting Period (ms)	<input type="text" value="750"/>	Refill Control Output	<input type="text" value="DB6.G1.O0"/> ▾
Low level	<input type="text" value="0"/>	High level	<input type="text" value="100"/>
<input type="button" value="Home"/>			

Figure 4-17 Level Meter Sensor Details page - Nitrogen tab

The page contains the following fields and controls:

- **Frequency at 0% (Hz)**
Enter the frequency of the sensor when the level is 0%.
- **Pulse Counting Period (ms)**
Enter the time period to be used for counting the sensor pulses.
Increasing the period improves the accuracy but lengthens the response time.
Decreasing the period degrades the accuracy but shortens the response time.
- **Low level**
Enter a percentage value for the required low level. When the level falls below this value, the refill valve opens. Note that if the valve is open but the level does not rise more than 1% in 10 minutes, the valve closes again.
- **Frequency at 100% (Hz)**
Enter the frequency of the sensor when the level is 100%.
- **Refill Control Output**
Select a digital output on the Auxiliary I/O board to drive a valve to refill the dewar.
- **High level**
Enter a percentage value for the required high level. When the level rises above this value, the refill valve closes.

4.2.7 Plot Configuration page

The Plot Configuration page allows the user to select one or more signals to be plotted against time.

To access the page:

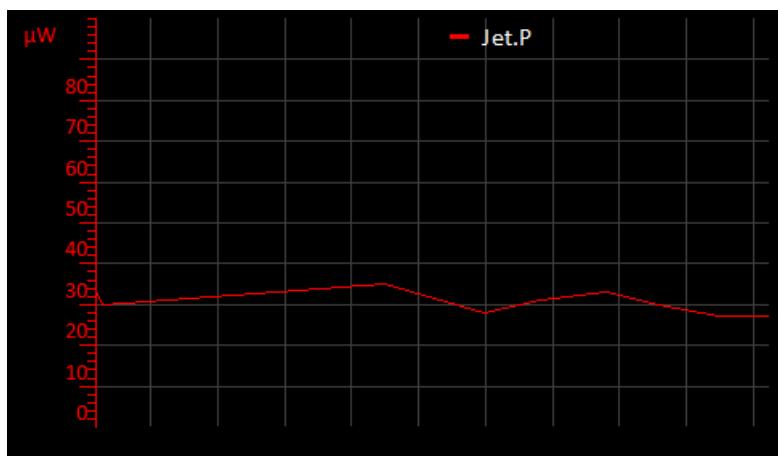
- 1 If no plots have been configured, tap the **Plot** button on the Home page.
- 2 If a plot is displayed, tap the plot area once. The Plot Configuration page appears as an overlay on the Plot page.



Figure 4-18 Plot Configuration page

The page contains the following fields and controls:

- **Device**
Select a device from a drop-down menu.
- **Signal**
Select a signal to display from a drop-down menu.
- **Close**
Tap once to close the Plot Configuration page without saving any changes that have been made.
- **Save**
Tap once to add the selected trace to the plot.
- **Delete**
Tap once to remove the selected trace from the plot.

Mercury iTC**4.2.8 Plot page****Figure 4-19 Typical Signal Monitor Plot page**

The Plot page can display up to six different values plotted against time.

If a plot has been configured, the trace updates in real time.

4.2.9**Control Loop Configuration page**

This page allows the user to configure a control loop. A control loop uses a temperature sensor to measure the sample temperature, and an associated heater or gas controller to control the sample temperature. An error message is displayed if this page is accessed and neither a heater nor gas controller have been configured for this sensor.

Control Loop Configuration	
Sensor	None
Heat(%)	Disabled Not Set
Flow(%)	Disabled Not Set
Set (K)	Disabled Not Set
PID	
Manual	
P	Not Set
I	Not Set
D	Not Set
Buttons:	
Home	Sweep
Gas Cfg	PID table

Figure 4-20 Control Loop Configuration page

Mercury iTC

The page contains the following fields and controls:

- **Sensor**

Select a sensor from a drop-down menu. Selecting a sensor enables other controls on the page.

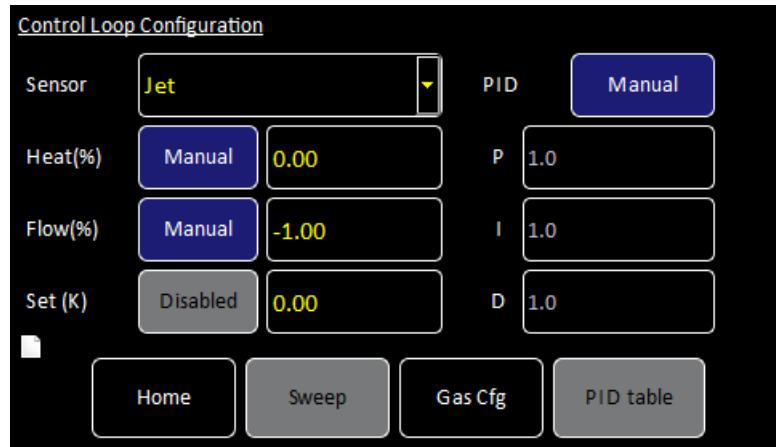


Figure 4-21 Control Loop Configuration page with a sensor selected

- **Heat (%)**

Select *Manual* or *Automatic* control of the heater. If *Manual* is selected, set a percentage output power for the heater in the numeric field.

- **Flow (%)**

Select *Manual* or *Automatic* control of the gas-flow controller. If *Manual* is selected, set a percentage flow in the numeric field.

- **Set (K)**

If the **Heat (%)** field is set to *Auto*, set a temperature setpoint (in Kelvin) in this field.

- **PID**

Select either *Manual* or *Automatic* PID values (see [Chapter 12](#) for information on PID control loops).

- **P**

If **PID** is set to *Manual*, enter a P parameter value (in K) in this field.

If **PID** is set to *Automatic*, this field displays the P parameter value that has been obtained from the PID table.

- **I**

If **PID** is set to *Manual*, enter an I parameter value (in minutes) in this field.

If **PID** is set to *Automatic*, this field displays the I parameter value that has been obtained from the PID table.

- **D**

If **PID** is set to *Manual*, enter a D parameter value (in minutes) in this field.

If **PID** is set to *Automatic*, this field displays the D parameter value that has been obtained from the PID table.

- **Sweep button**

Tap once to program temperature sweeps (see [Section 4.2.15](#)). This button is only active if **Heat** is set to *Auto*.

Mercury iTC

- **Gas Cfg**
Tap once to access the Gas Flow Configuration page (see [Section 4.2.10](#)).
- **PID Table**
Tap once to access the PID Table Editor page (see [Section 4.2.11](#)). This button is only active if **PID** is set to *Auto*.

4.2.10 Gas Flow Configuration page

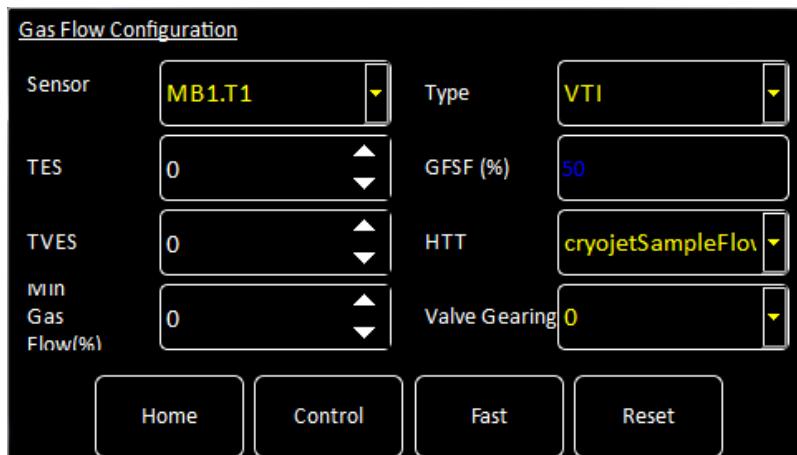


Figure 4-22 Gas Flow Configuration page

This page configures the gas-flow control loop, which is controlled by the optional auxiliary I/O daughter-board. The page contains the following fields and controls:

- **Sensor**
Select the sensor to be used for the gas-flow control from a drop-down menu.
- **TES**
Enter the Temperature Error Sensitivity as a power of 2. e.g. enter 7 to set 512 (2^7). TES controls how fast the needle valve responds to a temperature error. Increasing TES by 1 increases the response rate by a factor of 2.
- **TVES**
Enter the Temperature Voltage Error Sensitivity as a power of 2. e.g. enter 6 to set 256 (2^6). TVES controls how fast the needle valve responds to a heater-voltage error. Increasing TVES by 1 increases the response rate by a factor of 2.
- **Min Gas Flow (%)**
Enter a minimum valve position as a percentage of the maximum. Defining a minimum valve position prevents the valve from closing fully, and possibly sticking. Choose the minimum position so that there is no gas flow.
- **Type**
Select the type of gas flow control to be used.
Select *VTI* (Variable Temperature Insert) if the helium is supplied from a local bath (see [Section 12.3.3](#)).
Select *Syphon* if the helium is supplied from a dewar (see [Section 12.3.3.2](#)).
- **GFSF (%)**
Displays the gas flow scaling factor.

- **HTT**

Select a *Heater Target Table* file to use for the control.

- **Fast/Slow** button

When *Fast* is selected, the valve moves twice as fast as when *Slow* is selected.

- **Reset** button

Tap **Reset** to close the gas control valve.

- **Valve Gearing**

Enter a value between 0 and 7 to adjust the relationship between stepper-motor movement and valve movement. If the entered value is x , the number of stepper-motor steps that correspond to a valve movement from fully-closed to fully-open is $2^{16}/2^x$.

For example, to set 2^{16} steps for 0 to 100% valve opening, enter a value of 0, i.e. valve steps = $(2^{16}/2^0)$. Similarly, to set 2^{14} steps for 0 to 100% valve opening, enter a value of 2, i.e. valve steps = $(2^{16}/2^2)$.

For a typical stepper motor / gearbox combination used on OINS systems, 2^{16} steps would correspond to 3 complete needle valve shaft revolutions, 2^{15} steps would correspond to 3/2 (1.5) complete revolutions etc. However, this may vary from system to system.



Mercury iTC**4.2.11 PID Table Editor page****Figure 4-23 PID Table Editor page with an empty table**A screenshot of the Mercury iTC software interface titled "PID Table Editor". The title bar also displays "File: pid.tmp". The main area shows two rows of data in a table:

	T1 (K)	T2 (K)	P (K)	I (mins)	D (mins)
1	3.0000	10.0000	1.0000	30.0000	12.0000
2	10.0001	20.0000	1.1000	25.0000	10.0000

Below the table are six buttons: a minus sign (-), Home, Control, Save, Load, and a plus sign (+).

	T1 (K)	T2 (K)	P (K)	I (mins)	D (mins)
1	3.0000	10.0000	1.0000	30.0000	12.0000
2	10.0001	20.0000	1.1000	25.0000	10.0000

Figure 4-24 PID Table Editor with two rows of data

See [Section 12.2.7](#) for an explanation of PID tables.

The page displays a PID table. If the table is empty, only the first cell is displayed (see [Figure 4-23](#)). If the table contains data, one or more rows of values are displayed (see [Figure 4-24](#)).

The table contains the following columns:

- **T1 (K)**
Enter the lower temperature of the temperature range for this row in K.
- **T2 (K)**
Enter the higher temperature of the temperature range for this row in K. **T2 (K)** must be greater than **T1 (K)**.
- **P (K)**
Enter the width of the proportional band in K.

Mercury iTC

- **I (mins)**

Enter the I (Integral) parameter in minutes.

- **D (mins)**

Enter the D (Differential) parameter in minutes.

The page contains the following buttons

- -

Tap once to delete the currently selected row from the table. A confirmation message is displayed before the row is deleted. Tap **OK** to delete the row. Tap **Cancel** to exit without deleting the row.

- **Control**

Tap once to return to the Control page.

- **Save**

Tap once to save the table (see [Section 4.2.16](#)).

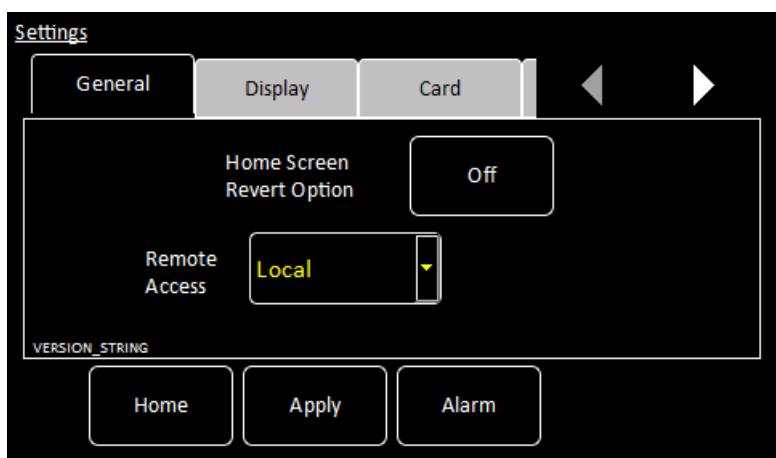
- **Load**

Tap once to load a table that has been previously saved (see [Section 4.2.17](#)).

- +

Tap once to add another row to the table. The new row is appended after the last row.



Mercury iTC**4.2.12 General Settings tab****Figure 4-25 General Settings tab**

The page contains the following fields and controls:

- **Home Screen Revert Option**

If Home Screen Revert mode is set *On*, the interface reverts to the Home page after a wait period, if no user activity is detected. If this field is set *Off*, the present page is displayed until the user navigates to another page.

- **Remote Access**

Select *Local* from the drop-down menu to allow the user to control the iTC from the GUI. Select an interface from the drop-down menu to enable remote control via the selected interface.

- **SCPI/Legacy field**

This field is only displayed if an interface is selected in **Remote Access**.

Select *SCPI* to use a command set based on SCPI (Signal Orientated Measurement Commands).

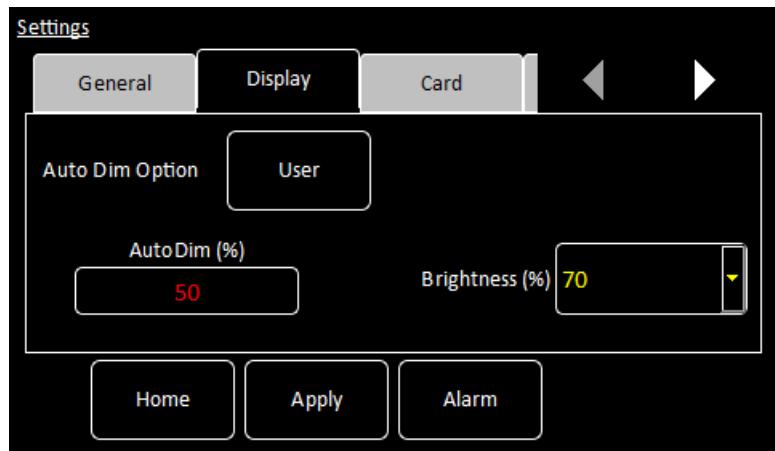
Select *Legacy* to use a command set that is compatible with legacy instruments.

The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.1 Display Settings tab



The page contains the following fields and controls:

- **Auto Dim Option**

When **User** is displayed, the auto-dim feature is turned off. When **Sensor** is displayed, the auto-dim feature is active (see [Section 5.1.1](#)).

- **Timeout value (sec)**

Set the time that must elapse (in seconds) before the display brightness changes. This field is only displayed if **Auto Dim Option** is set to **Sensor**.

- **Auto Dim (%)**

Enter a percentage brightness value for the display when it is automatically dimmed. **Auto Dim (%)** must be less than, or equal to, **Brightness (%)**.

- **Brightness (%)**

Select a percentage value from the drop-down menu to alter the brightness of the display.

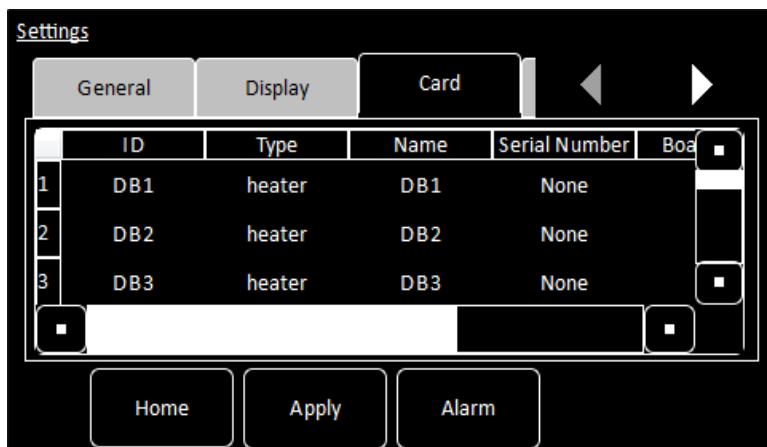
The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

Mercury iTC

4.2.12.2 Card settings tab



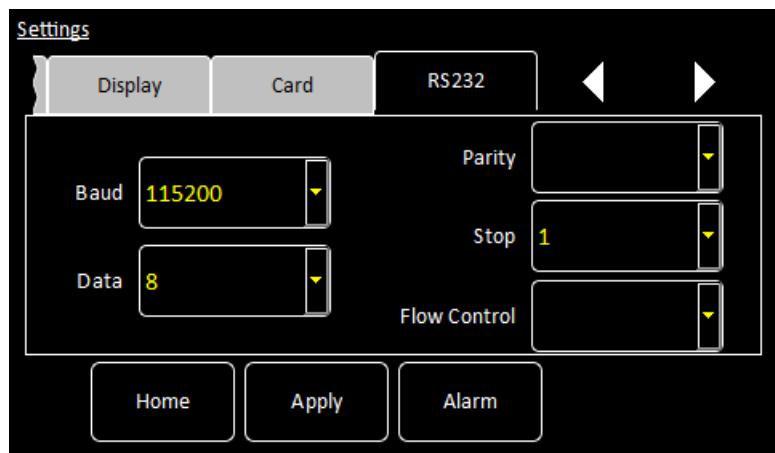
Each row of this table corresponds to an expansion slot in the iTC. The table lists which boards are fitted in which slot. The columns show:

- **ID**
The number of the slot.
- **Type**
The ID of the board fitted in this slot.
- **Name**
The type of board fitted in this slot.
- **Serial Number**
The name of the board fitted in this slot.
- **Board Rev**
The revision number of the board.
- **Firmware Ver**
The firmware version loaded onto the board.

The page contains the following buttons:

- **Alarm**
Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.3 RS232 Settings tab



The page contains the following fields and controls:

- **Baud**

Select a baud rate for the RS232 interface from the drop-down menu.

- **Data**

Select the number of data bits for the RS232 interface from the drop-down menu.

- **Parity**

Select a parity scheme for the RS232 interface from the drop-down menu.

- **Stop**

Select the number of stop bits for the RS232 interface from the drop-down menu.

- **Flow Control**

Select a flow-control scheme for the RS232 interface from the drop-down menu.

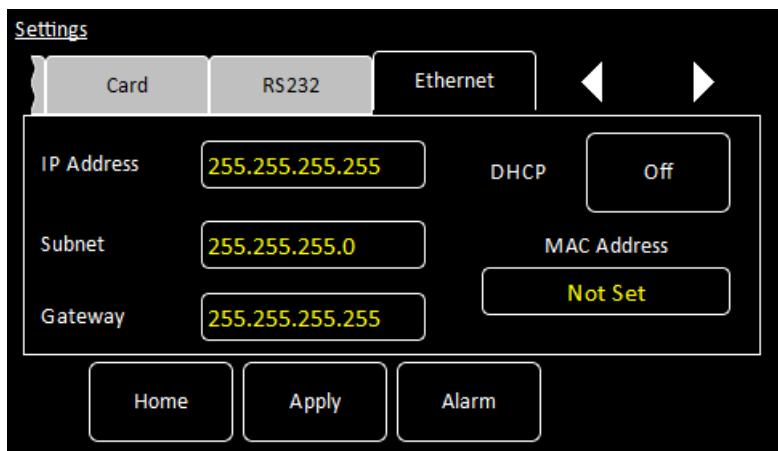
The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

Mercury iTC

4.2.12.4 Ethernet Settings tab



The page contains the following fields and controls:

- **IP Address**

If dynamic host configuration protocol (DHCP) is set *Off*, enter the ip address that has been assigned to the iTC ethernet connection.

- **Subnet**

If DHCP is set *Off*, enter the subnet mask that is to be used for the iTC ethernet connection.

- **Gateway**

If DHCP is set *Off*, enter the gateway address that is to be used for the iTC ethernet connection.

- **DHCP**

Select if DHCP is to be used or not. If DHCP is set to *On*, the iTC is automatically assigned an ip address, subnet mask, and gateway from the network. If DHCP is set to *Off*, the values entered in the **IP Address**, **Subnet** and **Gateway** fields are used.

- **MAC Address**

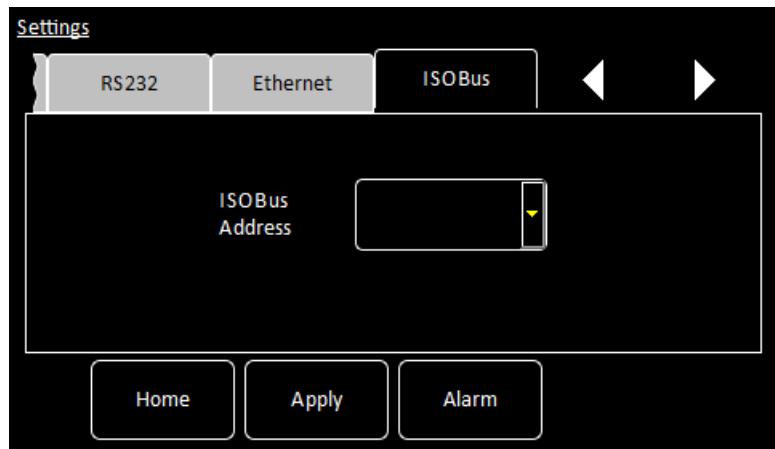
The MAC address of the iTC is displayed. This value is assigned at the factory and cannot be edited.

The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.5 ISOBus Settings tab



The page contains the following fields and controls:

- **ISOBus Address**

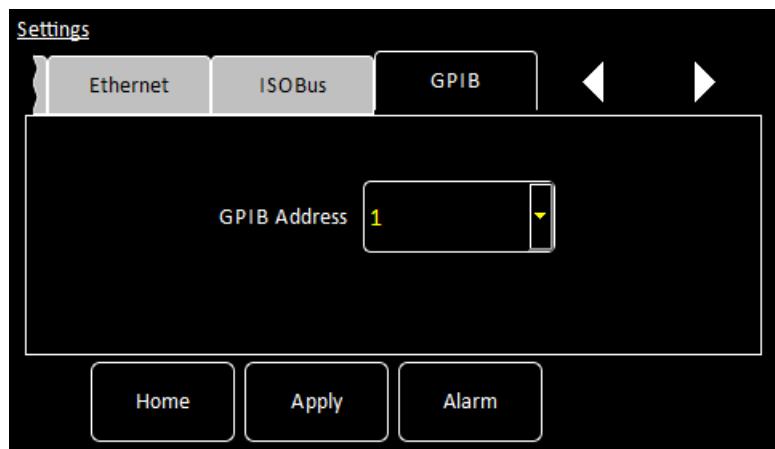
Select an ISOBus address for this instrument from the drop-down menu.

The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.6 GPIB Settings tab



The page contains the following fields and controls:

- **GPIB Address**

Select a GPIB address for this instrument from the drop-down menu.

The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

Mercury iTC

4.2.12.7 Clock Settings tab



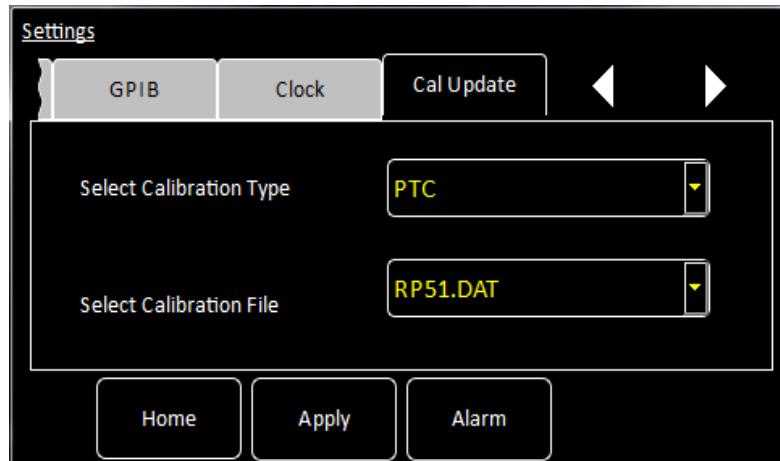
The page contains the following fields and controls:

- **Date time**
Displays the date and time that are currently set in the iTC.
- **Parameter**
Select a date or time parameter to be changed (e.g. Hour).
- **Value (offset)**
Enter a positive or negative offset value for the chosen parameter. The chosen offset value is added to the **Date time** field. The displayed date automatically changes if the offset value moves the time past 24 hours. (e.g. If the present time is shown as 15:21:17, an offset of +2 hours will change the time to 17:21:17. An offset of +9 hours, advances the date by one day and the time to 00:21:17.).

The page contains the following buttons:

- **Alarm**
Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.8 Cal Update settings tab

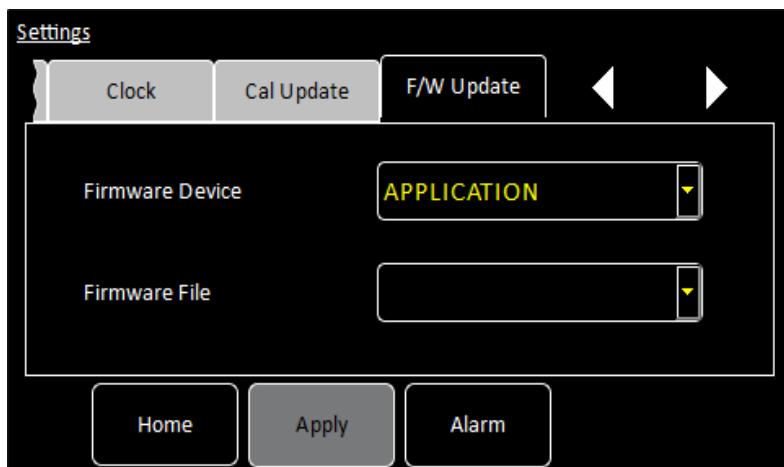


This page allows the user to load calibration files into the controller from a USB memory stick. The page contains the following fields:

- **Select Calibration Type**
Select the type of calibration file to be loaded.
- **Select Calibration File**
Select the file to be loaded from the memory stick. Once selected, the file is loaded automatically.

The page contains the following buttons:

- **Apply**
Tap once to apply the selected calibration file. Tap **Home** to exit without applying the file.
- **Alarm**
Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

Mercury iTC**4.2.12.9 F/W Update settings tab**

The page allows the user to update the iTC application or the firmware on a daughter board. The new firmware must be located on a USB memory stick. The system automatically disconnects any output signals while the firmware is being updated.

The page contains the following fields and controls:

- **Firmware Device**

Select the name of a board from a drop-down list to update the firmware on that board.

Select APPLICATION to update the application that is running on the iTC.

- **Firmware File**

Select the file on the memory stick to load onto the daughter board.

The page contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

4.2.12.10 EngMode tab



This page allows the user to enter *ENGINEERING* mode, to access features that are not available to normal users. The default engineering password is **abc123**. The user can change this password, if required.

The page contains the following fields and controls:

- **Password**

Enter the engineering password and tap **Enter**. Note that the password is case sensitive (e.g. **abc123** and **aBc123** are different passwords).

- **Alarm**

Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).

If the login is successful, two additional buttons appear:

- **Change**

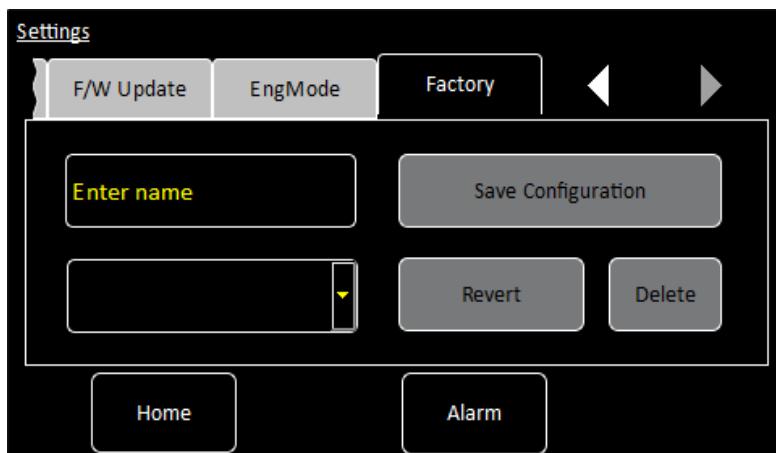
Tap to change the engineering password.

- **LogOff**

Tap to exit *ENGINEERING* mode.

Mercury iTC

4.2.12.11 Factory Settings tab



This page allows the user to save the configuration of the **Mercury iTC** as a file. The user can then load a previously saved configuration.

NOTE: The system configuration contains information that the user has entered via the GUI (such as names of sensors, paired signals, calibration etc.). It does not include the firmware versions.

The page contains the following fields and controls:

- **Save configuration**
To save the present system configuration, enter a filename in the **Enter Name** field and tap **Save Configuration**.
- Drop-down menu
Select a saved file to load or delete. Loading a file changes the unit's configuration to the saved configuration. Note that the original factory configuration is called FACTORY_OI.

The page contains the following buttons:

- **Alarm**
Tap once to access the Alarm Logs page (see [Section 4.2.13](#)).
- **Revert**
Tap once to load the selected configuration file and reboot the **Mercury iTC**.
- **Delete**
Tap once to delete the selected configuration file from the list of available files.

4.2.13 Alarm Logs page

This page displays a table of alarms that have been generated on the system.

Alarm Logs		
	Date/Time	Device UID
1	30.12.2011-11:43:12	MB1
2	30.12.2011-11:42:37	MB1
3	30.12.2011-11:42:37	MB1
4	30.12.2011-11:42:14	MB1

Home

Save

Figure 4-26 Alarm Logs page

The table contains an entry when an alarm is first raised, and another entry when the alarm is restored.

This table has the following columns:

- **Date/Time**
The date and time when the alarm was raised.
- **Device UID**
The identifier of the device that raised the alarm.
- **Alarm**
A brief description of the alarm (e.g. Short-circuit).

Mercury iTC

4.2.14 Heater configuration page

Heater #	Name	Lim(V)	Res(Ω)	P(W)
DB1.H1	SAMPLE_FLOW	233.60	21.00	0.000 0%
DB2.H1	SHIELD_HEAT	221.50	40.00	0.000 0%
DB3.H1	SHIELD_FLOW	150.00	40.00	0.000 0%
MB0.H1	Heater	135.00	40.00	0.000 0%
<input type="button" value="Home"/>		<input type="button" value="Control"/>		<input type="button" value="Calibrate"/>

Figure 4-27 Heater configuration page

This page displays a set of values for each heater that is configured. The following fields and values are displayed for each heater:

- **Heater #**
Displays the number of the heater. This number cannot be edited.
- **Name**
A name to identify the heater. Tap this field once to display an alpha-numeric keypad and enter a new name.
- **Lim (V)**
The maximum voltage to be applied to the heater. Tap this field once to display a numeric keypad and enter a new value.
- **Res (Ω)**
The electrical resistance of the heater in ohms. Tap this field once to display a numeric keypad and enter a new value.
- **P(W)**
This field displays the power that is currently being applied to the heater, both in watts and as a percentage of the maximum. This value cannot be edited.

The page also contains the following buttons:

- **Control**
Tap once to display the Control Loop Configuration page (see [Section 4.2.9](#)).
- **Calibrate**
Tap once to calibrate this measurement circuit. This routine takes approximately one minute. An error message is generated if the calibration fails for any reason.

4.2.15 Sweep Table page

Allows the user to configure a temperature sweep profile.

The screenshot shows the 'Sweep Table' configuration page. At the top, there is a table header with three columns: 'Final T (K)', 'Time To Final T (mins)', and 'Hold At Final T (mins)'. Below the header, there is a large empty black rectangular area for entering data. At the bottom, there are four buttons: a left arrow button, a 'Load' button, a 'Save' button, a 'Close' button, and a right arrow button.

Final T (K)	Time To Final T (mins)	Hold At Final T (mins)

-

Load

Save

Close

+

Figure 4-28 Sweep Table page with an empty table

The screenshot shows the 'Sweep Table' configuration page with two rows of data. The first row has values: '12' in 'Final T (K)', '10' in 'Time To Final T (mins)', and '5' in 'Hold At Final T (mins)'. The second row has values: '24' in 'Final T (K)', '10' in 'Time To Final T (mins)', and '6' in 'Hold At Final T (mins)'. The 'Hold At Final T (mins)' column for the second row is highlighted with an orange background. Below the table, there is a large empty black rectangular area. At the bottom, there are four buttons: a left arrow button, a 'Load' button, a 'Save' button, a 'Close' button, and a right arrow button.

Final T (K)	Time To Final T (mins)	Hold At Final T (mins)
12	10	5
24	10	6

-

Load

Save

Close

+

Figure 4-29 Sweep Sequence Editor page with two rows of data

The page displays a sweep table. If the table is empty, only the first row is displayed (see [Figure 4-28](#)). If the table contains data, one or more rows of values are displayed (see [Figure 4-29](#)).

The table contains the following columns:

- **Final T (K)**
Enter the required temperature setpoint in K.
- **Time to Final T (mins)**
Enter the time in minutes required to reach the temperature setpoint.
- **Hold at Final T (mins)**
Enter the time in minutes required for the temperature to remain at the setpoint.

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The page contains the following buttons

- - Delete the currently selected row from the table. A confirmation message is displayed before the row is deleted. Tap **OK** to delete the row. Tap **Cancel** to exit without deleting the row.
- **Save** Tap once to save the table (see [Section 4.2.16](#)).
- **Load** Tap once to load a table that has been previously saved (see [Section 4.2.17](#)).
- **Close** Tap once to exit without saving changes to the table.
- + Add another row to the table. The new row is appended after the last row.

4.2.16 Save File pages

There are several pages used to save files. All these pages function in the same way, so only one is described in this section.



Figure 4-30 Save File page

This page contains the following fields and controls:

- **Main area** Displays a list of the existing files of this type.
- **Filename** Tap once and enter the required filename, without a file extension.
- **Save** Tap once to save the file.
- **Cancel** Tap once to exit without saving the file.

4.2.17 Load File pages

There are several pages used to load files. All these pages function in the same way, so only one is described in this section.



Figure 4-31 Load File page

This page contains the following fields and controls:

- **Main area**
Displays a list of the existing files of this type. Tap a filename to select it. The name of the selected file is displayed in the Filename field
- **Filename**
If desired, tap once to enter the name of the file that you wish to load.
- **Load**
Tap once to load the selected file.
- **Cancel**
Tap once to exit without loading the file.

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This page is intentionally blank.

5 FUNCTIONAL DESCRIPTION

5.1 Main components

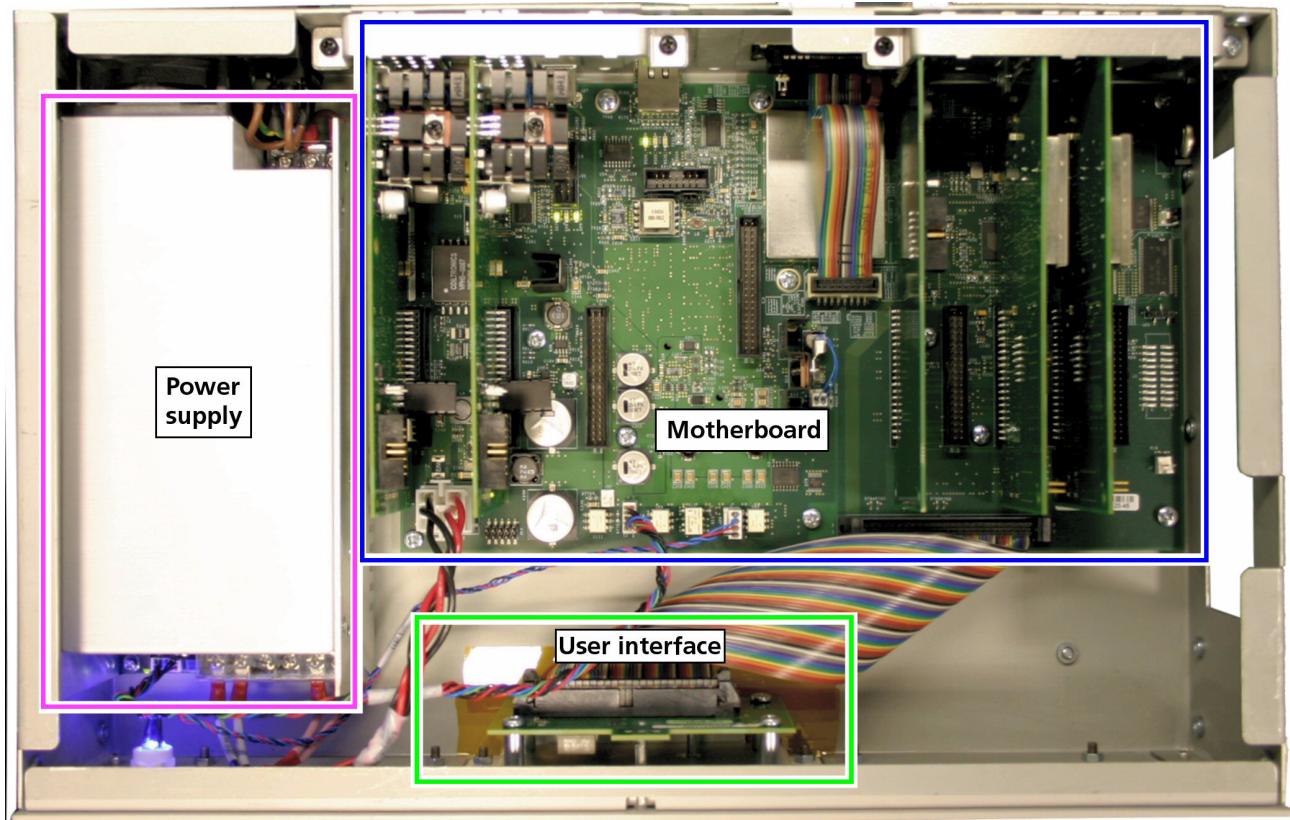


Figure 5-1 General view of the iTC

The unit consists of:

- a 2U high 19 inch rack or desktop enclosure
- a user interface (see [Section 5.1.1](#))
- a power supply
- a motherboard PCB which contains the basic unit functionality (see [Section 5.1.2](#))
- optional additional temperature sensor input(s) (on daughter boards). See [Section 5.2.2](#).
- optional additional heater output(s) (on daughter boards). See [Section 5.2.3](#).
- optional auxiliary I/O (stepper motor drive and logic I/O)
- optional GPIB (IEEE-488) interface

Mercury iTC

5.1.1 User interface

The user interface consists of a 420 x RGB x 272 pixel LCD-TFT display and touch-screen. A opto-sensor is fitted above the display to detect ambient light levels. The temperature controller can be configured to vary the display brightness to match the ambient light level (auto-dim feature).

5.1.2 Motherboard

The motherboard contains the processors that control the iTC. The operating program and control applications are stored on a flash drive. The motherboard also provides a single temperature-sensor input and a single heater output.

There are eight expansion slots, each of which can accept an optional daughter board (see [Section 5.3.1](#)).

5.2 iTC connections

5.2.1 Electrical power connection

The back panel contains an IEC C14 connector for the main electrical supply to the unit.

5.2.2 Temperature sensor inputs

The temperature sensor input is via 9-way D-connector on the rear panel of the iTC. Sensor connections are listed in [Table 5-1](#).

The basic iTC includes a single input channel for one temperature sensor. An additional 8 sensor inputs can be added to make a total of 9 inputs.

The unit can accept the following sensor types:

- Negative temperature coefficient (NTC) resistance
- Positive temperature coefficient (PTC) resistance
- Thermocouple
- Silicon diode

Each input can be read at a maximum rate of 10 Hz. The unit can detect short-circuit inputs and open-circuit inputs. The heater output is disabled if a faulty sensor is detected.

The iTC contains a temperature sensor that is used to compensate for fluctuations in ambient temperature.

See [Section 5.4](#) for an overview of the temperature measurement methods that are available on the iTC.

See [Section 13.3](#) for a description of the temperature measurement circuit.

5.2.3 Outputs

The heater output is via the same 9-way D-connector used for the temperature input. Heater connections are listed in [Table 5-1](#). The basic iTC includes a single 80 W heater output. An additional three 80 W outputs can be added (total 4 outputs).

An optional daughter-board can be added to drive a stepper motor. This is commonly used to control the motorised valve in a continuous-flow cryostat.

The iTC uses a PID loop to control each heater (see [Chapter 12](#) for information on PID loops). The control system includes a dead-man's-handle timer to confirm that the control loop is operating. If the control loop stalls, the heater output is disabled.

See [Section 14.3](#) for a description of the heater circuit.

5.2.4 Heater and sensor connections

The heater and sensor are connected via a 9-way D-socket on the rear panel.

Table 5-1 Channel pin connections

Pin Number	Connection
1	Sensor input high
2	Sensor input screen.
3	Sensor input low
4	Current source +ve
5	Current source -ve
6	Heater output +ve
7	Heater output -ve
8	Not used
9	Chassis ground.

Connections to the sensor vary depending on the type of sensor in use (see [Table 5-2](#)).

Table 5-2 Sensor connections

Connection	Thermocouple	Metal Resistor	Ge/Carbon Resistor	Si/Ga As Diode
Input High	V+	V+	V-	V-
Input Low	V-	V-	V+	V+
Current +ve	n/c	I+	I+	I+
Current -ve	n/c	I-	I-	I-

5.2.4.1 Connecting thermocouples

Thermocouples must be connected using the correct wire type to ensure measurement accuracy.



Mercury iTC

5.2.5 Communications interfaces

Connectors for the communications interfaces are located on the rear panel of the iTC. The unit has the following interfaces:

- Serial RS232 + ISOBUS (see [Section 5.2.5.1](#))
- Serial2 USB (see [Section 5.2.5.3](#))
- GPIB (IEEE-488) (optional) (see [Chapter 17](#))
- Ethernet 10/100 IEE802.3 (see [Section 5.2.5.4](#))

5.2.5.1 Serial RS232 interface

The RS232 interface is connected via a 25-way D-socket on the rear panel. The iTC is configured as Data Circuit-terminating Equipment (DCE), with the standard pin-assignments listed in [Table 5-3](#).

Most computer RS232 interfaces are configured as Data Terminal Equipment (DTE). If the computer has a 25-way D-plug, the cable must be connected pin-to pin (i.e. Pin 1 to Pin 1, Pin 2 to Pin 2 etc.). If the computer has a 9-way D-plug, a standard RS232 9-way to 25-way cable is required.

Table 5-3 RS232 connections on the iTC

Pin	Signal Name	Notes
1	FG	Linked to chassis ground inside the iTC.
2	TD	Data from the computer to the iTC.
3	RD	Data from the iTC to the computer.
4	RTS	Linked to Pin 5 inside the iTC.
5	CTS	Linked to Pin 4 inside the iTC.
6	DSR	Linked to +5 V when the iTC is powered.
7	SG	Linked to digital ground inside the iTC.
8	DCD	Linked to +5 V when the iTC is powered.
9 to 25		Open circuit.

The iTC does not require signals to be present on the RTS or DTR (pin 20) lines. The RTS signal is fed back to the computer as CTS. The iTC sends logic high levels (+5 V) to the computer on DSR and DCD.

Voltage levels for the transmitted and received data are listed in [Table 5-4](#).

Table 5-4 RS232 voltage levels

Signal	Allowed Voltage Level
Tx data high	>+5.5 V
Tx data low	<-5.5 V
Rx data high threshold	<+2.6 V
Rx data low threshold	>+1.4 V
Max Rx input voltage	±30 V

5.2.5.2

Oxford Instruments NanoScience ISOBUS

ISOBUS allows a single RS232 port on a computer to control a number of instruments independently. This arrangement requires an ISOBUS cable, which carries a single Master connector (25-way D-socket) and up to eight Slave connectors (25-way D-plug). Each slave connector incorporates full optical isolation, so that each slave is isolated from the master and from every other slave.

The slave connectors draw electrical power from the individual instruments, via the DCD signal. The master connector draws electrical power from either the DTR or RTS signals from the computer.

A special command protocol is required to use ISOBUS (see [Section 7.3](#)).

5.2.5.3

USB interface

The (USB) port allows one-to-one communication with a computer. USB 2.0 full-speed (12 MBits per second) is supported.

5.2.5.4

Ethernet interface

The ethernet interface is connected via an RJ45 connector on the rear panel. The iTC can be configured to use a fixed ipaddress, or to use dynamic host configuration protocol (DHCP).



Mercury iTC

5.3 Daughter boards

The iTC can accept up to 8 daughter boards. These can consist of combinations of the following board types:

- Temperature sensor
A board containing a single temperature sensor interface. A maximum of eight of these boards can be fitted (see [Chapter 13](#)).
- Heater
A board containing a single heater interface. A maximum of three heater boards can be fitted (see [Chapter 14](#)).
- Level meter
A board containing a single level meter, which is used to monitor the amount of gas or liquid in the system. Only one of these boards can be fitted (see [Chapter 16](#)).
- Auxiliary I/O board
A board containing a number of I/O lines. Some of these lines are used to drive a stepper motor to control gas-flow. Only one of these boards can be fitted (see [Chapter 15](#)).
- GPIB
A board which provides an external GPIB interface for connection to another device (e.g. a PC). Only one of these boards can be fitted (see [Chapter 17](#)).

The iTC automatically identifies every daughter board that is fitted.

5.3.1 Expansion slots

The daughter boards fit into expansion slots that are located on the mother board.

There are eight expansion slots in the iTC, and a dedicated slot for a GPIB board (see [Figure 5-2](#)). Slot number 1 is adjacent to the power supply unit in the iTC.

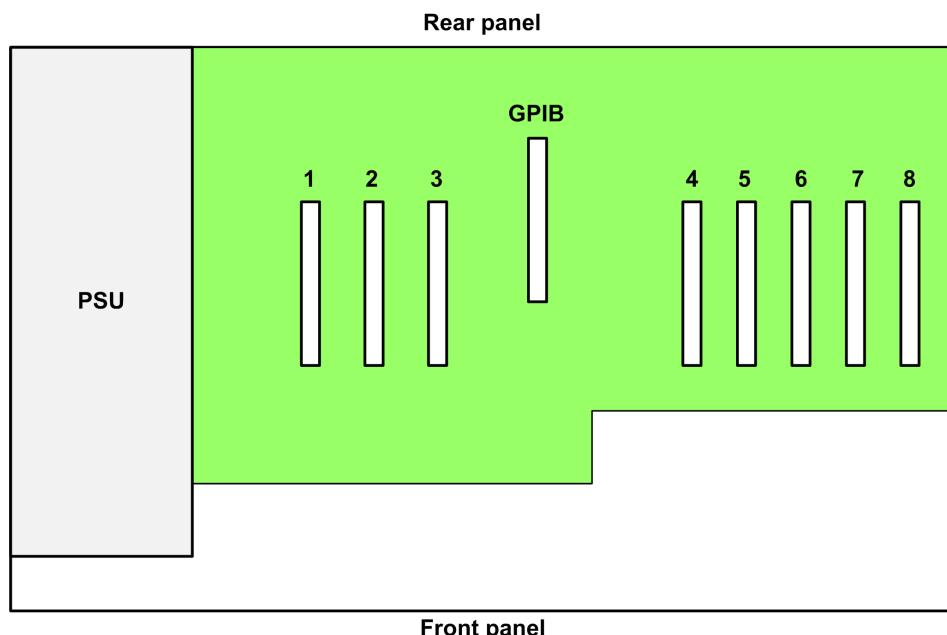


Figure 5-2 Expansion slots in the iTC

5.3.2 Positioning daughter boards

The following boards can be positioned in any location:

- Level sensor board
- Auxiliary I/O board
- Temperature sensor board that is not used to control a heater.

A GPIB board must be fitted in the dedicated GPIB expansion slot (see [Figure 5-2](#)).

A heater board must be positioned in slot 1, 2 or 3 (see [Section 5.3.2.1](#)).

A temperature board that is used to control a heater must be positioned in slot 6, 7 or 8 (see [Section 5.3.2.1](#)).

5.3.2.1 Interconnecting heater and temperature-sensor boards

A heater board is always associated with a temperature sensor board. The output of a heater board is hard-wired to the 9-way D-connector on an associated temperature controller board. These connections are listed in [Table 5-5](#)

Table 5-5 Locations of temperature sensor and heater boards

Heater Board Output		Temperature Sensor Board
Slot 1	is connected to	Slot 6
Slot 2	is connected to	Slot 7
Slot 3	is connected to	Slot 8

If one or more heater boards are fitted, temperature sensor boards must be fitted in the corresponding slots listed in [Table 5-5](#).

A control-loop must be configured before a heater board can be operated. Any temperature sensor can be configured to control any heater, as long as the hardware is connected to match this configuration.

For example:

- a) If a single heater board is fitted in slot 2, a temperature sensor board must be fitted in slot 7. The control loop must be configured so that the temperature sensor in slot 7 controls the heater in slot 2.



Mercury iTC

5.4 Overview of temperature measurement

5.4.1 Measurement principles

The iTC uses a highly accurate measurement circuit to measure the voltage produced by a sensor.

5.5 Types of temperature sensor

The iTC can use several types of temperature sensor:

- Thermocouples
A thermocouple comprises two junctions of dissimilar metals held at different temperatures. This acts as a voltage source, based on the Seebeck effect, the output voltage of which increases with increasing temperature difference. The iTC contains cold-junction compensation, so a reference junction is not required.
- Metallic resistance thermometers
The resistance of metallic resistors increases with increasing temperature due to the increase of scattering events of the conduction electrons. Over much of the temperature range the relationship is approximately linear until, at low temperatures, impurity scattering becomes significant and the sensor sensitivity flattens off. The iTC passes a constant current through the sensor and measures the voltage produced, using a 4-wire measurement. Resolution to 1 mK is possible at low temperatures, if a suitable resistor and energisation current are used.
- Semiconductor resistance thermometers
The resistance of semiconductor resistors decreases with increasing temperature. The relationship is non-linear. The iTC uses a 4-wire connection, applying a constant voltage across the resistor. The iTC then measures the current, which is used to calculate the temperature. The current through the resistor increases with temperature and its relationship to the temperature is more linear than the resistance of the resistor. Using a constant voltage ensures that power dissipation in the resistor decreases as the temperature decreases. Resolution to 0.1mK is possible at low temperatures.
- Semiconductor diodes
These devices produce a voltage that decreases as the temperature increases. The iTC passes a constant current through the diode and measures the voltage produced. Resolution to 1mK is possible at low temperatures.

The iTC includes calibration curves for the following sensor types.

Table 5-6 Sensor range data

Code	Sensor	Range
Lin ¹	Linear range	0-1677.7
NullRef:[1]	Centre zero	-838.9 to +838.9
Con 1	Conductance	0 to 20
TG 5	AuFe 0.03/Chr	2 to 500K
TG 5	AuFe 0.03/Chr	2 to 500K



Table 5-6 Sensor range data

Code	Sensor	Range
TG 5	AuFe 0.03/Chr	2 to 500K
TG_57	AuFe 0.07/Chr	2 to 500K
TG_57	AuFe 0.07/Chr	2 to 500K
TG_57	AuFe 0.07/Chr	2 to 500K
CN 3	Cernox resistor	1.5 to 300K
TT 5	Copper/Const	20 to 500K
TT 5	Copper/Const	20 to 500K
TT 4	Copper/Const	-250 to 400°C
TT 4	Copper/Const	-250 to 400°C
TK 10	Chromel/Alumel	0 to 1000°C
TK 10	Chromel/Alumel	0 to 1000°C
TK 13	Chromel/Alumel	-200 to 1370°C
TK 13	Chromel/Alumel	-200 to 1370°C
CR 11	Ruthenium oxide	0.25 to 10K
RF 52 ²	RhFe resistor	1.5 to 500K
RP 1	Platinum resistor	-200 to +100°C
RP 5 ³	Platinum resistor	20 to 500K
RP 51 ⁴	Platinum resistor	50 to 500K
RL 3	CLTS	2 to 300K
DS 32	Silicon diode (OI)	2 to 300K
DS 31	Silicon diode (LS)	2 to 300K
CC 35	C-glass CR500	2 to 300K
CA 21	100R Allen Bradley	4 to 250K
CA 22	270R Allen Bradley	4 to 250K
CS 01	470R Speer	0.25 to 9.999K

1. The Lin and Null ranges are general purpose ranges that may be configured for any required span and zero. Both ranges provide a linear relationship between input and display. The Lin range is unipolar while the Null range is bipolar.
2. The iTc includes two curves for 27 Ohm Rhodium/Iron sensors. Curve A is used for sensors having a resistance of 2 Ohms or greater at 4.2K. Curve B is used for sensors having a resistance of less than 2 Ohms at 4.2K. Using the appropriate curve should produce linearisation errors of less than 1% over the full temperature range. For a more accurate fit to a specific sensor, order a custom calibration.
3. This is for a pure platinum element.



Mercury iTC

4. This is for a platinum element that is ballasted to BS1904/DIN43760. This element is more readily available than a pure platinum element, but its performance is unspecified below 73K (the data between 50K and 70K is based on BS1904:964 rather than BS1904:1984).

5.5.1 Thermocouples

The iTC measures the voltage produced by the thermocouple and converts it to a corresponding temperature. A 2-wire connection is used for a thermocouple.

5.5.2 Resistance and diode sensors

Resistance and diode sensors require an excitation current. A 4-wire connection is used for these sensors.

When the circuit is configured to measure positive temperature coefficient (PTC) sensors, such as PT100 platinum resistance thermometers, the excitation current is generated by a high-stability current source.

When the circuit is configured to measure negative temperature coefficient (NTC) sensors, such as CERNOX ceramic oxi-nitride or RuO₂ ruthenium oxide resistance thermometers, the excitation is generated by a true voltage source.

The magnitude of the excitation current can be programmed to suit the application. Three types of excitation are available:

- Unipolar
The excitation current is always positive.
- Bipolar
The excitation changes polarity between each successive measurement. The displayed sensor value is an average of the results from the last two measurements. Thus every measurement is an average of values measured with positive and negative excitation currents.
- Soft edge
This is similar to bipolar excitation, except the current ramps between the positive and negative values. The current is maintained at a stable value between the ramps to allow a measurement to be taken. Soft-edge excitation might be used to reduce electrical interference produced by fast-changing currents.

5.5.3 Calibration for different sensors

The iTC uses calibration tables to store calibration data for different sensor types. The user can also create a new calibration file for a specific sensor. Calibration tables can be saved as files.

A calibration file contains a number of discrete data pairs, each mapping a sensor reading onto a temperature value. Linear interpolation is used to provide calibration at intermediate values.

The iTC calculates setpoint limits and sensor limits from the chosen calibration file.

6 BASIC OPERATING INSTRUCTIONS

6.1 Configuring the LCD

- 1 Tap **Settings** on the Home page. The Settings tabs are displayed.
- 2 Select the **Display** tab.
- 3 Tap the **Auto Dim Option** field to turn the auto-dim feature on or off. See [Section 5.1.1](#) for a description of auto-dim.
- 4 Adjust the **Brightness (%)** and **AutoDim (%)** fields as required.
- 5 Tap **Apply** to save the changes.
- 6 Tap **Home** to return to the Home page.

6.2 Changing a setpoint

6.2.1 Changing a heater setpoint

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap the **Heat(%)** button until it displays *Auto*.
- 4 Tap the **Set (K)** button until it displays *Manual*.
- 5 Enter the new setpoint in the **Set (K)** field.
- 6 Tap **Home** to return to the Home page.

6.2.2 Changing a gas-flow setpoint

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap the **Flow(%)** button until it displays *Manual*.
- 4 Enter the new gas-flow setpoint (as a percentage of the maximum flow) in the **Flow(%)** field.
- 5 Tap **Home** to return to the Home page.

6.3 Using the sweep function

6.3.1 The purpose of the sweep function

The sweep function allows the setpoint to be programmed to follow a fixed temperature vs time profile. The profile consists of a series of constant-temperature steps joined by linear ramps.

During a ramp, the system updates the temperature setpoint every 100 mSec.

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A program can contain up to 32 ramps and 32 steps. Each ramp and step lasts for a programmable time period. Once a sweep has been programmed, it can be repeated as often as desired. It is also be retained in non-volatile memory when the iTC is switched off.

The Auto-PID facility may be used in conjunction with the sweep function to provide optimum control over a wide temperature range. To avoid discontinuities during a sweep, it is recommended that the start and end temperatures for the sweep ramps should coincide with the Auto-PID segments.

6.3.2 Programming a sweep

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap **Sweep**. The Sweep Table page opens.
- 4 Tap **+** to add a row to the table.
- 5 Enter the temperature (in K) for the first step in the **Final T(K)** field in row 1 of the Sweep Sequence Editor.
- 6 Enter the time for the first ramp (in minutes) in the **Time To Final T(mins)** field in row 1 of the Sweep Sequence Editor.
- 7 Enter the time to hold the step temperature (in minutes) in the **Hold At Final T(mins)** field in row 1 of the Sweep Sequence Editor.
- 8 Tap **+** to add an additional row to the table.
- 9 When the complete sequence is programmed, tap **Save** to save the programmed sweep as a file.
- 10 Tap **Close** to return to the Control Loop Configuration page.
- 11 Tap **Home** to return to the Home page.

6.3.3 Loading a sweep

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap **Sweep**. The Sweep Table page opens.
- 4 Tap **Load** and select the filename of the sweep to be loaded (see [Section 4.2.17](#)).

6.3.4 Starting a sweep

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap the **Set (K)** button until it displays *Auto*. The **Set (K)** field value will change as the sweep proceeds.

6.3.5 Stopping a sweep

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature-sensor in the **Sensor** field.
- 3 Tap the Set (**K**) button until it displays *Manual*. The **Set (K)** field value is held at its present value.

6.4 Using the plot function

6.4.1 Configuring a plot

- 1 Tap **Plot** on the Home page. The Plot Configuration page is displayed.
- 2 Tap **Device** and select the first device to be used.
- 3 Tap **Signal** and select the first signal to be plotted.
- 4 Tap **Save** to plot the first signal.
- 5 To add traces to the plot, double-tap anywhere on the plot area and repeat steps 2 to 4.
- 6 By default the Plot page displays a scale on the Y-axis only (see [Figure 6-1](#)). To add the X axis scale, tap once on the bottom of the X axis (see [Figure 6-2](#)).

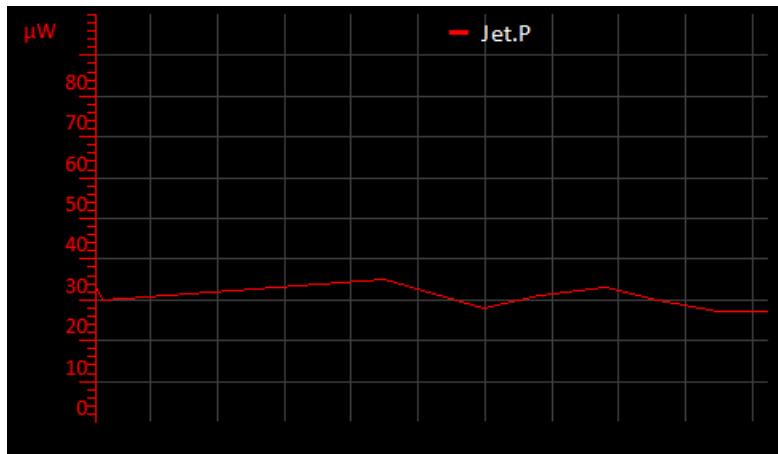


Figure 6-1 Signal Monitor Plot page with Y axis scale only

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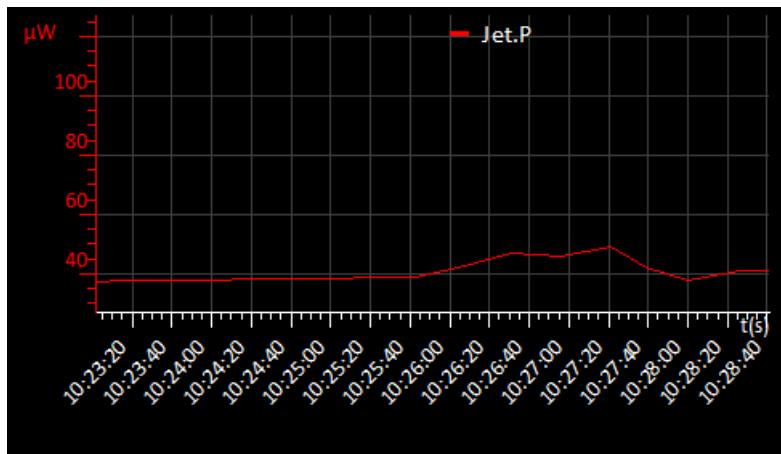


Figure 6-2 Signal Monitor Plot page with X and Y axis scales

6.4.2 To remove a trace from the plot

- 1 Tap **Plot** on the Home page. The Plot page is displayed.
- 2 Double-tap anywhere on the page. The Plot Configuration page is displayed.
- 3 Tap **Device** and select the required device.
- 4 Tap **Signal** and select the trace that is to be removed from the plot.
- 5 Tap **Delete**. The selected trace is removed from the plot.

6.4.3 To adjust the plot scaling

To adjust the scaling of a plot:

- 1 Place a finger on the region of interest of the plot. The re-scaled plot will be centred around this position.
- 2 Drag the finger to zoom in and out around the area of interest:
 - a) Drag the finger to the right to expand the X-axis (zoom in).
 - b) Drag the finger to the left to contract the X-axis (zoom out).
 - c) Drag the finger up to expand the Y-axis (zoom in).
 - d) Drag the finger down to contract the Y-axis (zoom out).

These motions can be combined. For example, dragging the finger towards the bottom right corner expands the X-axis and contracts the Y-axis (see [Figure 6-3](#)).

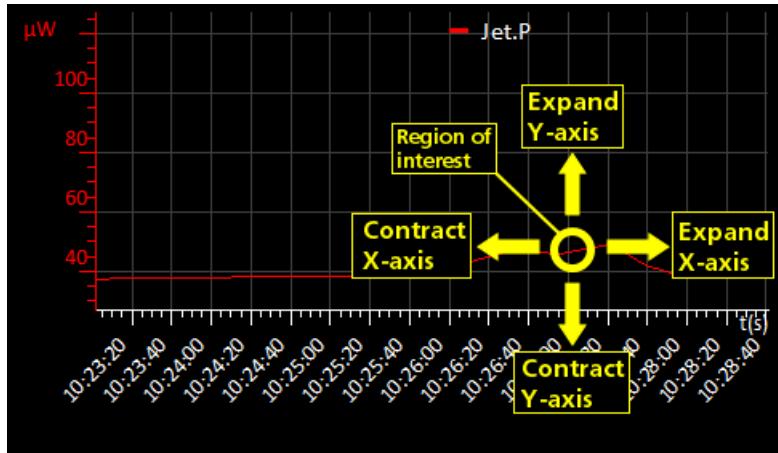


Figure 6-3 Scaling a plot

- 3 Double tap on a scale to return to the default scaling for that axis.

6.4.4 To exit the plot

- 1 Double-tap anywhere on the page. The Plot Configuration page is displayed.
- 2 Tap **Home** to return to the Home page.

6.5 Configuring external interfaces

Only one external interface can be used at a time. refer to the relevant section for information on configuring an external interface.

6.5.1 Configuring the ethernet interface (if required)

- 1 Obtain the required ethernet settings from the network administrator.
- 2 Tap **Settings** on the Home page.
- 3 Scroll to the **Ethernet** tab.
- 4 Tap **DHCP** and select either **On** or **Off**.
- 5 If **DHCP** is set **On**, the unit obtains its ipaddress from the network. No further configuration is required.
- 6 If **DHCP** is set **Off**, enter an **IP Address** for the unit.
- 7 If **DHCP** is set **Off**, enter a **Subnet Mask** for the unit.
- 8 If **DHCP** is set **Off**, enter a **Gateway** value for the unit.
- 9 Tap **Apply** to save the changes.
- 10 To enable the interface, see [Section 6.5.5](#).

Mercury iTC

6.5.2 Configuring the RS232 serial interface (if required)

- 1 Tap **Settings** on the Home page.
- 2 Scroll to the **RS232** tab.
- 3 Enter the required **Baud** rate.

NOTE: If replacing a legacy unit, set the baud rate to 9600.

- 4 Set the required number of **Data** bits.
- 5 Set the required **Parity** scheme.
- 6 Set the required number of **Stop** bits.
- 7 Set the required **Flow Control** scheme.
- 8 If ISOBUS is to be used, scroll to the **ISOBus** tab.
- 9 Set the ISOBUS address to a value between 1 and 8.
- 10 Tap **Apply**.
- 11 To enable the interface, see [Section 6.5.5](#).

6.5.3 Configuring the GPIB (if required)

- 1 Tap **Settings** on the Home page.
- 2 Scroll to the **GPIB** tab.
- 3 Enter a **GPIB Address** value between 0 and 31.

NOTE: Every unit connected to the GPIB must have a different GPIB address.

- 4 Tap **Apply**.
- 5 To enable the interface, see [Section 6.5.5](#).

6.5.4 Configuring the USB interface (if required)

No configuration is required for the USB interface.

To enable the interface, see [Section 6.5.5](#).

6.5.5 Enabling remote control of the iTC

- 1 Tap **Settings** on the Home page.
- 2 Tap the **Remote Access** field and select an interface from the drop-down menu.
- 3 Tap **Apply** to enable the selected interface.

6.5.6 Enabling local control of the iTC

- 1 Tap **Settings** on the Home page.
- 2 Tap the **Remote Access** field and select *Local* from the drop-down menu.
- 1 Tap **Apply** to enable local control of the iTC.



6.6 Re-configuring sensors and heaters

6.6.1 To clear a panel configuration

- 1 Double-tap the panel on the Home page that is to be cleared.
- 2 Tap the **Devices** field and select *None* from the drop-down menu.
- 3 Tap **Assign**.
- 4 The panel on the Home page should now display the name *None*.

6.6.2 Re-configuring a sensor

- 1 Tap a configured panel on the Home page.
- 2 Edit the sensor details on the Sensor Details Screen page.
- 3 Tap **Home** to return to the Home page.

6.6.3 Re-configuring a heater

- 4 Tap **Heater** on the Home page.
- 5 Edit the displayed values for the heater that is to be re-configured.
- 6 Tap **Home** to return to the Home page.

6.6.4 Re-configuring a control loop

- 1 Tap **Control** on the Home page.
- 2 Edit the displayed values and settings on the Control Loop Configuration page as required.
- 3 Tap **Home** to return to the Home page.

6.7 Changing control-loop parameters

6.7.1 Entering PID parameters manually

- 1 Tap **Control** on the Home page.
- 2 Tap the **PID** field until it displays *Manual*.
- 3 Tap the **P** field and enter a new proportional band value (in K), if required. Enter 0 for On/Off control.
- 4 Tap the **I** field and enter a new integral value (in minutes), if required. Enter 0 to turn off the integral action.
- 5 Tap the **D** field and enter a new derivative value (in minutes), if required. Enter 0 to turn off the derivative action.
- 6 Tap **Home** to return to the Home page.

6.7.2 Creating a PID table

See [Section 12.2.7.2](#).

Mercury iTC

6.8 Updating the firmware

The user can either update the firmware for a particular card, or the application for the whole system.

6.8.1 Updating the application

NOTE: The system automatically disconnects any output signals while the firmware is being updated. It also re-connects the outputs once the update is completed.

- 1 Tap **Settings** on the Home page.
- 2 Select the **F/W Update** tab.
- 3 Tap the **Firmware Device** field and select APPLICATION from the drop-down menu.
- 4 Tap the **Firmware File** field and select a firmware file from the drop-down list.
- 5 Tap **Apply**. The iTC installs the new firmware and starts up in *TRIAL* mode.

NOTE: Do not power-off the iTC in TRIAL mode

- 6 Run some standard operations to test that the iTC is working as expected.
- 7 If the new firmware is acceptable:
 - a) Tap **Settings** on the Home page.
 - b) Select the **F/W Update** tab.
 - c) Tap **Save Changes** to accept the new firmware version. (see [Figure 6-4](#))

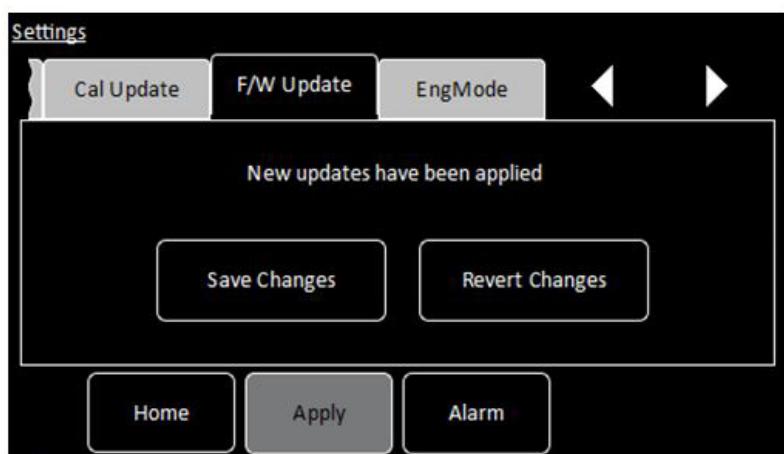


Figure 6-4 F/W Update tab in TRIAL mode

- 8 If the new firmware is not acceptable for some reason:
 - a) Tap **Settings** on the Home page.
 - b) Select the **F/W Update** tab.
 - c) Tap **Revert Changes** to revert to the old firmware version.

6.8.2 Updating the firmware on a board

NOTE: The system automatically disconnects any output signals while the firmware is being updated. It also re-connects the outputs once the update is completed.

- 1 Tap **Settings** on the Home page.
- 2 Select the **F/W Update** tab.
- 3 Tap the **Firmware Device** field and select the required device from the drop-down menu.
- 4 Tap the **Firmware File** field and select a firmware file from the drop-down list.
- 5 Tap **Apply**. The iTC installs the new firmware.
- 6 Run some standard operations to test that the iTC is working as expected.

6.9 Saving and restoring configurations

6.9.1 Saving a configuration

- 1 Tap **Settings** on the Home page.
- 2 Select the **Factory** tab.
- 3 Enter a name for the present configuration in the **Enter Name** field.
- 4 Tap **Save Configuration**.

6.9.2 Restoring a configuration

- 1 Tap **Settings** on the Home page.
- 2 Select the **Factory** tab.
- 3 Select a saved configuration from the drop-down box. Note that the original factory configuration is called **FACTORY_OI**.
- 4 Tap **Revert**. The system loads the selected configuration and reboots the **Mercury iTC**.

Mercury iTC

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7 REMOTE OPERATION

The iTC can be remotely operated via any of the following interfaces:

- RS232 or ISOBUS
- GPIB (IEEE-488)
- Ethernet
- USB

This allows a computer to interrogate the instrument and, if required, to take control of it.

7.1 Notes on instrument addresses

A iTC can have a GPIB address and an ISOBUS address. These addresses are distinct and can be different.

The ISOBUS address can be changed via ISOBUS (see [Section 7.3](#)).

The GPIB address is set from the GPIB Settings page on the unit (see [Section 4.2.12.6](#)).

The USB interface is a one-to-one connection, and no addresses are required.

7.2 Communication protocols for RS232 and GPIB

The same command protocols are used for the RS232 and the GPIB interfaces.

All commands consist of a string of printing American Standard Code for Information Interchange (ASCII) characters, terminated by a **Carriage Return** character. A **Line Feed** may optionally be sent after the **Carriage Return**, but the iTC ignores it.

Unless a command starts with a \$ (dollar) character, all commands evoke a response from the iTC. The response consists of a string of one or more printing ASCII characters, terminated by a **Carriage Return** character. This may optionally be followed by a **Line Feed** character.

If the first character of the command is \$, the command is obeyed but no response is sent.

Any response is normally sent immediately after the command is received. The following scenarios may delay the response:

- If a GUI button is tapped when the command is received, the response may be delayed until the button is released.
- If the RS232 interface is in use, the response is automatically sent as soon as the interface is available.
- If the GPIB is used, the response is sent when the instrument is next addressed to talk.



Mercury iTC

7.2.1 Commands and responses

Commands sent to the iTC consist of a single letter, optionally followed by a numeric parameter, terminated by a **Carriage Return**. All common operation commands are based on upper-case letters. Lower case letters are used for some specialised commands.

The response sent by the iTC varies depending on the command. Usually the response consists of the command letter received, followed by the value of any data requested. If a command instructs the iTC to perform an action rather than to send data, the response is just the command letter.

If a command is not recognised, has an illegal parameter, or cannot be obeyed for any reason, an error response is sent. This consists of a ? (question mark), followed by all or part of the command string that produced the error. To simplify error handling in the computer, the ? is always the first character returned.

The most common reason for a command error is attempting to execute a command while the iTC is in *LOCAL* mode. The X command can be used to determine the present status of the iTC to prevent this type of error.

7.2.2 Numeric parameters

All numeric parameters are treated as signed decimal numbers, and are sent as a string of decimal digits with a decimal point in the appropriate place.

7.3 Control via ISOBUS

To allow separate instruments on the bus to be distinguished, each instrument is allocated a unique address in the range 0 to 9.

When more than one instrument is connected to ISOBUS, all commands must start with a special ISOBUS control character. If the control character is omitted, all instruments connected to ISOBUS will reply together.

NOTE: Omitting the control character will result in lost data, but will not cause hardware damage.

The command following the control character (and any required parameter) follows the form described in [Section 7.2](#).

The response of the instrument depends on the initial control character:

@n (At)

addresses the command to instrument number **n**, where **n** is a digit in the range 0 to 9. The instrument obeys the command and returns its usual response. All other instruments ignore the command and send no reply.

\$ (Dollar)

instructs all instruments to send no reply. This character is normally sent before a command that is sent to all instruments simultaneously. This prevents the instruments from echoing the command together, which would cause a conflict.

& (Ampersand)

instructs an instrument to ignore any following ISOBUS control characters. This character is not used by the iTC. The command allows instruments that include @, \$, & or ! characters in their command set to be used on ISOBUS.

!n (Exclamation)

instructs the instrument that, from now on, its ISOBUS address is **n**. This command must not be used if more than one instrument is connected to ISOBUS, as it will set all connected instruments to the same address. This command does not affect the instrument's GPIB address.

NOTE: Use the \$ command with caution, as it suppresses all responses, including the ? error response. Thus the computer cannot determine if a command has been received.

NOTE: If a command is to be addressed to a specific instrument, but no reply is required, it is permissible to use \$ and @n together. The \$ must always come first.

NOTE: The ! command is only obeyed if a U command followed by a non-zero password is sent first. This is to avoid accidentally changing an instrument address.

7.4 GPIB interface

An instrument can be controlled by GPIB or by RS232, but not by both simultaneously.

7.4.1 Switching between RS232 and GPIB operation

If the iTC is using RS232 and GPIB has not been deliberately disabled, the instrument can be switched to GPIB operation at any time by asserting the GPIB IN-USE state. This occurs automatically when a GPIB controller asserts the Remote Enable (REN) line and addresses the interface to either talk or listen at the selected GPIB address.

Once the instrument is in the GPIB IN-USE state, it remains in that state until electrical power is removed or the instrument is reset.

7.4.2 Sending commands via the GPIB

Commands sent via the GPIB follow the same syntax as commands on the RS232 interface. Commands must be terminated by a **Carriage Return**. A **Line Feed** may be sent, if desired, but the iTC ignores it.

The iTC always accepts GPIB commands unless it is in TEST mode.

If a command produces a response message, the controller must read the response before sending a further command.

Mercury iTC

7.4.3 Accepting responses via the GPIB.

Messages issued by the iTC on the GPIB consist by default of an ASCII character string, terminated by a **Carriage Return**. The instrument can be configured to send an additional **Line Feed**, if required, by sending a initial **Q2** command after power-up. The Q2 message itself produces no response, but all subsequent responses are terminated by the **Carriage Return/Line Feed** pair.

The interface never asserts the **EOI** line at the end of a message. Instead it allows either **Carriage Return** or **Line Feed** to be used as the **End-of-String (EOS)** character.

7.4.4 Status byte and use of a serial poll

The GPIB controller must be able to determine when the iTC has data to be read. If the iTC is configured to talk, but no data is available, the controller will wait indefinitely unless a timeout period has been defined.

The program running on the GPIB controller can be written so that it only waits for a response when the last command sent is expected to produce data. However this is method is unreliable if some unexpected event occurs.

A better method is for the GPIB controller to read a status byte from the iTC by conducting a serial poll. The iTC always returns a status byte when a serial poll is conducted.

Three bits in the status byte are significant:

- Bit 6 (value 64 decimal)
RQS (requesting service)
- Bit 4 (value 16 decimal)
MAV (message available)
- Bit 1 (value 2 decimal)
BAV (byte available)

7.4.4.1 RQS bit

The position of the RQS bit is specified in the IEEE-488.1 and IEEE-488.2 standards. The RQS bit indicates that the iTC has requested service by asserting the GPIB SRQ line TRUE.

The RQS bit is reset when the GPIB controller reads the status byte, which allows the interface to clear the SRQ line. If the GPIB controller reads the status byte again, the RQS bit will be zero, even if the service request has not been actioned. The program running on the GPIB controller must remember that the iTC has requested service. The RQS bit is only set again if the iTC requests service again.

7.4.4.2 BAV bit

The BAV bit is set as soon as at least one byte of data is available to be read. The BAV bit always reflects the status of the iTC at the time that the status byte was read.

7.4.4.3 MAV bit

The MAV bit is set when a complete message (including the <CR> or <LF> character) is available to be read. The MAV bit always reflects the status of the iTC at the time that the status byte was read.

7.4.4.4 Status byte update rate

The iTCTC updates the status byte every millisecond. If the status byte is read within 1 ms of reading data from the interface, the BAV and MAV bits may still be set. If these bits are found to be set immediately after reading data, the GPIB controller should read the status byte again to confirm if data is still remaining.

7.4.5 Use of the service request line

The iTCTC issues a service request (by pulling the SRQ line) when a complete message is available to be read. The MAV bit will be set at the same time. The exception is when the iTCTC is already configured to talk. Since the GPIB controller is already reading data from the iTCTC, a service request is not required.

The GPIB controller can be programmed to monitor the SRQ line and to only read data from the iTCTC when the SRQ line is asserted. This is more efficient than reading the status byte at regular intervals.

7.4.6 Use of the device clear function

When the iTCTC receives a GPIB Device Clear message, it empties all communication buffers. It does not reset any of the temperature control functions. Device Clear can thus be safely used to empty the communication buffers of any unread messages.

Device Clear can be sent by either the GPIB DCL message (which clears all connected devices), or by the GPIB SDC message (which only clears the addressed device).

If an ISOBUS Gateway is in use, Device Clear only clears the buffers in the master instrument. If data is currently being transmitted from a slave instrument to the master instrument, the message will be read into the buffer after it has been cleared.

7.4.7 Use of the interface clear function

When the iTCTC receives a single-line Interface Clear (IFC) message, it clears the GPIB interface functions as specified by IEEE-488.1. The command does not clear any pending data in the buffers. The command does not affect any temperature control functions.

7.4.8 Non-implemented features of the GPIB

The GPIB Remote Enable (REN) line is only used to alert the iTCTC to the presence of an active controller. It is not used for switching between Local and Remote modes. Use the C command to switch between local and remote modes. This is simpler than the REN command and is also compatible with RS232 operation.

The GPIB Local Lockout and Go To Local commands have no effect on the iTCTC. Use the C command to perform these actions.

The iTCTC does not respond to a parallel poll request. Because the GPIB interface uses open-collector data-buffers, the iTCTC can co-exist on a GPIB that has other instruments that do have a parallel poll capability.

7.4.9 Compatibility with IEEE-488.2

The Mercury iTCTC cryogenic environment controller supports IEEE-488.2.

Mercury iTC

7.4.10 Writing a reliable GPIB control program

The GPIB interface in the iTC has been designed to be very reliable. However the GPIB control program must assume that data can be occasionally corrupted. The following sections describe features that must be built into the control program to ensure maximum reliability.

7.4.10.1 Timeouts

All commands that attempt to write or read data to an instrument must have a Timeout facility built in. This ensures that the bus only waits a specified time period for a response from an instrument.

When a timeout occurs, the controller must conduct a serial poll to attempt to discover what has caused the timeout. If the serial poll also generates a timeout, the controller must reset the interface using the Interface Clear (IFC) line. If a serial poll still fails, the controller must assume that the iTC has lost power, has been disconnected, or has failed in some way. The program must then alert the operator that a fault has occurred and, if possible, continue operating the remaining instruments on the GPIB.

8 PREVENTIVE MAINTENANCE

The iTC requires minimal maintenance. It is recommended that the following maintenance tasks are performed every six months.

8.1 Six-monthly maintenance

- 1 Clean the touch-screen (see [Section 8.1.1](#)).
- 2 Calibrate the temperature sensor boards (see [Section 8.1.2](#)).

8.1.1 Cleaning the touch-screen

Required items:

- A soft, microfibre cloth.

The touch-screen is a sensitive item that is easily scratched. Only use recommended cleaning products to clean the screen.

- 1 Switch off the instrument.
- 2 Wipe the touch-screen with a soft microfibre cloth to remove dust or any marks. Do not use solvents or abrasive cleaning products.

8.1.2 Calibrating the temperature-sensor circuits

This procedure calibrates the electronics in each temperature-sensor circuit that is fitted to the iTC. It does not calibrate the external temperature sensors.

- 1 Locate the summary panel on the Home page for the first temperature-sensor circuit to be calibrated.
- 2 Tap the panel once to display the Sensor Details page
- 3 Tap **Calibrate**.
- 4 Wait until the internal calibration routine has completed. This takes approximately one minute.
- 5 Repeat steps 1 to 4 for every temperature-sensor circuit that is configured.

8.1.3 Unscheduled maintenance

The lithium-ion coin-cell on the motherboard may have to be replaced. Only use a suitably approved lithium coin-cell with built-in protection (e.g. Panasonic 3V BR2032). Only trained personnel must replace this item.



Mercury iTC

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9 TROUBLESHOOTING

9.1 Fault-finding features of the iTC

9.1.1 The alarm-logs

The alarm-logs list alarms that have been raised, and the time that each alarm occurred. This is a useful tool if a fault occurs. For example the alarm-logs record if a particular temperature sensor is open-circuit or short-circuit.

To access the alarm-logs:

- 1 Tap **Settings** on the Home page.
- 2 Tap **Alarm** on the General Settings tab.
- 3 Scroll through the list to display more alarms.

9.2 Troubleshooting information

[Table 9-1](#) contains troubleshooting information for the iTC.

Table 9-1 iTC troubleshooting information

Symptom	Possible Cause	Action
A temperature input displays the incorrect temperature.	Incorrect sensor configuration information is programmed.	Check the relevant Sensor Details page.
	Bad temperature sensor connection.	Check the sensor connections.
	Incorrect excitation current programmed.	Check the programmed excitation current on the relevant Sensor Details page.
	Incorrect calibration file is selected.	Check the correct calibration file is selected on the relevant Sensor Details page.
The displayed temperature does not change when a new temperature setpoint is entered.	The associated heater is open circuit.	Check the heater connection.
	An incorrect heater limit voltage has been entered.	Check the Lim(V) field on the Heater configuration page.
A remote interface doesn't work.	The interface is not enabled.	Check the interface is enabled on the General Settings page.
	Bad interface connection	Check all interface connections.
	Incorrect interface settings	Check the interface settings on the relevant Settings page.
	Address conflict	Check that the ISOBUS or GPIB address is not the same as another instrument on the bus.
The level sensor doesn't work.	TBA	TBA



Mercury iTC

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10 COMMAND REFERENCE GUIDE

10.1 Nomenclature used in this section

The following conventions are used in this document when listing SCPI commands:

Capital letters designate a keyword that must be entered literally (e.g. SET).

Capital letters in angle brackets designate a parameter that must be substituted by the required value (e.g. <UID> might represent DB2, MB1 etc.).

Several words in square brackets, separated by vertical lines, indicate alternative values that a parameter can take (e.g. [LIN | SPL | LAGR]).

10.2 SCPI and legacy command sets

The iTC supports two separate sets of remote commands:

- SCPI

These commands are based on the SCPI command set, although the iTC may not be fully compliant with SCPI.

- Legacy commands

These commands were used in previous temperature controller models (e.g. ITC503).

The user configures the iTC to use one set or the other.

It is recommended that new applications use the SCPI command set, as these commands provide greater functionality. The legacy command set is provided so that the iTC is compatible with any existing remote applications that have been written to drive older OINS equipment.

10.3 SCPI command messages

This section specifies the command message format for communication using the SCPI (Signal Orientated Measurement Commands) derived protocol. Although the messaging protocol is based on SCPI, it is not SCPI compliant.

10.3.1 SCPI protocol conventions

The commands are case-sensitive.

Keywords are a maximum of four characters long. Keywords longer than four characters generate an invalid command response.

Keywords are separated by a colon : (ASCII 0x3Ah).

The maximum line length is 1024 bytes (characters), including line terminators.

All command lines are terminated by the new line character \n (ASCII 0x0Ah).



Mercury iTC

10.3.2 Reading the overall instrument configuration

Send the command:

*IDN?

The format of the reply is:

IDN:OXFORD INSTRUMENTS:MERCURY dd:ss:ff

Where:

dd is the basic instrument type (either **iPS**, **iTC** or **Cryojet**)

ss is the serial number of the main board

ff is the firmware version of the instrument

10.3.3 Basic SCPI command structure

The basic command structure is:

<VERB>:<NOUN>:<NOUN>

All commands generate an <INVALID> response if the command cannot be interpreted (see [Section 10.3.6](#)).

10.3.4 Verbs

The interface controller can only issue two verbs:

READ - A query command reading information on the specified noun.

SET - Updates information for the specified noun. An attempt to set a read-only noun returns an invalid response.

The iTC replies to both these verbs with a **STAT** (status) verb:

If responding to a **READ** verb, the **STAT** verb is followed by the requested data.

If responding to a **SET** verb, the **STAT** verb is followed by the value set.

10.3.5 Nouns

Elements within the iTC are addressed by a hierarchical structure:

A Board contains a number of Devices.

A Device contains a number of Signals.

The structure of NOUNS reflects this:

DEV:<UID>:<TYPE>:SIG:<TYPE>

DEV:<UID>:<TYPE> [TEMP | HTR | LVL | GAS]

SIG:<TYPE> [VOLT | CURR | POWR | RES | TEMP | SLOP]

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.

A SYS:CAT command must be executed to retrieve the device UIDs.

The general format of UIDs is:

DB# - for daughter boards, where # is the slot id.

MB# - for the motherboard.

A SIG is returned as a value, followed by the scale.

Scale is of the form:

n# - nano

u# - micro

m# - milli

- none

k# - kilo

M# - mega

where # is replaced by the relevant SI units, for example:

A - Amps

V - Volts

W - Watts



Mercury iTC

10.3.5.1 System commands

System commands are used for system-level settings.

SYS	system designator	N/A	
TIME	time in the 24 hour clock	Read/Set	hh:mm:ss
DATE	date	Read/Set	yyyy:mm:dd
MAN	manufacturing designator	N/A	
HVER	hardware version	Read only	version number
FVER	firmware version (GUI/APP)	Read only	version number
SERL	unit serial number	Read only	alphanumeric
MODE	mode of operation [NORM ENG]	Read/Set	enumerated value
PASS	engineering mode password	Set	alphanumeric. Required to enter ENG mode.
FLSH	amount of free space in flash memory	Read	free space in kByte
DISP	display designator	N/A	
DIMA	auto dim on/off	Read/Set	OFF, ON
DIMT	auto dim time	Read/Set	seconds
BRIG	brightness	Read/Set	10.0 to 100.0%
RST	reset the system	Set	N/A
CAT	catalogue	Read	

To enter engineering mode, send the following command:

SET:SYS:MODE:ENG:PASS:*****

To exit engineering mode, send the following command:

SET:SYS:MODE:NORM

To change the system password, you must be in engineering mode. Then you can send an issue password command:

SET:SYS:MODE:ENG:PASS:*****

SET:SYS:PASS:newpassword

SET:SYS:MODE:NORM

(where ***** is the existing password and newpassword is the new password).

Example of a system command

Send the following command to determine the unit configuration:

READ:SYS:CAT?

A system with no daughter boards would return the following:

STAT:DEV:MB0 :TEMP:DEV:MB1 :HTR

This message indicates the motherboard has one temperature sensor in id0 and one heater in id1.

A system with one set of daughter boards might return the following:

STAT:DEV:MB0 :TEMP:DEV:DB1 :TEMP:DEV:MB1 :HTR:DEV:DB2:HTR:DEV:DB3
:AUX:DEV:DB4 :LVL

This message indicates that there are two temperature sensors, two heaters, one auxiliary I/O board, and one level sensor.

10.3.5.2 Addressing a temperature sensor

To address a temperature sensor, use the following structure:

DEV:<UID>:TEMP

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.

The configuration settings for a temperature sensor are:

TEMP		Temperature sensor designator	N/A
MAN		Manufacturing designator	N/A
	HVER	Hardware version	Read only
	FVER	Firmware version	Read only
	SERL	Serial number	Read only
NICK		Nickname	Read/set
TYPE		[PTC NTC DDE TCE]	Read/set
EXCT		Excitation designator	N/A
	TYPE	Excitation type [UNIP BIP SOFT]	Read/set
	MAG	Excitation magnitude	Read/set
			Float value followed by a scale
CAL		Calibration designator	N/A
	FILE	Calibration file name	Read/set
	INT	Interpolation type [LIN SPL LAGR]	Read/set
	SCAL	Scaling factor	Read/set
	OFFS	Offset value	Read/set
	HOTL	Hot limit	Read only
			Float value
			[0.5 to 1.5]
			[-100.0 to 100.0]
			Float value



Mercury iTC

COLD	Cold limit	Read only	Float value
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The signals for a temperature sensor are:

VOLT	Most recent voltage reading	Read only	Float value
CURR	Most recent current reading	Read only	Float value
POWR	Most recent power reading	Read only	Float value
RES	Most recent resistance reading	Read only	Float value
TEMP	Most recent temperature reading	Read only	Float value
SLOP	Temperature sensitivity	Read only	Float value

NOTE: The signals that are available depend on the type of sensor being addressed. If a signal is unavailable, the message INVALID is returned.

Example of configuring a temperature sensor

The following command configures a temperature sensor:

```
SET:DEV:MB0 :TEMP:TYPE:PTC:EXCT:TYPE:UNIP:MAG:10uA:CALB:RP5:DAT
```

If this command is successfully completed, the following message is returned:

```
STAT:SET:DEV:MB0  
:TEMP:TYPE:PTC:EXCT:TYPE:UNIP:MAG:10uA:CALB:RP5:DAT
```

If the excitation type is not supported, the following message is returned:

```
STAT:SET:DEV:MB0 :TEMP:TYPE:PTC:EXCT:TYPE:INVALID:MAG:INVALID:  
CALB:RP5:DAT
```

NOTE: All the new settings that are valid are set. All the new settings that are invalid are not changed.

Example of reading a temperature sensor

The following command reads the sensor voltage:

```
READ:DEV:MB0 :SIG:VOLT?
```

The sensor returns the following message:

```
STAT:DEV:MB0 :SIG:VOLT:12.345:mV
```



10.3.5.3 Addressing a heater controller

To address a heater controller, use the following structure:

DEV:<UID>:HTR

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.

The configuration settings for a heater controller are:

HTR		Heater controller designator	N/A
MAN		Manufacturing designator	N/A
	HVER	Hardware version	Read only version number
	FVER	Firmware version	Read only version number
	SERL	Serial number	Read only alphanumeric
NICK		Nickname	Read/set alphanumeric
VLIM		Voltage limit	Read/set Float value [0.0 to 40.00]
RES		Nominal resistance	Read/set Float value [20.00 to 100.00]
PMAX		Maximum power supported	Read only Float value

The signals for a heater controller are:

VOLT	Most recent voltage reading/voltage to set	Read/set	Float value [0.0 to VLIM]
CURR	Most recent current reading	Read only	Float value
POWR	Most recent power reading/ power to set	Read/set	Float value [0.0 to Max Power]

10.3.5.4 Addressing a level meter sensor

To address a level meter sensor, use the following structure:

DEV:<UID>:LVL

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.



Mercury iTC

The configuration settings for a level meter sensor are:

LVL		Level sensor designator	N/A	
MAN		Manufacturing designator	N/A	
	HVER	Hardware version	Read only	version number
	FVER	Firmware version	Read only	version number
	SERL	Serial number	Read only	alphanumeric
HEL		Helium probe	N/A	
	RES	Resistance configuration	N/A	float value
	ZERO	Resistance at 0% (Ohms)	Read/set	float value
	FULL	Resistance at 100% (Ohms)	Read/set	float value
	PREP	Pre-pulse	N/A	
	MAG	Pre-pulse amplitude (mA)	Read/set	float value
	TIM	Pre-pulse duration (s)	Read/set	float value
	PULS	Measurement pulse	N/A	
	MAG	Measurement pulse amplitude (mA)	Read/set	float value
	TIM	Measurement pulse duration (s)	Read/set	float value
	DEL	Measurement pulse delay (s)	Read/set	float value
NIT		Nitrogen probe	N/A	
	FREQ	Frequency configuration	N/A	
	ZERO	Frequency at 0% (Hz)	Read/set	float value
	FUL	Frequency at 100% (Hz)	Read/set	float value
	PPS	Pulse counting period in ms	Read/set	float value

The signals for a level meter sensor are:

HEL		Helium probe	N/A	
	RES	Probe measured resistance (Ohms)	Read only	float value
	LEV	Probe calculated level (%)	Read only	float value
NIT		Nitrogen probe	N/A	
	COUN	Probe measured counter value	Read only	unsigned integer
	FREQ	Probe calculated frequency value (Hz)	Read only	float value
	LEV	Probe calculated level (%)	Read only	float value

10.3.5.5 Addressing an auxiliary I/O daughter board

To address an auxiliary board, use the following structure:

DEV:<UID>:AUX

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.

The configuration settings for an auxiliary board are:

AUX		Auxiliary board designator	N/A
MAN		Manufacturing designator	N/A
	HVER	Hardware version	Read only version number
	FVER	Firmware version	Read only version number
	SERL	Serial number	Read only alphanumeric
GMIN		Minimum gas flow setting	Read/set float value (0.0 to 20.0)
GFSF		Gas flow scaling factor	Read/set float value (0.0 to 99.0)
TES		Temperature error sensitivity	Read/set float value (0.0 to 20.0)
TVES		Temperature voltage error sensitivity	Read/set float value (0.0 to 20.0)
GEAR		Valve gearing	Read/set unsigned integer (0 to 7)
SPD		Stepper speed	Read/set unsigned integer (0=slow, 1= fast)

The signals for an auxiliary board are:

STEP	Present position of the stepper motor	Read only	unsigned integer (0.0 to Max Steps)
OPEN	Percentage open	Read/set	float value (0.0 to 100.0)

Mercury iTC

10.3.5.6 Addressing a control loop

To address a control loop, you must specify the temperature sensor that is associated with the control loop:

DEV:<UID>:TEMP:LOOP

Where <UID> is a unique identifier that is allocated to each board, based on its SPI location.

The configuration settings for a control loop are:

LOOP	Loop designator	N/A	
HTR:<ID>	Heater associated with the loop	Read/set	UID, put 0 to unset
AUX:<ID>	Auxiliary board associated with the loop	Read/set	UID, put 0 to unset
LVL:<ID>	Level meter associated with the loop	Read/set	UID, put 0 to unset
ENAB	Loop enabled (heater auto on/off)	Read/set	OFF, ON.
HSET	Percentage heater output	Read/set	0.0 to 100.0
TSET	Temperature setpoint	Read/set	Cold limit to hot limit
PIDT	PID auto (use PID table: zone control)	Read/set	OFF, ON
PSET	P value	Read/set	0.0 to 199.9
ISET	I value	Read/set	0.0 to 199.9
DSET	D value	Read/set	0.0 to 299.9
SWFL	The filename of the sweep file to be used	Read/set	Alphanumeric
SWMD	Sweep mode.	Read/set	OFF, ON

10.3.6 Invalid responses

Table 10-1 lists the possible responses if an invalid command is sent.

Table 10-1 Invalid responses

Response	Reason
<VERB>:INVALID	The verb cannot be interpreted.
<VERB>:<NOUN>:INVALID	The noun cannot be interpreted.
NOT_FOUND	The UID does not exist in the system being addressed.
N/A	The function does not apply to the device being addressed.
DENIED	The user does not have permission to change the parameter being addressed.

10.4 Legacy command messages

In the following sections, m and n represent integers or decimal numbers. The number format is specified in the relevant section.

10.4.1 Legacy monitor commands

10.4.1.1 Cn command - Set Control

The control command sets the power supply into *LOCAL* or *REMOTE* mode and determines whether the Remote Access menu on the GUI is locked or active. When the iTC is powered on, it defaults to the C0 state.

Allowed values of this command are:

- | | |
|----|----------------------------------|
| C0 | Local and Locked (default state) |
| C1 | Remote and Locked |
| C2 | Local and Unlocked |
| C3 | Remote and Unlocked |

In the C3 state, the GUI can be used to examine values on the display, but the values can not be changed. However the Remote Access menu is active and can be used to switch to the C2 state to change values.

If a GUI button is tapped in the C3 state, the instrument does not respond to any remote commands until the button is released. Instead these commands are stored and performed when the button is released. Computer programs should either be written to tolerate this delay, or should set the instrument into the C1 state to disable the GUI controls.

Mercury iTC**10.4.1.2 Rn command - Read Parameter**

The READ command allows the computer to interrogate a number of variables. The returned value is always a decimal number.

Possible values for the command are listed below:

R0	Set temperature	K
R1	Sensor 1 temperature	K
R2	Sensor 2 temperature	K
R3	Sensor 3 temperature	K
R4	Temperature error (+ve when setpoint>measured)	K
R5	Heater output (as % of current limit)	%
R6	Heater output (approximate)	volt
R7	Gas flow output (arbitrary units)	
R8	Proportional band	K
R9	Integral action time	minutes
R10	Derivative action time	minutes
R11	* Channel 1 frequency/4	
R12	* Channel 2 frequency/4	
R13	* Channel 3 frequency/4	

NOTE: Variables marked with a "*" are used for service diagnostics only.

10.4.1.3 V command - Read Version

The VERSION command requires no parameters. It returns a message indicating the instrument type and firmware version number.

10.4.1.4 X command - Examine Status

The EXAMINE command allows the computer to read the present iTC STATUS. The command requires no parameters and returns a message string with a fixed length of 15 characters.

The returned string is of the form:

XnAnCnSnnHnLn

Where:

Xn	System Status
m=0	Normal

An	Auto/Manual Status	
n=0	Heater manual, gas manual	
n=1	Heater auto, gas manual	
n=2	Heater manual, gas auto	
n=4	Heater auto, gas auto	
Cn	Local/Remote Status	
n=0	Local and locked	
n=1	Remote and locked	
n=2	Local and unlocked	
n=3	Remote and unlocked	
Snn	Sweep Status	
nn = 0 to 32, as follows:		
nn=0	Sweep not running	
nn=2P-1	Sweeping to step P	
nn=2P	Holding at step P	
Hn	Control Sensor	
n=1	Sensor 1 is selected for automatic control	
n=2	Sensor 2 is selected for automatic control	
n=3	Sensor 3 is selected for automatic control	
Ln	Auto PID status	
n=0	Auto PID is disabled.	
n=1	Auto PID is enabled.	



Mercury iTC

10.4.2 Legacy control commands

10.4.2.1 An command - Auto/Manual

The AUTO/MANUAL command sets control of the heater or the gas flow to *AUTO* or *MANUAL*. *MANUAL* means that the heater output or gas flow can be set directly using an Onnn or a Gnnn command.

Allowed values for this command are:

A0	Heater manual, gas manual
A1	Heater auto, gas manual
A2	Heater manual, gas auto
A3	Heater auto, gas auto

10.4.2.2 Dnnn, Innn and Pnnn commands - Set PID Control Terms

These commands set the PID control terms (see [Section 4.2.9](#)).

Dnnn	Set derivative control term	minutes
Innn	Set integral control term	minutes
Pnnn	Set proportional control term	K

10.4.2.3 Gnnn command - Set Gas Flow

The SET GAS FLOW command sets the gas flow to a defined value, when gas flow in is *AUTO* control. The value is a decimal percentage of the maximum flow, with a resolution of 0.1%.

10.4.2.4 Hn command - Set Heater Sensor

The HEATER SENSOR command specifies the sensor to be used for automatic control:

H1	Sensor 1 used for heater control.
H2	Sensor 2 used for heater control.
H3	Sensor 3 used for heater control.

10.4.2.5 Mnnc command - Set Maximum Heater Volts Limit

The MAXIMUM HEATER command sets the maximum heater voltage that the iTCT may deliver, either under automatic control or in response to an Onnn command. The parameter **nnc** is a decimal number with a resolution of 0.1 volt, and is approximate.

10.4.2.6 Onnn command - Set Output Volts

Sets the required heater output, when in *MANUAL*. mode. The parameter **nnc** is expressed as a percentage of the maximum heater voltage (set by the **Mnnc** command) with a resolution of 0.1% (i.e. the range of **nnc** is 0 to 99.9).

10.4.2.7 Tnnn command - Set Desired Temperature

The TEMPERATURE command sets a set point temperature. The parameter is the required temperature, sent as an signed decimal number.

Note that if a sweep is running, the temperature set by the **T** command is over-ridden by the sweep.

10.4.3 Legacy system commands

10.4.3.1 ! command - Set ISOBUS Address

See [Section 7.3](#).



Mercury iTC

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11 TECHNICAL SPECIFICATIONS

This chapter lists the technical specifications of the iTC.

11.1 Physical specification

Table 11-1 Physical specifications

Item	Specification
Width	426 mm
Depth	272 mm
Height	131 mm
Weight	6.5 kg

11.2 Electrical power supply

Table 11-2 Specifications of electrical power-supply

Item	Specification
Mains supply voltage	100 VAC to 240 VAC
Mains supply frequency	50 Hz to 60 Hz
Maximum supply power	650 W
Maximum mains voltage fluctuation	±10% of nominal voltage
Category II transient overvoltages can typically be present on the mains supply.	

11.3 Sensor inputs

Table 11-3 Specifications of sensor inputs

Item	Specification
Basic unit - single sensor input	Upgradeable to 9 sensor inputs
NTC resistance range	5 Ohms to 200 kOhms
Constant voltage	Typically <10 mV
PTC resistance range	5 Ohms to 3 kOhms
Constant current	0.1 to 1000 µA
Sensors to be connected with four wires (pins 1, 3, 4 and 5) of 9-way D-connector on iTC. Pin 2 is sense shield.	
Sensor ADC resolution	24 bit
Resistance-sensor excitation modes	Unipolar or bipolar
Sensor sampling rate	Typically 1 Hz. Maximum 10 Hz.



Mercury iTC

The unit can accommodate thermocouple sensors with cold-junction compensation (CJC).

The unit can accommodate silicon-diode sensors (constant current supply).

The unit detects short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground.

The unit can store calibration files for sensors and can automatically set range-limits from the calibration file.

The user does not need to set the zero or the span for calibrated sensors.

11.4 Heater outputs

Table 11-4 Specifications of heater outputs

Item	Specification
Basic unit - heater outputs.	Single fully-controlled 80 W output. Upgradeable to 4 fully-controlled 80 W outputs.
Maximum output current.	2 A
Voltage compliance limit.	40 V
Load resistance range	20 Ohms to 120 Ohms
Output resolution	18 bit

The output is filtered with co-wound inductors and decoupling capacitors.

The output is protected against short-circuits.

The unit has a dead-man's-handle timer that disables the heater outputs if the control loop stalls.

11.5 PC interfaces

Table 11-5 PC interface specifications

Item	Specification
Serial interface	RS232 + ISOBUS
Serial interface 2	USB
GPIB	IEEE-488 (optional)
Ethernet	10/100 IEE802.3

11.6 Electrical isolation

Table 11-6 Electrical isolation specifications

Item	Specification
Sensor terminals to chassis	>50 VDC
Heater terminals to chassis	>50 VDC
Communications 0 V to chassis	>50 VDC
Communications to sensor or heater	>50 VDC

The mains-supply to chassis conforms to EN61010 and UL/CSA standard.

The mains-supply is double-insulated from all other terminals.

11.7 Environmental specifications

Table 11-7 Environmental specifications

Item	Specification
Recommended ambient temperature	20°C to 30°C
Ambient temperature (with reduced performance)	0° to 40°C
Shipping and storage temperature	-30°C to 85°C
Atmospheric pressure	800 hPa to 1060 hPa (2000 m to sea-level)
Maximum relative humidity	80% for temperatures up to 31°C, decreasing linearly to 50% at 40°C
Pollution degree	2

Mercury iTC

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12

THEORY OF CONTROL LOOPS

This chapter describes the general principles of the control loops used in this unit.

12.1

General information on control loops

The iTC uses control loops to control the heater and optional gas valve.

- Temperature control of the heaters uses PID control.
- Temperature control of the gas valve uses a proprietary algorithm.

Control of temperature by varying the gas valve is slower than control by varying the heater output. The iTC can be configured to operate using three possible automatic control methods:

- Automatic control of the gas valve with the heater output fixed.
This method provides a slow response to changes in temperature.
- Automatic control of the heater output.
This method provides a fast response to rapid falls in temperature, but a slow response to rapid rises in temperature.
- Automatic control of both the gas valve and the heater output.
This usually provides the most stable control, as it can compensate quickly for rapid rises or falls of temperature

12.2

General information on temperature control loops

A temperature control system consists of the following parts:

- A means of measuring the sample temperature (the temperature sensor).
- A variable source of heat (the heater).
- A control device to monitor the sample temperature and to control the output of the heater.

A temperature control loop is designed to maintain the temperature of the system as close as possible to the setpoint. There are several factors that must be considered:

- The heat loss from the system, which may vary with time and temperature.
- There will be a delay between heat being applied to the heater and a change of the temperature reading of the sensor.
- The system must respond as quickly as possible to a change of setpoint.

When a steady-state is established, the heat provided by the controller exactly balances the heat loss to the surroundings.



Mercury iTC

The criteria for good control are:

- Control accuracy
The temperature of the sample must be as close as possible to the setpoint.
- Control stability
Fluctuations above and below the setpoint temperature must be as small as possible.
- Control response
The sample temperature must follow changes of setpoint as quickly as possible.

12.2.1 Open loop operation

In an open-loop system, a fixed heater power is applied and the system is allowed to reach equilibrium. Any changes in the heat loss from the system produce corresponding changes in the sample temperature. The system also takes a long time to reach equilibrium. Open loop control is obtained by setting the **Heat** field on the **Control Loop Configuration** page to **Manual** mode (see [Section 4.2.9](#)).

An example of open-loop control is a hot-plate on a domestic oven.

12.2.2 On-Off control

In an on-off control system, the heater power is either maximum (if the measured temperature is below the setpoint) or zero (if the measured temperature is above the setpoint). The control accuracy and control response can be very good with this control system. The system also responds to changes in heat loss from the sample.

Control stability is poor, since the sample temperature oscillates above and below the setpoint. The magnitude of this oscillation depends on the thermal properties of the system. This control system is an appropriate choice if the temperature oscillation it produces can be tolerated.

An example of on-off control is a thermostat controlling the temperature of a room.

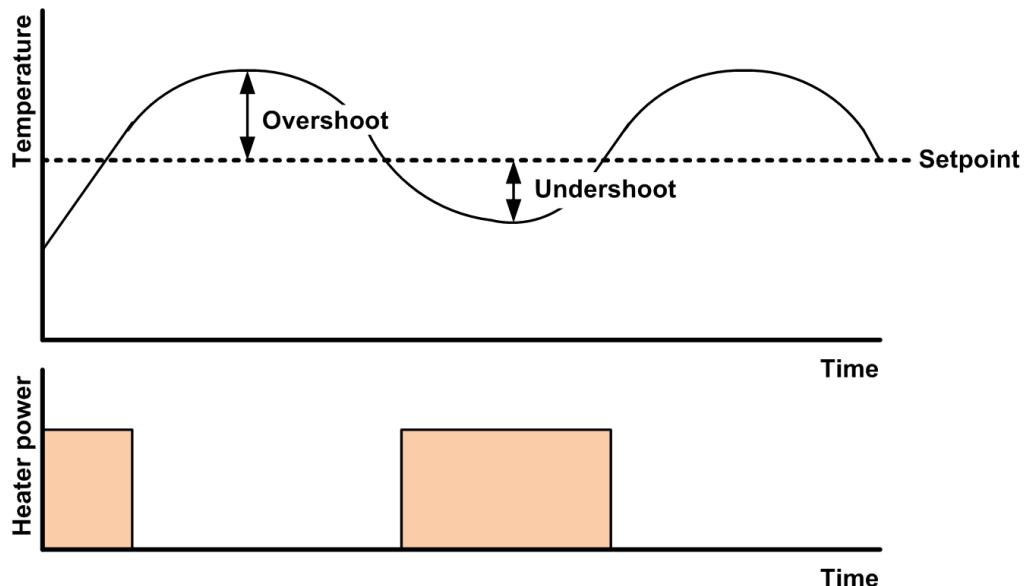


Figure 12-1 Response of an on-off control system

A PID controller can be made to operate in On-Off mode by setting the proportional band (P) parameter to zero.

12.2.3 Proportional control

A proportional control system allows the heater power to be continuously varied. This overcomes the oscillation problem produced by an on-off control system. The heater voltage at any instant is proportional to the error between the measured temperature and the setpoint. If the sample temperature drops, the heater voltage increases to compensate.

A proportional control system reaches equilibrium below the setpoint. This is because the heater output at the setpoint (when the error is zero) is zero. Thus a negative error is required to produce enough heater output to balance the heat-losses to the surroundings.

The temperature error can be reduced by making the proportional control apply to only a part of the temperature range of the system. Below this proportional band the heater voltage is at its maximum value. However reducing the proportional band too far produces temperature oscillations (in the limit, a proportional band of zero degrees produces on-off control).

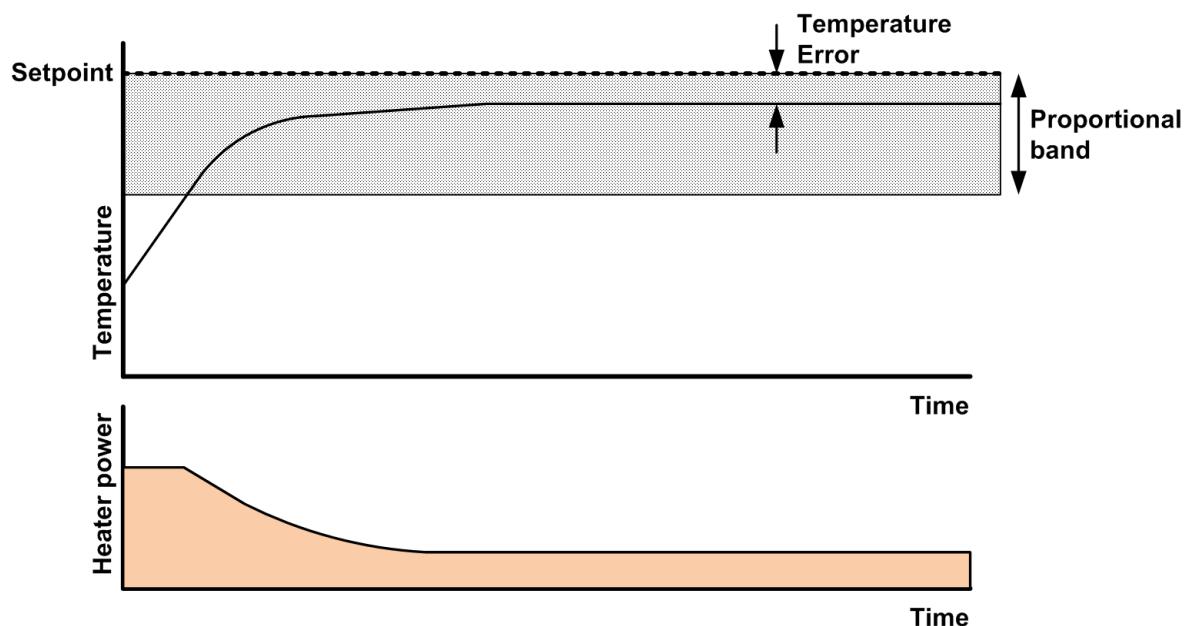


Figure 12-2 Proportional band control

A PID controller can be made to operate in proportional-band mode by setting the proportional band (P) parameter to a positive temperature value.

12.2.4 Proportional control with integral action

Adding an integrator into the proportional band control system can reduce the inherent temperature error to zero. The proportional band is set to a sufficiently large range to avoid oscillation. The error signal is then used as the input of the integrator. The output of the integrator is added to the output of the proportional control system.

If the sample temperature is below the setpoint, the negative error causes the output of the integrator to increase. This increases the heater output, which causes the sample temperature to rise. The output of the integrator stabilises at a positive value when the error is zero.

The integrator must be constrained to act more slowly than the response of the heater, to avoid oscillations. The control response of this system may be slow, because of this. The response of the integrator is characterised by the integrator action time. This is referred to as the I parameter in the PID control loop.

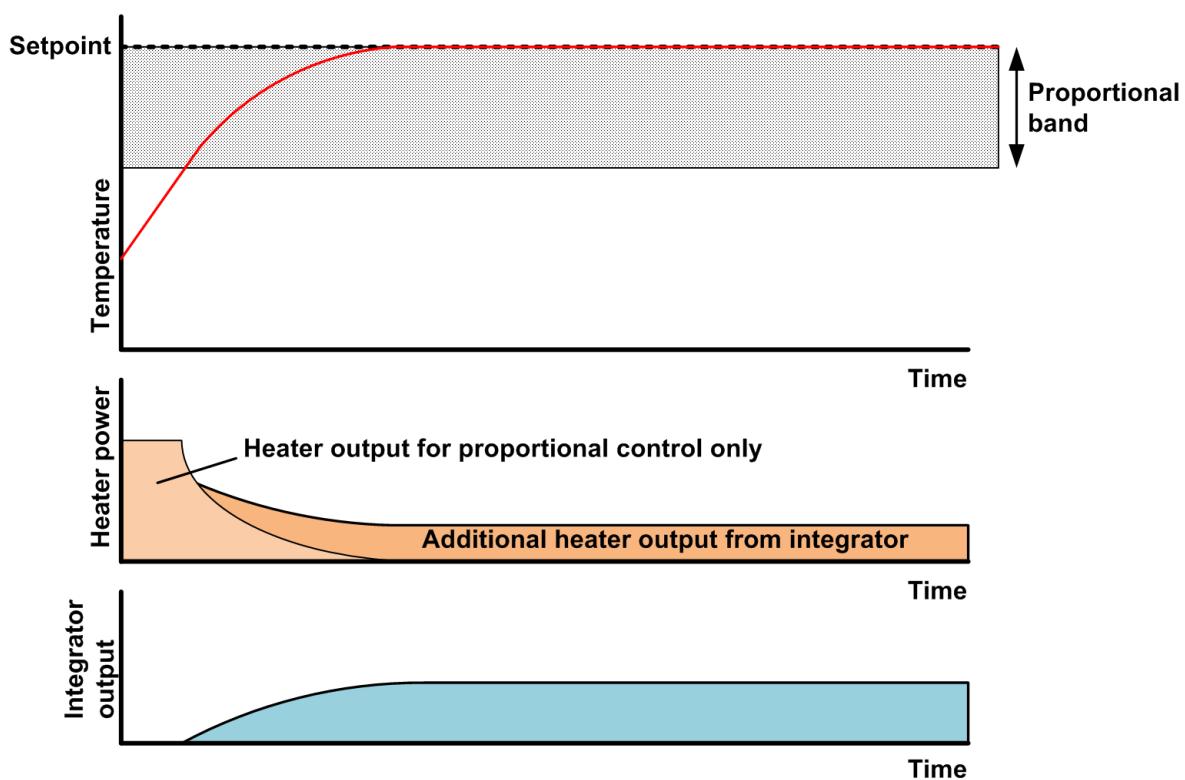


Figure 12-3 Proportional control with integrator action

If the setpoint increases by a large amount, the integrator output ramps up for all the time that the temperature error is negative. When the sample temperature reaches the proportional band, the integrator output may be at its maximum value. The integrator then takes significant time to reduce its output to the required value, resulting in a large temperature overshoot. To prevent this overshoot, the integrator output held at zero until the sample temperature is within the proportional band.

A PID controller can be made to operate in this mode by setting the proportional band (P) parameter to a positive temperature value, and the integral (I) parameter to a non-zero action time.

12.2.5 Proportional control with integral and derivative action

Adding derivative action to the proportional control loop can improve the control response. Derivative action monitors the rate of change of the measured temperature, and modifies the control output to minimise this rate of change.

Derivative action is characterised by an action time. If the measured temperature is changing at a rate of one proportional band per derivative action time, the derivative action contributes a signal sufficient to reduce a maximum control output to zero.

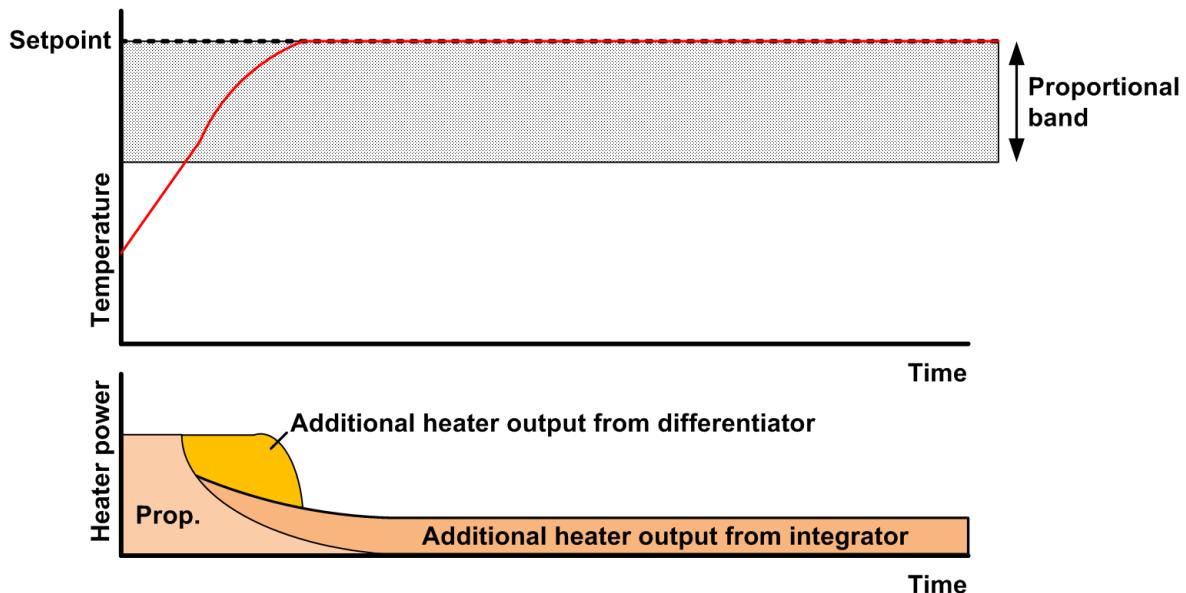


Figure 12-4 Proportional control with integral and differential action

Some control systems may have sufficient control response without using derivative action.

A PID controller can be made to operate in this mode by setting the proportional band (P) parameter to a positive temperature value, the integral (I) parameter to a non-zero action time, and the derivative (D) parameter to a non-zero action time.

12.2.6 North American terminology

In North America, a different terminology exists for describing 3-term control:

- Proportional band is replaced by its reciprocal, Gain.
- Integral Action is replaced by Reset. Reset may be specified as a time (as for Integral Action), or by its reciprocal Repeats Per Minute.
- Derivative Action is replaced by Rate. Rate may be specified as a time, or by its reciprocal Repeats Per Minute.



Mercury iTC

12.2.7 PID tables

Two alternative methods can be used to provide PID parameters to a control loop in the **Mercury iTC** cryogenic environment controller:

- Manual PID
The PID parameters are entered directly on the **Control Loop Configuration** page (see [Section 4.2.9](#)). The same parameters are used for the entire temperature range over which the control loop operates.
- Auto PID
The PID parameters are obtained from a PID table (see [Section 4.2.11](#)). This method allows the PID parameters to vary with the controlled temperature.

12.2.7.1 PID table operation

[Figure 12-5](#) shows an example PID table containing two rows. The values shown in this table are not from a real system.

	T1 (K)	T2 (K)	P (K)	I (mins)	D (mins)	
1	3.0000	10.0000	1.0000	30.0000	12.0000	
2	10.0001	20.0000	1.1000	25.0000	10.0000	

File: pid.tmp

-

Home

Control

Save

Load

+

Figure 12-5 PID table operation

12.2.7.2 Entering a PID table

- 1 Tap **Control** on the Home page. The **Control Loop Configuration** page is displayed.
- 2 Tap **Sensor** and select the temperature sensor that is to be configured.
- 3 Tap the **PID** field and set it to **Auto**.
- 4 Tap **PID Table**. The **PID Table Editor** page is displayed (see [Section 4.2.11](#)).
- 5 If a PID table is displayed, tap **Save** to save the present table (see [Section 4.2.16](#)).
- 6 Select the last row in the table and tap the **-** button. Tap **OK** in the confirmation field that appears to delete the row.
- 7 Continue deleting rows until the table is empty.
- 8 Tap **+** to insert a blank row.
- 9 Tap the first cell in the table and enter the lowest temperature to be controlled. The next cell in this row is displayed.

- 10 Tap the second cell in this row and enter the upper temperature for the first temperature range.
- 11 Tap the third cell in this row and enter the P parameter for this temperature range in K.
- 12 Tap the fourth cell in this row and enter the I parameter for this temperature range in minutes.
- 13 Tap the fifth cell in this row and enter the D parameter for this temperature range in minutes.
- 14 If required, tap + to add a new row. The first cell of the new row is automatically set to 0.001K above the upper temperature programmed in the previous row.
- 15 Continue adding rows until PID parameters have been entered for the entire temperature range to be used.
- 16 Tap **Save** to save the table.
- 17 Tap **Control** to return to the **Control Loop Configuration** page.

12.3 Theory of gas-flow control

12.3.1 Overview of gas control

The iTC can drive a motorised needle valve which controls the flow of a cooling gas. Controlling the gas-flow, regulates the cooling power, which provides control of the sample temperature.

There are two alternative algorithms that may be selected for automatic control:

- Variable Temperature Insert (VTI)
This algorithm is used if the coolant is supplied from a local bath.
- Syphon
This algorithm is used if the coolant is supplied from a dewar.

12.3.2 Manual control of the gas flow

When the gas control is set to *MANUAL* mode, the valve is driven to a fixed position to provide constant cooling power. Temperature control is then provided by controlling the heater output.

12.3.3 Automatic control of the gas flow

When the gas control is set to *AUTOMATIC* mode, the position of the needle valve is automatically controlled to provide variable cooling power. In conjunction with the heater, this enables accurate temperature control at cryogenic temperatures.

The position of the needle valve is controlled by a control function that operates relative to the present valve position rather than to an absolute position.

The output of the control function is related to the valve position by a Valve Gearing parameter. This parameter defines how many steps of the stepper motor exist between the valve fully-open and the valve fully-closed positions. Changing the Valve Gearing parameter allows the iTC to match a variety of stepper-motor and needle-valve combinations.

Mercury iTC

The control function is driven by two error signals:

- Temperature Error
the difference between the temperature measured by the sensor and the temperature set-point.
- Heater Voltage Error
the difference between the actual heater voltage delivered by the heater control loop and the target heater voltage.

Both error signals are scaled by the error sensitivities (see [Section 4.2.10](#)), and both are also compensated for non-linearity of the valve (the error sensitivity decreases with increasing temperature and decreasing flows).

The sensitivity to a temperature error is such that the valve responds to large temperature errors, but is relatively unaffected by small errors. This means that fine control of temperature near the setpoint is dominated by the heater.

When the system is in control at the setpoint, the temperature error is, by definition, zero. Control of the valve position is thus dominated by the heater voltage error, and the cooling is adjusted until the heater voltage reaches its target value. The system is at equilibrium when both the temperature error and the heater voltage error are zero.

12.3.3.1 Heater target tables

The target heater voltage is contained in the Heater Target Table (HTT). This table contains a set of target heater voltage values, each corresponding to a specified temperature range. The target voltage value in the table is scaled to the maximum heater output voltage (see [Section 4.2.14](#)), and is multiplied by the gas flow scaling factor (see [Section 4.2.10](#)), to obtain the final target heater voltage. The user can select which Heater Target Table to use, but can not edit a Heater Target Table. Contact OINS to obtain a Heater Target Table to suit your application.

12.3.3.2 Siphon algorithm

This algorithm is used when the coolant is supplied from a dewar. The algorithm controls in the same way as the VTI algorithm described above, with the following exceptions:

- a) If the present temperature is more than X degrees above the setpoint, the gas flow valve opens fully to provide fast cooling.
(Where X is 20% of the setpoint or 20 K, whichever is the greater).
- b) If the present temperature is rising, when it reaches 80% of the setpoint the gas flow changes to 50%. The automatic algorithm then starts controlling from this point.
- c) If the present temperature is less than 95% of the setpoint, the gas control valve remains at its present value. When the temperature rises to within 95% of the setpoint, the gas control valve controls automatically again.

13**TEMPERATURE SENSOR DAUGHTER BOARD**

This chapter describes the single and dual temperature sensor boards.

13.1**Overview of the temperature sensor board**

The unit can accept the following sensor types:

- Negative temperature coefficient (NTC) resistance
- Positive temperature coefficient (PTC) resistance
- Thermocouple
- Silicon diode

Each input can be read at a maximum rate of 10 Hz. The unit can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground.

The iTC contains a temperature sensor that is used to compensate for fluctuations in ambient temperature.

13.2**Installing a temperature sensor board****13.2.1****Fitting the board**

If a temperature board is not used to control a heater, it can be fitted in any expansion slot. It is preferable to locate temperature boards in slots that are physically separated from any heater boards that are fitted.

If a temperature sensor board is to be used to control a heater, it must be fitted in the correct slot (see [Table 5-5](#)).

- 1 Turn off electrical power to the iTC.
- 2 Remove the electrical power connector from the back of the unit.
- 3 Remove the screws that secure the lid of the iTC. There are 6 screws on each side panel of the iTC and 3 screws on the rear panel.
- 4 Lift off the lid.
- 5 Remove the two screws that secure the board-clamp. Remove the board clamp.



Figure 13-1 Board-clamp

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- 6** Remove the screw that secures the blanking panel in the location where the board is to be fitted. Keep the screw.

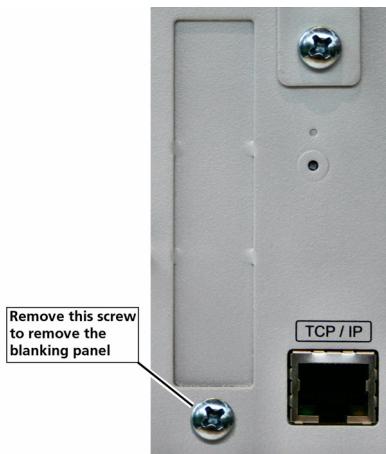


Figure 13-2 Daughter-board blanking-panel

- 7** Using appropriate ESSD precautions, fit the temperature board in the allocated expansion slot.
- 8** Secure the board using the screw that was removed in step **6**.
- 9** Refit the board-clamp, using the two screws that were removed earlier.
- 10** If a heater board is to be installed at the same time, fit the heater board in the allocated slot.
- 11** Fit the lid back onto the unit, using the screws that were removed earlier.

13.2.2 Connecting the sensor

A single-sensor board has a single 9-way D-connector.

13.2.3 Configuring the temperature sensor board

See [Section 2.5.1](#) for details.

13.3 Circuit description of the temperature sensor board

Depending on the sensor, the circuit can be configured to measure either resistance or voltage.

13.3.1 Description of voltage measurement mode

Voltage measurement mode is used with diode sensors or thermocouples.

MERCURY TEMPERATURE SENSOR DAUGHTER CARD : VOLTAGE MEASUREMENT MODE

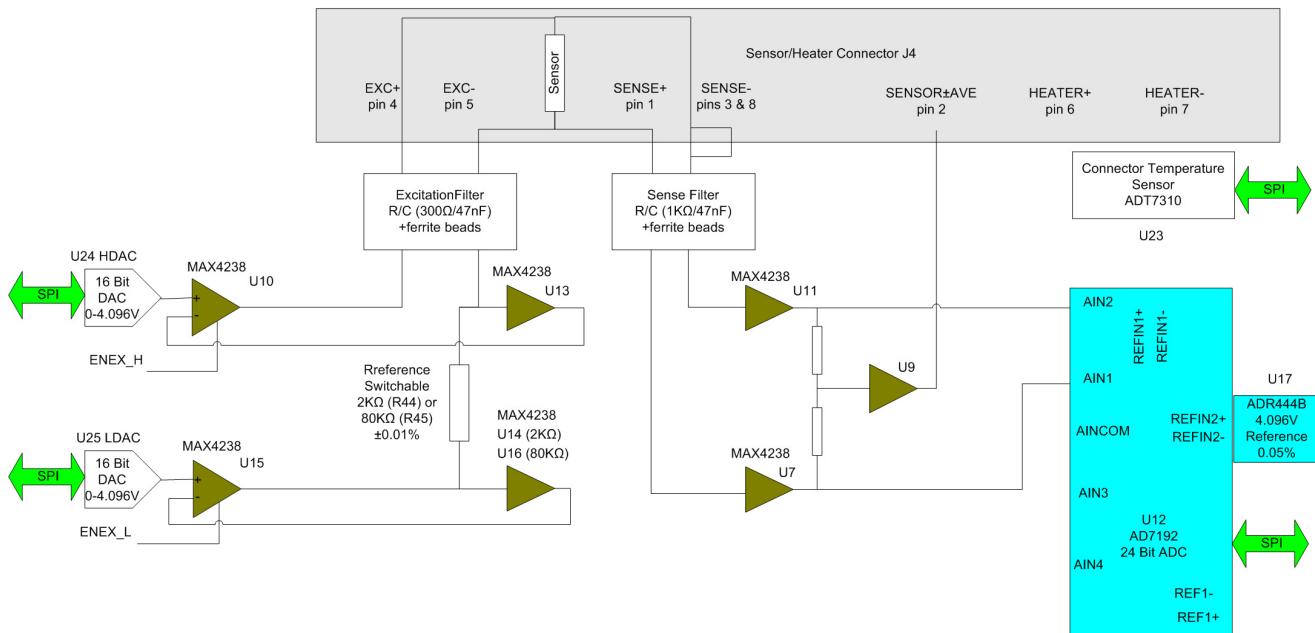


Figure 13-3 Block diagram of voltage measurement mode

If an excitation current is required, the sensor and a reference resistor (R44 or R45) are connected in series. Digital to analogue converters (DACs) U24 and U25 generate an upper and lower demand voltage. The upper voltage is buffered by U10 and applied to the upper end of the sensor resistor. The lower voltage is buffered by U15 and applied to the lower end of the reference resistor. The same current thus passes through the sensor and the reference resistor.

U13 and either U14 or U16 measure the voltage across the reference resistor and pass these feedback signals back to U10 and U15. This ensures that the voltage across the reference resistor is exactly equal to the difference between the output voltages of U24 and U25.

U11 and U7 measure the voltage across the sensor resistor. The outputs of these devices are passed to the inputs of a 24-bit analogue to digital converter (ADC). The ADC uses an accurate 4.096V reference for this measurement.

The reference resistors are 2kΩ and 80kΩ. Depending on the excitation current, the resistor and gain factor are chosen so that the ADC input voltage is in the optimum range.

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The sensor voltage is:

$$V_{\text{sensor}} = V_{\text{ref}} \times \text{ADCnorm}/\text{ADCgain}$$

Where:

ADCnorm is the ADC reading normalised to the range 0 to ± 1 V.

ADCgain is the gain setting of the ADC.

The temperature of the sensor to heater connection is measured for thermocouple correction.

If an excitation current is not required (i.e. for a thermocouple sensor), U10 and U15 are switched off.

13.3.2 Description of constant current measurement mode

Constant current measurement mode is used with sensors that have a positive temperature coefficient.

MERCURY TEMPERATURE SENSOR DAUGHTER CARD : CONSTANT CURRENT MODE

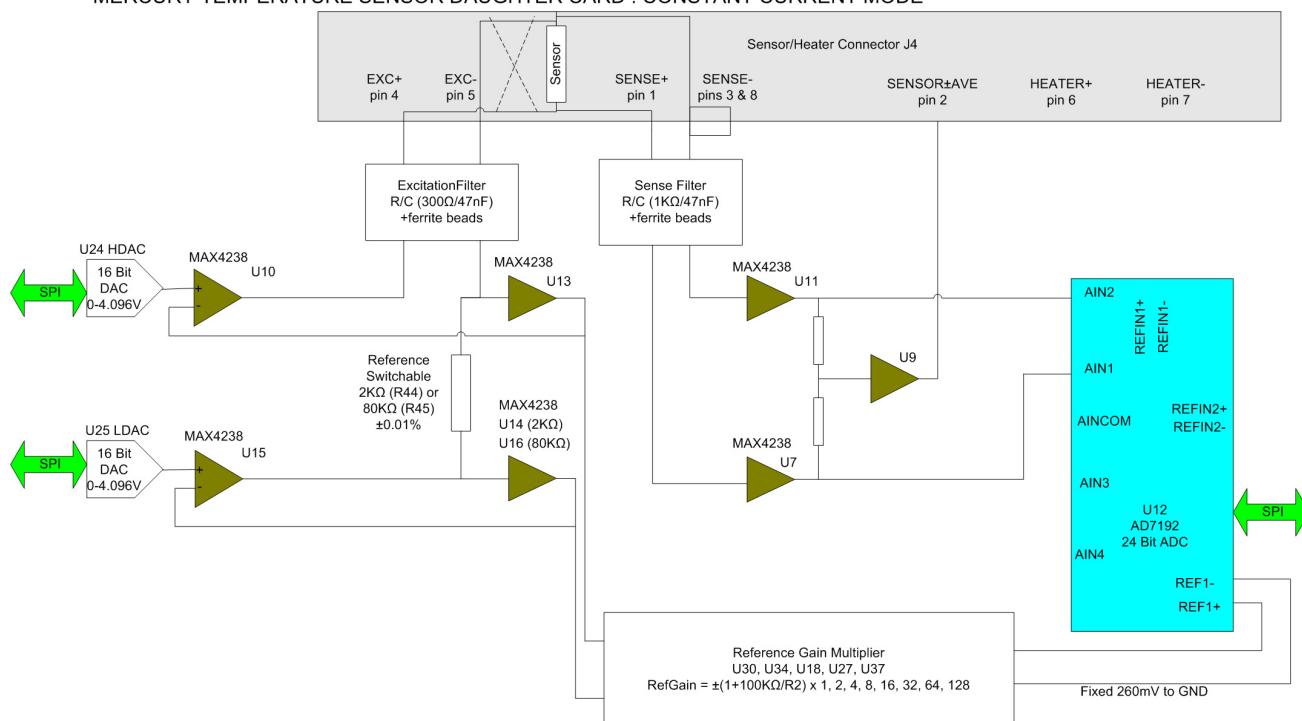


Figure 13-4 Block diagram of constant current measurement mode

The sensor and a reference resistor (either R44 or R45) are connected in series. Digital to analogue converters U24 and U25 generate an upper and lower demand voltage. This voltage is equal to the required current multiplied by the value of the selected reference resistor.

The upper voltage is buffered by U10 and applied to the upper end of the sensor resistor. The lower voltage is buffered by U15 and applied to the lower end of the reference resistor. The same current thus passes through the sensor and the reference resistor.

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U13 and either U14 or U16 measure the voltage across the reference resistor and pass these feedback signals back to U10 and U15. This ensures that the voltage across the reference resistor is exactly equal to the difference between the output voltages of U24 and U25.

The outputs of U13 and either U14 or U16 are also scaled by a reference gain multiplier, whose gain is selected to give an output in the range 1 V to 2.5 V. This voltage is then passed to the reference voltage inputs of the ADC (U12). This circuit configuration produces a ratiometric measurement technique.

The resistance of the sensor is:

$$R_{\text{sensor}} = R_{\text{ref}} \times |\text{ADCnorm}| \times \text{RefGain}/\text{ADCgain}$$

Where:

Ref is the reference resistance (either 2 kΩ or 80 kΩ).

ADCnorm is the ADC reading, normalised to the range 0 to ±1 V.

RefGain is the interpolated gain from the calibration tables.

ADCgain is the gain setting of the ADC.

The measurement accuracy of this circuit does not depend on the accuracy of the excitation current or the reference voltage. The accuracy primarily depends on the accuracy of the reference resistor plus any errors introduced by operational amplifiers.

13.3.3 Description of constant voltage measurement mode

Constant voltage measurement mode is used with sensors that have a negative temperature coefficient.

MERCURY TEMPERATURE SENSOR DAUGHTER CARD : CONSTANT VOLTAGE MODE

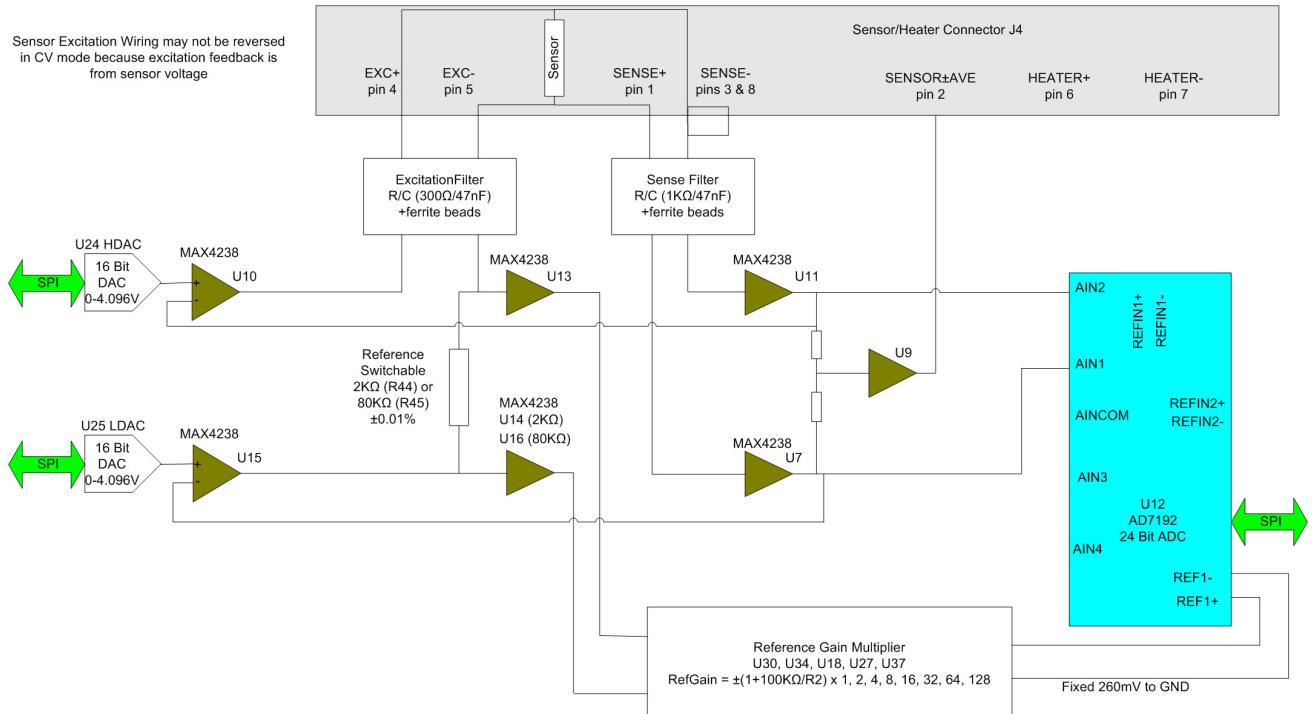


Figure 13-5 Block diagram of constant voltage measurement mode



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The sensor and a reference resistor (either R44 or R45) are connected in series. Digital to analogue converters U24 and U25 generate an upper and lower demand voltage. The upper voltage is buffered by U10 and applied to the upper end of the sensor resistor. The lower voltage is buffered by U15 and applied to the lower end of the reference resistor. The same current thus passes through the sensor and the reference resistor.

U7 and U11 measure the voltage across the sensor and feed the inputs of ADC U12. The outputs of U7 and U11 are also fed back to U10 and U15. This ensures that the voltage across the sensor is exactly equal to the demand voltage generated by U24 and U25.

U13 and either U14 or U16 measure the voltage across the reference resistor. This differential voltage is scaled by a reference gain multiplier, whose gain is selected to give an output in the range 1 V to 2.5 V. This voltage is then passed to the reference voltage inputs of the ADC (U12). This circuit configuration produces a ratiometric measurement technique. The resistance of the sensor is:

$$R_{\text{sensor}} = R_{\text{ref}} \times |\text{ADCnorm}| \times \text{RefGain}/\text{ADCgain}$$

Where:

Rref is the reference resistance (either 2 kΩ or 80 kΩ).

ADCnorm is the ADC reading, normalised to the range 0 to ±1 V.

RefGain is the interpolated gain from the calibration tables.

ADCgain is the gain setting of the ADC.

The measurement accuracy of this circuit does not depend on the accuracy of the excitation or reference voltages. The accuracy primarily depends on the accuracy of the reference resistor plus any errors introduced by operational amplifiers.

13.3.4 Calibrating the temperature measurement circuit

Figure 13-6 shows a block diagram of the temperature measurement circuit in calibration mode.

MERCURY TEMPERATURE SENSOR DAUGHTER CARD : CALIBRATION MODE

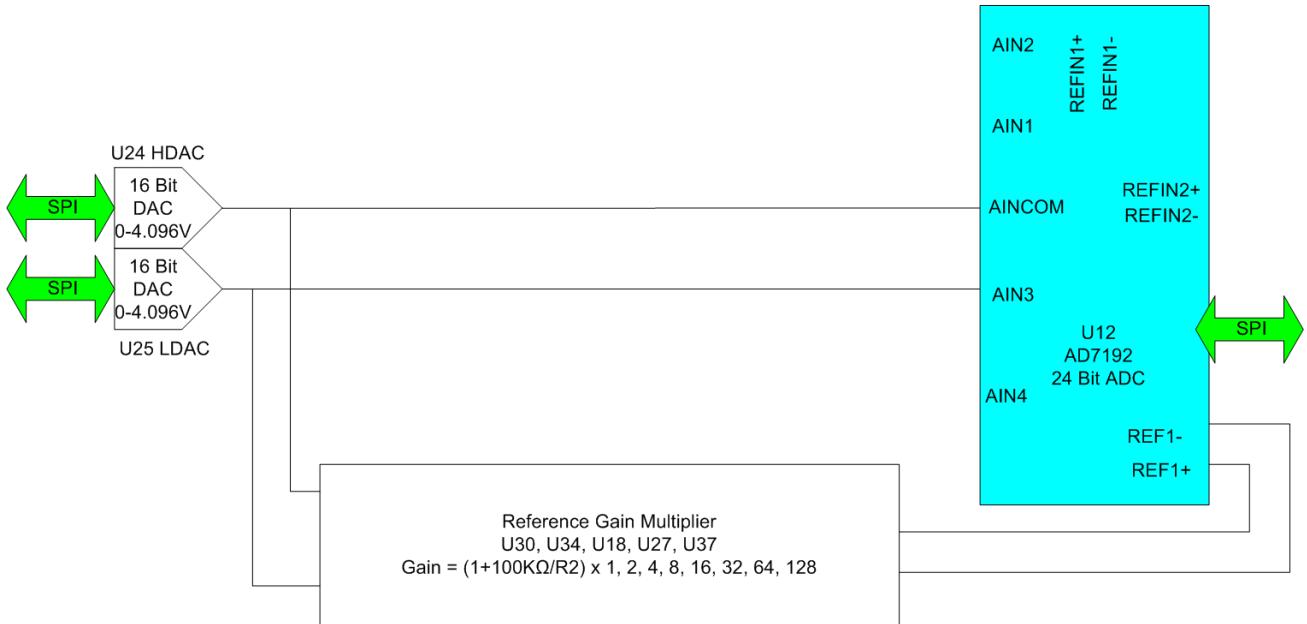


Figure 13-6 Temperature measurement circuit calibration

The calibration is performed using a ratiometric circuit configuration. In calibration mode, DACs U24 and U25 supply a differential calibration voltage to the input of ADC U12. This same differential voltage is scaled by a reference gain multiplier circuit, and supplied to the reference voltage inputs of U12.

The ADC input has a programmable gain amplifier (PGA) with five gain settings (1, 8, 16, 64 and 128). An autocalibration is performed for each range.

The reference gain multiplier is also programmable with eight gains (1, 2, 4, 8, 16, 32, 64 and 128). Each gain is calibrated at low and high reference voltages (1.2 V and 2.4 V). The exact gain that is used for calculating sensor resistance is a linear interpolation between these two values.

It is only necessary to perform this calibration using a positive excitation voltage. The ADC is operated in chop mode, which eliminates any offsets in the ADC.

Calibration is performed using the highest possible ADC accuracy setting, which is also the slowest acquisition time. The results are stored in flash memory for use during a measurement whenever a range is changed. Calibration is not performed every time a range is changed, as this would cause unacceptable measurement delays.

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14 HEATER DAUGHTER BOARD

This section describes the heater daughter-board.

14.1 Overview of the heater board

The heater board contains a single heater output. A heater board must be associated with a temperature sensor board.

14.2 Installing a heater board

14.2.1 Fitting the board

A heater board must be fitted in the correct slot so that it is connected to its associated temperature sensor board (see [Table 5-5](#)).

- 1 Turn off electrical power to the iTC.
- 2 Remove the electrical power connector from the back of the unit.
- 3 Remove the screws that secure the lid of the iTC. There are 6 screws on either side panel of the iTC and 3 screws on the rear panel.
- 4 Lift off the lid.
- 5 Remove the two screws that secure the board-clamp. Remove the board clamp.



Figure 14-1 Board-clamp

- 6 Remove the screw that secures the blanking panel in the location where the board is to be fitted. Keep the screw.

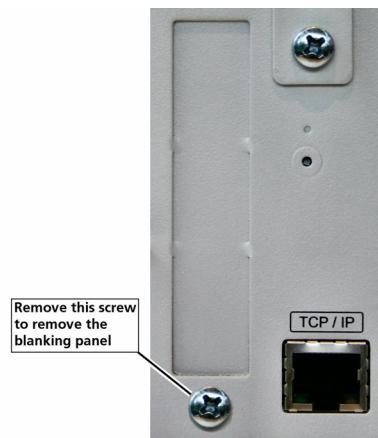


Figure 14-2 Daughter-board blanking-panel

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- 7 Using appropriate ESSD precautions, fit the heater board in the allocated expansion slot.
- 8 Secure the board using the screw that was removed in step 6.
- 9 Refit the board-clamp, using the two screws that were removed earlier.
- 10 Fit the lid back onto the unit, using the screws that were removed earlier.

14.2.2 Connecting the heater

The heater is connected to the 9-way D-connector on the associated temperature sensor board. Pin connections are listed in [Section 5.2.4](#).

14.2.3 Configuring the heater board

See [Section 2.5.2](#) for details.

14.2.4 Configuring the control loop.

See [Section 2.5.3](#) for details.

14.3 Circuit description of the heater board

Figure 14-3 shows a block diagram of the heater circuit.

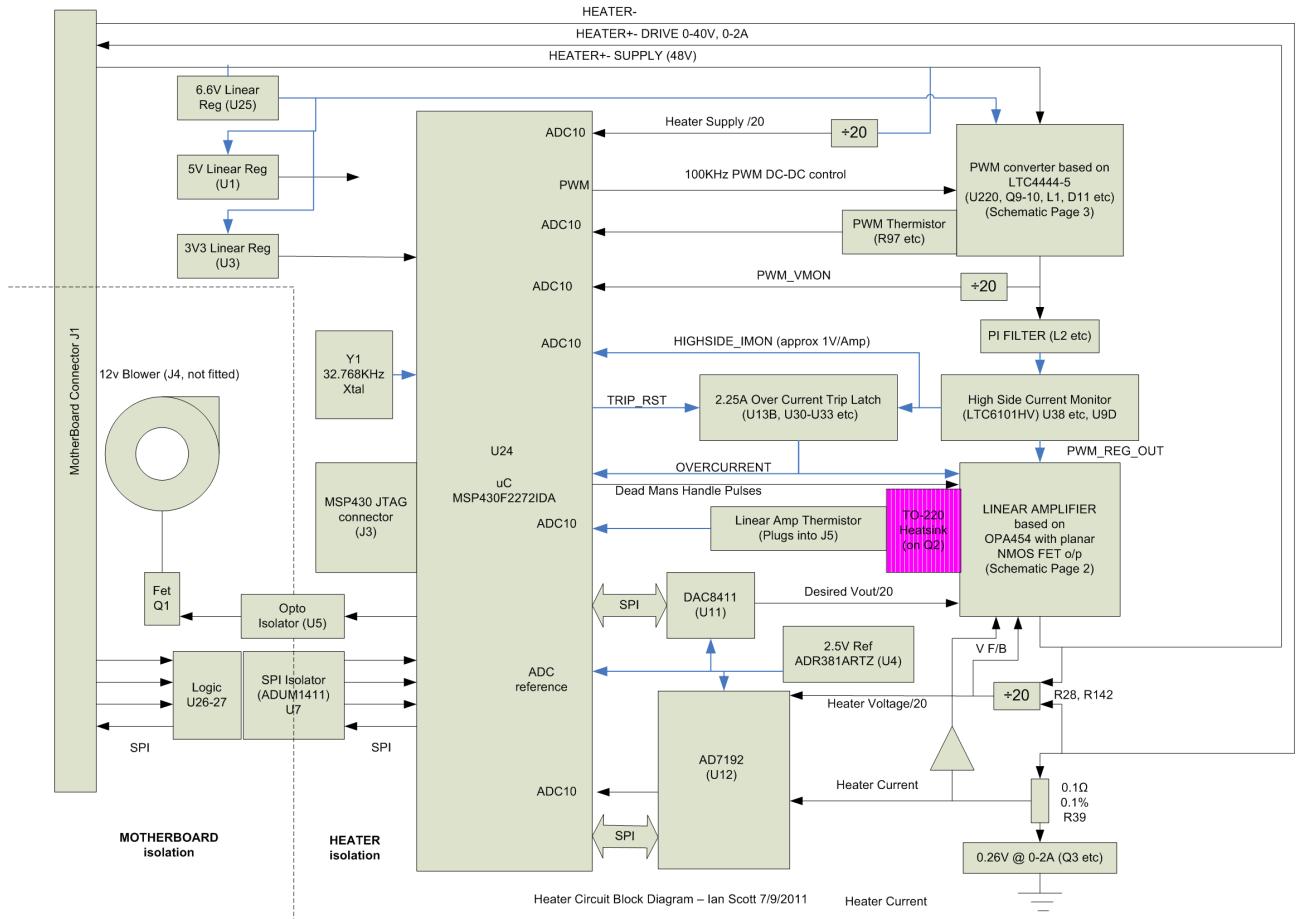


Figure 14-3 Block diagram of the heater circuit

14.3.1 Description of the heater circuit

Microcontroller U24 outputs a demand signal to DAC U11. U11 converts this signal to a demand voltage for the heater output, which is equal to the desired heater voltage divided by 20. This voltage is fed to the linear amplifier which outputs the heater drive (0-40 V, 0-2 Amp).

The measured upper and lower heater voltages are divided by 20 and fed back to ADC U12. U12 sends the resulting voltage back to the microcontroller U24.

The lower heater voltage signal passes to ground through a 0.1Ω resistor. The voltage across this resistor is equal to the heater current divided by 10. This voltage is also fed back to ADC U12, which sends the resulting signal to microcontroller U24. U24 can thus calculate the power dissipation in the heater, and adjust its heater demand signal accordingly.

The heater current and voltage/20 feedback signals are also passed to the linear amplifier.

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The power for the linear amplifier is provided by a pulse-width modulator converter, controlled by U24. The output of this converter is filtered and passed to the linear amplifier via a current monitor. This current signal is passed back to U24, and also drives an overcurrent trip circuit. If the measured current is too high, the current trip circuit latches on and disables the linear amplifier. The linear amplifier is also disabled if regular pulses are not received from the microcontroller (referred to as the “dead man’s handle” feature).

14.3.2 Calibrating the heater circuit

The ADC performs an internal self-calibration routine when the user requests a calibration. This calibrates each gain range (1, 8, 16, 32, 64, 128) on each input pair, at full-scale only. It is only necessary to perform this calibration using a positive excitation voltage. The ADC is operated in chop mode, which eliminates any offsets in the ADC.

15

AUXILIARY I/O DAUGHTER BOARD

The auxiliary I/O board can be fitted in any expansion slot in the iTC.

15.1 Description of the auxiliary I/O board

15.1.1 Auxiliary I/O board functions

The optional auxiliary board performs the following functions:

- It provides a stepper-motor drive and sense input. This can be used to drive an automatic gas-flow control accessory (AutoGFS).
- It provides an override input to disable the heater output. This allows an external over-temperature switch to disable the heater.
- It provides control signals for the high-power output unit OP3KW MkII (if fitted).
- It provides digital inputs that can be used for various functions.
- It provides digital outputs that can be used for various functions (e.g. control of a refill valve).

The auxiliary port connections are made via a 15-way D-socket on the rear panel.

The outputs are open-collector transistors, and each can sink up to 500 mA from a maximum supply voltage of +25 VDC. If the load is inductive, it is recommended that a diode is connected across the load to absorb the stored energy.

Low-power loads can be driven directly from pin 15, which is connected to the unregulated 11 V line via a diode and a fuse. Pin 15 can source a maximum current of 500 mA.

The input lines on the auxiliary port can either be driven by TTL levels, or by contact closures switching to +5 VDC. A 100 kOhm pull-down resistor (to 0 V) is fitted to each input.

The AutoGFS sense input must be linked to +5 VDC when an AutoGFS unit is connected.

If a temperature-switch is fitted, it must be connected so that an over-temperature condition pulls the input above +2.5 VDC. The internal 100 kOhm resistor may be shunted by an external resistor, if required to match the input to a sensor characteristic.

15.1.2

Gas-flow control using a motorised needle-valve

The auxiliary I/O board can control a motorised needle-valve, regulating the flow of cryogenic fluid in a cryostat. There are two possible configurations:

- Automatic needle valve
The needle-valve is fitted to the main cryostat and controls the flow between the cryogen reservoir and a variable-temperature insert.
- Automatic gas flow siphon
The needle valve is fitted in an automated gas-flow siphon, linking the cryostat to a separate cryogen storage-vessel.

The flow dynamics of these two arrangements are different.

See [Section 12.3](#) for a description of gas-flow control.

15.2 Installing an auxiliary I/O board

15.2.1 Fitting the board

An auxiliary I/O board can be fitted in any expansion slot.

- 1 Turn off electrical power to the iTC.
- 2 Remove the electrical power connector from the back of the unit.
- 3 Remove the screws that secure the lid of the iTC. There are 6 screws on either side panel of the iTC and 3 screws on the rear panel.
- 4 Lift off the lid.
- 5 Remove the two screws that secure the board-clamp. Remove the board clamp.



Figure 15-1 Board-clamp

- 6 Remove the screw that secures the blanking panel in the location where the board is to be fitted. Keep the screw.



Figure 15-2 Daughter-board blanking-panel

- 7 Using appropriate ESSD precautions, fit the auxiliary I/O board in the allocated expansion slot.
- 8 Secure the board using the screw that was removed in step 6.
- 9 Refit the board-clamp, using the two screws that were removed earlier.
- 10 Fit the lid back onto the unit, using the screws that were removed earlier.

15.2.2 Connecting to the auxiliary I/O board

The pin connections for the auxiliary port are listed in [Table 15-1](#).

Table 15-1 Auxiliary port pin assignments

Pin	Function
1	Output Bit 0 (Stepper Motor) or Compressor Disable.
9	Output Bit 1 (Stepper Motor)
2	Output Bit 2 (Stepper Motor)
10	Output Bit 3 (Stepper Motor)
3	Not used
11	Not used
4	Not used
12	Not used
5	Input K4 (Auto GFS Sense)
13	Input K5 (Spare)
6	Input K6 (Spare)
14	Input K7 (Over-temperature switch input)
7	+5 VDC
15	Driver protection / +11 VDC unregulated
8	0 V

15.2.3 Configuring an input on the auxiliary I/O board

- 1 Configure a panel on the Home page for an input on the auxiliary IO board.
- 2 Tap the configured panel once. The Digital IO Details page is displayed.

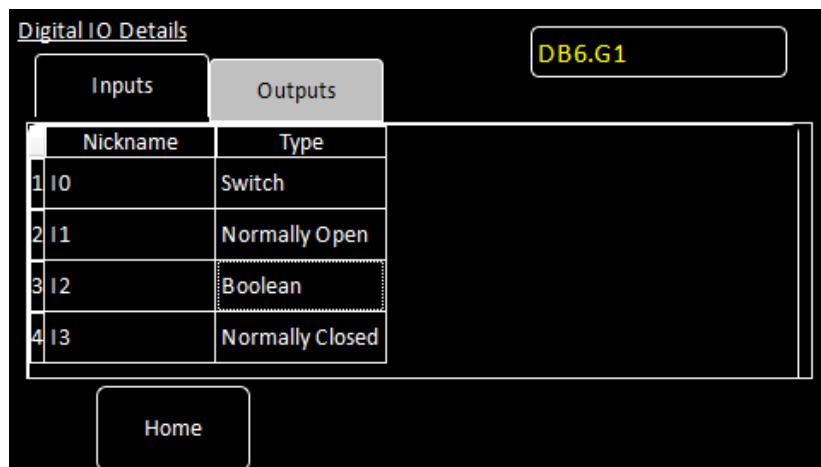


Figure 15-3 Digital IO Details page - Input tab

- 3 Select the Inputs tab.

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- 4 Enter a nickname for the input that is to be used.
- 5 Select a **Type** for the input. The input type that you select changes the displayed status of the input on the Home page.
The options are:
 - SWITCH** - The Home page displays ON when the input is high and OFF when the input is low.
 - NORMALLY OPEN** - The Home page displays CLOSED when the input is high and OPEN when the input is low.
 - NORMALLY OPEN** - The Home page displays OPEN when the input is high and CLOSED when the input is low.
 - BOOLEAN** - The Home page displays TRUE when the input is high and FALSE when the input is low.

15.2.4 Configuring an output on the auxiliary I/O board

- 1 Configure a panel on the Home page for an output on the auxiliary IO board.
- 2 Tap the configured panel once. The Digital IO Details page is displayed.

Digital IO Details	
Inputs	Outputs
	DB6.G1
Nickname	Type
1 00	Switch
2 016	Normally Open
3 02	Boolean
4 03	Normally Closed

Home

Figure 15-4 Digital IO Details page - Output tab

- 3 Select the Outputs tab.
- 4 Enter a nickname for the output that is to be used.
- 5 Select a **Type** for the output. The output type that you select changes the displayed status of the output on the Home page.
The options are:
 - SWITCH** - The Home page displays ON when the output is on and OFF when the output is off.
 - NORMALLY OPEN** - The Home page displays CLOSED when the output is on and OPEN when the output is off.
 - NORMALLY OPEN** - The Home page displays OPEN when the output is on and CLOSED when the output is off.
 - BOOLEAN** - The Home page displays TRUE when the output is on and FALSE when the output is off.

16

LEVEL-METER DAUGHTER BOARD

This chapter describes the level-meter daughter board.

16.1

Description of the level-meter board

The level-meter board monitors the level of cryogen in a reservoir. The board can be used with liquid helium and liquid nitrogen systems. The level-meter raises an error if the cryogen level falls below a safe level.

The level-meter board uses a superconducting-wire probe to measure the depth of liquid helium, or a capacitance probe to detect the level of liquid nitrogen.

There are two 9-way D connectors on the board; one for a nitrogen sensor and one for a helium sensor.

16.1.1

Principles of operation

16.1.1.1

Operation of the board with a helium-level probe

The probe is a length of superconducting wire extending from the bottom to the top of the helium reservoir. The probe is normally mounted vertically, although other geometries are possible.

The section of wire below the liquid surface is cooled more efficiently than the section in the gas above the liquid. The level-meter controls the current through the wire such that the temperature of the section in the gas is above the critical temperature (and is thus resistive), while the section in the liquid is below the critical temperature (and thus superconducting). The length of the resistive section of the wire thus depends on the level of liquid in the reservoir.

To minimise heating of the sample, the current in the wire is turned off after a measurement has been made. Because there is zero current through the probe, the whole length of wire becomes superconducting between measurements. When the next measurement is made, it is necessary to introduce heat into the section of wire in the gas to make it resistive. A small heater-resistor is mounted in thermal contact with the top of the wire to heat a small section of wire. If the current in the wire is sufficient, the resistive section propagates down the wire until it extends to the surface of the liquid.

When the measurement has been made, the current in the wire is turned off again. The measurement is performed at intervals between a few second to a few hours, depending on the expected rate of change of the liquid level. Do not perform measurements too often, as each measurement boils off a small quantity of helium. A fast sampling rate is available for use when the reservoir is being filled.

The maximum probe-length depends on the resistivity of the probe wire:

- For probes up to 1.4 m long, a wire resistivity of 166 Ohms/meter is used, with a current of 130 mA.
- For probes up to 2 m long, a wire of resistivity of 61.2 Ohms/meter is used, with a current of 250 mA.

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16.1.1.2 Operation of the board with a nitrogen-level probe

The nitrogen-probe consists of two concentric steel-tubes. The tubes act as the plates of a capacitor, while the annular space between them acts as a dielectric. Liquid-nitrogen has a relative permittivity of 1.45, so the capacitance of the section of probe under the liquid surface increases by approximately 45%.

The probe-head includes an oscillator whose frequency depends on the capacitance of the probe. Thus the oscillator frequency also depends on the level of liquid.

The probe-head requires no adjustment. the working range of the oscillator (5 kHz to 65 kHz) accommodates probes up to 2 metres long.

16.1.1.3 Explanation why different methods are used for the two liquids

Liquid helium has a relative permittivity of 1.055, which is similar to the relative permittivity of helium gas at 4.2 K. The capacitance probe is thus not sensitive to the liquid level when used with liquid helium.

It is possible to make a liquid-nitrogen probe using a wire made of a high-temperature superconductor. However this probe would be much less robust than a capacitive probe.

16.1.1.4 Refill control

The level meter board can control a valve to refill the unpressurised dewar from a pressurised dewar. The valve must be driven from an unused output of the auxiliary I/O board (see [Section 15.2.2](#)).

16.2 Installing the level-meter board

16.2.1 Fitting the board

The level-meter board can be fitted in any expansion slot. Only one level meter board can be fitted in a **Mercury iTC**, because of power consumption limitations.

- 1 Turn off electrical power to the iTC.
- 2 Remove the electrical power connector from the back of the unit.
- 3 Remove the screws that secure the lid of the iTC. There are 6 screws on either side panel of the iTC and 3 screws on the rear panel.
- 4 Lift off the lid.
- 5 Remove the two screws that secure the board-clamp. Remove the board clamp.



Figure 16-1 Board-clamp

- 6** Remove the screw that secures the blanking panel in the location where the board is to be fitted. Keep the screw.

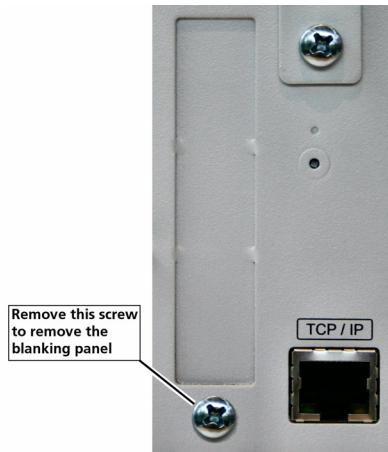


Figure 16-2 Daughter-board blanking-panel

- 7** Using appropriate ESSD precautions, fit the level-meter board in the allocated expansion slot.
8 Secure the board using the screw that was removed in step **6**.
9 Refit the board-clamp, using the two screws that were removed earlier.
10 Fit the lid back onto the unit, using the screws that were removed earlier.

16.2.2 Connecting the sensor

Connect the sensor to the appropriate 9-way D-connector on the rear panel of the board. The pin connections are listed in [Table 16-1](#).

Table 16-1 Level-meter sensor pin connections

Pin	Signal Name	Helium Probe	Nitrogen Probe
1	VHIGH	V sense (Top)	n/c
2	VLOW	V sense (Bottom)	n/c
3	(Unused)		
4	FREQ IN	Link to 5	OUTPUT FREQ (0 to 12 V)
5	FREQ OUT	Link to 4	n/c
6	I _{HIGH}	I (Top)	n/c
7	I _{LOW}	I (Bottom)	0 V
8	+12 V	n/c	+12V (20 mA maximum)
9	CHASSIS GND	Screen	Screen



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16.3 Configuring the level-meter board

If you are using the level-meter with liquid helium, see [Section 16.3.1](#).

If you are using the level-meter with liquid nitrogen, see [Section 16.3.2](#).

16.3.1 Configuring a liquid-helium sensor

- 1 Tap an unconfigured panel on the Home page. The Channel Display Configuration page is displayed.
- 2 Tap on the **Devices** field and select a level meter input.
- 3 Tap on the **Signals** field and select *Resistance*.
- 4 Tap **Assign** to save the changes.
- 5 Tap **Home**.
- 6 With the helium sensor at room temperature, record the sensor resistance value that is displayed on the Home page.
- 7 Fully immerse the sensor part of the probe in liquid helium.
- 8 Record the sensor resistance value that is displayed on the Home page. This value should be close to zero.
- 9 Tap the configured level-meter panel on the Home page. The Level Meter Sensor Details page is displayed.

- 10 Select the **Helium** tab.

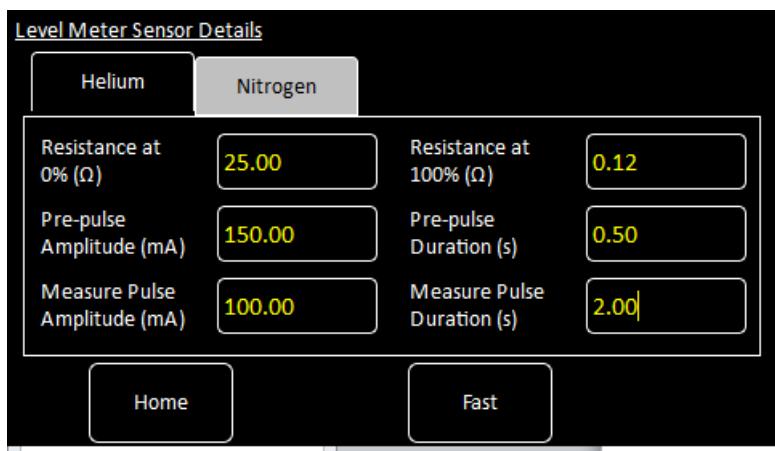


Figure 16-3 Level Meter Sensor Details page - Helium tab

- 11 Enter the resistance measured in step 6 in the **Resistance at 0% (Ω)** field.
- 12 Enter the resistance measured in step 8 in the **Resistance at 100% (Ω)** field.
- 13 Enter a value between 0 and 160 mA in the **Measurement Pulse Amplitude (mA)** field.
- 14 Enter a value in seconds in the **Measurement Pulse Duration (s)** field.
- 15 Tap the **Fast/Slow** button until it displays *Slow*.

NOTE: Select Fast sampling when filling the reservoir. Return the sampling rate to Slow when the reservoir is full, to conserve helium.

- 16 If a pre-pulse is required, enter a value between 0 and 160 mA in the **Pre-pulse Amplitude (mA)** field.
- 17 If a pre-pulse is required, enter a value in seconds in the **Pre-pulse Duration (s)** field.
- 18 Tap **Home** to return to the Home page.
- 19 If required, access the Channel Display Configuration page and change the displayed value from *Resistance* to *He Level*.

16.3.2 Configuring a liquid-nitrogen sensor

- 1 Tap an unconfigured panel on the Home page. The Channel Display Configuration page is displayed.
- 2 Tap on the **Devices** field and select a level meter input.
- 3 Tap on the **Signals** field and select *Pulse*.
- 4 Tap **Assign** to save the changes.
- 5 Tap **Home**.
- 6 With the nitrogen sensor at room temperature, record the sensor frequency that is displayed on the Home page.
- 7 Fully immerse the sensor part of the probe in liquid nitrogen.
- 8 Record the sensor frequency that is displayed on the Home page.
- 9 Tap the configured level-meter panel on the Home page. The Level Meter Sensor Details page is displayed.
- 10 Select the **Nitrogen** tab.

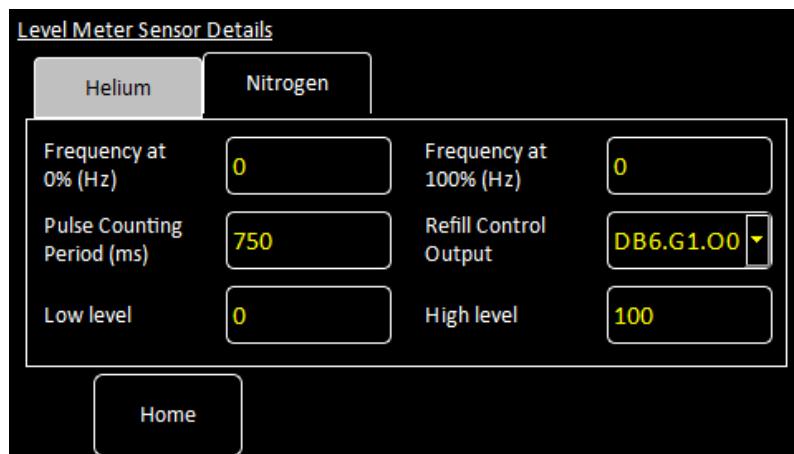


Figure 16-4 Level Meter Sensor Details page - Nitrogen tab

- 11 Enter the frequency measured in step 6 in the **Frequency at 0% (Hz)** field.
- 12 Enter the frequency measured in step 8 in the **Frequency at 100% (Hz)** field.



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- 13 If required, change the value displayed in the **Pulse Counting Period (ms)** field.
- 14 If required, select a digital output in the **Refill Control Output** field. This output on the auxiliary I/O board must be connected to control the refill valve on the liquid nitrogen system.
- 15 If using a refill valve, enter a value in the **Low Level** field. The selected refill output is activated when the liquid nitrogen level falls below the **Low Level** value.
- 16 If using a refill valve, enter a value in the **High Level** field. The selected refill output is de-activated when the liquid nitrogen level rises above the **High Level** value.
- 17 Tap **Home** to return to the Home page.
- 18 If required, access the Channel Display Configuration page and change the displayed value from *Pulse* to *N2 Level*.

16.4 Specification of the level-meter board

Table 16-2 Environmental specifications of the level meter

Parameter	Specification
Recommended ambient temperature	20°C to 30°C
Ambient temperature (with reduced performance)	0°C to 50°C
Altitude	Up to 2000 m
Vibration	Fixed laboratory installation

Table 16-3 Specification of the helium probe

Parameter	Specification
Excitation current settings	20 mA to 280 mA in 20 mA steps
Excitation current accuracy	±5%
Excitation voltage	40 V maximum
Probe resistance	0Ω to 300Ω
Probe resistance measurement accuracy	±0.2%
Probe resistance measurement stability	±0.1%
Probe resistance ADC measurement resolution	Better than 0.005%
Probe connections isolation to chassis	>50 VDC

Table 16-4 Specification of the nitrogen probe

Parameter	Specification
Probe source voltage	12 VDC
Probe source oscillator frequency range	5 kHz to 65 kHz
Probe sensing resolution (level)	0.1%
Probe sensing accuracy (level)	0.5%



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17 GPIB DAUGHTER BOARD

17.1 Description of the GPIB daughter board

GPIB is a parallel interface that allows a single computer to control a number of instruments independently. The GPIB interface on the iTC conforms to the standard IEEE-488.1. The GPIB must be connected using a standard GPIB cable.



CABLE DISCONNECTION

Do not connect or disconnect GPIB cables while the computer, or any of the instruments, are powered up. Equipment damage can result if this precaution is not observed.

DÉBRANCHEMENT DU CORDON

Ne pas brancher ou débrancher des cordons de bus d'interface général pendant que l'ordinateur, ou n'importe lequel des instruments, est sous tension. Ne pas respecter cette précaution risque d'endommager l'équipement.

The GPIB interface fully complies with IEEE-488.1-1987 as a talker/listener, able to generate service requests and to respond to serial poll and device clear commands. The interface does not support parallel polling and has no trigger function. Open-collector drivers are used on the bus lines, so the instrument does not prevent parallel polling of other devices connected to the bus.

The complete capability of the instrument is specified by the Capability Identification Codes:

SH1 AH1 T6 L4 SR1 RL0 PP0 DC1 DT0 C0 E1

17.2 Installing a GPIB board

17.2.1 Fitting the board

An GPIB board can only be fitted in the dedicated GPIB expansion slot.

- 1 Turn off electrical power to the iTC.
- 2 Remove the electrical power connector from the back of the unit.
- 3 Remove the screws that secure the lid of the iTC. There are 6 screws on either side panel of the iTC and 3 screws on the rear panel.
- 4 Lift off the lid.



Mercury iTC

- 5 Remove the two screws that secure the blanking panel in the location where the board is to be fitted. Keep the screws.

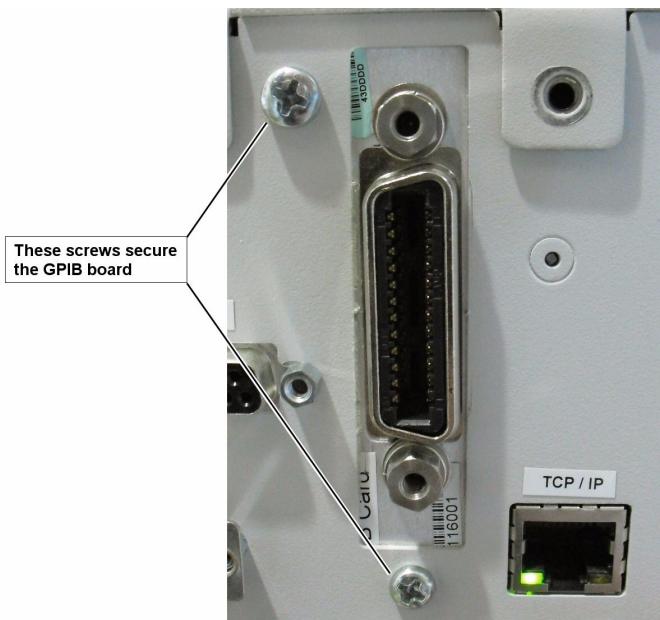


Figure 17-1 GPIB board

- 6 Using appropriate ESSD precautions, fit the GPIB board in the GPIB expansion slot.
- 7 Secure the board using the screws that were removed in step 5.
- 8 Refit the board-clamp, using the two screws that were removed earlier.
- 9 Fit the lid back onto the unit, using the screws that were removed earlier.

17.2.2

Connecting to a GPIB board

The GPIB board has a single GPIB connector. Connect the board to the GPIB bus, using a standard GPIB cable.

GLOSSARY

This glossary explains the acronyms, abbreviations and special terms used in this Instructions for Use Manual. The entries are presented in alphanumeric order.

Acronyms and abbreviations

ADC	Analogue to Digital Converter
ASCII	American Standard Code for Information Interchange
CJC	Cold Junction Compensation
DAC	Digital to Analogue Converter
DCE	Data Circuit-terminating Equipment
DHCP	Dynamic Host Configuration Protocol
DTE	Data Terminal Equipment
EPROM	Electrically Programmable Read-Only Memory
ESSD	Electrostatic Sensitive Devices
EOS	End of String
GPIB	General Purpose Interface Bus (IEEE-488)
GUI	Graphical User Interface
I/O	Input/output
LCD	Liquid Crystal Display
LED	Light Emitting Diode
N/A	Not Applicable
NTC	Negative Temperature Coefficient
PC	Personal Computer
PCB	Printed Circuit Board
PGA	Programmable Gain Amplifier
PTC	Positive Temperature Coefficient
PWM	Pulse Width Modulation
RT	Room Temperature
SCPI	Signal Orientated Measurement Commands (a command protocol)
SPI	Serial Peripheral Interface
TBA	To be Advised
UID	Unique Identifier
USB	Universal Serial Bus
VTI	Variable Temperature Insert

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