

# Oxford Instruments NanoScience

## MercuryITC

### Cryogenic environment controller

Issue 18 / Oct 2017 / Original Instructions



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## PREFACE

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

### Use of this manual

This Operator's Handbook provides all the information necessary for the safe and proper installation, operation and servicing of the **MercuryiTC** cryogenic environment controller..

Chapters 1 to 3 provide essential information that must be read and understood before operating the **MercuryiTC** for the first time.

### Intended users

Users of the **MercuryiTC** 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 MercuryiTC

The **MercuryiTC** 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 **MercuryiTC** is intended to be installed, used and operated only for the purpose for which the **MercuryiTC** 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

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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 **MercuryiTC** 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.

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### Revision history

This is issue 13 of the **MercuryiTC** Handbook, as shown in the header at the top 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 <b>MercuryiTC</b> Operator's Handbook
02	All pages	Changes to several GUI pages
03	All pages	Complete update of the <b>MercuryiTC</b> Operator's Handbook, describing version 2.0 of <b>MercuryiTC</b> software.
04	All pages	Minor edits: Generic Calibration, GPIB, CS addresses, to update to 2.2.x of <b>MercuryiTC</b> software (Cryosys).
05	All pages	Changes required for regulatory compliance updates
06	Pages 98-100	Added Ethernet port details
07	Pages 7 & 24	Amendments to compliance statement. Added background field caution statement.
08	Pages 108	Updated SCPI command list
09	Page 08	Updated certification information
10	Page 133	Correction on Auxiliary port pin functions
11	Page 8	Updated regulatory compliance
12	Various	Updates to safety information
13	Various	Operational updates resulting from firmware 2.3.0.0
14	Various	Operational updates resulting from firmware 2.4.0.0 New chapter for Lambda Point Fridge mode
15	Various	Disabling of plot functions
16	Page 144	Update to section 13.2.5 configuring the pressure sensor details.
17	Various	Remote command updates
18	Various	Updated and added Heliox commands (firmware 2.6.04.xxx and later)

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### Customer support

Oxford Instruments NanoScience has global customer support facilities that provide a coordinated response to customer 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.
- check the **Mercury** website at [www.mymercurysupport.com](http://www.mymercurysupport.com) for updates and technical notes.

If you are still unable to resolve the problem, please direct all queries through your nearest support facility (given on the last page of this manual) and have the following details available:

Product name	<b>MercuryiTC</b>
Serial number	A 9 character alphanumeric code starting with "TC" located on the iTC rear panel.
Application Firmware version number	From the home screen tap "Settings". On the "General" tab page, in the bottom-left corner, is a number of the form x.x.x(.x) e.g. 1.4.43 or 2.3.0.0. This is the Application firmware version number.
Device Firmware version number	From the home screen tap "Settings". Scroll across to the "Devices" tab. This page is a list of installed devices. The right-hand column contains the firmware version numbers of the form x.xx e.g. 2.3. This is the Device (e.g. temperature board) firmware version number.
Contact information	Your name, the name of your company or institution, and how we can contact you.
Problem	A description of the problem, with as much detail as possible, including any Alarms log entries.

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### Health and safety information

The **MercuryiTC** contains hazardous areas. Before working with the 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, it is advised that a copy of this handbook should be safely kept near the **MercuryiTC** when in operation.

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### 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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### Warranty

The Oxford Instruments customer support warranty is available to all our customers during the first 12 months of ownership from date of delivery. This warranty provides repair to faults that are a result of manufacturing defects at Oxford Instruments NanoScience.

### Acknowledgements

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

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## Acronyms

The following is a list of acronyms used in this manual.

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
DVM	Digital Volt Meter
EMC	Electromagnetic Compatibility
EPROM	Electrically Programmable Read-Only Memory
ESSD	ElectroStatic Sensitive Devices
EOS	End of String
GPIO	General Purpose Interface Bus (IEEE-488)
GUI	Graphical User Interface
I/O	Input/output
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPC	Lambda Point Controller
LPF	Lambda Point Fridge
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	Standard Commands for Programmable Instruments (a command protocol)
SPI	Serial Peripheral Interface
TBA	To be advised
TFT	Thin film transistor
UID	Unique Identifier
USB	Universal Serial Bus
VTI	Variable Temperature Insert

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## Certification compliance statements

The **MercuryiTC** cryogenic environment controller has been tested to the following standards and certifications:

- CE
- IEC61010-1: 2010 3<sup>rd</sup> Edition: Safety requirements for electrical equipment for measurement, control and laboratory use. (Intertek Report No. 101311638LHD-001)
- EN61326-1:2013: EMC Immunity standard, EN55011:2009+A1:2010 Emissions standard Electrical equipment for measurement, control and laboratory use: EMC requirements. (Intertek Report No.11053804B)



Conforms to ANSI/UL Std. 61010-1: 2012.

Cert. to CAN/CSA Std. C22.2 No. 61010-1-12

Control Number:

XXXXXX

Certification applied for.

- **cETL<sub>us</sub>** which is a harmonised standard with UL and CSA 

Note: The ETL mark is to be applied

China Restriction of Hazardous Substances



Signed: *M. N. Cuthbert*

Michael Cuthbert

Managing Director

Oxford Instruments NanoScience Limited

## MercuryiTC

### About Oxford Instruments

Oxford Instruments specialises in the design, manufacture and support of high-technology tools and systems for industry, research, education, space, energy, defence and healthcare.

We combine core technologies in areas such as low temperature and high magnetic field environments; X-ray, electron and optical based metrology; nuclear magnetic resonance, advanced growth, deposition and etching. Our aim is to be the leading provider of tools and systems for the emerging nanotechnology and bioscience markets.

### Oxford Instruments NanoScience Limited

Oxford Instruments NanoScience creates high performance environments for low temperature and high magnetic field applications in physical science research and process development down to the atomic scale.

The business has a strong capability in advanced cryogenics and applied superconductivity. Through the application of these technologies we deliver solutions that meet the exacting needs of scientists working at the forefront of fundamental physics, applied physics, materials science and next generation device development. With an extensive customer network, a strong reputation for performance and quality, we value the support we have provided to world leading research scientists in their pursuit of excellence.

### Oxford Instruments Direct

This provides one-stop shopping for cryogenics, magnetic, vacuum and associated laboratory products as well as hard to find references for low temperature physics, optics, thermometry and laboratory safety practices. You can also visit on-line at [www.oxinstdirect.com](http://www.oxinstdirect.com). Ordering parts is easy via phone, fax or email. Online ordering is available in North America.

## MercuryiTC

# 1 HEALTH AND SAFETY

This chapter describes all health and safety considerations relating to the Oxford Instruments NanoScience **MercuryiTC** 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 and functional 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 functional ground pillar on the rear panel, identified by a  symbol. This should be used to connect the cryostat chassis (or the experiment rig chassis if not a cryostat) to ensure the cryostat (or alternative chassis) is grounded. **Important Note: If the system being operated contains a superconducting magnet then the cryostat MUST be grounded to the magnet power supply (e.g. MercuryiPS) functional ground terminal, NOT the MercuryiTC functional ground terminal.**

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### 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 the screws and covers. To isolate this equipment, switch off the external AC electrical supply, and disconnect and remove the external supply cable. 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.

### 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. It is NOT sufficient to turn off the unit from the power-down button on the



front panel. It is also NOT sufficient to turn off the mains power switch on the rear panel

The unit MUST be disconnected from the mains supply. Also, the equipment contains capacitors that may remain charged after AC electrical power is removed. Wait at least 15 minutes after disconnecting the mains supply to ensure all the capacitors are discharged before starting work.

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### 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 contact.

## 1.2 Cautions

### 1.2.1 Electrostatic caution

#### *ELECTROSTATIC SENSITIVE EQUIPMENT*

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



#### *ÉQUIPEMENT SENSIBLE AUX DÉCHARGES ÉLECTROSTATIQUE*

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

### 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 **MercuryiTC** is to be rack mounted, to ensure an adequate airflow around the iTC, 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.*



#### *VENTILATION D'EQUIPMENT*

*Lorsque le **MercuryiTC** 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.*

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### 1.2.3 Acoustic noise caution

#### *MULTIPLE UNIT NOISE*

*If many **MercuryiTC** units are to be simultaneously operated in a confined space then background noise may become excessive.*



#### *UNITÉ MULTIPLE DE BRUIT*

*Si de nombreux MercuryiPS unités doivent fonctionner simultanément dans un espace confiné, puis le bruit de fond peut devenir excessive.*

## 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.

## MercuryiTC

## 2 MERCURY ITC BASICS

The **Mercury** Integrated Temperature Controller (iTC) is a high-performance laboratory temperature-controller designed for use in cryogenic applications.

The iTC is usually used to control the temperature of a sample whose properties are being investigated. The sample is in thermal contact with a sensor monitoring its temperature, a method of cooling the sample to cryogenic temperatures, and an optional heater for temperature control. The iTC can be configured to control the application of heat to a cooling medium, as this method provides better control than adjusting the refrigeration process. The **MercuryiTC** 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. A four-part number, such as 2.3.0.x, indicates the firmware version number. The first digit of this number indicates a major version of the firmware and the second part indicates a functional upgrade. The third part indicates minor revisions and the fourth part minor bug fixes.

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

The basic iTC includes a single input channel for one temperature sensor and a single 80 W heater output. The **MercuryiTC** can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground. For instance, the heater output is disabled if a faulty sensor is detected.

The **MercuryiTC** can accommodate up to eight optional daughter boards to allow additional features to be added, as follows:

Board description	Options
Temperature sensor boards	8 more, giving a total of 9 inputs
Heater boards (80W each)	3 more, giving a total of 4 outputs
Auxiliary board (general purpose and stepper motors)	Up to 8
Pressure sensor boards	Up to 8
Cryogen (helium and nitrogen) level meter board	Up to 8
GPIB board	1 only

# MercuryiTC

## 2.1 MercuryiTC front and rear panels

Figure 1 shows the front panel of the **MercuryiTC** and identifies the main features.

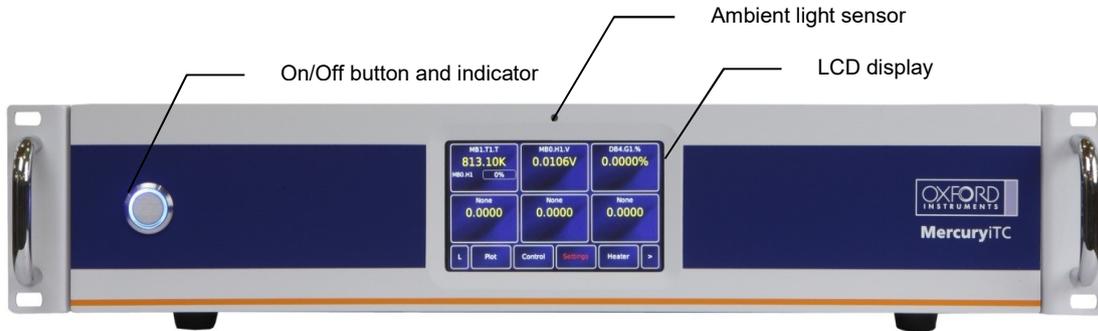


Figure 1 MercuryiTC front panel

The On/Off button on the front panel switches the iTC into/out of STANDBY mode. When the switch is off, electrical power is still supplied to the switch-mode power supply inside the iTC. The On/Off button illuminates blue when the iTC is powered up.

Figure 2 shows the rear panel of a **MercuryiTC**. This photo will not look exactly like your iTC as it depends on the number and type of boards fitted.

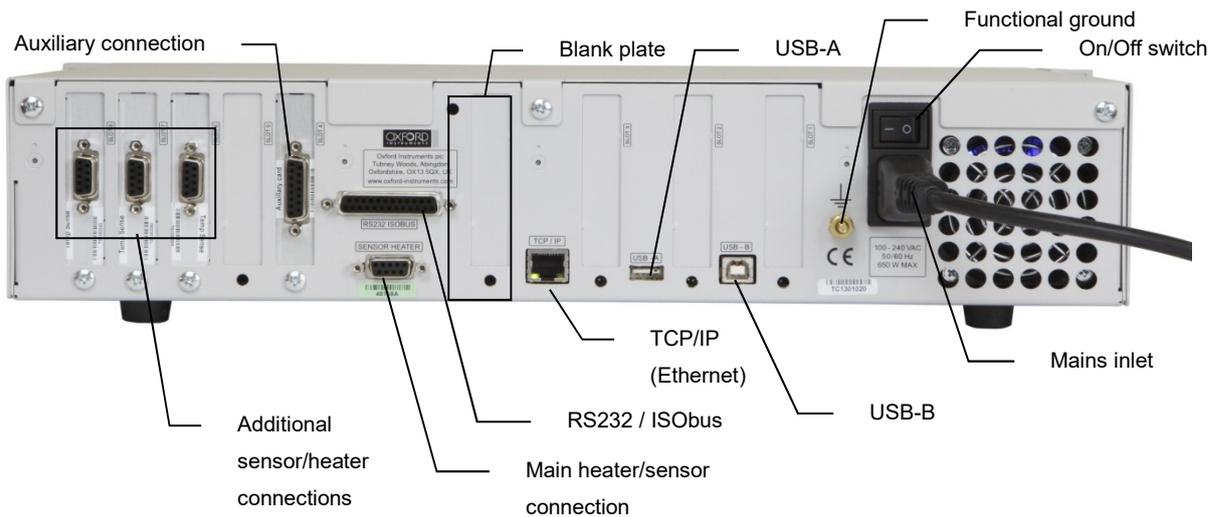


Figure 2 MercuryiTC rear panel (example)



The switch on the rear panel turns electrical power on and off. All connectors are labelled.

## MercuryiTC

### 2.2 Display and touch-screen

The **MercuryiTC** 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 front panel is also fitted with an ambient-light sensor. The iTC can be configured to change the display brightness automatically to match ambient light conditions.

### 2.3 Electrical power supply

The **MercuryiTC** 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.

Details of supply parameters are listed in section 18.2.

### 2.4 Temperature sensor circuits

The **MercuryiTC** can use 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.

### 2.5 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. Up to three additional heaters can be driven by adding daughter boards.

## MercuryiTC

### 2.6 Optional cooling circuit control

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.

Controlling the gas-flow regulates the cooling power, which provides control of the sample temperature. When the gas control is set to AUTO 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.

There are two possible configurations. The flow dynamics of these two arrangements are different.

- 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.

In the previous generation of Oxford Instruments temperature controllers, the position of the needle valve was controlled by a function that operated relative to the present valve position rather than to an absolute position. The output of the control function was related to the valve position by a Valve Gearing parameter that defined how many steps of the stepper motor were present between the valve fully-open and the valve fully-closed positions.

The current release of **Mercury** firmware allows real-time tracking of the needle valve position. Rather than update its state at the end of an open/close action, it does so as the valve moves along. This results in faster response time, more accuracy, and removes synchronization issues, since the reading is absolute. Now, only mechanical faults will result in losing track of the motor position.

## 2.7 Remote interfaces

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

- Serial RS232 and ISOBUS.
- Universal serial bus (USB).
- Ethernet 10/100 IEEE802.3.
- Optional general purpose interface bus (GPIB) (IEEE-488). This requires a GPIB daughter board.

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

Connectors for the communications interfaces are located on the rear panel of the iTC.

### 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.

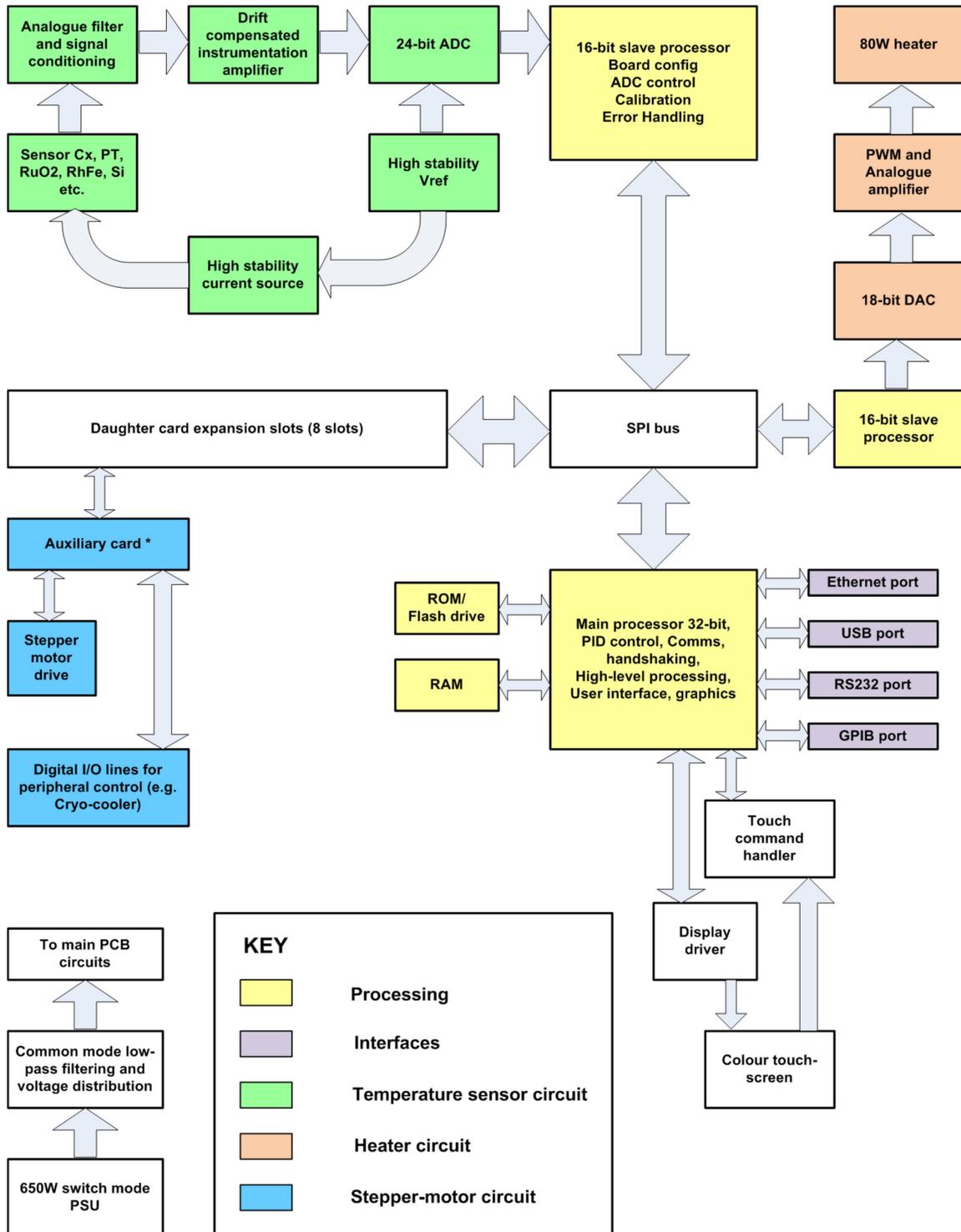
The slave connectors draw electrical power from the individual instruments, via the DCD signal. The master connector draws electrical power from either the DTR or RTS signals from the computer.

A special command protocol is required to use ISOBUS (see section 9.4.1).

# MercuryiTC

## 2.8 Functional Description

A block diagram of the MercuryiTC is given below.



## MercuryiTC

### 2.9 Main components

This section gives a brief description of the internal components of the MercuryiTC. Figure 3 shows how these components are arranged inside the **MercuryiTC** enclosure.

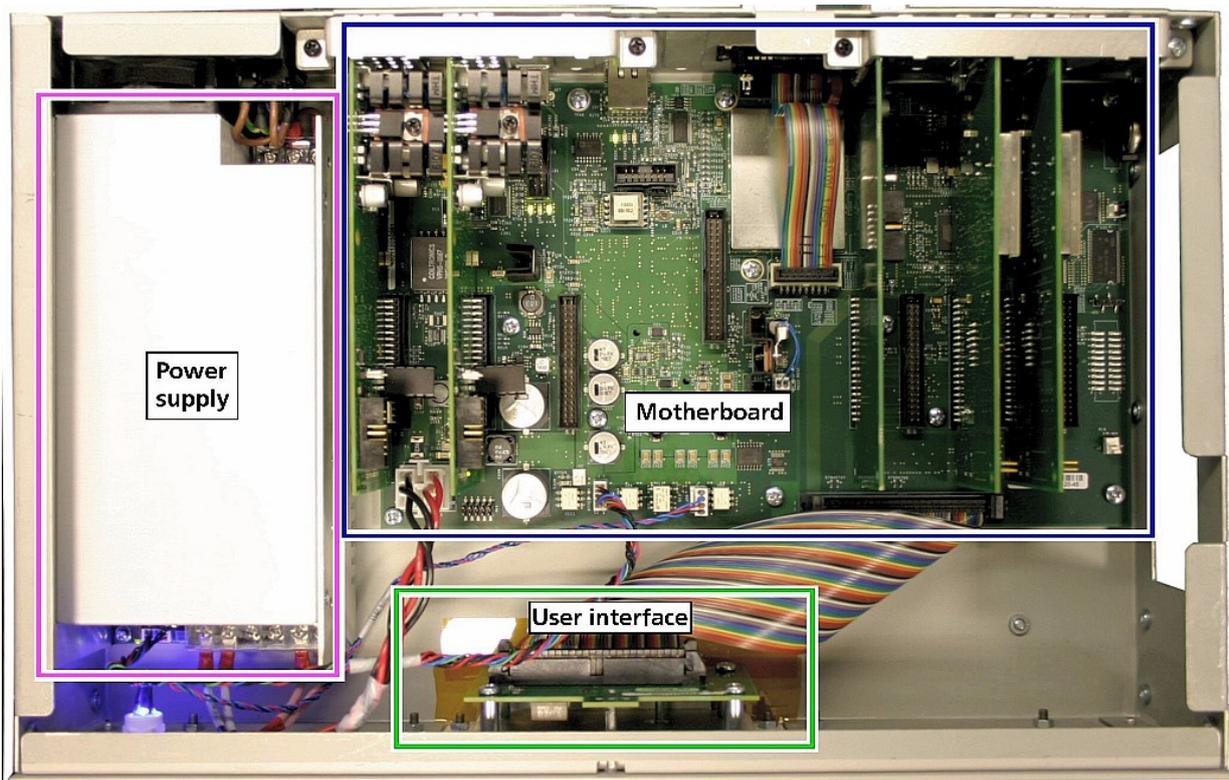


Figure 3 View of internal layout of MercuryiTC

The **MercuryiTC** consists of:

- a 2U high 19 inch rack or desktop enclosure
- a touch-screen user interface
- a power supply
- a motherboard PCB which contains the basic iTC functionality
- optional additional temperature sensor input(s) (on daughter boards)
- optional additional heater output(s) (on daughter boards)
- optional auxiliary I/O (stepper motor drive and logic I/O)
- optional GPIB (IEEE-488) interface.

## MercuryiTC

### 2.9.1 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.

### 2.9.2 Expansion slots and daughter boards

There are eight expansion slots on the iTC motherboard, each of which can accept an optional daughter board. There is a dedicated slot for a GPIB board. Slot number 1 is adjacent to the power supply in the iTC.

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

- **Temperature sensor**  
This is a board containing a single temperature sensor interface. A maximum of eight of these boards can be fitted. Chapter 10 gives a full technical description.
- **Heater**  
This is a board containing a single heater interface. A maximum of three heater boards can be fitted. Chapter 11 gives a full technical description.
- **Level meter**  
This is a board containing a single level meter, which is used to monitor the amount of gas or liquid in the system. A maximum of eight of these boards can be fitted. Chapter 5 gives a full technical description.
- **Auxiliary I/O board**  
This is a board containing a number of input/output (I/O) lines. Some of these lines are used to drive a stepper motor to control gas-flow. A maximum of eight of these boards can be fitted. Chapter 12 gives a full technical description.
- **GPIB**  
This is 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. Chapter 14 gives a full technical description.
- **Pressure**  
This is a board which measures signals from a pressure transducer. It can be used to control

## MercuryiTC

pressure in a cryogenic system. A maximum of eight of these boards can be fitted. Chapter 13 gives a full technical description.

The iTC automatically identifies every daughter board present.

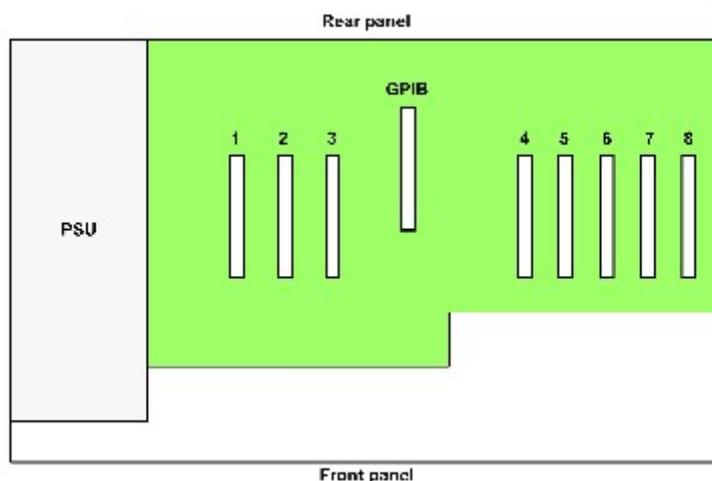


Figure 4 Layout of MercuryiTC expansion slots

The location of daughter boards is subject to certain constraints, as given in the following table.

Board	Allowed position	Typical position
Level sensor	Any	5
Auxiliary I/O	Any	4
Temperature sensor not used to control heater	Any	
GPIB	GPIB only	
Heater	1, 2 or 3	
Temperature sensor used to control heater	6, 7 or 8	
Pressure	Any	

### 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. If one or more heater boards are fitted, temperature sensor boards must be fitted in the corresponding slots listed below.

## MercuryiTC

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	

A control loop must be configured before a heater board can be operated. Any temperature sensor can be configured to control any heater. However, the cabling must conform to the above table. Configuration is described in section.4.5.

## 2.10 Alarms and interlocks

The **MercuryiTC** is designed to identify common faults, such as wiring errors that produce open-circuit or short-circuit conditions.

For errors that require immediate user intervention, the **MercuryiTC** sounds a 1kHz buzzer. The buzzer sounds intermittently, with the repetition rate increasing for more serious errors.

For some alarm conditions, an interlock operates to provide a safety feature. For instance, the heater output is disabled if a sensor fault is detected.

Chapter 17 gives a complete list of alarms and help to diagnose faults.

## MercuryiTC

### 3 GETTING STARTED

Ensure that you have read and understood the information in Chapter 1 before installing or operating this equipment.

#### 3.1 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 **MercuryiTC** automatically configures itself to match the supplied electrical power supply. If the voltage and frequency are within the specified ranges (see section 18.2), no user intervention is required.

#### 3.2 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 MercuryiTC is to be rack mounted, to ensure an adequate airflow around the iTC 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.*



##### VENTILATION D'EQUIPEMENT

*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.*

## MercuryiTC

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 iTC.

### 3.2.1 Background magnetic field



*The iTC should not be positioned in a background magnetic field of strength  $\geq 25$  gauss. Erratic behavior of the unit may result if this requirement is not observed.*

*Le iTC ne devrait pas être placé dans un champ magnétique de fond de la résistance  $\geq 25$  gauss. Comportement erratique de l'appareil peut se produire si cette exigence est pas observée*

### 3.3 Connecting electrical power



**USE THE SUPPLIED MAINS CABLE**

*Only use the electrical supply cable included with the equipment.*

**UTILISEZ UNIQUEMENT LE CÂBLE FOURNI**

*Utilisez uniquement le câble d'alimentation électrique fourni avec l'équipement..*

Connect the equipment to an electrical supply using the mains cable supplied.

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 national 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.

# MercuryiTC

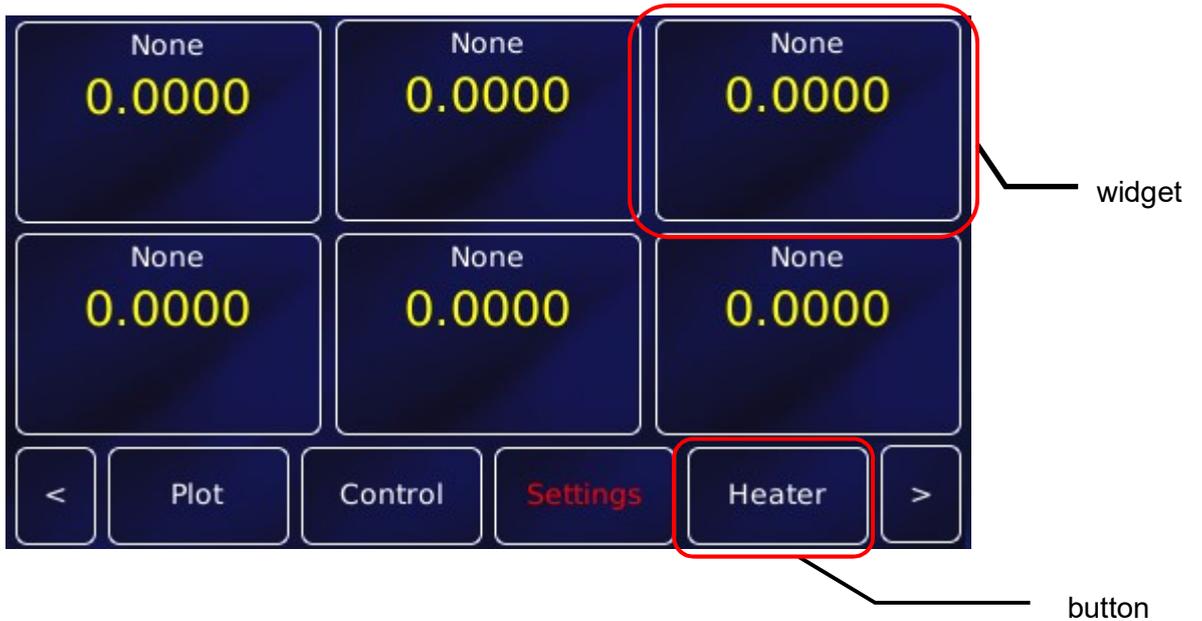
Green/yellow covered conductors must only be used for connection to protective ground terminals.

The back panel contains an IEC C14 connector for the main electrical supply to the **MercuryiTC**. Section 18.2 gives mains electrical requirements.

## 3.4 Powering up the MercuryiTC for the first time



- 1 Operate the switch on the rear panel of the **Mercury** so that the **1** is depressed.
- 2 Press the **Power** button on the left of the front panel. The button illuminates blue.
- 3 The **MercuryiTC** initialises, then the **Home** page appears on the touch screen.



• This screenshot shows the default home page. A different home page will appear if Oxford Instruments has pre-configured the iTC for your system.

## 3.5 The MercuryiTC touch screen

The touch screen is the graphical user interface (GUI) for the **MercuryiTC**.

## MercuryiTC

The complete set of information visible on the touch screen at any one time is called a **page**.

The label (if any), found in the top left corner, will be used to identify the page.

The Home page has 6 configurable regions where sensor parameters can be displayed. These are known as **widgets**.

Each page of the GUI contains a number of active areas. To initiate an action, tap the relevant active area once.

The bottom of the Home page shows examples of **buttons**. To initiate an action, tap the button once. The button will change colour when active, either flashing ORANGE or switching between ORANGE and a dark background colour (BLUE/BLACK), depending on context.

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

### 3.5.1 The home page



The **Home** page contains the following features:

- Six channel-summary widgets. Each displays summary information for a channel that is enabled (see section 3.5.3).
- 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.

# MercuryiTC

**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 blue 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 **Error! Reference source not found.**).
- **Control** button. Tap once to display control-loop information. Heater power (section 4.5) and gas flow (section 4.8) can be controlled.
- **Settings** button. Tap once to display the General Settings tab, one of a number of Settings pages (chapter 6). If the text is RED, as shown above, then check the alarm log (section 17.1).
- **Heater** button. Tap once to display the Heater Configuration page (see section 4.3).
- Left and right scroll-buttons to display two more **home** pages. This provides a total of 18 configurable widgets.

### 3.5.2 Custom home pages

For certain products, such as Heliox and Cryojet, one of the three home pages has been extensively re-configured in the factory to suit the special features of the product. A full description of these “Custom home pages” is provided with the appropriate product manual.

Custom home pages cannot be re-configured by the user.

### 3.5.3 Channel summary widget

Typical channel-summary widgets on the **Home** page are shown below.



If the widget has not been configured it displays the name None and the value 0.0000.

If the widget has been configured, it displays the following information:

## MercuryiTC

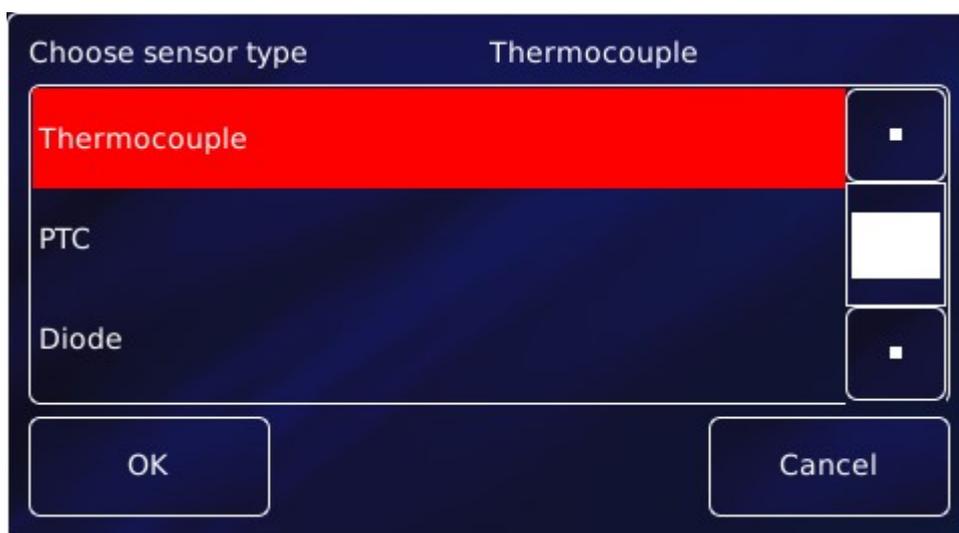
- Channel identifier or nickname.
- The main display value for the channel (e.g. measured temperature).
- Identifier of the channel heater (if applicable).
- Output power of the channel heater (if applicable).
- Identifier of the gas-flow controller (if applicable).
- Percentage flow for the gas-flow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

### 3.5.4 Drop-down menus

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



- 1 Tap once, anywhere in the parameter box, 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.



## MercuryiTC

### 3.5.5 Scrolling

On some pages there is not enough space to display all the keys or information associated with

the page. This is indicated by a button with the label  or .

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



### 3.5.6 Soft keypads

Certain parameter boxes in the GUI require the user to enter alphanumeric characters. Tap the parameter box to display a keypad.

There are two types of keypad that may be displayed. If a parameter box requires numeric data only, a numeric keypad is displayed.



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

This keypad contains 10 single-digit keys and a decimal point key.

- Tap **Del** once to delete the last character entered.

## MercuryiTC

- To delete or edit a single digit within the number, touch the digit to highlight it, then tap **Del** or tap the new digit
- To delete or edit several digits within the number, touch the digits until they are highlighted, then tap **Del** or tap the new digits.
- Tap **OK** to save the number entered.
- Tap **Quit** to close the keypad without saving the number that has been entered.

**CAPS** is not used.

If a parameter box requires alphanumeric data, an alphanumeric keypad is displayed.



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

This keypad contains 10 character-entry keys and a decimal-point key.

- Tap **Del** to delete the last entered character.
- To delete or edit a single digit within the string, touch the character to highlight it, then tap **Del** or tap the new character
- To delete or edit several characters within the string, touch the characters until they are highlighted, then tap **Del** or tap the new characters.
- Tap **OK** to save the text that has been entered.

## MercuryiTC

- Tap **CAPS** to use capital letters. The characters on the keypad change to match the selection.
- Tap **Quit** to exit the keypad without saving the number that has been entered.

Each character-entry key represents several characters.

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

For example:

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

### 3.5.7 Using arrows to adjust integer values

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



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

- Tap  once to increase the displayed value.

### 3.5.8 Button labels

The label on some buttons changes depending on the button function. The label on most buttons describes the present state of the iTC. For example, the button shown on the left below is labelled Auto, indicating that the function is in automatic mode. Tap the button once to select Manual mode.

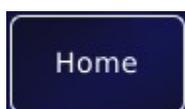
## MercuryiTC

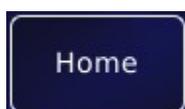


Some buttons operate differently to the method just described. The operation of these buttons is described in the text.

### 3.5.9 Common touch screen features

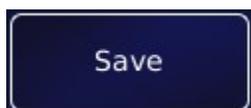
The following buttons appear on several pages of the GUI.

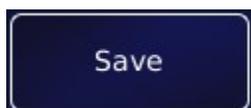


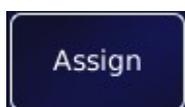
- Tap  once to return to the Home page.

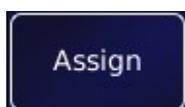


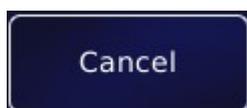
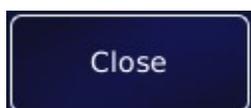
- Tap  once to load a file (such as a sweep table or PID table).

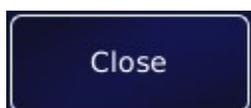


- Tap  once to save changes in a table.



- Tap  or  once to save changes to the page.



- Tap  or  to leave the current page without making any changes.

### 3.5.10 Setting the date and time

This process is a simple example showing how the touch screen is used.

- 1 Tap **Settings** on the Home page. This displays the first of several Settings pages.

## MercuryiTC



- 2 Scroll the tabs using  until the Clock tab is displayed.



- 3 Edit the date and time using the scroll buttons  .
- 4 Tap **Apply** to apply the changes.
- 5 Tap **Home** to return to the **Home** page.

## 4 HOW TO MEASURE AND CONTROL TEMPERATURE

Standard **Mercury**iTCs are fitted with one temperature board and one heater board. The temperature board is used to measure temperature and is normally combined with the heater board to control the temperature. The iTC uses a PID loop to control each heater (see chapter 15 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.

A temperature sensor board can also be combined with an optional auxiliary I/O daughter board to control a stepper motor. This is commonly used to control the motorised valve in a continuous-flow cryogenic cooling system.

The iTC 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 iTC 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.

This chapter covers the following topics.

- Cabling requirements
- Configuring the temperature sensor
- Configuring the heater
- Configuring the heater control loop
- PID control and PID tables
- Configuring the gas control loop (optional)

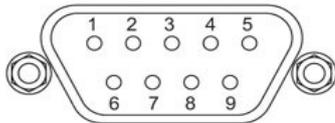
## MercuryiTC

- Using a generic calibration file (if applicable) + generic sensor adjustment
- More about thermocouples

See chapter 10 for a description of the temperature sensor circuit and chapter 11 for a description of the heater circuit.

### 4.1 Heater and sensor connections

The temperature sensor input and heater output are connected via the 9-way D-connector on the rear panel of the iTC.

Pin number	Connection	Male plug (cable)
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	Connected to pin 3	
9	Chassis ground.	

Connections to the sensor vary depending on the type of sensor in use, as summarized in the next table.

Connection	Thermocouple	Metal resistor	Ge/C resistor	Si/GaAs diode
Sensor Input High	V+	V+	V-	V+
Sensor Input Low	V-	V-	V+	V-
Current source +ve	Connect pins 3,4,5 together	I+	I+	I+
Current source -ve	Connect pins 3,4,5 together	I-	I-	I-

#### 4.1.1 Connecting thermocouples

Thermocouples must be connected using the correct wire type to ensure accurate measurements.

Stability of the measurement is improved by biasing thermocouples above the ground plane of the iTC. This is achieved by connecting together pins 3, 4 and 5 of the 9 way D connector (see table above). Biasing the thermocouple in this way prevents error currents flowing in the

## MercuryiTC

thermocouple even if the equipotential isothermal junction is grounded, as the iTC measurement circuit is fully isolated.

To reduce noise and increase accuracy, the connector should have a hood fitted with a cable gland (seal between cable and hood) to minimise any air current flowing around the thermocouple connection pins. It is preferable for this hood to be plastic, rather than metal, since this allows the connection pins to more closely match the iTC's internal reference temperature.

## 4.2 Configuring a temperature sensor

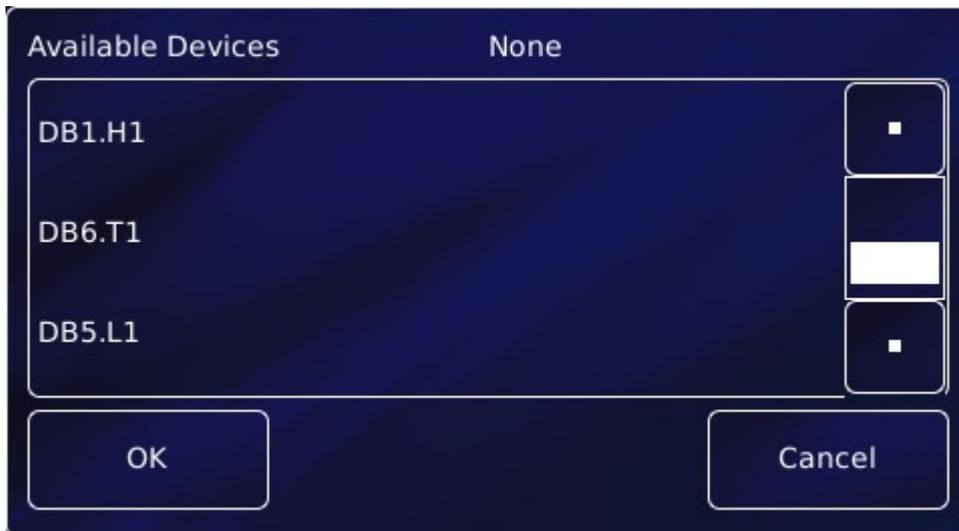
The home page shows six widgets and four buttons. If the iTC is not yet configured, all six widgets will display None and 0.0000. Additional widgets can be displayed by scrolling left or right by tapping the appropriate scroll button.

- 1 Tap once on an unconfigured widget. The Channel Display Configuration page is displayed.



- 2 Tap the **Device** parameter box and choose a temperature sensor input from the drop-down list. This will be labelled **\*\*\*.T1** (DB6.T1 in the example below). Then tap **OK**.

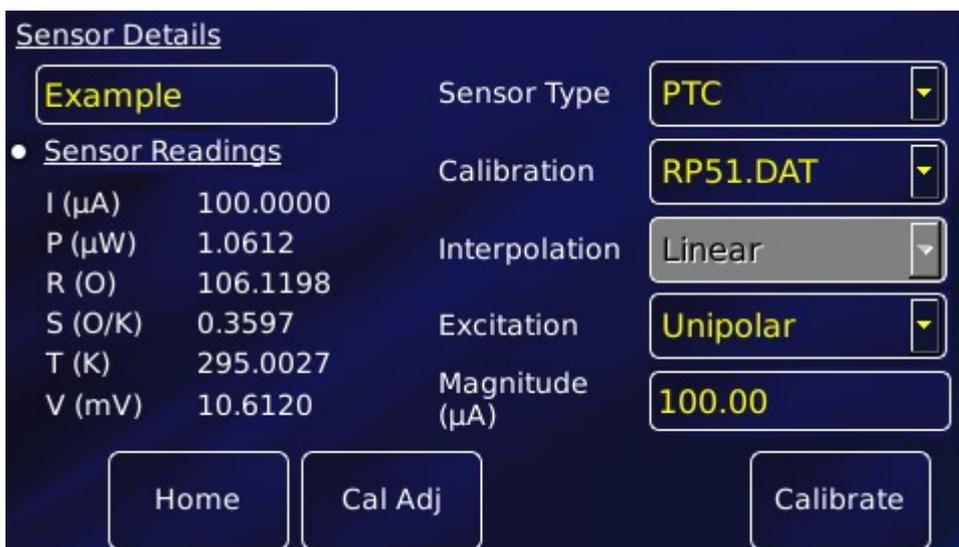
# MercuryiTC



- 3 Tap **Signal** and select **Temperature**. Then tap **OK**.
- 4 Finally, tap **Assign** to save the changes and to return to the **Home** page.
- 5 If required, configure other widgets on the Home page in a similar fashion.

## 4.2.1 Configuring the sensor details

- 1 Tap a configured widget on the **Home** page. The **Sensor Details** page is displayed.



The list of Sensor Readings depends on the type of sensor but will generally include

- I** (µA) - the sensor excitation current in µA.
- P** (µW) - the power dissipated in the sensor in µW.

## MercuryiTC

**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 excitation voltage in mV.

2 Tap the **Sensor Type** parameter box and select a sensor type from the drop-down menu.

Sensor types include

(a) thermocouple

(b) PTC - positive temperature coefficient sensor

(c) NTC - negative temperature coefficient sensor

(d) Diode

A detailed description of sensor types is given in section 4.10.

3 Tap the **Calibration** parameter box and select a calibration file from the drop-down menu.

The list of files available depends on which sensor type is selected. If you select a Generic calibration file, you can later adjust the calibration to suit a particular sensor (see section 4.9).

4 **Interpolation**

Linear interpolation is used to calculate the calibration curve from the calibration table.

5 Tap the **Excitation** parameter box and select an excitation mode from the drop-down menu (see section 4.10.5).

6 Tap the **Magnitude** parameter box and enter an excitation value using the numeric keypad:

(a) If **Sensor Type** is set to PTC, enter an excitation current in  $\mu\text{A}$ .

(b) If **Sensor Type** is set to Diode, enter an excitation current in  $\mu\text{A}$ .

(c) If **Sensor Type** is set to NTC, enter an excitation voltage in mV.

(d) If **Sensor Type** is set to Thermocouple, this value is ignored.

Tap OK to accept the value and return to the **Sensor Details** page.

7 If desired, tap the parameter box containing the name of the sensor and enter a new name. (e.g. Change **DB3.T1** to **Example**).

8 **Cal Adj**

Tap once to access the Generic Sensor Adjustment page (see section 4.9.2). This allows the user to adjust the scale and offset of a generic calibration curve to suit a particular sensor.

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### 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.

- 10 Tap **Home**. The Home page is displayed. If the sensor has been configured correctly (and is connected), the selected page will display a sensor reading.

### 4.2.2 To clear a widget configuration

- 1 Double-tap the widget on the **Home** page.
- 2 Tap the **Device** parameter box and select **None** from the drop-down menu.
- 3 Tap **Assign**.

The widget on the Home page should now display the name None.

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### 4.3 Setting heater properties

This page displays a set of values for every configured heater, in particular voltage limits for individual heaters. If your **MercuryiTC** is supplied as part of a system, this page will be set up already.

Tap **Heater** on the Home page to view the heater properties page.

Heater #	Name	Lim(V)	Res( $\Omega$ )	P(W)
DB2.H1	DB2.H1	1	10	0.000 0%
DB1.H1	DB1.H1	1	10	0.000 0%
MB0.H1	MB0.H1	1	10	0.000 0%
No Device	Not Set	Not Set	Not Set	0.0000

Home      Control      Calibrate

The following parameter boxes and values are displayed for each heater:

- Heater #**  
 This displays the UID of the heater. This number cannot be edited.
- Name**  
 A name to identify the heater. Tap this parameter box once to display an alpha-numeric keypad and enter a new name, if required.
- Lim (V)**  
 The maximum voltage to be applied to the heater. Tap this parameter box once to display a numeric keypad and enter a new value, if required.
- Res ( $\Omega$ )**  
 The electrical resistance of the heater in ohms. Tap this parameter box once to display a numeric keypad and enter a new value, if required.

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- **P(W)**

This parameter box 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 4.5 for heater control and 4.8 for gas control).

- **Calibrate**

Tap once to calibrate this measurement circuit. This routine takes approximately one minute for each heater. An error message is generated if the calibration fails for any reason.

## 4.4 Configuring a heater control loop

- 1 Double-tap a configured widget on the **Home** page. The Channel Display Configuration page is displayed.



- 2 Tap **Pair**. The Device Pair Configuration page is displayed. This is used to “pair” or “join up” a heater and a sensor. A temperature sensor is normally paired with a heater. The page contains a table with 7 columns. You must scroll to the right to see them all. The appearance of the page with no configured pairings is shown below.

## MercuryiTC

Device Pair Configuration

	Sensor	Heater	Flow	Ctrl Samples	Disp Samples	Cold Limit	Hot Limit
1	DB4.P1	None	DB3.G1			0.0000K	1.5000K
2	DB6.T1	DB1.H1	None	1	8	0.0000K	1000.00K
3	DB7.T1	None	None	1	8	0.0000K	1000.00K
4	DB8.T1	DB2.H1	None	1	8	0.0000K	318.15K
5	MB1.T1	None	None	1	8	0.0000K	1000.00K

Home

Device Pair Configuration

	Flow	Ctrl Samples	Disp Samples	Cold Limit	Hot Limit	Hot Action	Cutoff
1	G1			0.0000K	1.5000K	Cut This Htr	None
2		1	8	0.0000K	1000.00K	Cut This Htr	None
3		1	8	0.0000K	1000.00K	Cut This Htr	None
4		1	8	0.0000K	318.15K	Cut All Htrs	None
5		1	8	0.0000K	1000.00K	Cut This Htr	None

Home

- Tap to select the name of the required temperature sensor in the **Sensor** column. The soft keypad opens to allow you to edit the sensor name, if required. **Quit** to return.
- Tap the adjoining cell in the **Heater** column. A list of available heaters appears, one for each heater board fitted. Select the heater and tap OK. Select **None** to remove this pairing.
- Tap the adjoining cell in the **Flow** column. A list of available gas flow controllers appears, one for each Auxiliary I/O board fitted. Choose and tap OK. Select **None** to remove this pairing.
- Cold Limit** This value can only be changed in engineering mode. Section 7.7 describes how to access engineering mode.  
Enter a lower temperature limit. If the sensor temperature falls below this limit, the gas flow

## MercuryiTC

is disabled. From 2.3.0.0 it is possible to set this to a negative value which is useful for pressure control as the gauges can return a small negative value.

- 7 **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 output is switched off.
- 8 **Hot Action** This value can only be changed in engineering mode.  
From firmware version 2.3.0.0 onward, there is an option in the table to configure the “Hot Limit” via “Hot Action” to switch off all of the heater outputs. So, with this option set to “Cut All Htrs”, if the iTC is running 4 PID loops controlling 4 heaters, if the sensor controlling this loop exceeds its Hot Limit all 4 heaters will be switched off.
- 9 **Cut off** This value can only be changed in engineering mode.  
This is an additional safety feature, normally set to the end of the calibration range. An external input from the auxiliary I/O card (if fitted) cuts off the heater if the sensor reaches the indicated temperature.
- 10 Tap Home to return to the **Home** page.

## 4.5 Controlling the heater

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, if a single heater board is fitted in slot 2, a temperature sensor board must be fitted in slot 7. The control loop can be configured such that the slot 2 heater (DB2.H1) is controlled by any temperature sensor (eg MB1.T1). However, the heater output voltage will appear on slot 7 (pins 1 and 2) so the cabling must be designed accordingly.

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

## MercuryiTC

- 3 Tap the **Heat(%)** button to select either Manual or Auto Control. **Manual** configures the heater for open-loop control (see section 4.5.1). **Auto** configures the heater and associated temperature sensor in a closed control loop (see section 4.5.2).

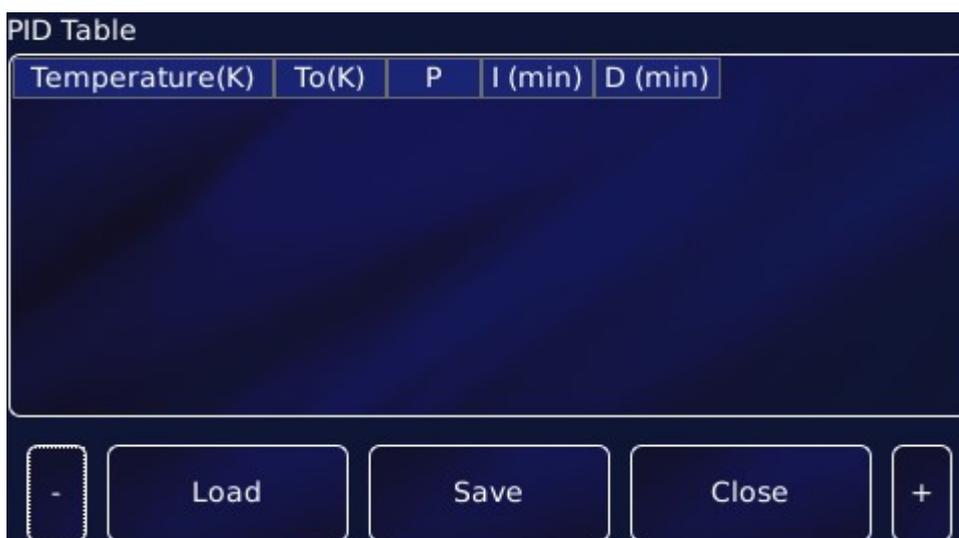
### 4.5.1 Configuring manual heater control

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

### 4.5.2 Configuring automatic heater control

The **MercuryiTC** uses a PID table to control the heater. For a detailed description of the principles involved, please consult chapter 15.

- 1 If you selected **Auto** 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. 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** parameter boxes.
- 3 If you selected Automatic PID operation, tap **PID Table**. The **PID Table** editor page is displayed. This example shows an empty table.



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- Tap **Temperature (K)** to edit the lower temperature of the temperature range for this row of the table.
- Tap **To (K)** to edit the higher temperature of the temperature range for this row of the table.

The value of **To (K)** must be greater than **Temperature (K)**.

- Tap **P** to enter the width of the proportional band. Tap **I** and **D**, respectively, to enter values for the integral and differential parameters.
- Alternatively, tap **Load**, select a file from the list, then tap **Load** again, to load an existing PID table.

PID Table		Microhe.pid		
Temperature(K)	To(K)	P	I (min)	D (min)
1.0000	15.000	50.00	1.000	0.000
15.000	30.000	40.00	1.000	0.000
30.000	60.000	30.00	1.000	0.000
60.000	115.00	20.00	1.000	0.000
115.00	225.00	15.00	1.000	0.000

Buttons: -, Load, Save, Close, +

- You can edit this table, as follows.

Tap any cell to edit its value using the soft keypad.

Tap  once to delete the entire row containing a selected cell. Tap **OK** to confirm.

Tap  once to add a row to the table below the row containing a selected cell. The first cell of the new row is automatically set to 0.001K above the upper temperature programmed in the previous row.

- Tap **Save** once to save the new table. You will be prompted for a filename. Tap the filename parameter box and use the soft keypad to create a name.

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- 10 Tap **Close** to return to the Control Loop Configuration page. If changes have not been saved, they will be ignored.
- 11 Tap **Home** to return to the Home page.

### 4.5.3 Changing a temperature set point in automatic control

- 1 Tap **Control** on the Home page. The **Control Loop Configuration** page is displayed.
- 2 Select the required temperature sensor. Tap the **Sensor** parameter box and select the sensor from the list. Tap **OK**.
- 3 Tap the **Heat(%)** button until it displays **Auto**.
- 4 Tap the **Set Point** button until it displays **Fixed**.
- 5 Tap the set point parameter box to open a numeric window. Enter the new set point.
- 6 Tap **Home** to return to the Home page.

### 4.5.4 Switching control modes

When switching control modes the iTC will attempt to maintain loop stability. Switching from auto (closed loop) to manual (open loop) the iTC will fix the heater voltage output at the value at the point of switching. From firmware versions 2.3.0.0 onwards, when switching from manual to auto, the iTC will make a calculation to pre-load the PID integrator to provide the correct output to maintain stability. Note: for best results, change the set point to the current control signal value (temperature for a temperature control loop or pressure for a pressure control loop).

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Control Loop Configuration

Sensor	Example	PID (H)	Auto
Heat(%)	Auto 0.00	P	15
Flow(%)	Manual 0.00	I	1.0
Set Point	Fixed 123.45K	D	0

Home Sweep Gas Cfg PID table

## 4.6 Using the sweep function

### 4.6.1 The purpose of the sweep function

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

During a sweep, the system updates the temperature set point every 100 mSec.

A program can contain as many sweeps and steps as required. Each sweep 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 retained in non-volatile memory when the iTC is switched off.

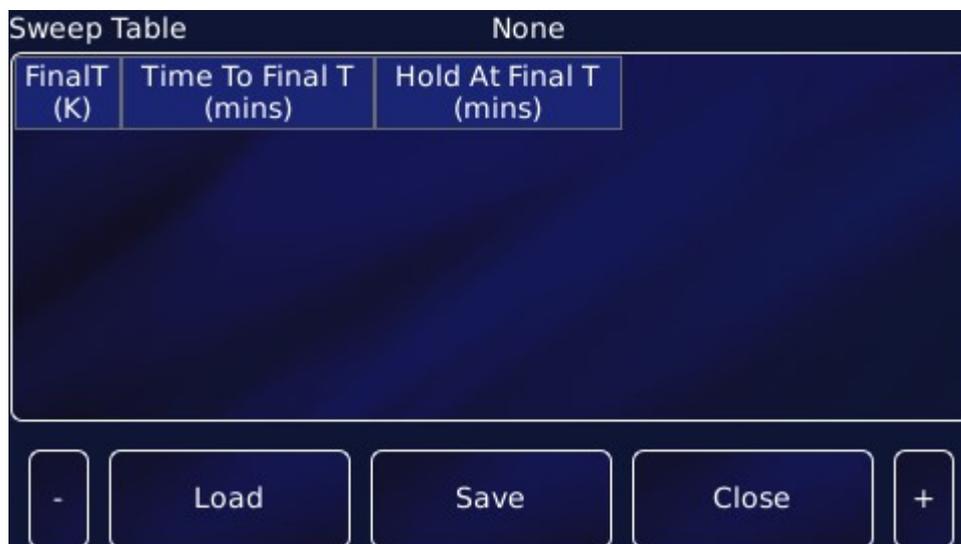
The Auto-PID facility may be used in conjunction with the sweep function to provide optimum control over a wide temperature range. To avoid discontinuities during a sweep, it is recommended that the start and end temperatures for the sweep coincide with Auto-PID segments.

### 4.6.2 Using the sweep function

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature sensor from the list in the **Sensor** parameter box.
- 3 Tap **Heat(%)** to read Auto.

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- 4 Tap the **Sweep** button. The Sweep Table page opens.



- 5 Tap  to add a row to the table.

- 6 Enter the temperature (in K) for the first step in the **FinalT(K)** parameter box in row 1 of the Sweep Table.

- 7 Enter the time for the first ramp (in minutes) in the **Time To Final T(mins)** parameter box in row 1.

- 8 Enter the time to hold the step temperature (in minutes) in the **Hold At Final T(mins)** parameter box in row 1.

- 9 Tap  to add another row to the table and repeat steps 6 – 8.

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Sweep Table		Sweep2
FinalT (K)	Time To Final T (mins)	Hold At Final T (mins)
297.00	1.000	1.000
299.00	1.000	1.000
305.00	1.000	2.000
315.00	15.000	5.000

Below the table are five buttons: a minus sign (-), a button labeled "Load", a button labeled "Save", a button labeled "Close", and a plus sign (+).

10 Tap a cell in the table, then tap  to remove a complete row.

11 When the complete sequence is programmed, tap **Save** to save the programmed sweep as a file.

12 Tap **Close** to return to the Control Loop Configuration page.

13 Tap **Home** to return to the Home page.

### 4.6.3 Loading a sweep

1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.

2 Select the required temperature sensor from the list in the **Sensor** parameter box.

3 Tap **Sweep**. The **Sweep Table** page opens.

4 Tap **Load** and select the filename of the sweep to be loaded.

### 4.6.4 Starting a sweep

1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.

2 Select the required temperature sensor from the list in the **Sensor** parameter box.

3 Tap the **Set point** button until it displays **Sweep**. The Set point parameter box value will change as the sweep proceeds.

## MercuryiTC

### 4.6.5 Stopping a sweep

- 1 Tap **Control** on the Home page. The Control Loop Configuration page is displayed.
- 2 Select the required temperature sensor from the list in the **Sensor** parameter box.
- 3 Tap the **Set point** button until it displays **Fixed** . The Set point parameter box value is held at its current value.

## 4.7 Using the ramp function

### 4.7.1 The purpose of the ramp function

Firmware version 1.4.40 introduced additional functions to provide set point ramps. A ramp rate is set in K/m (Kelvin per minute) and when the ramp mode is enabled, any change in the set point will occur at this rate.

### 4.7.2 Using the ramp function

Ramp mode can only be enabled (or disabled) by remote SCPI commands.

The mode is control loop specific so for iTCs with multiple PID control loops configured, setting one of them into ramp mode will not set the others into ramp mode. To use ramp mode, follow these steps.

- 1 Send a remote command to set the desired ramp rate (K/min)

```
SET:DEV:MB1.T1:TEMP:LOOP:RSET:5.25
```

This command sets the ramp rate to 5.25K/min for the control loop controlled by the MB1 temperature sensor input. The system returns

```
STAT:SET:DEV:MB1.T1:TEMP:LOOP:RSET:VALID
```

- 2 Send a remote command to read the temperature

```
READ:DEV:MB1.T1:TEMP:SIG:TEMP
```

The system returns

```
STAT:DEV:MB1.T1:TEMP:SIG:TEMP:xxx.xxxxK
```

where xxx.xxxx is the value of the temperature.

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Please note that the ramp will start from the current setpoint, not the current temperature. The ramp starts as soon as the new set point is entered.

- 3 Send a remote command to set the set point to the temperature just read as a starting point for the ramp.

```
SET:DEV:MB1.T1:TEMP:LOOP:TSET:xxx.xxxx
```

This command sets the temperature set point to xxx.xxxxK for the control loop controlled by the MB1 temperature sensor input. The system returns

```
STAT:SET:DEV:MB1.T1:TEMP:LOOP:TSET:VALID
```

- 4 Send a remote command to put the loop in ramp mode

```
SET:DEV:MB1.T1:TEMP:LOOP:RENA:ON
```

This command sets Ramp mode ENABled (RENA) ON for the control loop controlled by the MB1 temperature sensor input. The system returns

```
STAT:SET:DEV:MB1.T1:TEMP:LOOP:RENA:VALID
```

### 4.7.3 Starting a ramp

To start the ramp, send a remote command to set the set point to the desired temperature, such as:

```
SET:DEV:MB1.T1:TEMP:LOOP:TSET:300.0
```

This command sets the temperature set point to 300.0K for the control loop controlled by the MB1 temperature sensor input. This will start the loop set point ramping at the ramp rate previously set.

```
STAT:SET:DEV:MB1.T1:TEMP:LOOP:TSET:VALID
```

### 4.7.4 To disable ramp mode

To disable ramp mode, send a remote command such as:

```
SET:DEV:MB1.T1:TEMP:LOOP:RENA:OFF
```

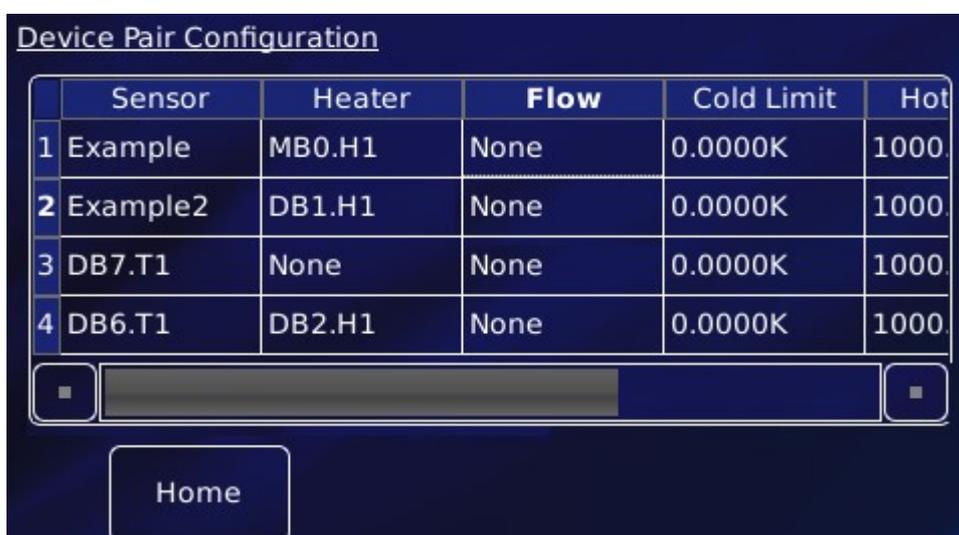
## MercuryiTC

This command sets Ramp mode ENABled (RENA) OFF for the control loop. The system returns

```
STAT:SET:DEV:MB1.T1:TEMP:LOOP:RENA:VALID
```

### 4.8 Configuring a gas valve

- 1 Double tap any configured widget on the **Home** page.
- 2 Tap **Pair**. The Device Pair Configuration page appears.



- 3 In the row for the desired sensor, tap the cell in the **Flow** column. Select the gas controller from the drop-down menu (not shown).
- 4 Tap **OK** to save the configuration. The example below shows a gas controller in daughter board number 4.

## MercuryiTC

Device Pair Configuration

	Sensor	Heater	Flow	Cold Limit	Hot
1	Example	MB0.H1	None	0.0000K	1000
2	Example2	DB1.H1	DB4.G1	0.0000K	1000
3	DB7.T1	None	None	0.0000K	1000
4	DB6.T1	DB2.H1	None	0.0000K	1000

Home

- 5 Tap **Home** to return to the Home page.
- 6 Tap **Control** . The Control Loop Configuration page opens.

Control Loop Configuration

Sensor **Example2** PID (H) **Manual**

Heat(%) **Manual** **0.00** P **1.0**

Flow(%) **Manual** **0.00** I **1.0**

Set Point **Disabled** **nanK** D **1.0**

Home Sweep Gas Cfg PID table

- 7 Select the sensor that you want to configure in the **Sensor** parameter box.
- 8 Tap the **Flow(%)** button to select either **Manual** or **Auto** Control. **Manual** configures the gas controller for open-loop control (see section 4.8.1). **Auto** configures the gas controller and associated temperature sensor in a closed control loop (see section 4.8.2).

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### 4.8.1 Configuring manual control of the gas valve

- 1 If **Manual** is selected in the **Flow(%)** parameter box, 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.

**Gas Flow Configuration**

Sensor	Example2	Type	VTI
TES	0	GFSF (%)	50
TVES	0	HTT	None
MIN Gas Flow(%)	0	Valve Gearing	0

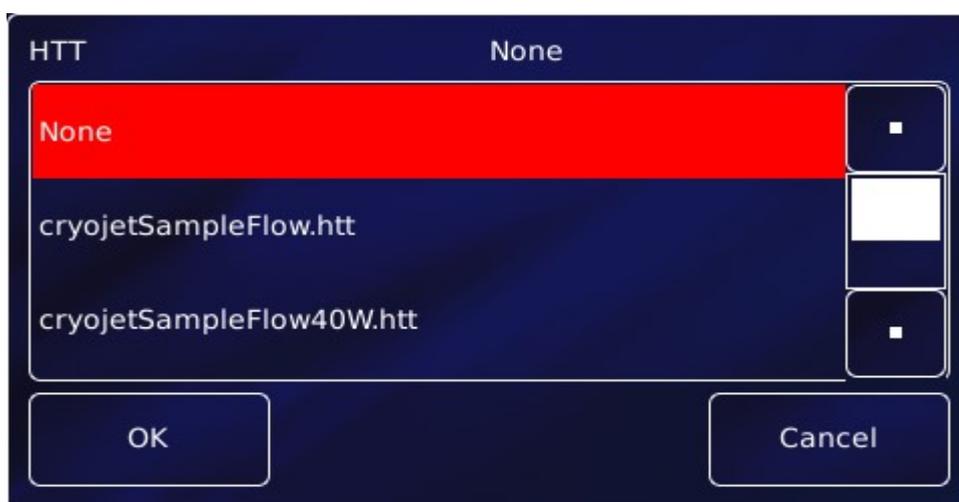
Home Control Reset

- 3 Tap **Valve Gearing** and enter the required value. See section 15.3 for an explanation of Valve Gearing.
- 4 Tap **Home** to return to the Home page.

### 4.8.2 Configuring automatic control of the gas valve

- 1 If **Auto** is selected in the Flow(%) parameter box, tap **Gas Cfg**. The Gas Flow Configuration page opens, as above.
- 2 Tap **HTT** and select a Heater Target Table (file) from the drop-down list to be used for controlling the valve.

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- 3 Tap **Valve Gearing** and enter the required value. See section 15.3 for an explanation of Valve Gearing.
- 4 If required, adjust the **TES** value. See section 15.3.
- 5 If required, adjust the **TVES** value. See section 15.3.
- 6 If required, adjust the **Min Gas Flow (%)** value to define a minimum opening position for the needle valve. See section 15.3.
- 7 Tap **Type** and select either Siphon or VTI depending which type of flow system you are using. See also section 15.3.

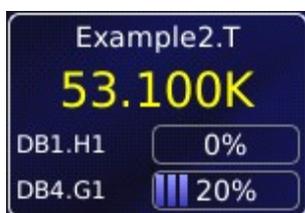


- 8 Tap **Home** to return to the Home page.

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### 4.8.3 Changing a gas flow set point

- 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(%)** so that it displays Manual.
- 4 Enter the new gas-flow set point (as a percentage of maximum flow) in the **Flow (%)** parameter box.
- 5 Tap **Home** to return to the Home page. The sensor widget will show the gas flow setting.



## 4.9 Using a generic calibration-file

### 4.9.1 Overview

Some generic calibration files are supplied for common sensors having reasonably predictable forms of measured variable (e.g. resistance) as a function of temperature, for example sensors that conform to the 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. This process can be used for PTC and NTC sensors.

The adjustment is applied to the measured variable, 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-value end of the measure variable and the offset at the low-value 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.

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Once the scaling adjustment has been made, change to the low-value parameter 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-value parameter point after the offset has been adjusted. A few iterations of these adjustments may be required to achieve the desired accuracy.

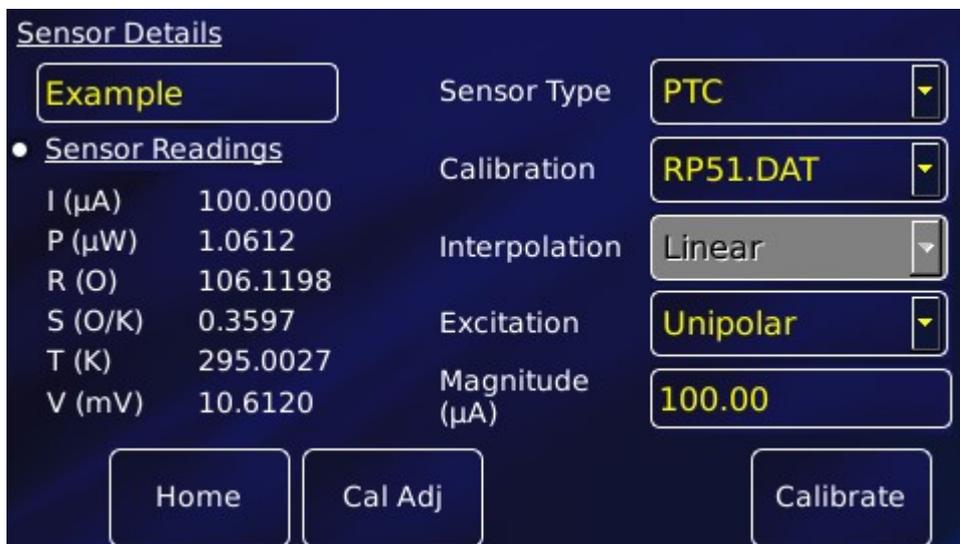
## 4.9.2 Adjusting a generic calibration file

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 by applying scale and offset corrections. The calculated correction parameters will be applied to every reading of this sensor but will not be applied to any other sensor in the system, even sensors of the same type using the same generic calibration curve.

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 widget on the home page. The Sensor Details page is displayed.



2 Tap **Calibration** and from the drop-down list select the generic file corresponding to the sensor. This example selects RP51.dat for a PT100.

3 Tap **Cal Adj** to open the **Generic Sensor Adjustment** page.

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**Generic Sensor Adjustment**

Measured	71.1000	Actual T	▼ 205.00000 ▲
Temp	199.98K	Scale	▼ 1.00000 ▲
Adj Temp	199.98K	Offset	▼ 0.00000 ▲

**Last Reference Point**

Measured	100.67K
Adjusted	105.00K

Buttons: Home, Save, Calculate

- 4 Place the sensor in a location with known temperature T1.
- 5 Edit **Actual T** to equal the true temperature T1. Tap **Calculate**.
- 6 Place the sensor in a location with known temperature T2.
- 7 Edit **Actual T** to equal the true temperature T2. Tap **Calculate**.
- 8 Tap **Calculate** to request the iTC to do the calculations.
- 9 Tap **Save** to save the new calibration.
- 10 Tap **Home** to return to home page.

In the sequence above, tapping “Calculate” in step 5 writes the pair of values ‘measured variable value’ and ‘Actual T1 for a T1 reference point to an internal table. Tapping “Calculate” in step 7 does the same for a T2 reference point. Tapping “Calculate” again will perform iterative adjustments of ‘Scale’ and ‘Offset’ to find the best small correction to fit the generic curve to the actual reference point data with the minimum error.

## 4.10 Types of temperature sensor

The **MercuryiTC** can use several types of temperature sensor.

### 4.10.1 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

## MercuryITC

with increasing temperature difference. The iTC contains cold-junction compensation, so a reference junction is not required.

### 4.10.2 Metallic resistance thermometers (positive temperature coefficient)

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.

### 4.10.3 Semiconductor resistance thermometers (negative temperature coefficient)

Semiconductor resistance thermometers (negative temperature coefficient)

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.

### 4.10.4 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.

### 4.10.5 Excitation current

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

## MercuryiTC

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 oxo-nitride or RuO<sub>2</sub> 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.

### 4.10.6 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.

The MercuryiTC accepts calibration files with .dat or .prn extensions.

- A calibration file contains a number of discrete data pairs, each mapping a sensor reading on to a temperature value. The first column is the output (eg. temperature, pressure) and the second column is the input (eg. resistance, voltage, current).
- By default, values are assumed to be in SI units. However, a header for each column may be used to define the units. Both columns must have valid units or both will be ignored completely. Other headers are also ignored.

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- .dat files are space separated. Tabs or multiple spaces are acceptable.
- Numbers may be expressed in regular (0.0134) or scientific (1.34e-2) notation.
- Linear interpolation is used to provide calibration at intermediate values.
- There is no theoretical limit to the number of sets of data points, but a practical limit is about 1000.

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

## MercuryiTC

### 4.10.7 Available generic calibration files

The **MercuryiTC** includes calibration curves for the following sensor types.

Code	Sensor	Temperature range
Lin <sup>1</sup>	Linear range	0-1677.7
Null	Centre zero	-838.9 to +838.9
Con 1	Conductance	0 to 20
TG 5	AuFe 0.03/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 4	Copper/Const	-250 to 400°C
TK10_13	Chromel/Alumel	-200 to 1370°C
CR 11	Ruthenium oxide	0.25 to 10K
RF 52 <sup>2</sup>	RhFe resistor	1.5 to 500K
RP 1	Platinum resistor	-200 to +100°C
RP 5 <sup>3</sup>	Platinum resistor	20 to 500K
RP 51 <sup>4</sup>	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
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

Your **MercuryiTC** may not have all the above calibration files pre-loaded.

<sup>1</sup> 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.

<sup>2</sup> 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 linearization errors of less than 1% over the full temperature range. For a more accurate fit to a specific sensor, order a custom calibration.

<sup>3</sup> This is for a pure Platinum element.

<sup>4</sup> 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 for 50-70K is based on BS1904:964 rather than BS1904:1984.

## MercuryiTC

Newer files, with a higher density of data points, are available for some sensors. These have the prefix Merc, such as MercTG57-2.

### 4.11 More about thermocouples

#### 4.11.1 Thermocouple principles

A thermocouple consists of two parallel conductors of dissimilar materials, usually alloys, joined at one end, or possibly both ends but with a break-out for voltage measurement. One junction is placed on the sample at unknown temperature, the other at some reference temperature, so that there is a temperature gradient,  $\Delta T$ , along both conductors.

The inhomogeneous distribution of electrons along the conductor gives rise to a thermoelectric emf  $\theta(T)$  which is a function of the temperature gradient  $\Delta T$ . The precise form of  $\theta(T)$  is determined by scattering of the conduction electrons by the lattice which is, in turn, energy dependent. Therefore, the shape of the Fermi surface of the metal or alloy and the conduction electron mean-free path are significant factors in determining the detail of  $\theta(T)$ .

In practice, however, thermocouples suffer from poor low temperature sensitivity and are subject to errors arising from inhomogeneities in the metals used. In addition,  $\theta(T)$  is usually magnetic field dependent. For these reasons, a resistance thermometer normally provides better performance, especially at low temperature.

#### 4.11.2 Configuring for thermocouples

The **Home** page below shows a **MercuryiTC** configured for a Au-Fe/chromel thermocouple with a liquid nitrogen reference. The widgets have been configured as follows:

## MercuryiTC



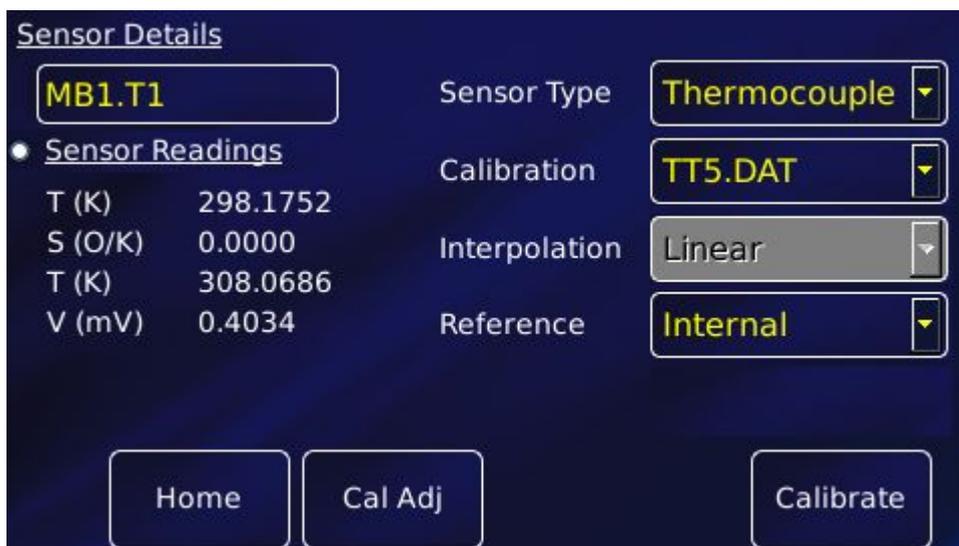
- Top left widget: heat exchanger (H\_X) temperature measured with a Au-Fe/chromel thermocouple using liquid nitrogen reference.
- Top centre widget: measured thermocouple voltage.
- Top right widget: heater voltage.
- Bottom centre widget: heater interlock status.

When setting the sensor details for the **Home** page widget (section 4.2), set the sensor type to “Thermocouple”. In the example page below, the reference is External, since a liquid nitrogen reference is used, rather than the ADT7310.

Under “Sensor readings”, the upper T(K) is the internal reference temperature, always displayed for thermocouples.

In the **Temperature Sensor Details** page (see below), the sensor type is **Thermocouple**. Where a calibration file with a “Merc” prefix is available, such as MercTG57-2.dat, then this is preferred. Such files have a higher data point density than those used in the previous generation of Oxford Instruments temperature controllers (eg. TG57-2.dat). See also section 4.10.7.

## MercuryiTC



### 4.11.3 Reference junction compensation

The MercuryiTC configuration options permit an internal or external reference junction to be used. Each iTC temperature sensor circuit has a built-in temperature reference chip (ADT7310) adjacent to the 9 way D-connector. The real-time temperature reported by this chip is used to compensate the thermocouple voltage measurement.

The accuracy of the internal reference is limited by the ADT730 device, which has an accuracy of 0.5C.

differences in temperature between pins 1 and 3 of the D-connector, which can be 0.5C or more.

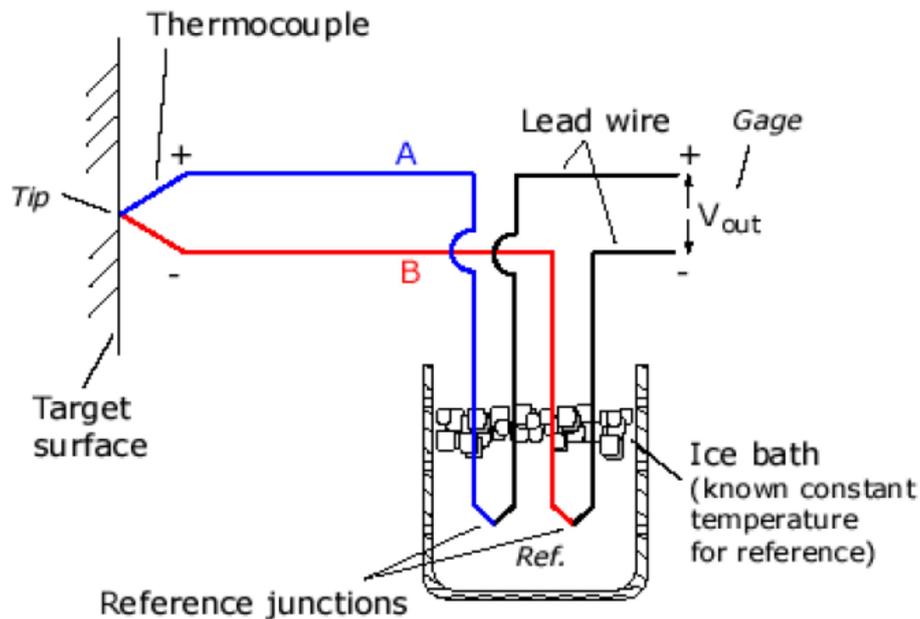
an assumption that the internal reference chip is 2.0C warmer than pins 1 and 3 in the 9 way D-connector. This figure, derived from tests, is also limited by the accuracy of the ADT7310 chip. Under some circumstances (eg. multiple heater cards installed and running at a high output) this assumption may not be correct.

### 4.11.4 External reference junctions

For the above reasons, external referenced junctions are preferred for high accuracy thermometry with thermocouples.

For cryogenic temperature measurement, the reference junction should also be at low temperature. This is usually achieved with a liquid nitrogen bath. This is because the thermocouple sensitivity drops off at low temperature, which has the effect of amplifying errors from a room temperature reference.

## MercuryiTC



The simple diagram above shows the use of an ice bath to maintain the temperature of the reference junctions. A calibration file with a zero voltage at the ice point must be used.

#### 4.11.5 Heater control interlock

If a thermocouple is being used to control a heater and uses a cryogenic reference junction, it is important to consider what happens if the reference junction cold bath runs out of cryogen.

If this occurs, the reference junction will warm up. Since the thermocouple voltage is a function of the temperature difference between the reference and measurement junctions, the measured voltage will decrease. The **MercuryiTC** assumes that the temperature of the reference junction is fixed so the voltage reduction is interpreted as a reduction of the temperature of the measurement junction.

If the iTC is using a heater to control at a set point, the reduction in the apparent temperature of the measurement junction will cause the heater output power to be increased.

As the reference junction continues to warm up, the heater power will continue to increase.

To prevent this from happening, Oxford Instruments' cryogenic systems include a semiconductor device fitted to the cryogenic reference bath, together with the thermocouple reference junction itself.

## MercuryiTC

The **MercuryiTC** auxiliary I/O daughter board is used to detect if the voltage from the semiconductor device (typically 1.8V) is exceeded, which it will if the device warms above about 85K. This switches the state of the digital signal on input line 2 of the auxiliary I/O board which is then used as an interlock for the heater.

The heater is locked off if the semiconductor warms up because the liquid nitrogen has run out.

This protects the cryostat system from being over-heated.

A more detailed version of this section on thermocouples is given in a technical note at [www.mymercurysupport.com](http://www.mymercurysupport.com)

## 5 CRYOGEN LEVEL-METER

The level of cryogen in a reservoir can be measured using the level-meter board. 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.

### 5.1 Principles of operation

#### 5.1.1 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

## MercuryITC

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 178 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.

### 5.1.2 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.

### 5.1.3 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.

## 5.2 Installing the level-meter board

### 5.2.1 Removing the top cover

- 1 Turn off electrical power to the iTC.
- 2 Disconnect all cables from the rear of the iTC and remove the iTC from any instrument rack.
- 3 Remove the 4 screws holding each rack handle.

## MercuryiTC

- 4 Remove the 2 screws holding each side panel.
- 5 Remove the 3 screws on the back panel that secure the top cover of the iTC.
- 6 Slide the top cover back (it can be quite tight) and lift it off.

### 5.2.2 Fitting the board

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

- 1 Choose a slot for the level meter board.
- 2 Remove the two screws that secure the top clamping bracket (Figure 5). Remove the board clamp.



Figure 5 MercuryiTC daughter board clamp

- 3 Knock out the blanking plate (Figure 6) in the location where the board is to be fitted. The blanking plates are held in place by 2 metal tongues (4 metal tongues on early iTCs).
  - For the 2 tongue iTC, gently swivel the blanking plate back and forward until the retaining tongues break.
  - For the 4 tongue iTC, use a small chisel (or similar) and small hammer to break 2 of the tongues with a firm tap. Then gently swivel the blanking plate backwards and forwards until the remaining tongues break. Remove the blanking plate.
- 4 Remove the upper retaining screw holding the Helium probe 9 way D connector to the Level Meter board back plate.

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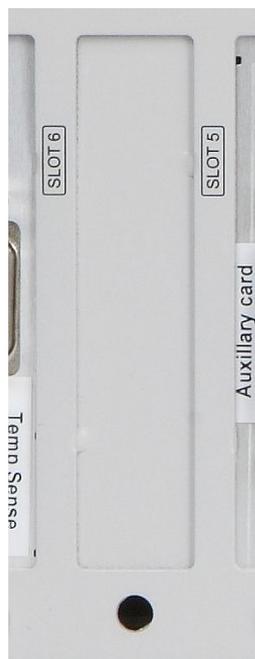


Figure 6 MercuryiTC daughter board blanking plate

- 5 Using appropriate ESD precautions, including wearing an anti-static wrist strap, fit the board in the allocated expansion slot. Align the board with the appropriate slot. Slide the board faceplate inside the iTC back plane. Lower the board into the iTC until the appropriate 40-way header on the main PCB mates with the PCB connector of the board. Push the board firmly into the main PCB header.
- 6 From the rear panel of the iTC, insert the retaining screw to hold the card. Do not tighten at this time.
- 7 From the top of the iTC, replace the top retaining bracket and replace its screws. Make any small adjustments to the card position to ensure that it is seated correctly and the cut-out in the card face plate aligns with the tongue on the retaining bracket. When the board is positioned correctly, tighten the retaining bracket screws and the board.

It is important to ensure that the daughter board retaining screw is correctly tightened in order to provide a low impedance connection to the **Mercury** chassis for low-noise measurements and outputs and EMC compliance.

- 8 Replace the upper retaining screw holding the Helium probe 9 way D connector to the Level Meter board back plate.

This step only applies to the level meter board.

## MercuryiTC

- 9 Replace the top cover on to the iTC, reversing the procedure for removal.

### 5.2.3 Basic check of board operation

- 1 Power up the **MercuryiTC**. If fitted correctly, the iTC will detect the board and may request permission to use it.
- 2 Put the iTC in Local mode by tapping the local/remote toggle button on the iTC **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

## 5.3 Connecting the level probe

Connect the level probe to the appropriate 9-way D-connector on the rear page of the board using the cable supplied. For reference, the pin connections are as follows.

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

## 5.4 Configuring MercuryiTC for helium level meter

- 1 Tap an unconfigured widget on the **Home** page to display the **Channel Display Configuration** page.
- 2 Tap the **Device** box and select a level meter device from the drop down list (an example is shown).

## MercuryiTC

- 3 Tap the **Signal** box and select **Resistance**. This is the resistance of the probe.
- 4 Tap **Assign** to save the changes and return to the Home page.

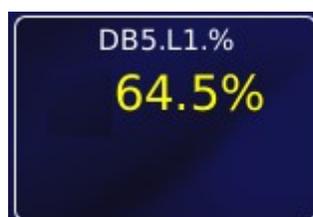


- 5 Connect the helium level probe to the level meter board at the rear of the iTC using the cable supplied.
- 6 Tap the level meter widget on the Home page to open the **Level Meter Sensor Details** page.
- 7 Tap the **Helium** tab.
- 8 Set the **Resistance at 0%** equal to  $178 \times \text{active length (m)}$ . The active length of the probe (in mm) is engraved on the Fischer connector housing.
- 9 **Resistance at 100%** can be left at zero.
- 10 Enter a value between 0 – 160mA in the **Measurement Pulse Amplitude (mA)** parameter box. 80mA is a suitable value.
- 11 Enter a value in seconds in the **Measurement Pulse Duration (s)** parameter box. 3s is a suitable value.
- 12 Tap the **Fast/Slow** button to display **Fast**. The example page below shows typical values for all parameters.

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- 13 Tap **Home** to return to the **Home** page.
- 14 Tap the level meter widget twice to return to the **Channel Display Configuration** page.
- 15 Tap **Signal** and select Helium Level.
- 16 Tap **Assign** to save the changes and return to the Home page. The level meter widget now reads the helium level (%).



## 5.5 Configuring MercuryiTC for nitrogen level meter

- 1 Tap an unconfigured widget on the **Home** page to display the **Channel Display Configuration** page.
- 2 Tap the **Device** box and select a level meter device from the drop down list (an example is shown).
- 3 Tap the **Signal** box and select **Pulse**

## MercuryiTC

- 4 Tap **Assign** to save the changes and return to the Home page.

The board should start measuring after about 10s, giving an actual pulse count measurement of the probe. If the probe is warm (eg. out of the system), this reading should be converted and used for **Frequency at 0%** value.



- 5 With the nitrogen probe at room temperature, record the sensor frequency displayed on the **Home** page widget for 0% level.
- 6 Fully immerse the probe in liquid nitrogen and record the sensor frequency for 100% level.
- 7 Tap the level meter widget on the Home page to open the **Level Meter Sensor Details** page.
- 8 Tap the **Nitrogen** tab.
- 9 Set the **Pulse Counting Period (ms)** to 750.
- 10 Connect the nitrogen level probe to the level meter board at the rear of the iTC using the cable supplied.
- 11 Fit the probe to the system and fill it with liquid nitrogen. Wait for the boiling to subside. Record the pulse count reading and use this for **Frequency at 100%** value.

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- 12 Tap **Home** to return to the **Home** page.
- 13 Tap the level meter widget twice to return to the **Channel Display Configuration** page.
- 14 Tap **Signal** and select N2 Level.
- 15 Tap **Assign** to save the changes and return to the Home page.

Increasing the pulse period improves the accuracy but lengthens the response time.  
Decreasing the pulse period degrades the accuracy but shortens the response time.

## 5.6 Setting up liquid nitrogen auto-fill

The nitrogen level meter can be used to control a liquid nitrogen auto-fill system. It opens a valve when the **fill** limit is detected and closes the valve when the **full** limit is detected. This also requires an auxiliary I/O board.

- 1 Tap the nitrogen level meter widget on the **Home** page to open the **Level Meter Sensor Details** page (as above).
- 2 Select the Auxiliary Daughter board DBx.G1.Oy where x is the board number and y the output number. An example is shown above.
- 3 Enter a percentage value for the required **Low Level** (typically 10%). The auto-fill valve opens when the level falls below the **Low Level** value.

## MercuryiTC

- 4 Enter a percentage value for the required **High Level** (typically 90%). The auto-fill valve closes when the level rises above the **High Level** value.
- 5 Tap **Home** to return to the **Home** page.

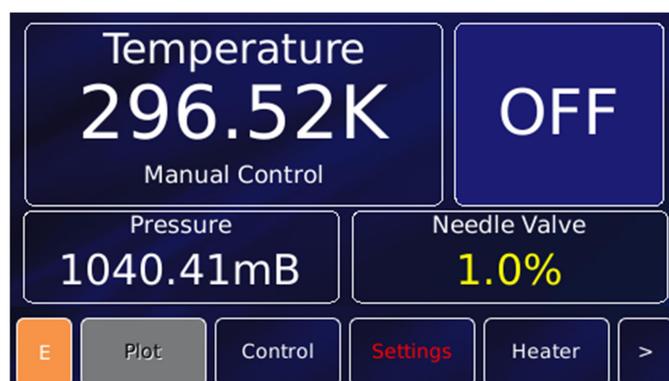
## MercuryiTC

## 6 LAMBDA MODE

It is possible to configure the Mercury iTC to operate in Lambda control mode so that the unit becomes the Lambda Point Controller (LPC) of a Lambda Point Fridge (LPF). The details of the LPF would be described in the system manual so this section will focus on the operation of the LPC or “Lambda Mode” of the iTC. Lambda mode can be invoked by loading the “lambda” template. This can be run in parallel with normal iTC control operations with the following restrictions:-

- Devices configured by the lambda template cannot be used for any other function. By default these devices are the motherboard based temperature sensor input (MB1.T1), the pressure card which must be present in slot 8 (DB8.P1) and the auxiliary card as a gas controller which must be present in slot 4 (DB4.G1).
- Only 1 template mode can run on any unit at any one time. So, for example, lambda mode cannot run simultaneously as heliox mode.

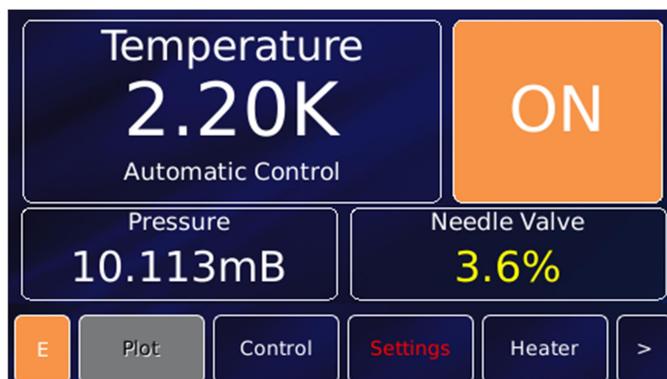
When the lambda mode is invoked, one of the units home screens will become the LPC home screen.



In the screen image above the temperature is the signal from the device input MB1.T1, the pressure is the signal from the device input DB8.P1 and the needle valve opening is the signal from the device input DB4.G1. The screen shows the LPC in manual mode which is designated by the “Manual Control” status message under the temperature and the control button in the top-right of the screen in “OFF” mode meaning that LPC auto control is OFF. In this mode the valve opening can be set directly by tapping the needle valve display to open the control and entering a value using the arrows or keypad.

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In auto control mode the top-right button will change to “ON” and the status message to “Automatic Control” (see below).



In automatic control the user cannot set the needle valve opening. Now control is determined by the internal algorithm forming the key part of the LPF control. In this mode the LPF will attempt to cool the LPF to a temperature as close as possible to 2.20K by adjusting the flow through the LPF based on the LPF pressure signal for control feedback. There is a defined sequence of steps, which are indicated by the status message, and there are 3 “zones” of operation.

### 6.1 LPF operation description

A lambda point fridge consists of a cooling loop mounted on a heat exchange plate immediately above the magnet that is to be cooled. Liquid helium is admitted from the main helium bath to the loop via an adjustable needle valve. The other end of the loop is connected via a pumping line to a rotary pump. A pressure sensor is mounted on the pumping line outside the cryostat. One or more temperature sensors are mounted on the magnet or in the helium bath near the fridge. Helium liquid flash evaporates at the needle valve producing cooling in the loop and hence cooling the helium in the main bath. The cooled helium, having a higher density, sinks to the bottom of the cryostat and is replaced by liquid at 4.2 K. Cooling continues until the liquid below the lambda fridge (and hence the magnet which is immersed in this liquid) is all at 2.2 K. At this temperature liquid helium becomes superfluid. Hence further cooling does not produce any further fall in temperature at the magnet, instead the boundary between 2.2 K helium and 4.2 K helium starts to move further up the cryostat.

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### 6.2 Lambda control sequence

When switching into auto mode the LPC will step through a sequence of states:-

In operation the pump runs continuously and the needle valve is adjusted to control the rate of cooling. When the fridge is first switched to automatic control, the normal procedure is to run the pump with the needle valve shut. The pressure is monitored until a stable low pressure value is achieved corresponding to a good roughing vacuum. This is taken as the baseline pressure. The initial part is to wait with the needle valve shut until a LPF pressure below 20mbar is achieved. During this period the status message indicates "*Establishing baseline pressure*".

Once the LPF pressure is below 20mbar a short time delay is included to allow the pressure to stabilise. During this period the status message indicates "*Waiting for pressure to stabilise*".

The needle valve is then opened until the pressure rises to a target value in the 20 to 50 mbar region, known to give optimal cooling performance. During this period the status message indicates "*Waiting for pressure to drop*". This state will drop into the Automatic Control state if the LPF pressure is below the "High Pressure" threshold which has a default value of 35mbar.

#### 6.2.1 Automatic Control

As the magnet cools, the temperature immediately above it is monitored, whilst the needle valve is controlled as required to keep the correct pressure in the pumping line. When the temperature reaches 2.2 K the needle valve may be closed to achieve a rather lower pressure and a lower cooling rate, sufficient to keep the magnet at 2.2 K whilst it is energised. During this period the status message indicates "*Automatic Control*".

There are 3 zones of control delimited by temperature. Above 25K the pressure control set point is at the "High Pressure" band, which by default is  $35\pm 2$ mbar. Between 25K and 2.3K the pressure control set point is at the "Mid Pressure" band, which by default is  $20\pm 1$ mbar. Below 2.3K the pressure control set point is at the "Low Pressure" band, which by default is  $10\pm 1$ mbar.

These values are hard coded in the template as they have been found to be optimum values for Oxford Instruments LPF's. In the auto control mode the controller will adjust the needle valve by 0.3% on each control loop iteration to keep the LPF pressure within the target band. If the pressure is within the target band, no valve adjustment will be made.

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### 6.2.2 Remote Commands

See section 9.3.6 “Addressing in Lambda control mode”

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# 7 MANAGING YOUR MERCURY

This chapter describes

- general operation of the **MercuryiTC**, and how this can be configured to suit the user.
- how to manage software updates
- how to Save and Load files, such as PID and calibration files.

Pages 7.1 to 7.8 are accessed by tapping **Settings** on the **Home** page and using the scroll button. GUI pages for remote operation (RS232, GPIB, Ethernet) are described in chapter 8 below.

## 7.1 General

View the General settings page by selecting the **General** tab.



The page contains the following parameter boxes 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 parameter box is set Off, the present page is displayed until the user navigates to another page.

- **Remote Lock**

If Remote Lock mode is set On, a message "Remote User" appears on the Home page and

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all GUI controls are disabled. Set Remote Lock to Off to allow (normal) GUI control of the iTC. However, the Settings features are disabled. The **Remote Lock** function may be accessed remotely.

- **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 parameter box**

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

Select **SCPI** to use a command set based on SCPI.

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 17.1.1). If the text is RED an alarm condition exists.

- **Apply**

Tap once to apply (save) changes made on this page.

- **Home**

Tap once to return to the **Home** page.

The **General** page also displays the firmware version in use.

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## 7.2 Display

Tap **Settings** on the Home page, then tap the **Display** tab. Use this to configure the display.



The page contains the following parameter boxes and controls:

- **Auto Dim**

An 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. Toggle On/Off to turn on/off the auto-dim feature.

- **Timeout (sec)**

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

- **Brightness (%)**

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

- **Dim (%)**

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

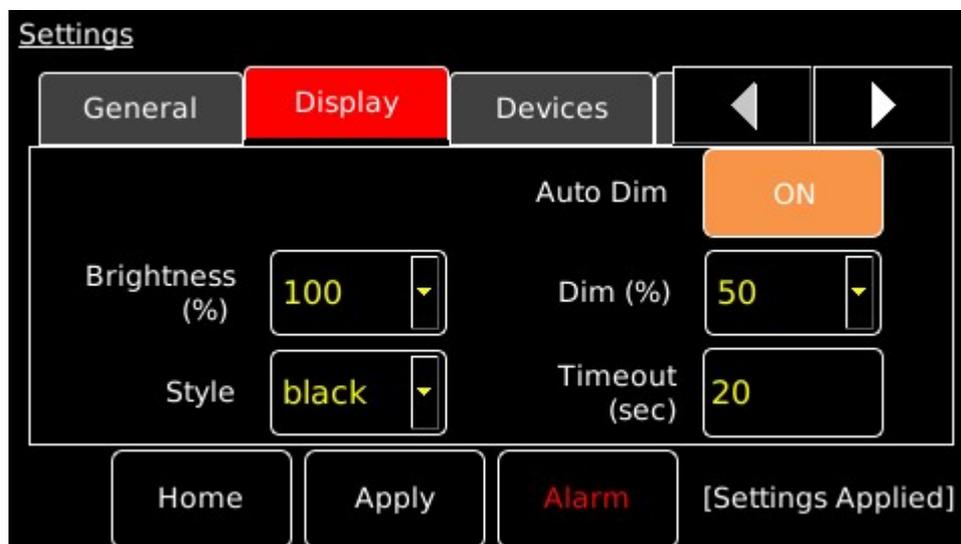
- **Style**

There are two choices for the display colours.

**oi** is the name of the default textured blue style.

## MercuryiTC

**black** refers to the style with a plain black background, as shown in the example below.



The **Display** page also contains the following buttons:

- **Alarm**  
Tap once to access the Alarm Logs page (see section 17.1.1). If the text is RED an alarm condition exists.
- **Apply**  
Tap once to apply (save) changes made on this page.
- **Home**  
Tap once to return to the Home page.

# MercuryiTC

## 7.3 Devices

The Devices page is viewed by selecting the **Devices** tab.



	ID	Type	Name	Serial No	Boa
1	DB1	heater	DB1.H1	120950233	
2	DB2	heater	DB2.H1	122250363	
3	DB3	None	N/A	0	

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:

- **Row number**  
The number of the slot.
- **ID**  
The ID (identity) of the board fitted in this slot, MB for mother board, DB for daughter board, and a number.
- **Type**  
The type (function) of the board fitted in this slot.
- **Name**  
The name (or user-defined nickname) of the device associated with the board fitted in this slot.
- **Serial No**  
The serial number of the board fitted in this slot.
- **Board Rev.**  
The revision number of the board.

# MercuryiTC

- **Firm. Ver**  
The firmware version loaded on to the board.

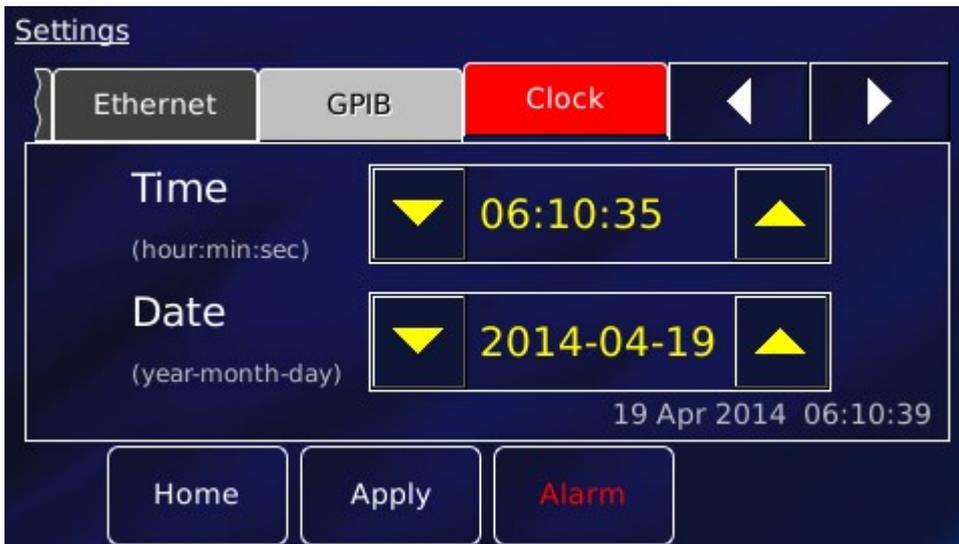
The page contains the following buttons:

- **Alarm**  
Tap once to access the Alarm Logs page (see section 17.1.1). If the text is RED an alarm condition exists.
- **Home**  
Tap once to return to the Home page.

Tap once in any row to switch to the appropriate configuration page for the device.

## 7.4 Clock

Select the **Clock** tab to reset the **MercuryiTC** internal clock.



The page contains the following parameter boxes and controls:

- **Time**  
Tap the part of the displayed time that you wish to edit and use the   buttons.

- **Date**  
Tap the part of the displayed date that you wish to edit and use the   buttons.

## MercuryiTC

The Clock page also contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see section 17.1.1). If the text is RED an alarm condition exists.

- **Apply**

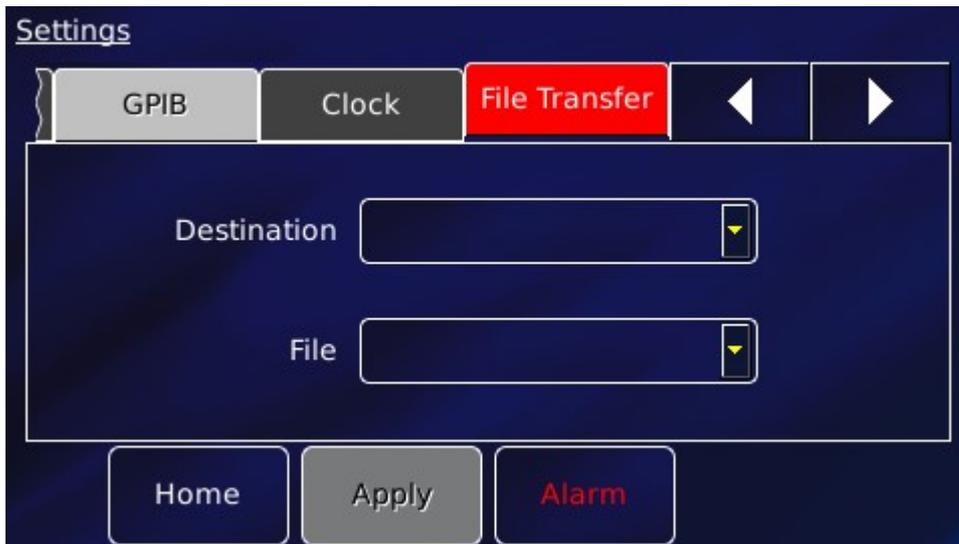
Tap once to apply (save) changes made on this page.

- **Home**

Tap once to return to the Home page.

## 7.5 File transfer

Select **File Transfer** to view a page used to load calibration files into the controller from a USB memory stick. The memory stick is fitted into the USB-A socket on the rear panel of the iTC.



The page contains the following parameter boxes:

- **Destination**

Select the type of calibration file to be loaded. The list of file types comprises: Diode, Dummy, NTC, PTC, Thermocouple, HTT, Pressure, sweep\_tables, pid\_tables.

- **File**

Select the file to be loaded from the memory stick. Once selected, the file is loaded automatically.

## MercuryiTC

The File Transfer page also contains the following buttons:

- **Alarm**  
Tap once to access the Alarm Logs page (see section 17.1.1). If the text is RED an alarm condition exists.
- **Apply**  
Tap once to apply (save) changes made on this page.
- **Home**  
Tap once to return to the Home page.

## 7.6 Updates

Users are able to take advantage of software developments without the need to return the **MercuryiTC** to the factory. The terminology used is as follows.

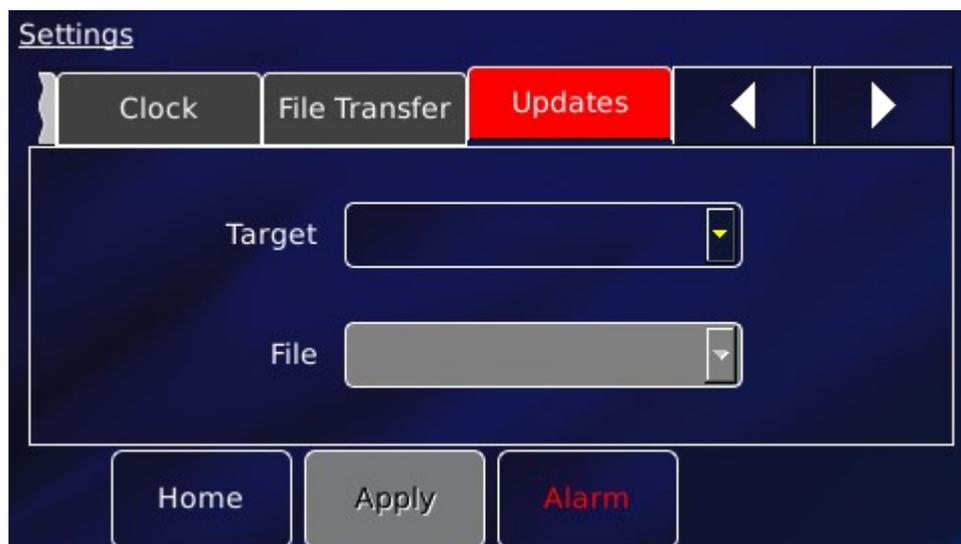
The Mercury **application** is software that runs on the **MercuryiTC** and allows the user to interact with the instrument using the touch screen GUI. It translates and communicates user commands to the appropriate device (board).

The device (board) **firmware** is small program embedded on each individual board, including the mother board.

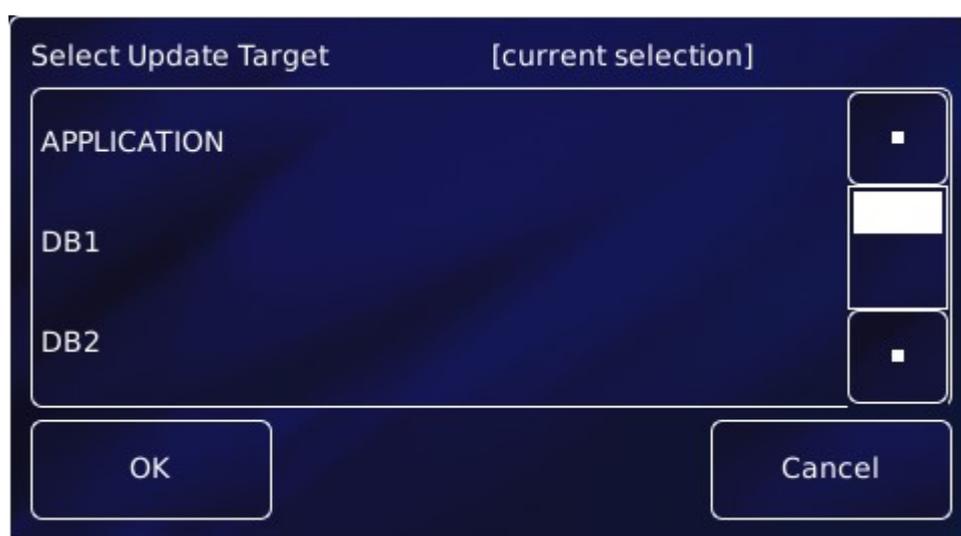
Both **application** and **firmware** are updated using the **Updates** page.

- 1 You are advised to save the current configuration so that you can return to it if necessary. This procedure is described in section 7.8 below.
- 2 Locate the new firmware on [www.mymercurysupport.com/downloads/firmware](http://www.mymercurysupport.com/downloads/firmware).
- 3 Download and extract the firmware to the root folder of a USB memory stick.
- 4 Fit the USB stick to the USB-A socket on the rear panel of the iTC. Allow a few seconds for the flash drive to be detected and scanned.
- 5 Select the **Updates** tab.

## MercuryiTC



- 6 With the iTC in **Local** mode, tap Target to open the **Select Update Target** page, a list of available update files. Select APPLICATION from the list.



- 7 Tap **File** and select the firmware file, which is *cryosys\_update.tar*
- 8 Tap **Apply**. Confirm that you wish to update by tapping the OK button on the pop-up window.

The iTC installs the new firmware and calibrates the heater board(s) and pressure board (if fitted). It then re-boots and starts up in TRIAL mode. Do not power-off the iTC in TRIAL mode!

## MercuryiTC

- 9 Run some standard procedures to test that the iTC is working as expected.
- 10 With the iTC in **Local** mode and if the new firmware is acceptable:
  - a) Tap **Settings** on the **Home** page.
  - b) Select the **Updates** tab.
  - c) Tap **Save Changes** to accept the new firmware version.
- 11 With the iTC in **Local** mode and if the new firmware is not acceptable:
  - a) Tap **Settings** on the **Home** page.
  - b) Select the **Updates** tab.
  - c) Tap **Revert Changes** to revert to the old firmware version.
  
- 12 Power the system down and wait 30 seconds before applying power again.

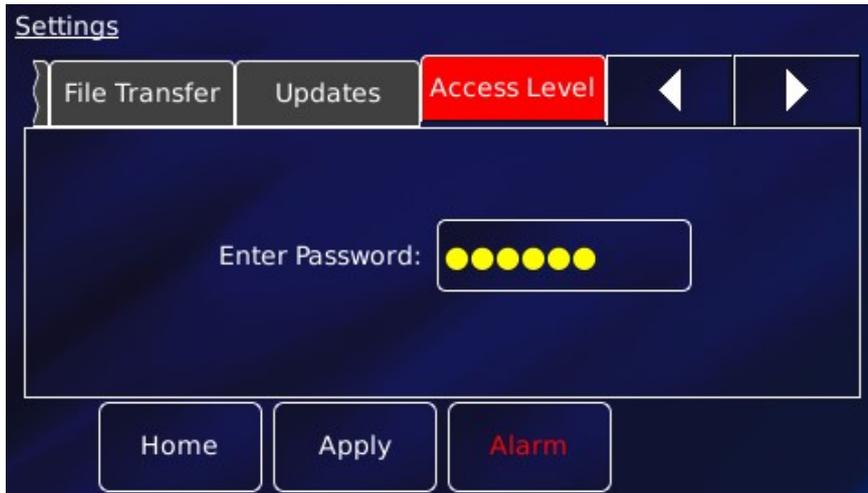
## 7.7 Access Level

This page allows the user to enter ENGINEERING mode, to access features that are not available to normal users. The default engineering password is available on request but should be used with caution. In ENGINEERING mode it is possible to change all the system parameters and damage could occur on some systems if these parameters are changed to inappropriate values. The user can change this password, if desired (see below).

### Entering engineering mode

- 1 Tap **Settings** on the Home page.
- 2 Scroll right until the **Access Level** tab is visible.
- 3 Tap **Access Level**. The engineering mode page opens.

# MercuryiTC



- 4 Tap the Enter Password box. The alphanumeric window opens. Enter the password.
- 5 Tap **Apply**. With the correct password, the message “Password Correct! Engineering mode now enabled” appears.



- 6 Tap **Change Password** to change the engineering password.

## Leaving engineering mode

- 1 Tap **Settings** on the Home page.
- 2 Scroll right until the **Access Level** tab is visible.
- 3 Tap **Access Level**. The engineering mode page opens with the message “Engineering mode is enabled”, as shown above.
- 4 Tap **Exit Mode**. The iTC is no longer in engineering mode. The previous page reappears with the prompt for password.

## MercuryiTC

### 7.8 Factory

This page allows the user to save the configuration of the **MercuryiTC**. The user can then restore a previously saved configuration.



The page contains the following parameter boxes and controls:

- **Save configuration**

To save the present system configuration, enter a filename in the Enter Name parameter box and tap **Save Configuration**.

- Drop-down list

Select a saved configuration to load or delete. Loading a file changes the iTC's configuration to the saved configuration. Note that the original factory configuration is normally called FACTORY\_OI.

- **Revert**

Tap once to load the selected configuration file and reboot the **MercuryiTC**.

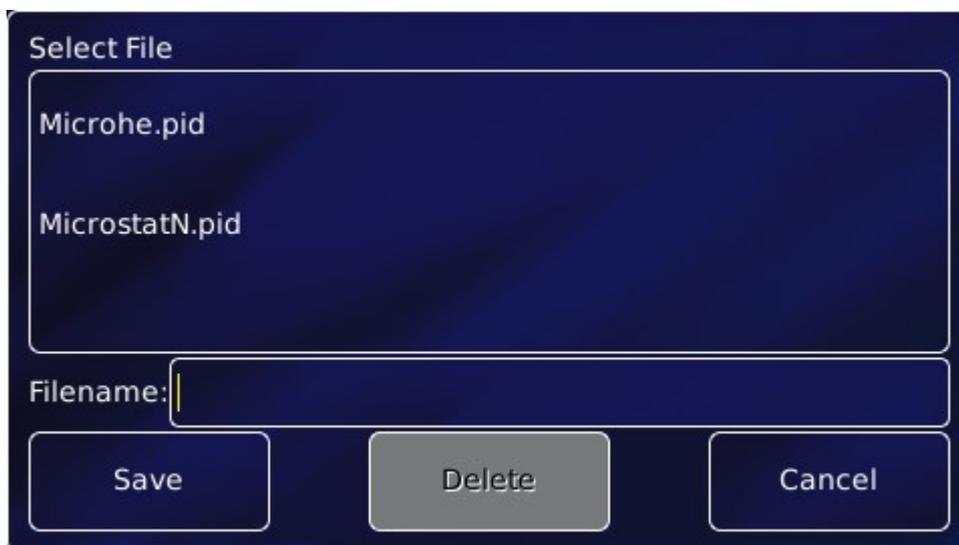
- **Delete**

Tap once to delete the selected configuration file from the list of available files.

### 7.9 Save File pages

## MercuryiTC

There is a **Save** button on several pages. All function in the same way, so only one is described in this section. This page (below) appears when editing a PID file.



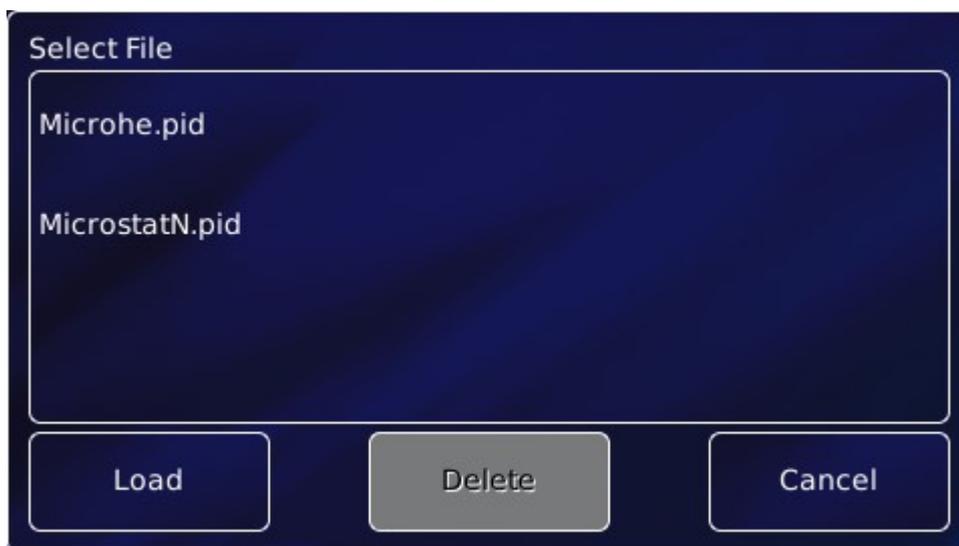
This page contains the following parameter boxes and controls:

- **Main area**  
Displays a drop down list of existing files of this type, if any.
- **Filename**  
Tap once and enter the required filename, without a file extension.
- **Save**  
Tap once to save the file.
- **Delete**  
Tap once to delete a selected file.
- **Cancel**  
Tap once to exit this page without saving the file.

## 7.10 Load File pages

There is a **Load** button on several pages. All function in the same way, so only one is described in this section. This page (below) appears when editing a PID file.

## MercuryiTC



This page contains the following parameter boxes 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 parameter box
- **Filename**  
Tap once and enter the required filename, without a file extension.
- **Load**  
Tap once to load the selected file.
- **Delete**  
Tap once to delete a selected file.
- **Cancel**  
Tap once to exit without loading the file.

## 8 REMOTE OPERATION

### *HUMIDITY REQUIREMENT WITH PC CONNECTION*

*When connecting to a pc the system maybe connecting to a pc that conforms to an older version of the 60950-1 standard where the specific humidity conditioning level is lower. In this operation should not occur above a humidity level of 91% at 20°C.*



### *CONTRÔLER EXIGENCE d'HUMIDITÉ AVEC PC CONNEXION*

*Lors de la connexion à un PC le système peut se connecter à un PC qui est conforme à une ancienne version de la norme 60950-1 où le niveau de conditionnement d'humidité spécifique est inférieure. Dans cette opération ne doit pas se produire au-dessus d'un niveau d'humidité de 91% à 20 ° C.*

The **MercuryiTC** can be remotely operated using 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.

## 8.1 Remote operation using RS232 or ISOBUS

### 8.1.1 Configuring RS232 and ISOBUS

- On the **Home** page, tap **Settings**.
- Scroll to the RS232 tab and select it.

## MercuryiTC



This page contains the following parameter boxes and controls:

- **ISOBus address**  
Select an ISOBus address from the drop-down menu.
- **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 also contains the following buttons:

- **Alarm**  
Tap once to access the Alarm Logs page (see section 17.1). If the text is RED an alarm condition exists.

## MercuryiTC

- **Apply**  
Tap once to apply (save) changes made on this page.
- **Home**  
Tap once to return to the Home page.

### 8.1.2 Serial RS232 cabling requirements

The RS232 interface is connected via a 25-way D-socket on the rear page. The iTC is configured as Data Circuit-terminating Equipment (DCE), with the standard pin-assignments listed in the table below.

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.

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 as follows.

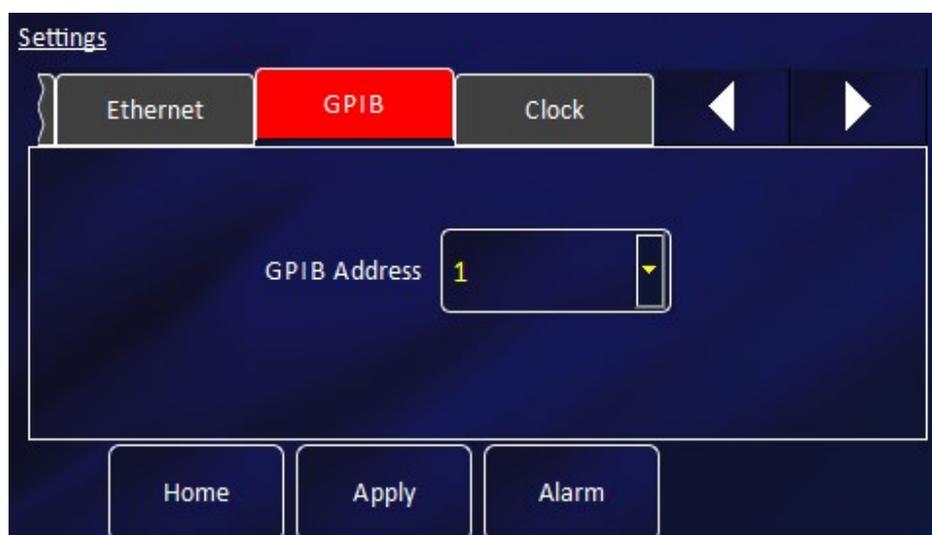
Signal	Allowed voltage
Tx data high	>+5.5 V
Tx data low	<-5.5 V
Rx data high threshold	<+2.6 V
Rx data low threshold	>+1.4 V

Max Rx input voltage  $\pm 30$  V

## 8.2 Remote operation using GPIB

### 8.2.1 Configuring GPIB

- On the **Home** page, tap **Settings**.
- Scroll to the GPIB tab and select it.



The page contains one parameter box:

- **GPIB Address**

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

NOTE: This sets the GPIB "Primary Address". When using the SCPI command set the GPIB "Secondary Address" is invoked. This is always set to 1 but must be set in any applications trying to access the iTC using SCPI commands via GPIB. If the Legacy command set is being used the "Secondary Address" is not invoked and therefore is not required.

The page also contains the following buttons:

## MercuryiTC

- **Alarm**

Tap once to access the Alarm Logs page (see section 17.1). If the text is RED an alarm condition exists.

- **Apply**

Tap once to apply (save) changes made on this page.

- **Home**

Tap once to return to the Home page.

### 8.2.2 GPIB Cabling requirements

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.*

- 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.

## 8.3 Remote operation using Ethernet

### 8.3.1 Configuring Ethernet

The iTC can be configured to use a fixed IP address, or to use dynamic host configuration protocol (DHCP). **Note: The port is always 7020**

## MercuryiTC

- On the **Home** page, tap **Settings**.
- Scroll to the Ethernet tab and select it.



The page contains the following parameter boxes and controls:

- **DHCP**

Select On/Off as required. 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 parameter boxes are used.

- **IP Address**

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

- **Subnet**

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

- **Gateway**

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

- **MAC Address**

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

## MercuryiTC

- **Port**

Not shown on the details page but the port is always 7020.

The page also contains the following buttons:

- **Alarm**

Tap once to access the Alarm Logs page (see section 17.1). If the text is RED an alarm condition exists.

- **Apply**

Tap once to apply (save) changes made on this page.

- **Home**

Tap once to return to the Home page.

### 8.3.2 Ethernet cabling requirements

The ethernet interface is connected via the RJ45 connector found on the **MercuryiTC** rear panel.

## 8.4 Remote operation using USB

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

### 8.4.1 Configuring USB

Since USB is a one-to-one connection, no addresses are required.

### 8.4.2 USB Cabling requirements

The **MercuryiTC** rear panel is fitted with a standard USB type B receptacle. Use a standard USB A to B cable between PC and iTC.

### 8.4.3 USB drivers

USB drivers for Windows OS are available to download from the **Mercury** support website [www.mymercurysupport.com](http://www.mymercurysupport.com). These enable a PC to communicate with a **MercuryiTC** over the USB port. Instructions are included in the download.

## MercuryiTC

The USB drivers support 32-bit and 64-bit version of Windows 7 / Vista / XP / NT / 98.

### 8.5 Switching MercuryiTC control between local and remote

To switch to remote:

- Tap **Settings** on the Home page and scroll to the **General** tab.
- Tap the **Remote Access** parameter box and select an interface from the drop-down menu.
- Tap **Apply** to enable the selected interface.

To switch to local:

- Tap **Settings** on the Home page and scroll to the **General** tab.
- Tap the **Remote Access** parameter box and select Local from the drop-down menu.
- Tap **Apply** to enable local control of the iTC.

### 8.6 Testing remote connections

An executable application for the PCs (WindowsXP and Windows7) is available from the Mercury support website [www.mymercurysupport.com](http://www.mymercurysupport.com). This can be used to check remote connections to the **MercuryiTC** via RS232/Isobus, USB, Ethernet or GPIB.

The application is LabView based and the installer includes the LV run-time engine.

### 8.7 Programming examples

Further programming assistance and examples can be found on the Mercury support website [www.mymercurysupport.com](http://www.mymercurysupport.com). On the issue date of this manual, these include

- NI LabView VIs. This is a library of Vis for National Instruments LabView version 8.6 and later.

### MercuryiTC

- Communication with MagLab over ISOBUS. This document is a guideline on how to establish communication between MagLab software and MercuryiTC over the serial ISOBUS interface.
- Teslatron (OxSoft) Installer. This is an installation package including executable installer, source code, **MercuryiTC** driver and an operation manual.

## 9 COMMAND REFERENCE GUIDE

### 9.1 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]).

### 9.2 SCPI and legacy command sets

The iTC supports two separate sets of remote commands:

- SCPI commands are based on the SCPI command set, although the iTC may not be fully compliant with SCPI.
- Legacy commands were used in previous 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 earlier Oxford Instruments equipment.

### 9.3 SCPI commands

This section specifies the command message format for communication using the SCPI derived protocol. The Mercury instrument uses a proprietary defined command set which is similar in architecture to the SCPI (Standard Commands for Programmable Instruments 1990 (IEEE 488.2)) command architecture but does not claim to fully support this architecture. Below are examples of standard SCPI commands which are NOT supported:-

## MercuryiTC

- \*CLS Clear Status Command
- \*ESE Standard Event Status Enable Command
- \*ESE? Standard Event Status Enable Query
- \*ESR? Standard Event Status Register Query
- \*OPC Operation Complete Command
- \*OPC? Operation Complete Query
- \*RST Reset Command
- \*SRE Service Request Enable Command
- \*SRE? Service Request Enable Query
- \*STB? Read Status Byte Query
- \*TST? Self-Test Query
- \*WAI Wait-to-Continue Command

The identification command IS supported...

- \*IDN? Identification Query

### 9.3.1 SCPI protocols

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).

### 9.3.2 Reading the instrument identity

Send the command:

- \*IDN? (plus termination `\n`)

## MercuryiTC

The format of the reply is:

IDN:OXFORD INSTRUMENTS:MERCURY dd:ss:ff

Where:

**dd** is the basic instrument type (iTC , iPS, Cryojet etc.)

**ss** is the serial number of the main board

**ff** is the firmware version of the instrument

### 9.3.3 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 9.3.6). This appears immediately after the term that cannot be interpreted.

### 9.3.4 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.

#### Examples:

Send:            READ:SYS:TIME                    (meaning 'read system time')

Response:       STAT:SYS:TIME:13:57:23   (meaning 'status system time is 13:57:23')

Send:            SET:DEV:MB1.T1:TEMP:TSET:4.321                   (meaning 'set device motherboard1, temperature1, temperature signal target value to 4.321K')

## MercuryiTC

Response: STAT:DEV:MB1.T1:TEMP:TSET:4.321:VALID (meaning 'status device motherboard1, temperature1, temperature signal target value setting to 4.321K is valid and has been set')

### 9.3.5 Nouns

Elements within the iTC are addressed by a hierarchical structure:

A Unit contains a number of Devices.

A Device contains a number of Signals.

The structure of NOUNS reflects this:

For instance, DEV:<UID>:<TYPE1>:SIG:<TYPE2> encompasses

- examples for <TYPE1> = TEMP, HTR, LVL, GAS
- examples for <TYPE2> = VOLT, CURR, POWR, RES, TEMP, SLOP, HEL, NIT

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

The scale is of the form:

n# - nano

u# - micro Note: The iTC returns the Greek letter 'μ' for 'micro'.

m# - milli

# - none

k# - kilo

M# - mega

where # is replaced by the relevant SI unit. For example:

## MercuryiTC

A – Amps, V – Volts or W – Watts.

### 9.3.5.1 System commands

System commands are used for system-level settings.

COMMAND		OPTIONS		Read/Write	DESCRIPTION
SYS	CAT			R	Returns a list of existing hardware devices
SYS	DISP	DIMA	OFF:ON	R/W	Set automatic display brightness Sets the time for the automatic dimming
SYS	DISP	DIMT	0 - 10	R/W	Sets the brightness
SYS	DISP	BRIG	0 - 100	R/W	Reads Hardware version of the Box
SYS	MAN	HVER		R	Cryosys version
SYS	MAN	FVER		R	Serial number of the box
SYS	MAN	SERL		R	Serial number of the box
SYS	TIME		hh:mm:ss	R/W	Sets the time of the box
SYS	DATE		yyyy:MM:dd	R/W	Sets the date of the box
SYS	USER		NONE:GUEST:NORM:ENG	R/W	Sets the remote user level (a password may be required after the level)
SYS	PASS			W	Sets a new password for the present user level
SYS	LOCK		OFF:SOFT:ON	W	Sets the lock mode on the unit when in remote mode
SYS	RST			W	Resets the hardware
SYS	FLSH			R	Reads the available memory in the box
SYS	RAM			R	Reads the available RAM in the box
SYS	ALRM			R	Lists current alarms
SYS	RUN		Command Name	W	Runs pre-loaded system commands
SYS	GUI	CHAN	UID signal name	R/W	Set the signal display for a given channel widget
SYS	GPIB	ADDR	1- 31	R/W	Sets the GPIB address of the box
SYS	TCP	ADDR	###.#	R/W	Sets the IP address of the box
SYS	TCP	DHCP	OFF:ON	R/W	Sets DHCP search
SYS	TCP	GATE	###.#	R/W	Sets the gateway
SYS	TCP	SUBN	###.#	R/W	Sets the subnet mask
SYS	RS232	ADDR	1-255	R/W	Sets the Isobus address
SYS	RS232	BAUD	9600:19200:38400:57600:115200	R/W	Sets the Baudrate
SYS	RS232	STOP	1 - 2	R/W	Sets the number of stop bits
SYS	RS232	DATA	7 - 8	R/W	Sets the number of data bits
SYS	RS232	PAR	none:odd:even:mark:space	R/W	Sets the parity
SYS	RS232	FLOW	none:hardware:Xon/Xoff	R/W	Sets the flow control

## MercuryiTC

To enter engineering mode, send the following command:

```
SET:SYS:USER:ENG:*****
```

To exit engineering mode, send the following command:

```
SET:SYS:USER:NORM
```

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

```
SET:SYS:USER:ENG:***** (to enter engineering mode)
```

```
SET:SYS:PASS:newpassword (to enter a new password)
```

```
SET:SYS:USER:NORM
```

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

### Example of a system command

Send the following command to determine the iTC 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.

### 9.3.5.2 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 DEV:<UID>:TEMP followed by:

## MercuryiTC

COMMAND	OPTIONS	Read/Write	DESCRIPTION
MAN	HVER	R	Reads the hardware version of the daughter card
MAN	FVER	R	Reads the firmware version of the daughter card
MAN	SERL	R	Reads the serial number of the daughter card
NICK		R/W	Sets the name of the device
TYPE	DUM:PTC:NTC:TCE:DDE	R/W	Sets the sensor type
EXCT	TYPE UNIP:BIP:SOFT	R/W	Sets the excitation type
EXCT	MAG 0 - 1000	R/W	Sets the excitation magnitude
CAL	OFFS 0 - 1000	R/W	Sets the offset of the calibration curve
CAL	SCAL 0 - 1000	R/W	Sets the scale of the calibration curve
CAL	FILE	R/W	Sets the calibration file to use to calculate the temperature
CAL	INT NONE:LIN:SPL:LAGR	R/W	Sets the interpolation method for the calibration file. SPL and LAGR options not yet implemented.
CAL	HOTL 0 - 2000	R/W	Set the maximum value for temperature setpoint (hot limit)
CAL	COLDL 0 - 1000	R/W	Set the minimum value for temperature setpoint (cold limit)
CAL	CAL	R/W	Calibrates the hardware. Reads the time of the last calibration (seconds since 1970-01-01 00:00:00 UTC)
CSMP		R/W	Control filter buffer length (number of samples)
CSMP		R/W	Signal filter buffer length (number of samples)

The signals for a temperature sensor are DEV:<UID>:TEMP followed by:

COMMAND	Read/Write	DESCRIPTION
SIG VOLT	R	Sensor voltage
SIG CURR	R	Sensor current
SIG TEMP	R	Measured temperature
SIG CTMP	R	Control temperature
SIG RTMP	R	Raw temperature
SIG POWR	R	Sensor power dissipation
SIG RES	R	Measured resistance (PTC/NTC)
SIG SLOP	R	Temperature to resistance ratio (PTC/NTC)
SIG REF	R	Thermocouple reference temperature

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:

## MercuryiTC

```
SET:DEV:MB1.T1 :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:MB1.T1
:TEMP:TYPE:PTC:EXCT:TYPE:UNIP:MAG:10uA:CALB:RP5.DAT:VALID
```

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

```
STAT:SET:DEV:MB1.T1 :TEMP:TYPE:PTC:EXCT:TYPE:INVALID:MAG:INVALID:
CALB:RP5.DAT
```

### Example of reading a temperature sensor

The following command reads the sensor voltage:

```
READ:DEV:MB1.T1 :TEMP:SIG:VOLT
```

The sensor returns the following message:

```
STAT:DEV:MB1.T1 :TEMP:SIG:VOLT:12.345:mV:VALID
```

### 9.3.5.3 Addressing a temperature control loop

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

```
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 control loop are DEV:<UID>:TEMP: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
LOOP HTR	UID	R/W	Assign Heater device to Temperature Loop
LOOP AUX	UID	R/W	Assign Auxiliary device to Temperature Loop
LOOP P		R/W	Read/Set the P Value
LOOP I		R/W	Read/Set the I Value
LOOP D		R/W	Read/Set the D Value
LOOP SIG		R	Read the PID loop interpolated output
LOOP PIDT	OFF:ON	R/W	Read/Sets automatic PID values (from table)
LOOP PIDF	OFF:ON	R/W	Sets the file to read from for the automatic PID Table

## MercuryiTC

LOOP	THTF	OFF:ON	R/W	Sets the file to read from for the Target Heater Table
LOOP	SWFL		R/W	Sets the file to read from for the Sweep Table
LOOP	SWMD	FIX:SWP	R/W	Sets the sweep mode
LOOP	ENAB	OFF:ON	R/W	Enables(Auto)/disables(Manual) the PID control
LOOP	TSET	0 - 2000	R/W	Sets the temperature set point
LOOP	HSET	0 - 100	R/W	Sets the Heater percentage (in Manual)
LOOP	FSET	0 - 100	R/W	Sets the flow percentage (Manual flow)
LOOP	RSET	0-inf	R/W	Sets the ramp rate for when the loop is in ramp mode
LOOP	FAUT	OFF:ON or Manual:Auto	R/W	Enables/Disables flow control. (Use Manual:Auto instead of OFF:ON for Cryosys 1.0.11 and older)
LOOP	RENA	OFF:ON	R/W	Enables/Disables ramp mode

### 9.3.5.4 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 DEV:<UID>: HTR followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
MAN	HVER	R	Reads the hardware version of the daughter card
MAN	FVER	R	Reads the firmware version of the daughter card
MAN	SERL	R	Reads the serial number of the daughter card
NICK		R/W	Sets the name of the device
VLIM	0 - 40	R/W	Sets the Maximum voltage limit for the heater
STAT		R	Reads the alarm flags of the device (Hex Format)
RES	10 - 2000	R/W	Sets the heater resistance
PMAX	0 - 80	R	Indicates the maximum power of the heater
CAL		W	Calibrates the hardware

The signals for a heater controller are DEV:<UID>: HTR followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
SIG	VOLT	R/W	Heater voltage

## MercuryiTC

SIG	CURR	R	Heater current
SIG	POWR	R	Heater power dissipation

### 9.3.5.5 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.

The configuration settings for a level meter sensor are DEV:<UID>:LVL: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION		
MAN	HVER	R	Reads the hardware version of the daughter card		
MAN	FVER	R	Reads the firmware version of the daughter card		
MAN	SERL	R	Reads the serial number of the daughter card		
NICK		R/W	Sets the name of the device		
STAT		R	Reads the alarm flags of the device (Hex Format)		
NIT	FREQ	ZERO	R/W	Sets the frequency value equivalent to 0% Nitrogen level	
NIT	FREQ	FULL	R/W	Sets the frequency value equivalent to 100% Nitrogen level	
NIT	PPS		R/W	Sets the read interval for the nitrogen level	
HEL	RES	ZERO	R/W	Sets the resistance value equivalent to 0% Helium level	
HEL	RES	FULL	R/W	Sets the resistance value equivalent to 100% Helium level	
HEL	PULS	TIM	.3 - 60	R/W	Sets the measurement time for the helium level
HEL	PULS	DEL	0 - 60	R/W	Sets the measurement delay for the helium level
HEL	PULS	MAG	0 - 280	R/W	Sets the excitation magnitude for the helium measurement
HEL	PULS	SLOW	0-1	R/W	Sets the Fast/Slow mode for Helium reading
HEL	PREP	TIM	0 - 1000000	R/W	Sets the preparation time for the helium measurement
HEL	PREP	MAG	0 - 280	R/W	Sets the excitation magnitude for the preparation of helium measurement
HEL	LOW			R/W	Sets/reads the threshold for low Helium that activates the audible alarm
HEL	HIGH			R/W	Sets/reads the threshold for high Helium level
HEL	RFL			R/W	

The signals for a level meter sensor are DEV:<UID>:LVL: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION	
SIG	HEL	LEV	R	Helium level
SIG	HEL	RES	R	Helium sensor resistance
SIG	NIT	COUN	R/W	Nitrogen sensor pulse count

## MercuryiTC

SIG	NIT	FREQ	R	Nitrogen sensor measured frequency
SIG	NIT	LEV	R	Nitrogen sensor level

### 9.3.5.6 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 DEV:<UID>:AUX: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
MAN	HVER	R	Reads the hardware version of the daughter card
MAN	FVER	R	Reads the firmware version of the daughter card
MAN	SERL	R	Reads the serial number of the daughter card
NICK		R/W	Sets the name of the device
STAT		R	Reads alarm flags for the device (Hex Format)
GFSF		R/W	Sets the THT scaling factor
GMIN	0 - 20	R/W	Sets the minimum flow
SPD	0 - 1	R/W	Sets the speed of the valve (Slow, Fast)
TES	0 - 20	R/W	Sets the Temperature error sensitivity
TVES	0 - 20	R/W	Sets the Voltage error sensitivity
GEAR	0 - 7	R/W	Sets the gearing factor for the valve

The signals for an auxiliary board are DEV:<UID>:AUX: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION	
SIG	PERC	R	Valve open percentage	
SIG	STEP	R	Valve position	
SIG	In	OFF:ON	R	Input state
SIG	On	OFF:ON	R/W	Output state

### 9.3.5.7 Addressing a pressure sensor

To address a pressure board, use the following structure:

DEV:<UID>:PRES

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 DEV:<UID>:PRES: followed by:

## MercuryiTC

COMMAND		OPTIONS	Read/Write	DESCRIPTION
MAN	HVER		R	Reads the hardware version of the daughter card
MAN	FVER		R	Reads the firmware version of the daughter card
MAN	SERL		R	Reads the serial number of the daughter card
NICK			R/W	Sets the name of the device
STAT			R	Reads alarm flags for the device (Hex Format)
TYPE		DUM:CUR:VOLT:RAT	R/W	Sets/Reads the pressure transducer type
EXCT	TYPE	None:10V:15V	R/W	Sets/Reads the pressure transducer excitation
CAL	OFFS	0 - 1000	R/W	Sets the offset of the calibration curve
CAL	SCAL	0 - 1000	R/W	Sets the scale of the calibration curve
CAL	FILE		R/W	Sets the calibration file to use to calculate the temperature
CAL	INT	NONE:LIN	R/W	Sets the interpolation method for the calibration file
CAL	HIGL	0 - 1000	R/W	Set the maximum value for temperature setpoint (hot limit)
CAL	LOWL	0 - 1000	R/W	Set the minimum value for temperature setpoint (cold limit)
CAL	CAL		W	Calibrates the hardware

The signals for a pressure board are DEV:<UID>:PRES: followed by:

COMMAND		OPTIONS	Read/Write	DESCRIPTION
SIG	VOLT		R	Sensor voltage
SIG	CURR		R	Sensor current
SIG	PRES		R	Measured pressure
SIG	POWR		R	Sensor power dissipation

### 9.3.5.8 Addressing a pressure control loop

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

DEV:<UID>:PRES:

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 DEV:<UID>:PRES: followed by:

COMMAND		OPTIONS	Read/Write	DESCRIPTION
LOOP	HTR	UID	R/W	Assign Heater device to Temperature
LOOP	AUX	UID	R/W	Assign Auxiliary device to Temperature
LOOP	P		R/W	Set the P Value

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LOOP	I		R/W	Set the I Value
LOOP	D		R/W	Set the D Value
LOOP	PIDT	OFF:ON	R/W	Sets automatic PID values (from table)
LOOP	PIDF		R/W	Sets the file to read from for the automatic PID Table
LOOP	THTF		R/W	Sets the file to read from for the Target Heater Table
LOOP	SWFL		R/W	Sets the file to read from for the Sweep Table
LOOP	SWMD	OFF:ON	R/W	Sets the sweep mode
LOOP	ENAB	OFF:ON	R/W	Enables(Auto)/disables(Manual) the PID control
LOOP	TSET	0 - 2000	R/W	Sets the pressure set point
LOOP	HSET	0 - 100	R/W	Sets the Heater percentage (in Manual)
LOOP	FSET	0 - 100	R/W	Sets the flow percentage (Manual flow)
LOOP	FAUT	OFF:ON	R/W	Enables/Disables flow control

### 9.3.6 Addressing in Lambda control mode

To address an iTC in LPF mode, to monitor and control the LPF functions, use the commands in the following table. The protocol varies a little from the standard method used to address devices because the specific device addressing is now handled by a "Lambda" template within the iTC. The template requires the iTC to be in a specific configuration and that specific devices are installed and associated with the LPF. The motherboard based temperature sensor input (MB1.T1) must be the temperature sensor associated with the LPF, there must be a pressure card installed in slot 8 (DB8.P1) and there must be an auxiliary card as a gas controller installed in slot 4 (DB4.G1).

To address the LPF functions you must use a UID of "lambda":

DEV:lambda:LPC:...

The control settings for the LPF are DEV:lambda: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
LPC	FAUT	"ON OFF" or "0 1"	Switch LPC between auto and manual control
LPC	FSET	0 - 100	In manual mode set the needle opening between 0 and 100 percent

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The signals for LPC mode are DEV:lambda:LPC: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
SIG	OPEN	R	LPF Valve open percentage
SIG	PRES	R	LPF Pressure
SIG	TEMP	R	LPF Temperature

Note: It is still possible to access the devices configured in the LPC template via their usual device commands. The above “lambda” commands will only work if the “lambda” mode has been invoked on the unit.

### 9.3.7 Addressing in HelioxX control mode

To address an iTC in HelioxX mode, to monitor and control the single-shot Heliox <sup>3</sup>He insert with pressure control and automatic re-generation, use the commands in the following table. The protocol varies a little from the standard method used to address devices because the specific device addressing is now handled by a “HelioxX” template within the iTC. The template requires the iTC to be in a specific configuration and that specific devices are installed and associated with the HelioxX:-

Device	Type	Association in HelioxX mode
MB1.T1	Temperature Sensor	He3 Sorb temperature sensor
MB0.H1	Heater Drive	He3 Sorb heater
DB6.T1	Temperature Sensor	1K plate temperature sensor
DB7.T1	Temperature Sensor	He3 pot temperature sensor - High
DB8.T1	Temperature Sensor	He3 pot temperature sensor - Low
DB1.H1	Heater Drive	1K plate heater
DB2.H1	Heater Drive	He3 pot heater
DB3.P1	Pressure Sensor	1K plate coil pressure sensor
DB4.G1	Stepper motor drive	1K plate coil needle valve

To address the HelioxX functions you must use a UID of “HelioxX”:

DEV: HelioxX:HEL:...

The control settings for the HEL are DEV:HelioxX: followed by:

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COMMAND	OPTIONS	Read/Write	DESCRIPTION
HEL	LOWT	R/W	Cross over temperature between low and high temperature modes
HEL	RCTD	R/W	Temperature difference between set point and actual temperature to trigger rapid cooldown
HEL	RCTE	R/W	Rapid cooldown sequence end point
HEL	RCST	R/W	He4 Sorb target temperature during rapid cooldown
HEL	NVHT	R/W	Target 1K plate pressure for high temperature operation
HEL	NVLT	R/W	Target 1K plate pressure for low temperature operation
HEL	NVCN	R/W	Target 1K plate pressure for He3 regeneration
HEL	PE	R/W	Temperature threshold. If the 1K pot temperature rises above this it is considered to be "empty"
HEL	RGNA	R/W	Temperature threshold. If the He3 pot temperature rises above this the regeneration routine is triggered
HEL	BT	R/W	Typical base temperature of He3 pot
HEL	SRBR	R/W	He3 Sorb target temperature during regeneration
HEL	SRBH	R/W	He3 Sorb target temperature during high temperature operation
HEL	PCT	R/W	He3 pot target temperature for start of condensation phase
HEL	SCT	R/W	He3 pot temperature to be achieved for regeneration sequence to be considered finished
HEL	TSET	R/W	Target temperature of the Heliox (He3 pot)

The signals for HEL mode are DEV:HelioxX:HEL: followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION
SIG	STAT	R	HEL Status – operational mode
SIG	TEMP	R	He3 pot Temperature (for backward compatibility)
SIG	TSET	R	He3 pot target temperature
SIG	H3PS	R	He3 pot Stable
SIG	H3PT	R	He3 pot Temperature
SIG	H3PH	R	He3 pot Heater percentage
SIG	H4PS	R	1K pot Stable
SIG	H4PT	R	1K pot Temperature
SIG	SRBS	R	He3 sorb Stable
SIG	SRBT	R	He3 sorb Temperature
SIG	SRBH	R	He3 sorb Heater percentage

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Note: It is still possible to access the devices configured in the HEL template via their usual device commands. The above “HelioxX” commands will only work if the “HelioxX” mode has been invoked on the unit.

### 9.3.8 Invalid responses

The following table lists the possible responses if an invalid command is sent.

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.

## 9.4 Legacy commands

### 9.4.1 Legacy command protocols

The commands are case-sensitive.

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

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

All command lines are terminated by the carriage return character **CR** or **\r** (ASCII 0x0D)

### 9.4.2 Legacy monitor commands

#### 9.4.2.1 Cn command - Set Control

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

Allowed values of this command are:

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C0	Local and Locked	The remote interface locks itself out and will no longer be able to connect to the Mercury.
C1	Remote and Locked	The remote interface is enabled and the front screen is disabled for all operations (only monitoring is enabled).
C2	Local and Unlocked	This state does not exist on the current version of Mercury, since the local mode disables all incoming connections. Setting C2 is the equivalent of setting C3.
C3	Remote and Unlocked	The remote interface is enabled and functioning, but it is also possible to control the Mercury from the front screen.

In the C3 state, the GUI can be used to examine values on the display, but the values cannot 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.

### 9.4.2.2 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	

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### 9.4.2.3 V command - Read Version

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

### 9.4.2.4 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  $X_n A_n C_n S_{nn} H_n L_n$  where

$X_n$		System Status
	$m=0$	Normal
$A_n$		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
$C_n$		Local/Remote Status
	$n=0$	Local and locked
	$n=1$	Remote and locked
	$n=2$	Local and unlocked
	$n=3$	Remote and unlocked
$S_{nn}$		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
$H_n$		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.
$L_n$		Auto PID status
	$n=0$	Auto PID is disabled.

n=1      Auto PID is enabled.

## 9.4.3 Legacy control commands

### 9.4.3.1 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 are:

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

### 9.4.3.2 Dnnn, Innn and Pnnn commands - Set PID Control Terms

These commands set the PID control terms (see section 15).

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

### 9.4.3.3 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%.

### 9.4.3.4 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.

### 9.4.3.5 Mnnn command - Set Maximum Heater Volts Limit

The MAXIMUM HEATER command sets the maximum heater voltage that the iTC may deliver, either under automatic control or in response to an Onnn command. The parameter **nnn** can

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take any decimal value within the corresponding range (which depends on the configuration). So, both M12 and M12.345 are valid.

### 9.4.3.6 Onnn command - Set % Output Volts

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

### 9.4.3.7 Tnnn command - Set Desired Temperature

The TEMPERATURE command sets a set point temperature. The parameter is the required temperature, sent as a signed decimal number, The parameter **nnn** can take any decimal value within the corresponding range (which depends on the configuration). So, both T12 and T12.345 are valid.

## 9.4.4 Legacy system commands

### ! command - Set ISOBUS Address

This is equivalent to setting the ISOBUS address using the RS232 Settings page (section 8.1.1).

## 10 TEMPERATURE SENSOR DAUGHTER BOARD

This chapter describes the single and dual temperature sensor boards.

### 10.1 Overview of the temperature sensor board

The iTC 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 iTC can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground.

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

### 10.2 Installing a temperature sensor board

#### 10.2.1 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 present.

If a temperature sensor board is to be used to control a heater, it must be fitted in the correct slot, as shown in the following table.

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

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The procedure for fitting a daughter board has already been described in section 5.2.

## 10.2.2 Basic check of board operation

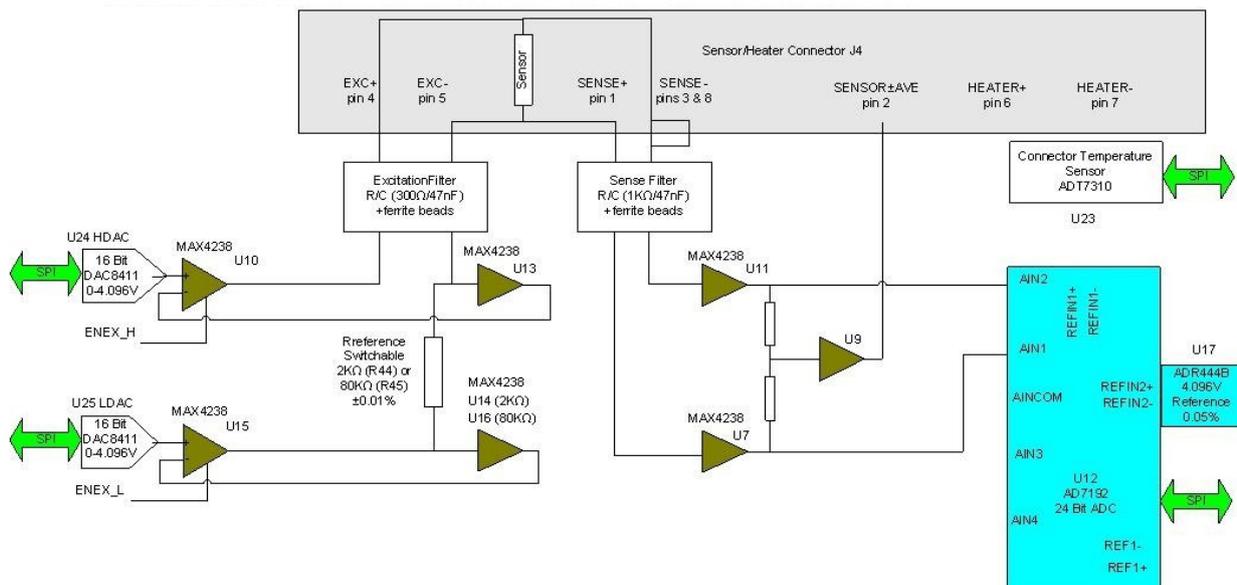
- 1 Power up the **MercuryiTC**. If fitted correctly, the iTC will detect the board and may request permission to use it.
- 2 Put the iTC in Local mode by tapping the local/remote toggle button on the iTC **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

## 10.3 Circuit description of the temperature sensor board

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

### 10.3.1 Voltage measurement mode

Voltage measurement mode is used with diode sensors or thermocouples. The following block diagram summarises the principles.



## MercuryiTC

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 measurement is not ratiometric and its accuracy depends primarily on the accuracy of the voltage reference (ADR444B =  $\pm 0.05\%$ ).

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

The sensor voltage is:

$$V_{\text{sensor}} = V_{\text{ref}} \times \text{ADC}_{\text{norm}} / \text{ADC}_{\text{gain}}$$

Where:

**ADC<sub>norm</sub>** is the ADC reading normalised to the range 0 to  $\pm 1$  V.

**ADC<sub>gain</sub>** is the gain setting of the ADC.

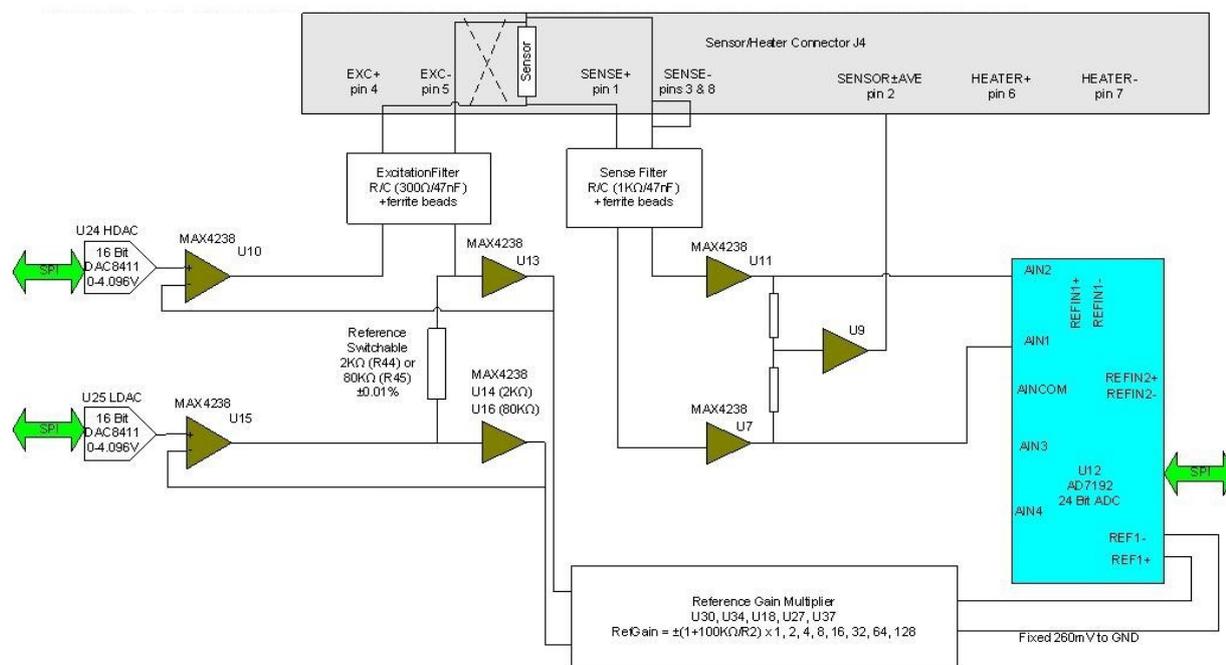
The temperature of the sensor to heater connection is measured to provide thermocouple correction.

For thermocouples, the excitation DACs are set to a middle value to correctly bias the sensor input away from the voltage rails. U10 and U15 are switched ON.

## MercuryiTC

## 10.3.2 Resistance measurement in constant current mode

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



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.

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:

# MercuryiTC

$$R_{\text{sensor}} = R_{\text{ref}} \times | \text{ADC}_{\text{norm}} | \times \text{RefGain} / \text{ADC}_{\text{gain}}$$

Where:

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

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

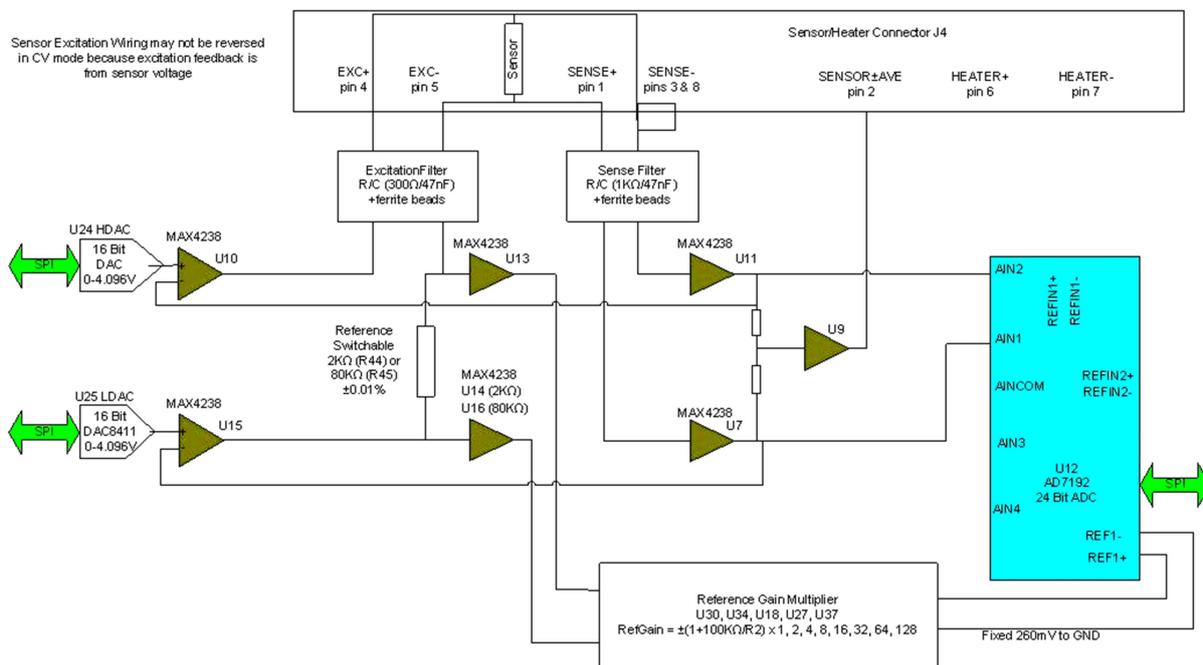
**RefGain** is the interpolated gain from the calibration tables.

**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.

### 10.3.3 Resistance measurement in constant voltage mode

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



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

## MercuryiTC

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:

$$R_{\text{sensor}} = R_{\text{ref}} \times \left| \frac{\text{ADC}_{\text{norm}}}{\text{ADC}_{\text{gain}}} \right| \times \text{RefGain}$$

Where:

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

**ADCnorm** is the ADC reading, normalised to the range 0 to  $\pm 1$  V.

**RefGain** is the interpolated gain from the calibration tables.

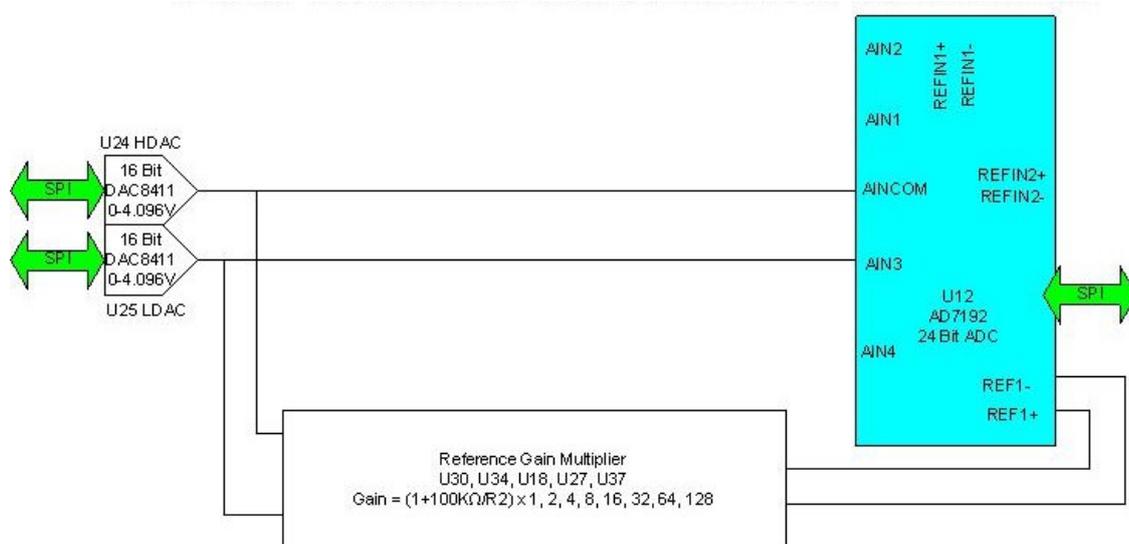
**ADCgain** is the gain setting of the ADC.

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.

### 10.3.4 Calibrating the temperature measurement circuit

A block diagram of the temperature measurement circuit in calibration mode is given below.

## MercuryiTC



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 MSP430 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.

## 11 HEATER DAUGHTER BOARD

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

### 11.1 Installing a heater board

#### 11.1.1 Fitting the board

The heater board must be fitted in the correct slot so that it is connected to its associated temperature sensor board, as shown in the following table.

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

The procedure for fitting a daughter board has already been described in section 5.2.

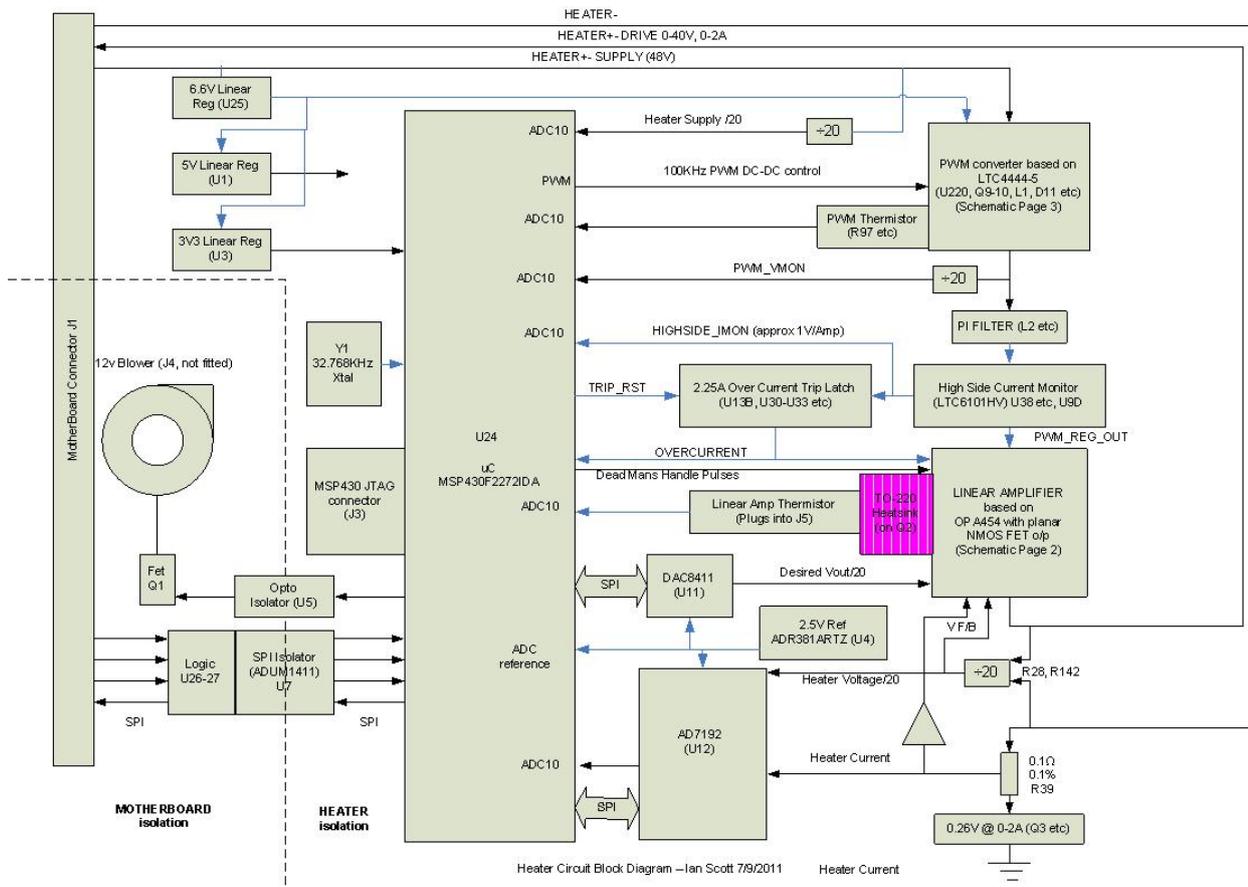
#### 11.1.2 Connecting the heater

The heater is connected to the 9-way D-connector on the associated temperature sensor board. Pin connections are shown in section 4.1.

### 11.2 Circuit description of the heater board

The image below shows a block diagram of the heater circuit.

# MercuryiTC



## 11.2.1 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.

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

## MercuryiTC

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).

### 11.2.2 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.

## 12 AUXILIARY I/O DAUGHTER BOARD

The auxiliary board combines digital inputs and outputs with a stepper motor drive and a PWM signal. This board is generally used to operate system valves for flow control of gas and cryogenic liquids.

### 12.1 Description of the auxiliary I/O board

#### 12.1.1 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 such as an automatic needle valve on a helium transfer siphon or variable temperature insert.
- 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).
- It provides a PWM signal proportional to the gas opening.

The auxiliary port connections are made via a 15-way D-socket on the iTC 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 be driven either 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 iTC 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.

## MercuryiTC

### 12.1.2 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 15.3 for a full description of gas-flow control.

## 12.2 Installing an auxiliary I/O board

### 12.2.1 Fitting the board

An auxiliary I/O board can be fitted in any expansion slot (except GPIB slot).

The procedure for fitting a daughter board has already been described in section 5.2.

### 12.2.2 Basic check of board operation

- 1 Power up the **MercuryiTC**. If fitted correctly, the iTC will detect the board and may request permission to use it.
- 2 Put the iTC in Local mode by tapping the local/remote toggle button on the iTC **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

## MercuryiTC

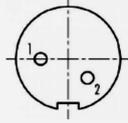
### 12.2.3 Connecting to the auxiliary I/O board

The pin connections for the 15-way D connector auxiliary port are listed in the table below.

Pin	Function
1	Output Bit 0 (Stepper Motor) or Compressor Disable.
9	Output Bit 2 (Stepper Motor)
2	Output Bit 1 (Stepper Motor)
10	Output Bit 3 (Stepper Motor)
3	Not used
11	Not used
4	PWM output proportional to gas opening
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 / +12 VDC unregulated
8	0 V

Pin connections for the 2-way miniature connector are as follows.

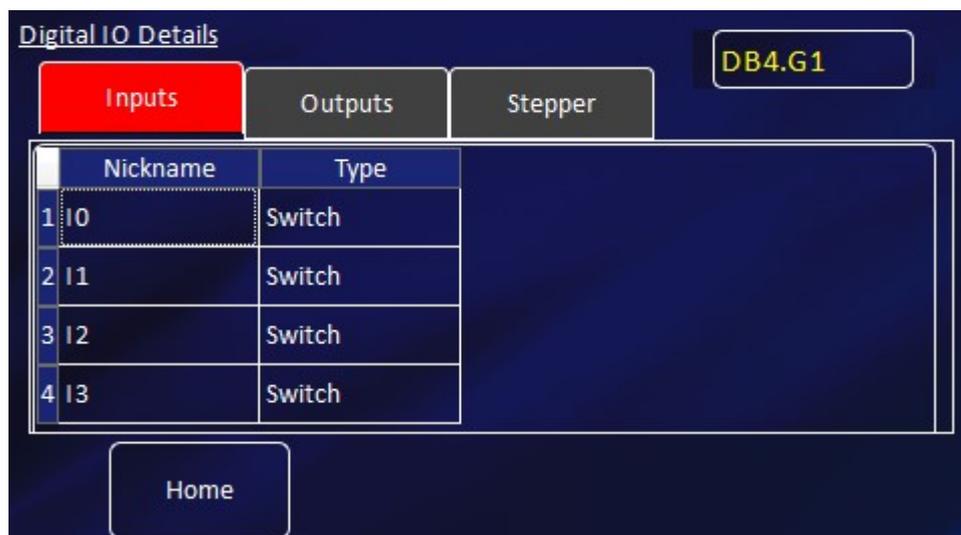
Pin	Function
1	+ve
2	ground



### 12.2.4 Configuring an input on the auxiliary I/O board

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

## MercuryiTC



- 3 Select the Inputs tab.
- 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.

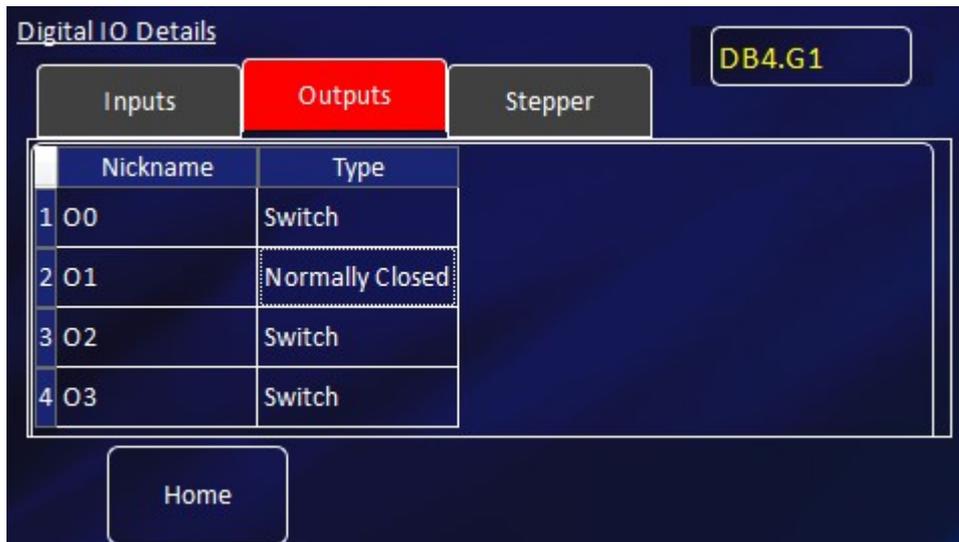
**NORMALLY OPEN** - The Home page displays OPEN when the input is high and CLOSED when the input is low.

**BOOLEAN** - The Home page displays TRUE when the input is high and FALSE when the input is low.

## 12.2.5 Configuring an output on the auxiliary I/O board

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

## MercuryiTC



- 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.

## 13 PRESSURE BOARD

This board provides isolated, precision pressure measurements from a pressure transducer.

The pressure board can interface with 3 types of pressure transducer:

- 6 Absolute Current Output (eg. Omega **PX309-015AI**) 2 wire
- 7 Absolute Voltage Output (eg. Omega **PX309-015A5V**) 3 wire
- 8 Ratiometric Voltage Output (eg. Omega **PX309-015AV**) 4 wire.

### 13.1 Description of the pressure board

The pressure card provides 10 volt or 15 volt on-board excitation for voltage output transducers and up to 25mA at up to 15volts for absolute current output transducers. The absolute voltage and absolute current transducers may also be energised from an external supply but this is not supported for ratiometric voltage transducers.

4-20mA current and 0-10 volt transducer outputs are measured on an auto-ranging 24 bit sigma delta ADC with a 0.04% accurate voltage reference. Together with other high precision components and automatic self-calibrating, this results in high accuracy and stability and low noise measurements.

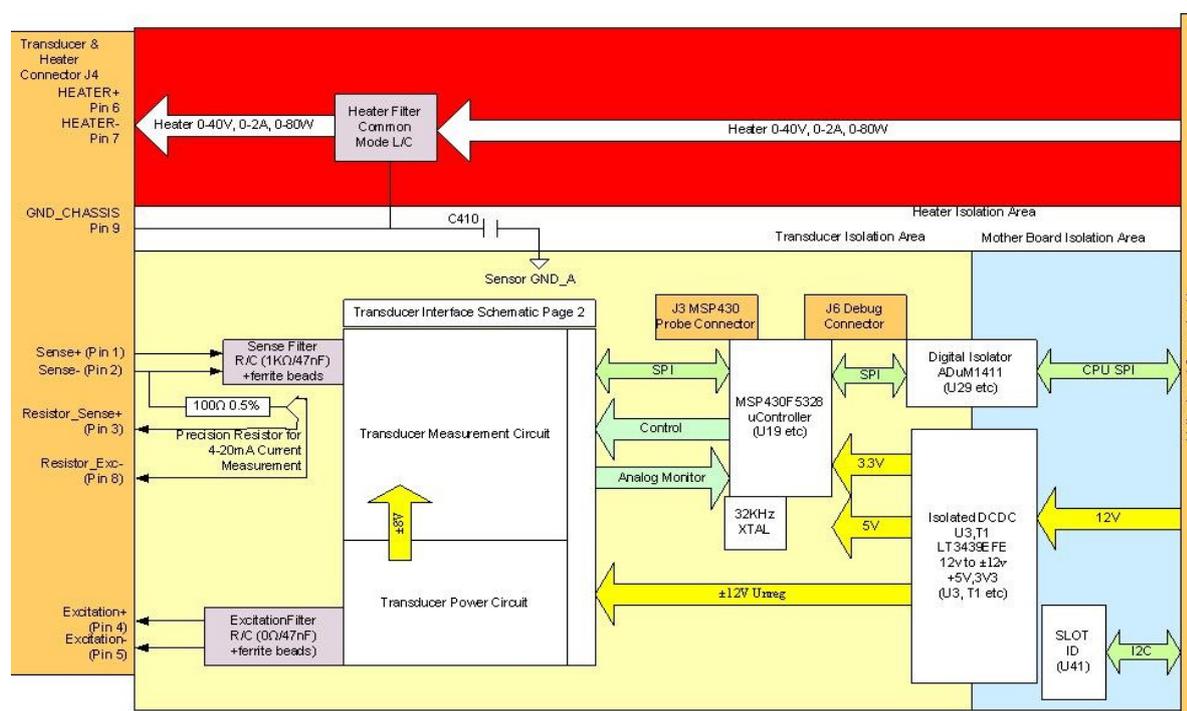
The pressure sensor input is via 9-way D-connector on the rear panel of the iTC. A filtered 80 watt heater is available on this connector when the board is fitted in slot 6, 7 or 8, with a corresponding heater board in slot 1, 2 or 3.

Extensive power-on diagnostics and continuous circuit monitoring assure the user that circuits are fully functional, operating correctly and that sensors remain properly connected. All external pins are diode protected to the power rails and current limiting resistors are fitted to the excitation supply as protection against short circuits.

#### 13.1.1 Description of the pressure board circuit

A block diagram of the pressure board is given below.

## MercuryiTC



The circuit is powered from the CPU board 12 Volt supply. This enables the board to be used in both **MercuryiTC** and iPS systems. The transducer interface is individually isolated on this board. An isolated, low noise DC-DC converter is implemented by a LT3439EFE power supply and transformer. The rectified and smoothed output provides  $\pm 12V$  unregulated supplies to power the transducer interface, from which the +3.3V logic and +5V analog supplies are derived using low noise fixed linear regulators.

The board is an SPI bus slave to the CPU board. A digital isolator chip (U29) drives Clock, SIMO (Slave in Master out) Data and Chip select to the on board MSP430 from the CPU board. SOMI Data is driven back to the CPU from the MSP430.

A slot identifier Chip U41 can be read by the CPU to give PCB type and version via the I<sup>2</sup>C bus.

The microcontroller is a 25MHz 16 bit mixed signal microcontroller from TI. It has 128Kbytes of flash memory and 10Kbytes of SRAM. In addition to the SPI bus to the CPU board, a local SPI bus interfaces to the external 24 bit ADC used to make pressure readings during operation. An internal 12 bit ADC, using the same precision reference as the external ADC, is used to monitor the transducer excitation during operation. An external crystal ensures accurate timing. A bank of 5 diagnostic LEDs is fitted at the top of the board. Connector J3 is an I/O port to initially program the microcontroller in production. An additional serial/general purpose debug port is provided on J6, although this is not currently used for user applications.

## MercuryiTC

The heater connections on pins 6 and 7 and heater output filter are identical to the Temperature Sensor board. The filter consists of a Common Mode Choke (L2) capacitors and 48v back to back zener diodes to GND\_CHASSIS and ferrite beads. The purpose is to comfortably exceed EMC emission specifications and give a low-noise heater output.

The pressure transducer interface pins 1,2,4 and 5 are filtered with ferrite beads and r/c filters. A 100Ω 0.05% resistor, R187, is fitted to measure 4-20mA output transducers. Standard 4-wire connections are made to this resistor to eliminate cable and connector resistances from the measurement, for optimum accuracy.

Capacitor C410 provided an AC connection between GND\_CHASSIS and isolated transducer interface ground GND\_A, for noise reduction.

The measurement circuit operation depends on the type of pressure sensor used.

- 1 **Absolute Current** sensors typically provide a 4-20mA output. This is passed through the on-board precision 100Ω resistor; the voltage across this resistor is applied giving 0.4V to 2.0V referenced to Excite- across the Sensor+ and Sensor- inputs. This results in 80mV to 400mV between AIN1 and AIN2 of the ADC. The measurement is then made in a similar way to the Absolute Voltage case described more fully below. The card passes the Current reading in mA to the system, which uses the Transducer Calibration Table to determine the pressure reading.
- 2 **Absolute Voltage** sensors give outputs Sensor+ normally 0-5V or 0-10V referenced to Excite- (-5V for 10V excitation or -7.5V for 15V excitation) tied to the Sensor- input. The inputs pass through the analog multiplexer (U32) to the Buffer Attenuator, resulting in approximately 0-2V or 0-1V between AIN1-AIN2 of the ADC(U12), offset so both inputs are within the 0-5V range of the ADC. The ADC measures AIN1-AIN2 differentially against the precision 2.5V reference (U17). The ADC has an internal programmable gain amplifier (PGA) with fixed gains of 1,8,16,32,64,128. The firmware selects the correct gain to auto-range the input for maximum precision over several cycles. The ADC has variable length and selectable type of filters so that maximum accuracy is achievable in the available time. This circuit can make readings at variable rates from 1Hz to 10Hz as required by the system settings. The card passes a voltage reading to the system, which used the Transducer Calibration Table to determine the pressure reading. The circuit is pre-calibrated to improve accuracy, as explained below.

## MercuryiTC

- 3 **Ratiometric Voltage** sensors normally provide an output 0-100mV (for 10V excitation) referenced about GND\_A. This results in 0-20mV at the ADC. The ADC internal PGA will be set to a minimum gain of 8 with auto-ranging and the measurement is made as described in the Absolute Voltage case described above. The excitation voltage is measured exactly by the EXCITE\_VMON+ and EXCITE\_VMON- signals feeding the MSP430 ADC12. The voltage fed to the system is normalised as if the excitation voltage were precisely 10.0V and the pressure is determined with reference to the Transducer Calibration Table.

## 13.2 Installing a pressure board

### 13.2.1 Fitting the board

A pressure board can be fitted in any expansion slot (except GPIB slot).

The procedure for fitting a daughter board has already been described in section 5.2.

### 13.2.2 Basic check of board operation

- 1 Power up the **MercuryiTC**. If fitted correctly, the iTC will detect the board and may request permission to use it.
- 2 Put the iTC in Local mode by tapping the local/remote toggle button on the iTC **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

### 13.2.3 Connecting to the pressure board

The pin connections for the 9-way D connector on the pressure board are listed in the table below.

Pin	Name	Function
1	Sense +	High Impedance transducer Input +
2	Sense -	High Impedance transducer Input -
3	Resistor_Sense+	4-20mA current Sense Resistor – Sense+
4	Excitation +	
5	Excitation -	
6	(Heater +)	
7	(Heater -)	

# MercuryiTC

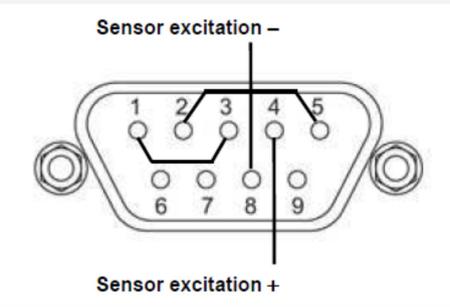
8	Resistor_Exc-	4-20mA current Sense Resistor Supply(-)
9	(Chassis)	

Wiring requirements for all pressure sensors are given in the table below.

Sensor and energisation options	9 way D connector wiring details
---------------------------------	----------------------------------

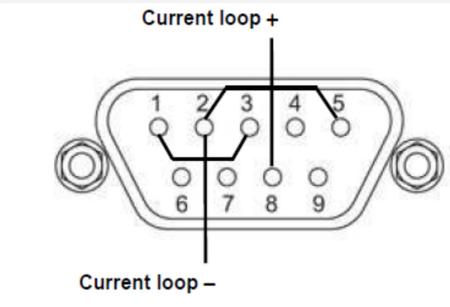
**Absolute Current Output (2 wire) sensors** using 15V excitation from the pressure board to energise the sensor.

Pins (1,3) and (2,5) are linked inside the connector shell.  
Pins 2 and 3 are not interchangeable.



**Absolute Current Output (2 wire) sensors** using external excitation to energise the sensor.

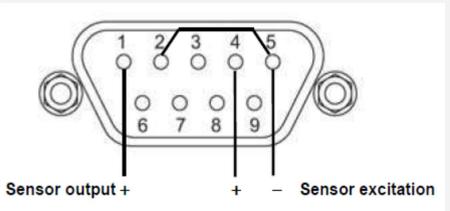
Pins (1,3) and (2,5) are linked inside the connector shell.  
Pins 2 and 3 are not interchangeable.



**Absolute Voltage Output (3 wire) sensors** using 10V or 15V excitation from the pressure board to energise the sensor.

Pins (2,5) are linked inside the connector shell.

Pins 2 and 3 are interchangeable but the wiring shown is recommended

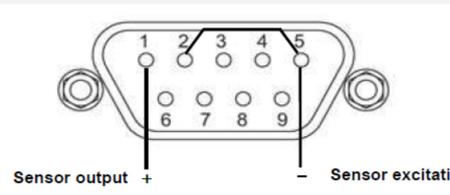


**Absolute Voltage Output (3 wire) sensors** using external excitation to energise the sensor.

Pins (2,5) are linked inside the connector shell.

Note: If the sensor output can exceed 5V then configure the board to give additional excitation to bias the sensor output between +5V and -5V.

Pins 2 and 3 are interchangeable but the wiring shown is recommended

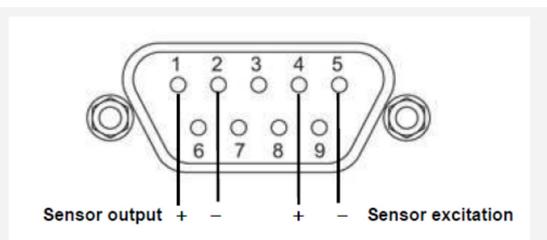


## MercuryiTC

**Ratiometric output** (4 wire) sensors require 10V or 15V excitation from the pressure board to energise the sensor.

Pins (2,3) are interchangeable, but the wiring shown is recommended.

Use of an external supply to energise ratiometric sensors is not supported.



### 13.2.4 Configuring the pressure board

- 1 Tap once on an unconfigured widget. The Channel Display Configuration page is displayed.



- 2 Tap the **Device** parameter box and choose a pressure sensor input from the drop-down list. This will be labelled **\*\*\*.P1** (DB8.P1 in the example below). Then tap **Assign**.
- 3 Tap **Signal** and select **Pressure**.
- 4 Tap **OK** to save the changes and to return to the **Home** page.

### 13.2.5 Configuring the pressure sensor details

- 1 Tap a configured widget on the **Home** page. The **Sensor Details** page is displayed.

## MercuryiTC

Sensor Details

DB8.P1

Sensor Type: Current

Calibration: None

Interpolation: Linear

Excitation: 10V

Sensor Readings

I (mA)	0.0262
p (mB)	0.0262

Home Cal Adj Calibrate

- 2 Tap the **Sensor Type** parameter box and select a sensor type from the drop-down menu, as follows:

Choose sensor type Current

Current

Voltage

Ratiometric

OK Cancel

The values listed under **Sensor Readings** on the Sensor Details page depends on the type of pressure sensor used.

- 3 Tap the **Calibration** parameter box and select a calibration file (or None) from the drop-down menu. The list of files available depends on which sensor type is selected. An example page is:

## MercuryITC



- 4 Tap the **Excitation** parameter box and select None, 10V or 15V depending on the type of sensor (and advice give in section 13.2.3).
- 5 If desired, tap the parameter box containing the name of the sensor and enter a new name. (e.g. Change **DB8.P1** to **Pressure**).

### 6 Calibrate

Tap once to calibrate the measurement circuit against its internal references. This routine takes approximately one minute. An error message is generated if the calibration fails for any reason. It is recommended that the user calibrates at least once a year with the iTC warmed up to normal operating temperature (i.e. at least 20 minutes after power-on). It is also advisable to calibrate before any critical measurements are made.

### 7 Cal Adj

Tap once to access the Generic Sensor Adjustment page. This allows the user to adjust the scale and offset of a generic calibration to suit a particular sensor:-

- a. With actual line pressure at or close to zero, enter the offset (in Bar) into the "Offset" spin box to make the "Pres" reading as close to actual as possible. Press "Save" to instantly see the change in "Pres" value.
- b. Then with the actual line pressure at or close to the full scale value enter a suitable scaling factor into the "Scale" spin box to make the "Pres" reading as close to actual as possible. Press "Save" to instantly see the change in "Pres" value.

## MercuryiTC

- c. The adjustment procedure uses  $y = mx + b$ . This assumes that the sensor is linear, which might not be the case, in which case a specific device calibration file will be required.
  - d. If the “Cal Adj” adjustment fails to achieve the expected results due to non-linearity of the sensor it would be possible to create a proper calibration file/table for the sensor, but of course this would require that the specific sensor has calibration data that can be used to populate the file.
- 8 Tap **Home**. The Home page is displayed. If the sensor has been configured correctly (and is connected), the selected page will display a sensor reading.

### 13.3 Using the pressure board to control a pressure

The principles of control loops apply to pressure control in the same way as temperature control (chapter 15).

To control a pressure using a heater, follow the steps described in chapter 4, substituting pressure (board) for temperature (board).

## 14 GPIB DAUGHTER BOARD

### 14.1 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.

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 GPIB conformance of the instrument is specified by the Capability Identification Codes:

SH1 AH1 T6 L4 SR1 RL0 PP0 DC1 DT0 C0 E1

### 14.2 Installing a GPIB board

#### 14.2.1 Fitting the board

A GPIB board can only be fitted in the dedicated GPIB expansion slot. Otherwise, the procedure for fitting a GPIB board is as described in section 5.2.

#### 14.2.2 Basic check of board operation

- 1 Power up the **MercuryiTC**. If fitted correctly, the iTC will detect the board and may request permission to use it.
- 2 Put the iTC in Local mode by tapping the local/remote toggle button on the iTC **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

## 14.3 Connecting to the GPIB board

### *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.

## 15 THEORY OF CONTROL LOOPS

This chapter describes the general principles of the control loops used in the **MercuryiTC**.

### 15.1 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

### 15.2 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.

## MercuryiTC

- 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.

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.

### 15.2.1 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** parameter box on the **Control Loop Configuration** page to **Manual** mode (see section 4.3).

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

### 15.2.2 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.

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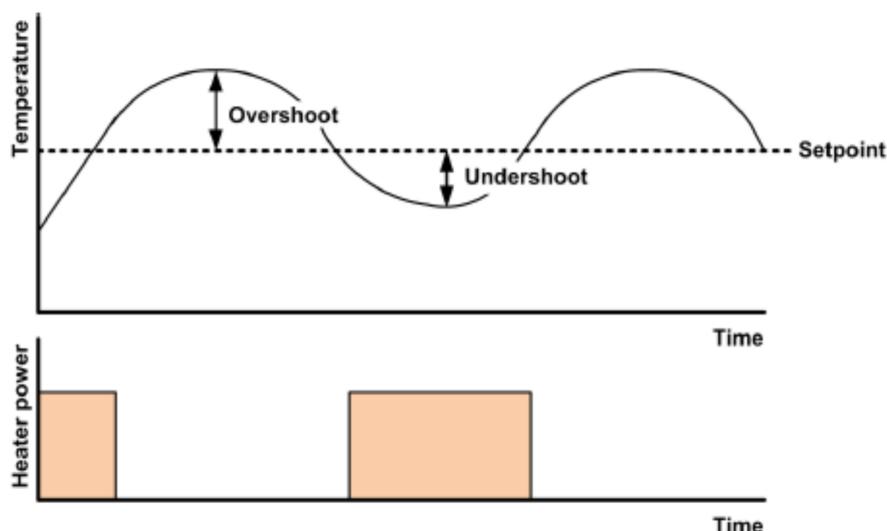


Figure 7 Response of an on-off control system

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

### 15.2.3 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).

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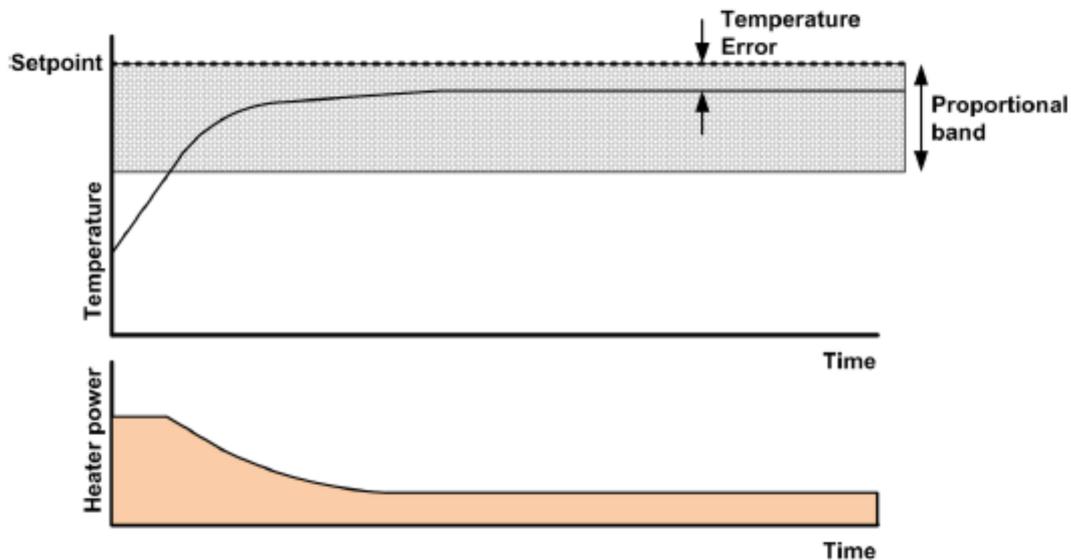


Figure 8 Proportional band control

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

### 15.2.4 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.

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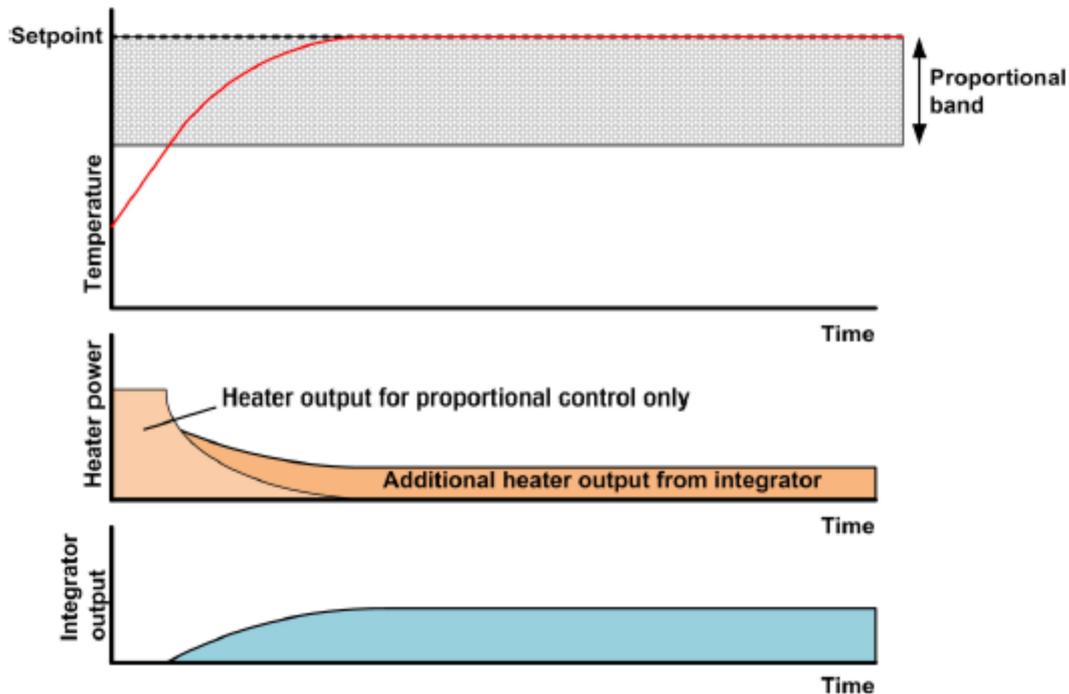


Figure 9 Proportional control with integrator action

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.

### 15.2.5 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.

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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.

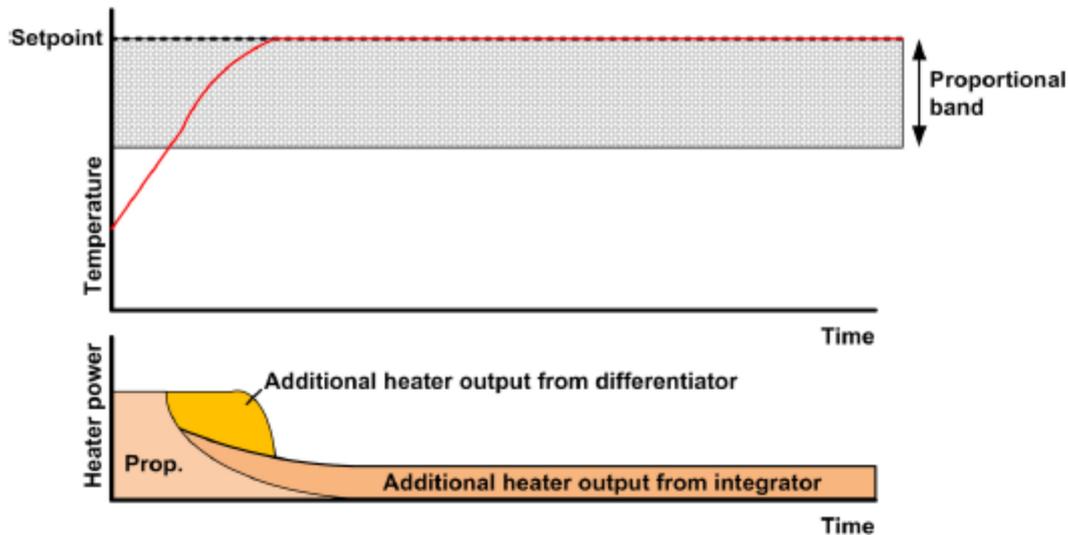


Figure 10 Proportional control with integral and differential action

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.

### 15.2.6 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.

### 15.2.7 PID tables

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

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- Manual PID

The PID parameters are entered directly on the *Control Loop Configuration* page (see section 4.3 for heater control and 4.8 for gas control). 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 4.5.2). This method allows the PID parameters to vary with the controlled temperature.

The image below shows an example PID table containing two rows. The values shown in this table are not from a real system.

Temperature(K)	To(K)	P	I (min)	D (min)
5	10	10	2	12
10	25	15	3	5

PID values used between 5 – 10K

PID values used between 10 - 25K

- Load Save Close +

## 15.3 Theory of gas-flow control

### 15.3.1 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.

- Siphon

This algorithm is used if the coolant is supplied from a dewar.

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### 15.3.2 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.

### 15.3.3 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.

The control function is driven by two error signals:

- Temperature Error Sensitivity (TES)  
the difference between the temperature measured by the sensor and the temperature set-point.
- Target Voltage Error Sensitivity (TVES)  
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 4.8.1), 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

## MercuryiTC

both the temperature error and the heater voltage error are zero, at which point the valve opening remains constant.

### 15.3.4 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 4.3), and is multiplied by the gas flow scaling factor (see section 4.8.2), 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 Oxford Instruments NanoScience to obtain a Heater Target Table to suit your application.

### 15.3.5 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:

- 1 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).
- 2 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.
- 3 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.

## 16 PREVENTIVE MAINTENANCE

The **MercuryiTC** requires minimal maintenance. It is recommended that the following maintenance tasks are performed every six months, unless stated otherwise.

### 16.1 Cleaning the touch-screen

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

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

### 16.2 Calibrating the temperature sensor circuits

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

For each temperature sensor that is configured:

- 1 Tap the widget on the **Home** page once to display the **Sensor Details** page.
- 2 Tap **Calibrate**, then wait until the internal calibration routine has completed. This takes approximately one minute.

### 16.3 Lubricating the fan

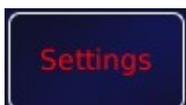
Lubricate the fan every couple of years using a water displacing aerosol lubricant, such as WD40.

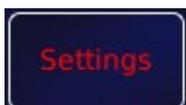
## 16.4 Lithium-ion coin cell replacement

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.

## 17 ALARMS, INTERLOCKS AND TROUBLESHOOTING

### 17.1 Alarms and interlocks



When an error is identified by the iTC, the  and  button text changes to red.

There may be an audible alarm (see 17.3).

An interlock may be triggered for safety reasons (see 17.3).

#### 17.1.1 Alarm Logs and Alarms History pages

The **Current Alarm Logs** page records every alarm as it is generated. The entry for an active alarm disappears when the alarm is corrected.

The Historic Alarm Logs page records every alarm as it is generated and another entry when the alarm is corrected.

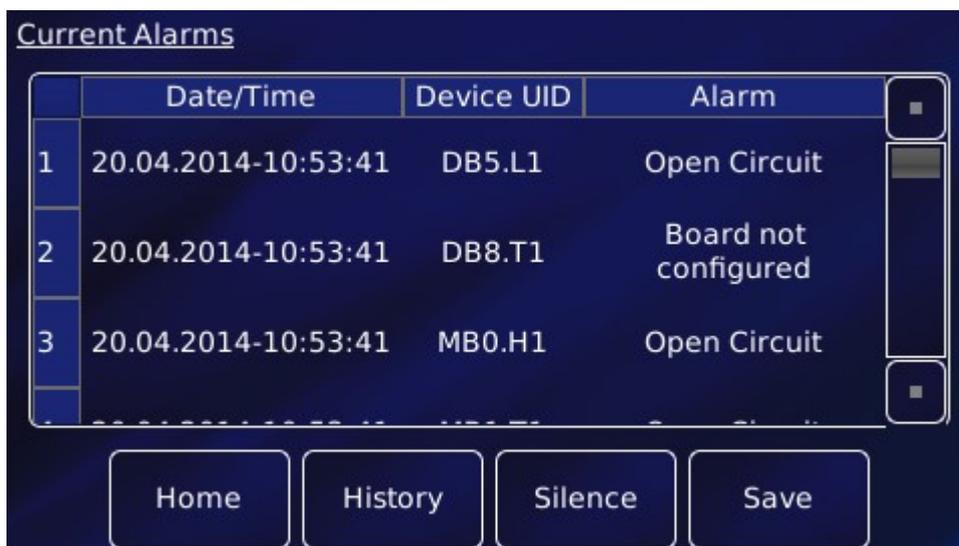
Safety interlocks are also registered in the alarms log.

From the **Home** page, tap **Settings**, then scroll to the **General Settings** tab. Tap **Alarm**.

Alternatively, tap **Alarm** on any page where it appears.

This opens the **Current Alarms** page.

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	Date/Time	Device UID	Alarm
1	20.04.2014-10:53:41	DB5.L1	Open Circuit
2	20.04.2014-10:53:41	DB8.T1	Board not configured
3	20.04.2014-10:53:41	MB0.H1	Open Circuit

Buttons: Home, History, Silence, Save

This table has the following columns:

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

The page contains the following buttons:

- **Silence**  
Tap once to silence the buzzer (audible alarm), if any. The buzzer remains off until a new alarm is triggered.
- **Save**  
Tap once to save alarms to a USB memory stick.
- **Home**  
Tap once to return to the **Home** page.
- **History**  
Tap once to access the **Historic Alarm Logs** page.

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Historic Alarm Logs

	Date/Time	Device UID	Alarm	
9	24.03.2014-16:18:34	DB8.T1	Board not configured	■
10	17.03.2014-13:20:58	DB1.H1	Open Circuit	■
11	17.03.2014-13:20:52	DB1.H1	Restored: Open Circuit	■

Home Back Save

- **Save**  
Tap once to save alarm history to a USB memory stick, as described above.
- **Back**  
Tap once to go back to the **Current Alarms** page.

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### 17.2 Troubleshooting

It is useful to distinguish between internal and external alarms. Some alarms arise because of an event internal to the **MercuryiTC**; other alarms are triggered by a fault in the system being controlled.

The next two sections summarise good practice when attempting to diagnose and correct faults. A reference list of alarms is given in section 17.3.

#### 17.2.1 Internal faults

Software (firmware) alarms can often be cleared very simply. Follow the instructions in the next table and check after each step to see if the alarm has cleared.

Step	Action
1	Switch <b>MercuryiTC</b> OFF then ON.
2	Update board firmware (section 7.6)
3	Recalibrate board

#### 17.2.2 External faults

The majority of external faults are the result of wiring problems such as short circuits and open circuits. Diagnosis will require the use of a DVM.

Step	Action
1	Check that cables are in the correct sockets on the <b>MercuryiTC</b> and securely fastened. The connector should be flush with the iTC and the locking screws tightened.
2	Check the cable between the iTC and your cryogenic system. Repair or replace if faulty.
3	Check resistances at the system connector socket. Compare these values with those in your System Data. If a fault is found, refer to your system handbook.

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### 17.3 Directory of alarms

The following table provides a complete list of alarms, together with associated interlocks, as appropriate.

Alarm	Interlock	What to do
<b>Temperature board</b>		
Open circuit	Heater OFF	Look for open circuit on the sensor input
Short circuit		Look for short circuit on the sensor input
Calibration error		Recalibrate
Firmware error		Error in Board firmware. Update firmware.
Board not configured		Firmware not loaded correctly. Update firmware.
<b>Heater board</b>		
Open circuit	Heater OFF	Look for open circuit on the heater output
Short circuit		Look for short circuit on the heater output
Over current		Look for partial short circuits (low impedance)
Over temperature		Look for ventilation problems or high ambient temperature
Calibration error		Recalibrate
Firmware error	Heater OFF	Error in Board firmware. Update firmware.
Board not configured		Firmware not loaded correctly. Update firmware.
<b>Auxiliary I/O board</b>		
Firmware error		Error in Board firmware. Update firmware.
Board not configured		Firmware not loaded correctly. Update firmware.
<b>Level meter board</b>		
Open circuit		Look for open circuit on the probe input
Short circuit		Look for short circuit on the probe input
ADC error		This is on-board diagnostic. Recalibrate.
Over demand		This is on-board diagnostic. Recalibrate.
Over temperature		
Firmware error		Error in board firmware. Re-start iTC
Board not configured		Firmware not loaded correctly. Update firmware.
No reserve	Autofill stops after 2hr	The auto fill valve is open but the dewar is not filling
<b>Pressure board</b>		
Open circuit		Look for open circuit on the sensor input
Short circuit		Look for short circuit on the sensor input
Calibration error		Recalibrate
Firmware error		Error in board firmware Update firmware.
Board not configured		Firmware not loaded correctly. Update firmware.
Over current		Look for partial short circuits (low impedance)
Current leakage		Look for short to ground

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Power on fail	Re-start iTC
Checksum fail	Re-start iTC
Clock fail	Re-start iTC
ADC fail	On-board diagnostic. Recalibrate.
Mains fail	Re-start iTC
Reference fail	Re-start iTC
12V fail	Re-start iTC
-12V fail	Re-start iTC
8V fail	Re-start iTC
-8V fail	Re-start iTC
Amp gain error	Re-start iTC
Amp offset error	Re-start iTC
ADC offset error	Re-start iTC
ADC PGA error	Re-start iTC
ADC XTAL failure	Re-start iTC
Excitation + error	Re-start iTC
Excitation - error	Re-start iTC

### Control loop

Over temperature	Heater OFF until temp <95% limit or limit + 5K	Sensor temperature is above specified limit. Look for overheating caused by incorrect PID, heater or sensor configuration or other heat sources.
Over cooling	Gas flow OFF until temp >105% limit or limit + 5K	Sensor temperature is below specified limit. Look for incorrect PID, sensor or gas flow configuration or other cooling sources.

If you are experiencing difficulties, please

- check the relevant sections of this manual
- upgrade application/firmware to the latest versions, as described in section 7.6.
- check FAQs on the **Mercury** website at [www.mymercurysupport.com](http://www.mymercurysupport.com).

If you are still unable to resolve the problem, please contact your nearest support facility (see below) and have the following details available:

Product name	<b>MercuryiTC</b>
Serial number	A 6 character alphanumeric code located on the iTC rear panel.
Contact information	Your name, the name of your company or institution, and how we can contact you.
Problem	A description of the problem, with as much detail as possible.

## MercuryiTC

# 18 TECHNICAL SPECIFICATIONS

This chapter lists the technical specifications of the **MercuryiTC**.

## 18.1 Physical specification

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

## 18.2 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
Compliance Standard	CE, cETLus (UL and CSA recognised standard)
Maximum mains voltage fluctuation	±10% of nominal voltage
Category II transient overvoltages can typically be present on the mains supply.	

## 18.3 Sensor inputs

Item	Specification
Basic iTC – 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 $\mu$ A
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.

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### The MercuryiTC

- can accommodate thermocouple sensors with cold-junction compensation (CJC).
- can accommodate silicon-diode sensors (constant current supply).
- can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground.
- can store sensor calibration files.
- can automatically set range-limits from the calibration file.

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

## 18.4 Heater outputs

Item	Specification
Basic iTC - 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 2500 ohms
Output resolution	16 bit

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

The output is protected against short-circuits.

The MercuryiTC has a “dead-man’s-handle” timer that disables the heater outputs if the control loop stalls.

## 18.5 PC interfaces

Item	Specification
Serial interface	RS232 + ISOBUS
Serial interface 2	USB
GPIB	IEEE-488 (optional)
Ethernet	10/100 IEEE802.3

## MercuryiTC

### 18.6 Electrical isolation

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.

### 18.7 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	75% non-condensing
Maximum humidity	91% at 20°C when connected to a pc compliant with a 60950-1 standard.
Pollution degree	2

### 18.8 Level meter board

#### Helium probe specifications

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	0 to 300 ohms
Probe resistance measurement accuracy	±0.2%
Probe resistance measurement stability	±0.1%
Probe resistance ADC measurement resolution	Better than 0.005%

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Probe connections isolation to chassis >50 VDC

### Nitrogen probe specifications

Parameter	Specification
Probe source voltage	12 VDC
Probe source oscillator frequency range	5 kHz to 90 kHz
Probe sensing resolution (level)	0.1%
Probe sensing accuracy (level)	0.5%

## 18.9 Pressure board

Parameter	Specification
Measurement absolute accuracy	$\pm 0.1\%$ full scale in each range
Measurement Resolution	24 bits
Voltage Measurement Ranges	10V, 1.6V, 0.8V, 0.4V, 0.2V, 0-0.1V (Auto-ranging)
Current Measurement Ranges	4-20mA (20mA, 16mA, 8mA, 4mA Auto-ranging)
Measurement Frequency	1Hz-10Hz
Sensor Excitation Voltage	0 V(off) , 10V $\pm 5\%$ or 15V $\pm 5\%$
Sensor Excitation Current	0 - 20 mA
Sensor Excitation Current Trip	>30mA
Short Circuit Protection Duration	Indefinite
Isolation From Mercury Chassis	50 Volts
Over Voltage Protection	Diode on each connector pin: 50V/200mA

## MercuryiTC

# 19 CUSTOMER SUPPORT

### Europe, RoW, Main Office

Tubney Woods, Abingdon, Oxon, OX13 5QX, UK  
Telephone: +44(0)1865 393200 (sales)  
Telephone: +44(0)1865 393311 (support)  
Fax: +44(0)1865 393333 (sales and support)  
E-mail: [helpdesk.nanoscience@oxinst.com](mailto:helpdesk.nanoscience@oxinst.com) (support)  
E-mail: [nanoscience@oxinst.com](mailto:nanoscience@oxinst.com) (sales)  
Web: [www.oxford-instruments.com](http://www.oxford-instruments.com)

### Germany, Austria & Switzerland (direct)

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