

# Oxford Instruments NanoScience

## MercuryiPS

### Power Supply for Superconducting Magnets

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# Contents

<b>PREFACE</b> .....	<b>1</b>
Use of this manual .....	1
Customer support.....	4
Health and safety information .....	5
Disclaimers.....	6
Acknowledgements .....	6
Acronyms .....	7
Certification compliance statements .....	9
About Oxford Instruments .....	10
<b>1 HEALTH AND SAFETY</b> .....	<b>11</b>
1.1 Warnings.....	11
1.1.1 Protective and functional ground .....	11
1.1.2 High voltage hazard .....	12
1.1.3 Maintenance and adjustment.....	12
1.1.4 Restrictions on use .....	12
1.2 Cautions.....	13
1.2.1 Electrostatic caution.....	13
1.2.2 Cooling caution .....	13
1.2.3 Acoustic noise caution .....	14
1.3 Solid waste.....	14
<b>2 MERCURY IPS BASICS</b> .....	<b>15</b>
2.1 MercuryIPS front and rear panels .....	16
2.2 Electrical power supply.....	17
2.3 Temperature sensor circuits .....	18
2.4 Remote interfaces .....	19
2.6 Main components .....	20
2.6.1 Chassis .....	21
2.6.2 Power Supply.....	21
2.6.3 User interface.....	21

## MercuryiPS

2.6.4	Motherboard.....	22
2.6.5	Magnet control board.....	24
2.6.6	Filter board.....	24
2.6.7	Run-down resistors.....	24
2.7	Alarms and interlocks.....	25
<b>3</b>	<b>GETTING STARTED.....</b>	<b>26</b>
3.1	Checking the electrical supply.....	26
3.2	Mounting the equipment.....	26
3.2.1	Background magnetic field.....	27
3.3	Connecting electrical power.....	27
3.4	Powering up the MercuryiPS for the first time.....	28
3.5	The MercuryiPS touch screen.....	28
3.5.1	The magnet home page.....	29
3.5.2	Custom home pages.....	31
3.5.3	Channel summary widget.....	31
3.5.4	Drop-down menus.....	31
3.5.5	Scrolling.....	32
3.5.6	Soft keypads.....	32
3.5.7	Using arrows to adjust integer values.....	35
3.5.8	Button labels.....	35
3.5.9	Common touch screen features.....	35
3.5.10	Setting the date and time.....	36
<b>4</b>	<b>HOW TO CONFIGURE THE IPS FOR YOUR MAGNET.....</b>	<b>38</b>
4.1	Quench.....	39
4.2	Slaves Detected.....	40
4.3	Magnet Type.....	41
4.4	The Configuration Table (Figure 9).....	42
4.4.1	Config.....	42
4.4.2	Limit(A).....	45
4.4.3	Limit(V).....	45
4.4.4	I to H (A/T).....	46

## MercuryiPS

4.4.5	Ind (H) .....	46
4.4.6	Trans (ms).....	46
4.4.7	Switch.....	46
4.4.8	Sw Cur (mA).....	46
4.4.9	Mode .....	47
4.4.10	Safety .....	47
4.4.11	Limit (K).....	48
4.4.12	Limit (L) .....	48
4.4.13	Sw Intel .....	48
4.4.14	Htr Res ( $\Omega$ ).....	49
4.4.15	Sw Res ( $\Omega$ ).....	49
4.4.16	Lead ( $\Omega$ ).....	49
4.4.17	SW on (ms) .....	50
4.4.18	SW off (ms) .....	50
4.4.19	Catch.....	50
4.4.20	Current Epsilon (A) .....	50
4.4.21	Voltage Epsilon (V) .....	51
4.4.22	Lead Resistance and Load Inductance determination .....	52
<b>5</b>	<b>OPERATING THE MAGNET .....</b>	<b>55</b>
5.1	Rate Limits .....	56
5.2	Fast Rates / Slow Rates .....	59
5.3	Editing the Rate Limits table .....	59
5.4	Quench .....	59
5.5	Vector Rotate mode .....	60
<b>6</b>	<b>TEMPERATURE MEASUREMENT .....</b>	<b>62</b>
6.1	Sensor connections .....	62
6.1.1	Connecting thermocouples .....	63
6.2	Configuring a temperature sensor .....	63
6.2.1	Configuring the sensor details .....	64
6.2.2	To clear a widget configuration .....	66
6.4	Using a generic calibration-file.....	67
6.4.1	Overview .....	67

## MercuryIPS

6.4.2	Adjusting a generic calibration file .....	67
6.5	Types of temperature sensor .....	69
6.5.1	Thermocouples .....	69
6.5.2	Metallic resistance thermometers (positive temperature coefficient).....	69
6.5.3	Semiconductor resistance thermometers (negative temperature coefficient) .....	69
6.5.4	Semiconductor diodes .....	70
6.5.5	Excitation current .....	70
6.5.6	Calibration for different sensors .....	71
6.5.7	Available generic calibration files.....	72
6.6	More about thermocouples .....	73
6.6.1	Thermocouple principles.....	73
6.6.2	Configuring for thermocouples.....	73
6.6.3	Reference junction compensation .....	75
6.6.4	External reference junctions .....	75
<b>7</b>	<b>CRYOGEN LEVEL-METER.....</b>	<b>77</b>
7.1	Principles of operation .....	77
7.1.1	Operation of the board with a helium-level probe .....	77
7.1.2	Operation of the board with a nitrogen-level probe.....	78
7.1.3	Why different methods are used for the two liquids.....	78
7.2	Installing the level-meter board.....	78
7.2.1	Removing the top cover .....	78
7.2.2	Fitting the board .....	79
7.2.3	Basic check of board operation.....	81
7.3	Connecting the level probe .....	81
7.4	Configuring MercuryIPS for helium level meter .....	81
7.5	Configuring MercuryIPS for nitrogen level meter.....	83
<b>8</b>	<b>LAMBDA MODE.....</b>	<b>86</b>
8.1	LPF operation description.....	87
8.2	Lambda control sequence .....	88
8.2.1	Automatic Control .....	88
8.2.2	Remote Commands .....	89

# MercuryIPS

<b>9</b>	<b>MANAGING YOUR MERCURY</b>	<b>90</b>
9.1	General	90
9.2	Display	92
9.3	Devices	94
9.4	Clock	95
9.5	File transfer	96
9.6	Updates	97
9.7	Access Level	99
9.8	Factory	101
9.9	Save File pages	102
9.10	Load File pages	103
<b>10</b>	<b>REMOTE OPERATION</b>	<b>104</b>
10.1	Remote operation using RS232 or ISOBUS	104
10.1.1	Configuring RS232 and ISOBus	104
10.1.2	Serial RS232 cabling requirements	106
10.2	Remote operation using GPIB	107
10.2.1	Configuring GPIB	107
10.2.2	GPIB Cabling requirements	108
10.3	Remote operation using Ethernet	108
10.3.1	Configuring Ethernet	108
10.3.2	Ethernet cabling requirements	110
10.4	Remote operation using USB	110
10.4.1	Configuring USB	110
10.4.2	USB Cabling requirements	110
10.4.3	USB drivers	110
10.5	Switching MercuryIPS control between local and remote	111
10.6	Testing remote connections	111
10.7	Programming examples	111

# MercuryiPS

<b>11</b>	<b>COMMAND REFERENCE GUIDE .....</b>	<b>113</b>
11.1	Nomenclature used in this section .....	113
11.2	SCPI and legacy command sets.....	113
11.3	SCPI commands.....	113
11.3.1	SCPI protocols .....	114
11.3.2	Reading the instrument identity .....	114
11.3.3	Basic SCPI command structure.....	115
11.3.4	Verbs.....	115
11.3.5	Nouns.....	116
11.3.6	Addressing in Lambda mode .....	126
11.3.7	Invalid responses .....	127
11.4	Legacy commands .....	127
11.4.1	Legacy command protocols .....	127
11.4.2	Legacy monitor commands.....	127
11.4.3	Legacy control commands .....	129
11.4.4	Legacy system commands .....	130
<b>12</b>	<b>TEMPERATURE SENSOR DAUGHTER BOARD .....</b>	<b>132</b>
12.1	Overview of the temperature sensor board.....	132
12.2	Installing a temperature sensor board.....	132
12.2.1	Fitting the board .....	132
12.2.2	Basic check of board operation.....	132
12.3	Circuit description of the temperature sensor board.....	133
12.3.1	Voltage measurement mode.....	133
12.3.2	Resistance measurement in constant current mode .....	135
12.3.3	Resistance measurement in constant voltage mode.....	136
12.3.4	Calibrating the temperature measurement circuit.....	137
<b>13</b>	<b>AUXILIARY I/O DAUGHTER BOARD .....</b>	<b>139</b>
13.1	Description of the auxiliary I/O board.....	139
13.1.1	Auxiliary I/O board functions .....	139
13.1.2	Gas-flow control using a motorised needle-valve .....	140
13.2	Installing an auxiliary I/O board.....	140

## MercuryiPS

13.2.1	Fitting the board .....	140
13.2.2	Basic check of board operation.....	140
13.2.3	Connecting to the auxiliary I/O board .....	141
13.2.4	Configuring an input on the auxiliary I/O board .....	141
13.2.5	Configuring an output on the auxiliary I/O board .....	142
<b>14</b>	<b>PRESSURE BOARD.....</b>	<b>144</b>
14.1	Description of the pressure board.....	144
14.1.1	Description of the pressure board circuit .....	144
14.2	Installing a pressure board .....	147
14.2.1	Fitting the board .....	147
14.2.2	Basic check of board operation.....	147
14.2.3	Connecting to the pressure board .....	147
14.2.4	Configuring the pressure board .....	149
14.2.5	Configuring the pressure sensor details .....	149
<b>15</b>	<b>GPIB DAUGHTER BOARD .....</b>	<b>152</b>
15.1	Description of the GPIB daughter board .....	152
15.2	Installing a GPIB board.....	152
15.2.1	Fitting the board .....	152
15.2.2	Basic check of board operation.....	152
15.3	Connecting to the GPIB board .....	153
<b>16</b>	<b>PREVENTIVE MAINTENANCE .....</b>	<b>154</b>
16.1	Cleaning the touch-screen.....	154
16.2	Calibrating the temperature sensor circuits.....	154
16.3	Lubricating the fan.....	154
16.4	Lithium-ion coin cell replacement.....	155
<b>17</b>	<b>ALARMS, INTERLOCKS AND TROUBLESHOOTING .....</b>	<b>156</b>
17.1	Alarms and interlocks .....	156
17.1.1	Alarm Logs and Alarms History pages .....	156
17.2	Troubleshooting.....	159



**MercuryiPS**

17.2.1	Internal faults.....	159
17.2.2	External faults .....	159
17.3	Directory of alarms .....	160
<b>18</b>	<b>TECHNICAL SPECIFICATIONS.....</b>	<b>163</b>
18.1	Physical specification .....	163
18.2	Electrical power supply.....	163
18.3	Magnet outputs.....	163
18.4	Sensor inputs .....	164
18.5	PC interfaces.....	165
18.6	Electrical isolation.....	165
18.7	Environmental specifications .....	165
18.8	Level meter board.....	166
18.9	Pressure board.....	166
<b>19</b>	<b>CUSTOMER SUPPORT.....</b>	<b>167</b>

## MercuryiPS

# PREFACE

Welcome to the Operator's Handbook for the Oxford Instruments NanoScience **MercuryiPS** cryogenic environment controller. The **MercuryiPS** is a high performance laboratory magnet power supply, with a number of features specifically intended for use in cryogenic applications as required for superconducting magnets.

## Use of this manual

This Operator's Handbook provides all the information necessary for the safe and proper installation, operation and servicing of the **MercuryiPS** magnet power supply.

Chapters 1 to 5 provide essential information that must be read and understood before operating the **MercuryiPS** for the first time.

### Intended users

Users of the **MercuryiPS** 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 MercuryiPS

The **MercuryiPS** has been designed for superconducting magnet control. The equipment has been designed to operate within the process parameter limits that are outlined in this manual.

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

## MercuryiPS

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 **MercuryiPS** 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.

## MercuryiPS

### Revision history

This is issue 15 of the **MercuryiPS** 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>MercuryiPS</b> Operator's Handbook
02	All pages	Changes to several GUI pages
03	All pages	Complete update of the <b>MercuryiPS</b> Operator's Handbook, describing version 2.0 of <b>MercuryiPS</b> software.
04	All pages	Minor edits – Generic Calibration, GPIB, customer support addresses, to update to 2.2.x of <b>MercuryiPS</b> software.
05	All pages	Additional safety and warning notices for regulatory compliance updates.
06	Pages 111-113	Additional SCPI commands for magnet device added
07	Pages 119-123	Added legacy commands
08	Page 7 & 25	Amendments to compliance statement. Added background field caution statement.
09	Page 111-113	Updated remote command list.
10	Page 08	Updated certification information
11	Page 134	Correction on Auxiliary port pin functions
12	Many Pages	Certification updates and updates relating to firmware 2.2.6.12
13	Page 52	Added Epsilon parameter
14	Various	Changes to H&S statements and Intelligent switch.
15	Various	Functional changes resulting from firmware 2.3.0.0
16	Various	Functional changes resulting from firmware 2.4.0.0 Plus Lambda Point Fringe functions
17	Various	Functional changes resulting from firmware 2.5.05.0 Inductance check
18	Various	Removal of misleading references to driving a heater.

## MercuryIPS

### 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>MercuryIPS</b>
Serial number	A 9 character alphanumeric code (starting with "MM" or "MS" located on the iPS 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. 1.26. This is the Device (e.g. magnet 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 **MercuryiPS** contains hazardous areas. Before working with the iPS, 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 **MercuryiPS** 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.

The policy of Oxford Instruments NanoScience is one of continued improvement. The Company reserves the right to alter without notice the specification, design or conditions of supply of any of its products or services. Although every effort has been made to ensure that the information in this manual is accurate and up to date, errors may occur. Oxford Instruments NanoScience shall have no liability arising from the use of or reliance by any party on the contents of this manual and, to the fullest extent permitted by law, excludes all liability for loss or damages howsoever caused.

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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
FET	Field Effect Transistor
FPGA	Field Programmable Gate Array
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



## MercuryiPS

USB	Universal Serial Bus
VTI	Variable Temperature Insert

# MercuryiPS

## Certification compliance statements

The **MercuryiPS** power supply for superconducting magnets 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  <sub>US</sub>

Note: The ETL mark is to be applied

China Restriction of Hazardous Substances 

Signed: 

Michael Cuthbert

Managing Director

Oxford Instruments NanoScience Limited

## 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.

## MercuryiPS

# 1 HEALTH AND SAFETY

This chapter describes all health and safety considerations relating to the Oxford Instruments NanoScience **MercuryiPS** magnet power supply.

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 ground pillar on the rear panel, identified by a  $\perp$  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.

## MercuryiPS

### 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.

### 1.1.4 Restrictions on use

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

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

## MercuryiPS

### 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 **MercuryiPS** is to be rack mounted, to ensure an adequate airflow around the iPS, 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 **MercuryiPS** 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.*

### 1.2.3 Acoustic noise caution

#### *MULTIPLE UNIT NOISE*

*If many **MercuryiPS** 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.

## MercuryIPS

# 2 MERCURY IPS BASICS

The **MercuryIPS** is a high-precision, highly stable power supply designed for driving a superconducting magnet in laboratory applications. The supply is capable of sourcing and sinking current and it also accurately controls the slew of the current. The power supply includes a bank of high-power load-resistors to dissipate stored energy from the magnet.

On power-up, the contacts of an internal clamp relay are connected across the magnet output terminals. The clamp relay contacts open to allow current to flow in the external (magnet) circuit. The contacts close if a fault (such as a power failure) occurs.

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

The basic unit includes a bipolar magnet output. Additional slave units can be connected to increase the output power capability. Slave units can be connected in series or in parallel with the master unit, or can be connected to separate magnet-coils, for example in a vector-rotate arrangement.

The unit accommodates up to eight optional daughter-boards to allow additional features to be added.

The Mercury iPS includes a single persistent-switch output (see See Switch-heater output). This output is used to drive an optional persistent-switch in the magnet.

The unit also includes a temperature sensor input that can accept a wide variety of temperature sensors. The unit can detect short-circuit inputs, open-circuit inputs, and inputs that are shorted to ground.

Optional expansion boards can be added:-

1. to monitor the level of cryogenics (typically Helium and Nitrogen) in a reservoir
2. to measure temperature
3. to measure pressure
4. to control a stepper motor (e.g. to control a lambda plate fridge when combined with 2 and 3 above).



## MercuryIPS

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

### 2.1 MercuryIPS front and rear panels

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

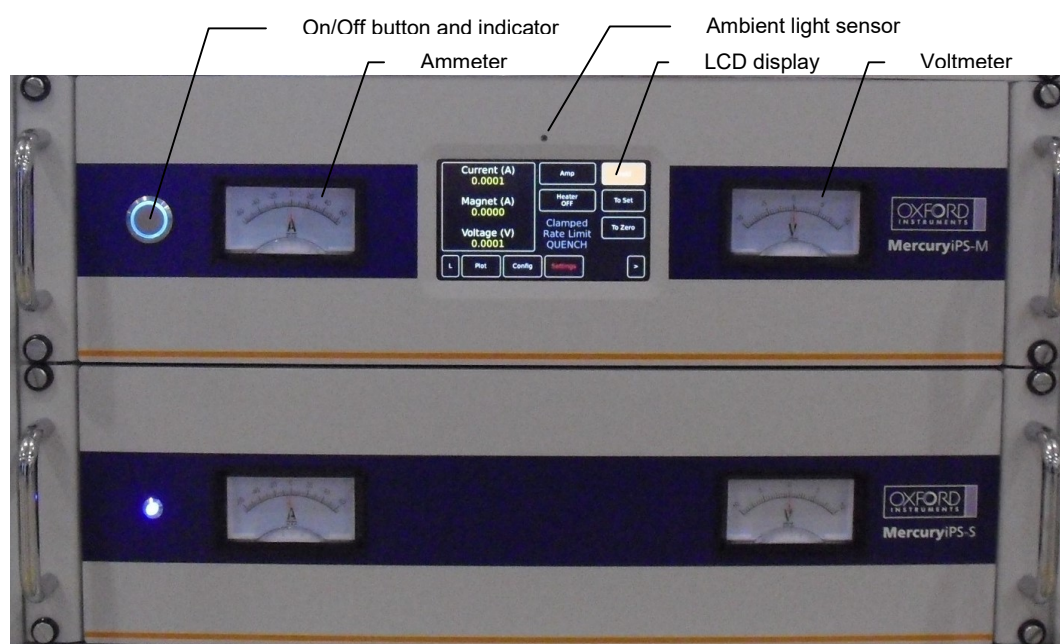


Figure 1 MercuryIPS-M (Master) and iPS-S (Slave) front panels

The On/Off button on the front panel switches the iPS-M (Master) into/out of STANDBY mode. When the switch is off, electrical power is still supplied to the switch-mode power supply inside the iPS-M. The On/Off button illuminates blue when the iPS is powered up. The iPS-S (Slave) has a blue indicator LED to show when it is powered up. Any Slave connected to a Master will be powered-up as part of the Master's boot sequence. Each Slave will be powered-up and configured in sequence as the Master boots and configures the total power supply system.

Figure 2 shows the rear panel of a **MercuryIPS-M** (Master) and iPS-S (Slave). This photo may not look exactly like your iPS-M as it depends on the number and type of boards fitted. The picture shows the RS485/Modbus connector of the Master which is used as the communication bus between the Master and Slave unit(s).

# MercuryIPS

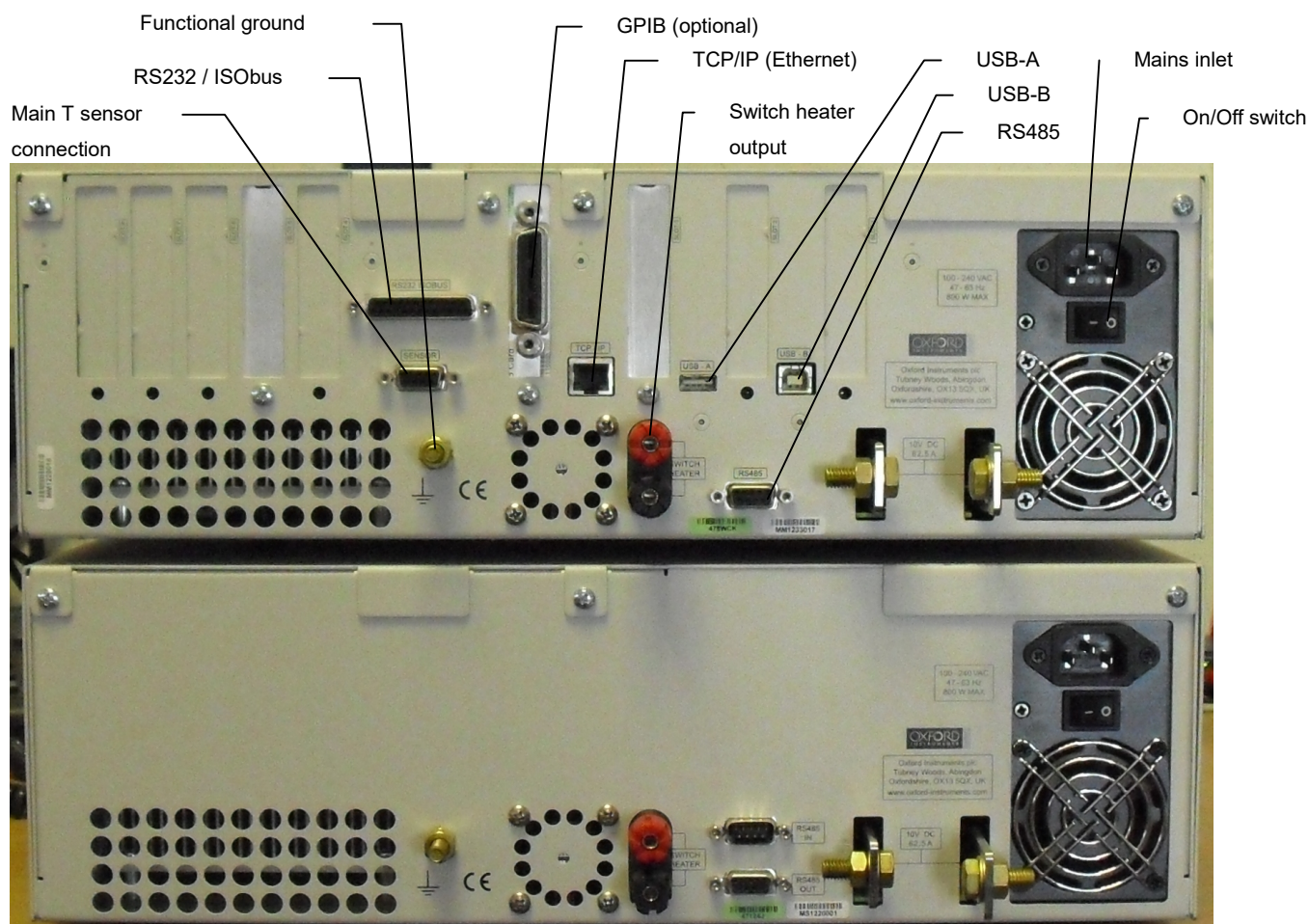


Figure 2 MercuryIPS rear panel (example)



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

## 2.2 Electrical power supply

The **MercuryIPS** 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 iPS powers all devices that are connected to it.

## MercuryIPS

Details of supply parameters are listed in section 18.2.

### 2.3 Temperature sensor circuits

The **MercuryIPS** 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 iPS can monitor one temperature sensor. Additional sensors can be monitored by adding daughter boards.

## 2.4 Remote interfaces

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

- Serial RS232 and ISOBUS.
- USB 2.0 (Universal serial bus).
- Ethernet 10/100 IEEE802.3.
- Optional GPIB (General Purpose Interface Bus) (IEEE-488). This requires a GPIB daughter board.

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

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

### 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 11.4.1).

## MercuryiPS

### 2.6 Main components

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

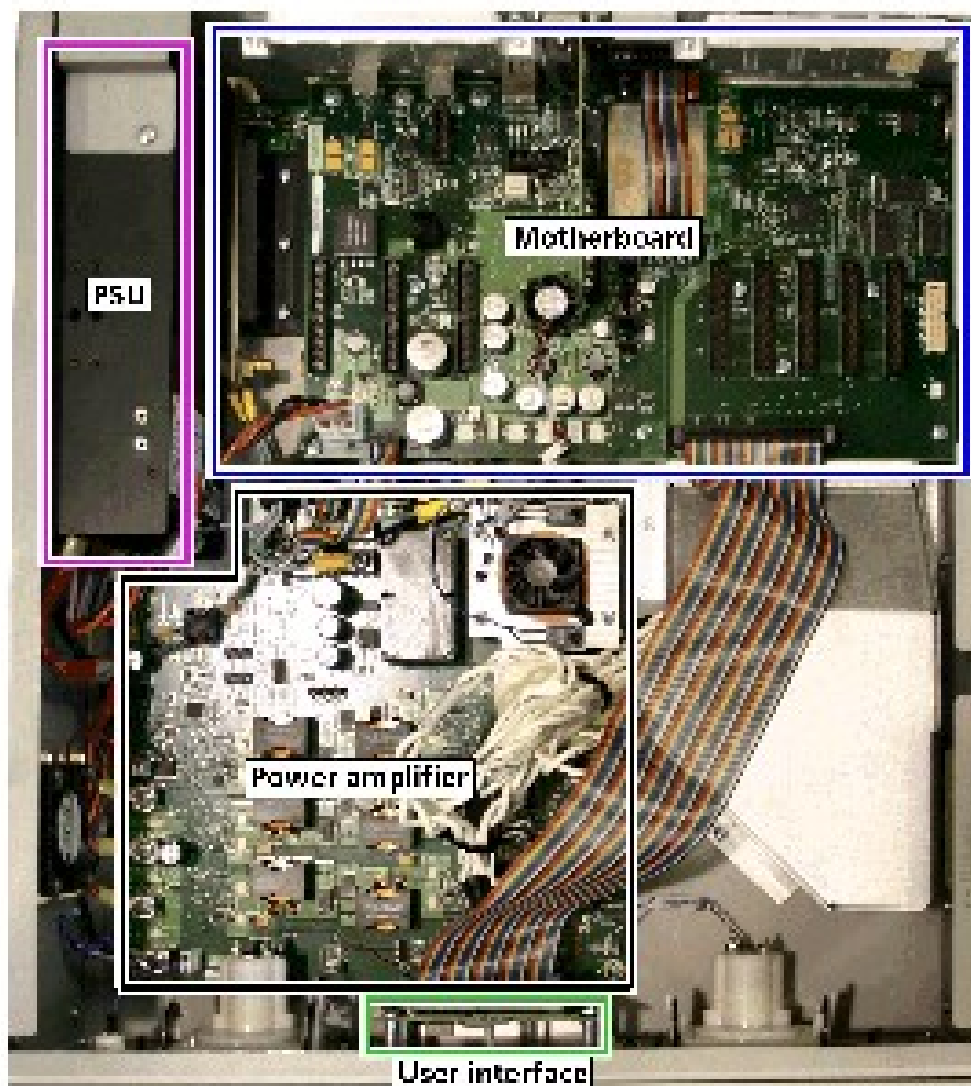


Figure 3 View of internal layout of MercuryiPS

The **MercuryiPS** consists of:

- a 3U high 19 inch rack or desktop enclosure
- a power supply

## MercuryIPS

- a touch-screen user interface
- a motherboard PCB which contains the basic iPS functionality
- a magnet current control board (power amplifier) which includes a switch heater output
- an output filter board
- a bank of heat-sink mounted power resistors with cooling fan and ducting
- optional additional temperature sensor input(s) (on daughter boards)
- optional auxiliary I/O (stepper motor drive and logic I/O)
- optional GPIB (IEEE-488) interface.

### 2.6.1 Chassis

The iPS chassis is a rugged steel construct designed for standard 19" rack mounting. Each unit is supplied with rack mounting brackets and handles as standard. There are 4 fans in the unit to provide the cooling for the various high current devices. An inlet fan on the left side (viewed from the front) provides a cooling air stream across the magnet control board. An exhaust fan at the back of the unit extracts the heated air from the rear of the unit. A third high-power fan is used to cool the large, finned aluminium heat-sink of the run-down power resistors. This fan only cuts in when required, usually during a fast rundown of a large magnet.

### 2.6.2 Power Supply

This is an off-the-shelf 12V, 63A, 800W low-noise switch-mode power supply. It is universally adaptable to all the common supply voltages and frequencies commonly found in all world regions. Its output is controlled by the magnet control board to be as efficient as possible to prevent unnecessary power dissipation inside the chassis.

### 2.6.3 User interface

The **Mercury**iPS contains a 4.3 inch full-colour, 480xRGBx272 pixel, liquid crystal display (LCD) with a touch-screen overlay. The touch screen is a 4-wire resistive type and is the main input device to the iPS. The functionality of the various GUI screens are described later in the manual.

The front panel is also fitted with an ambient-light sensor. The iPS can be configured to change the display brightness automatically to match ambient light conditions, for example if the unit is to be used in an optics lab where low-light conditions are required.

## 2.6.4 Motherboard

The motherboard contains the processor that handles the top-level control the iPS. The operating program and control applications are stored on a flash drive. This issues top level instructions to the magnet control board in the Master and any Slave units attached via the RS485/modbus interface. It also drives the display and touch screen interface as well as managing the remote communication ports. The motherboard also provides a single temperature-sensor input.

### 2.6.4.1 Expansion slots and daughter boards

There are eight expansion slots on the iPS 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 iPS.

The iPS 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 12 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 7 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 13 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 15 gives a full technical description.

## MercuryIPS

- Pressure

This is a board which measures signals from a pressure transducer. It can be used to control pressure in a cryogenic system. A maximum of eight of these boards can be fitted. Chapter 14 gives a full technical description.

The iPS automatically identifies every daughter board present.

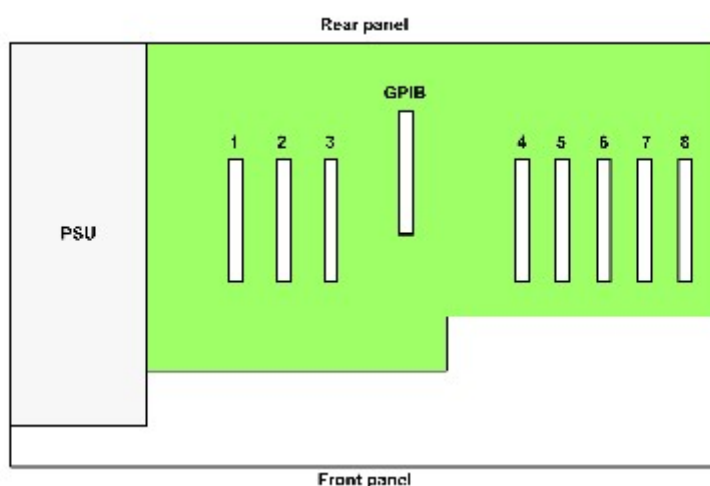


Figure 4 Layout of MercuryIPS expansion slots

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	Any	6, 7 and/or 8
GPIB	GPIB only	
Pressure	Any	8



## MercuryIPS

### 2.6.5 Magnet control board

This is the board which regulates the output current to the magnet and controls the heater for the persistence switch. The main current output is supplied from the switch-mode power supply and is controlled by the PWM of 3 parallel sets of push-pull FET's switching at 200kHz, each set 120° out-of-phase with the next set, to form a Class-D amplifier output stage. The FET switch timing is controlled by an on-board clock and FPGA giving very precise control. The push-pull architecture allows seamless sweeping from the negative limit to the positive limit with no output perturbation passing through zero.

Top-level output demand instructions come from the user interface via the motherboard. These ramp instructions are converted to output demand 10 times a second by a microcontroller on the magnet control board. The digital demand is converted to an analogue voltage signal by a 20-bit DAC. This signal is inverted and passed to an error amplifier where it is summed with the buffered output voltage from a precision, high-power, low temperature coefficient, sense resistor which is measuring the main output current. The sense resistor is temperature controlled at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  at all times. The output of the error amplifier is used to drive the board output so that the output tracks the demand via a 10Hz control loop. The main output current is then filtered to remove any PWM ripples to supply a dc current to the magnet.

In addition, the output signal from the sense resistor is measured by a 24-bit ADC and fed back to the microcontroller as a secondary check of ramp and hold performance.

The persistence switch heater output is a configurable current output from 0.1 to 120mA with a 12V compliance. It is switchable from the main control GUI and by remote command.

### 2.6.6 Filter board

Final stage filter for the main current output at the back for the iPS unit where the main current busbars exit the iPS. This board also mounts the modbus port.

### 2.6.7 Run-down resistors

A bank of 6 power resistors, 300W each with a resistance of 1.5 ohms mounted on a large aluminium finned heat exchanger. They are individually FET switched and form parallel current

## MercuryIPS

paths when switched in. Thus if all the resistors are switched in the total resistance is 0.25 ohms with a power dissipation of 1800W per **MercuryIPS** unit.

During run-down, when the Mercury units are sinking current back from an energised magnet, the rundown resistors will be switched in to maintain the voltage required to keep the run-down rate at the target ramp rate. If the power being dumped in the heat-exchanger is sufficient to raise the temperature significantly the powerful fan will cut in to prevent the run-down resistors from over-heating. It would be normal to hear the run-down fan cutting in during magnet rundown, although with small magnets or slow rundowns the fan may not be required.

## 2.7 Alarms and interlocks

The **MercuryIPS** 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 **MercuryIPS** 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.

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

## MercuryiPS

### 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 **MercuryiPS** 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, 3U 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 MercuryiPS is to be rack mounted, to ensure an adequate airflow around the iPS 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.*

## MercuryiPS

If the iPS 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 iPS.

### 3.2.1 Background magnetic field



*The iPS 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 iPS 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.

# MercuryiPS

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 **MercuryiPS**. Section 18.2 gives mains electrical requirements.

## 3.4 Powering up the MercuryiPS 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 **MercuryiPS** initialises, then the **Home** page appears on the touch screen (Figure 6).

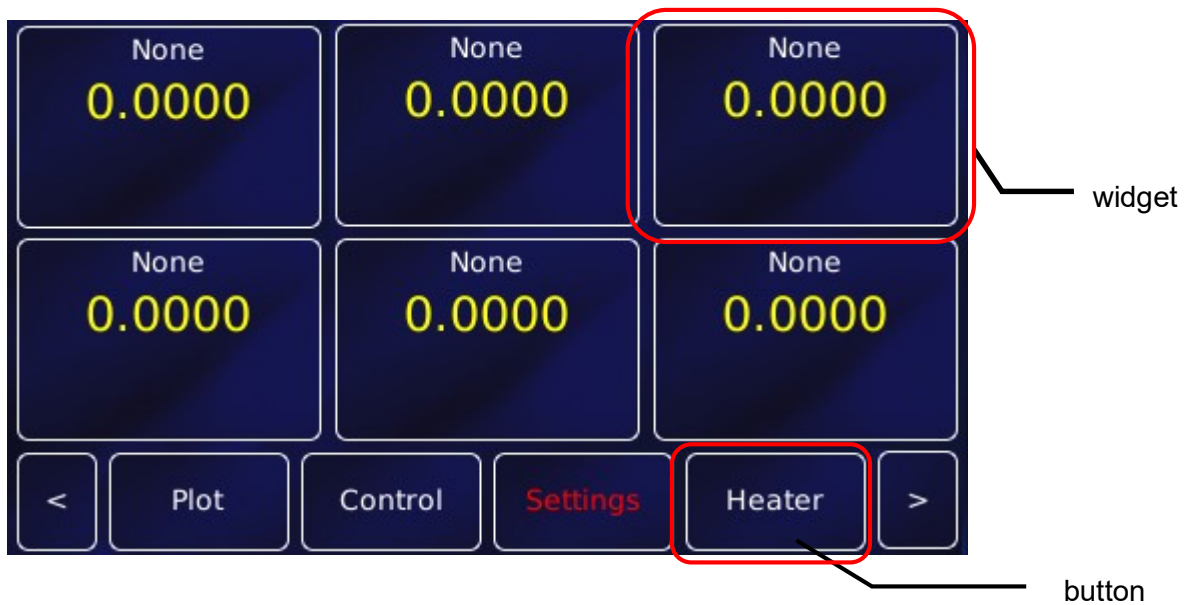


Figure 5. Default Mercury screen showing the standard 6 configurable widgets and standard buttons.

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

## 3.5 The MercuryiPS touch screen

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

## MercuryiPS

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 default 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 magnet home page

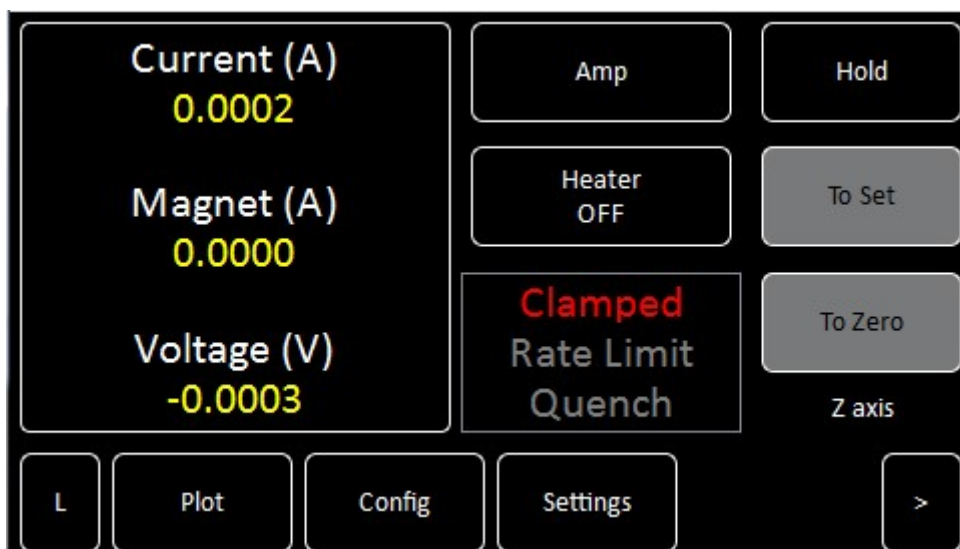


Figure 6. Mercury iPS home screen for the standard Solenoid configuration.

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

- Magnet status information panel showing the power supply output current (or equivalent field strength in Tesla) the magnet current in amps (or field strength in Tesla), the power supply terminal voltage.

## MercuryIPS

- Tapping on the Current (A) (or Field (T)) indicator opens the “Set Point / Set Rate” screen (Figure 14).
- A set of magnet control buttons, Hold, To Set, To Zero and Heater ON/OFF.
  - **Hold** is used to unclamp the output to make the magnet power supply ready for use. It can also be used to pause a ramp or to reset the power supply after a magnet quench.
  - **To Set** is used to ramp (sweep) the magnet current to a preset target current, either positive or negative, at a preset rate.
  - **To Zero** is used to ramp (sweep) the magnet current to zero amps (Tesla), at a preset rate.

- **Amp/Tesla** button to switch the display between current (Amp) and field (Tesla) modes.

- Interface connect/disconnect button. The button displays one of the following letters:

**E** if the ethernet interface is selected.

**I** if the Isobus interface is selected.

**U** if the USB interface is selected.

**G** if the GPIB interface is selected.

**L** if local control is selected.

The button is orange if the selected interface is connected.

The button is 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.**).
- **Config** button. Tap once to display or set the magnet configuration table information (section 4.4).
- **Settings** button. Tap once to display the General Settings tab, one of a number of Settings pages (chapter 8). If the text is RED, as shown above, then check the alarm log (section 17.1).
- Left and right scroll-buttons to display two more **home** pages. This provides a total of 18 configurable widgets.

## MercuryIPS

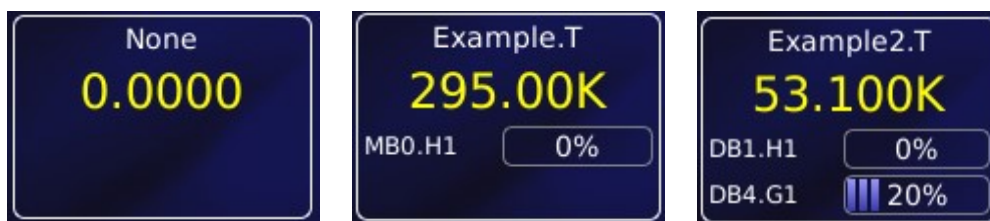
### 3.5.2 Custom home pages

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 default **Home** page are shown below.



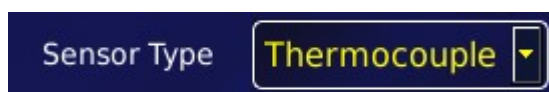
If the widget has not been configured it displays the name None and the value 0.0000.

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

- 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.

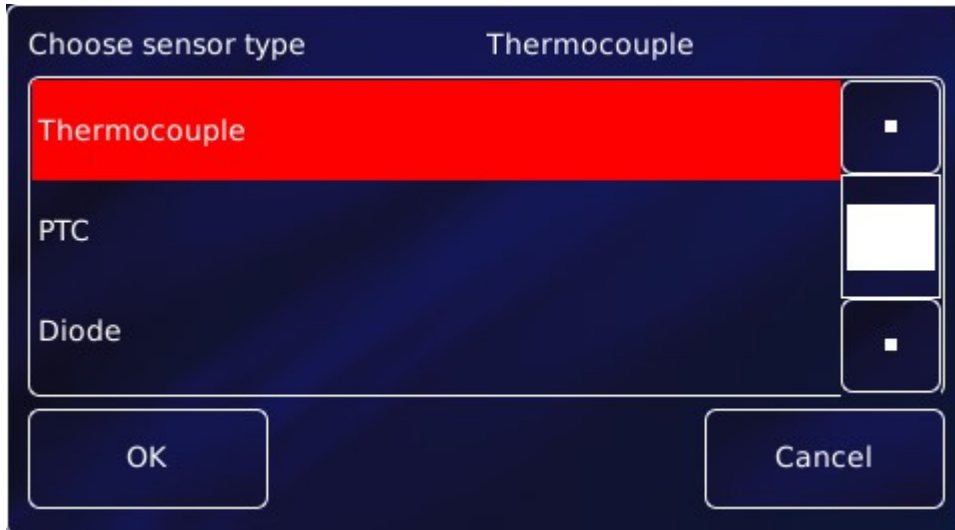


- 1 Tap once, anywhere in the parameter box, to display the drop-down menu. It is not necessary to tap the arrow.





# MercuryIPS



- 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.



### 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.

## MercuryiPS



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.
- 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.

## MercuryiPS



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.
- 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:



## MercuryiPS

- 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 iPS. 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.




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.

# MercuryiPS



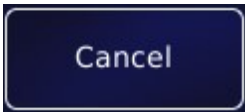
- Tap **Load** once to load a file (such as a sweep table or PID table).



- Tap **Save** once to save changes in a table.



- Tap **Assign** or **Apply** once to save changes to the page.



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

### 3.5.10 Setting the date and time

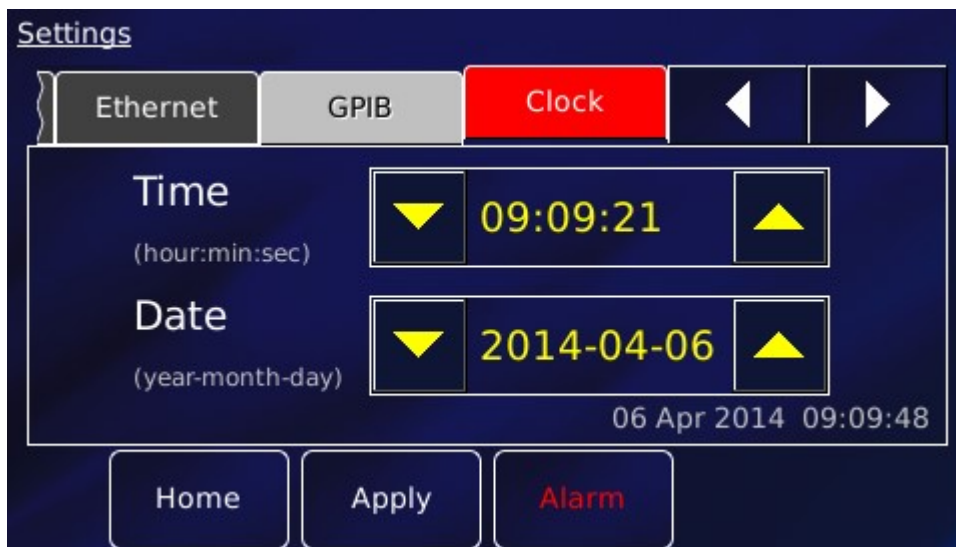
This process is a simple example showing how the touch screen is used.

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



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

## MercuryiPS



- 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.

## MercuryIPS

## 4 HOW TO CONFIGURE THE IPS FOR YOUR MAGNET

The superconducting magnet will consist of a solenoid or set of coils. Across (in parallel with) the coils will be a protection circuit consisting of high-power, low-value resistors and high-power diodes. Also, typically, across the coil set will be a superconducting link co-constructed with a separately wired heater which acts as a superconducting “switch”. The impedance of the switch in its superconducting state will be very much less than the magnet, and in its resistive state very much greater than the magnet. The switch will also have its own protection circuit.

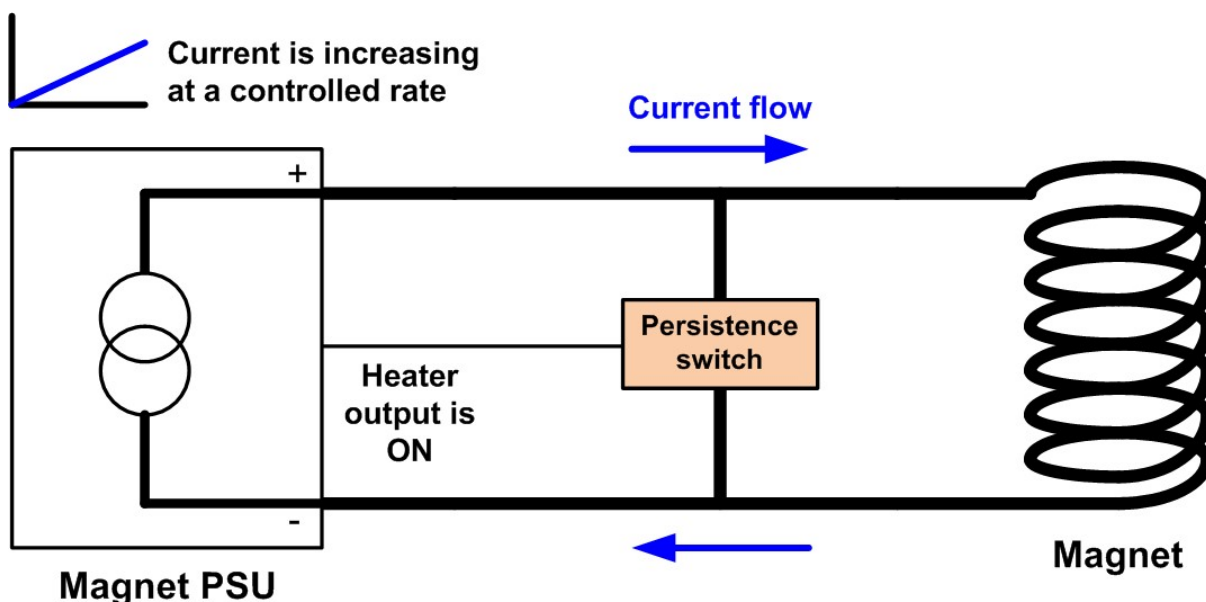


Figure 7. Diagram showing a simple solenoid magnet fitted with a persistence switch. In this example the persistence switch heater is ON, the switch is “open” and the current from the psu flows through the magnet.

When the switch heater is ON the superconducting link across the magnet is in its ‘normal’ resistive state so any current supplied from the magnet psu will flow through the lower impedance path of the magnet. The basic configuration is shown in Figure 7 (protection circuits not shown). The stability of the ramped current is dependent upon the self-inductance of the solenoid (or set of coils), the lead resistance of the current leads, the output filter of the power supply and the control loop parameters set in the power supply.

When the switch heater is OFF the superconducting link across the magnet is in its ‘superconducting’ state so any current supplied from the magnet psu will flow through the lower impedance path of the superconducting switch and not through the magnet. The switch is

# MercuryiPS

usually used to energise the magnet to a target current (switch heater ON) then to run down the power supply, with the switch heater OFF, to leave the magnet energised at the target current. The basic configuration is shown in Figure 8 (protection circuits not shown). It is important to remember that the current in the switch equals the difference between the magnet current and the power supply current

$$I_{switc} = I_{mag} - I_{psu}$$

thus when running down the leads (power supply) after energising a magnet the switch will be approaching its maximum as the power supply current approaches zero. It is important not to ramp the leads too fast as this is the rate at which current is building in the switch. Switches can quench (break open) because they over heat if they are ramped too fast.

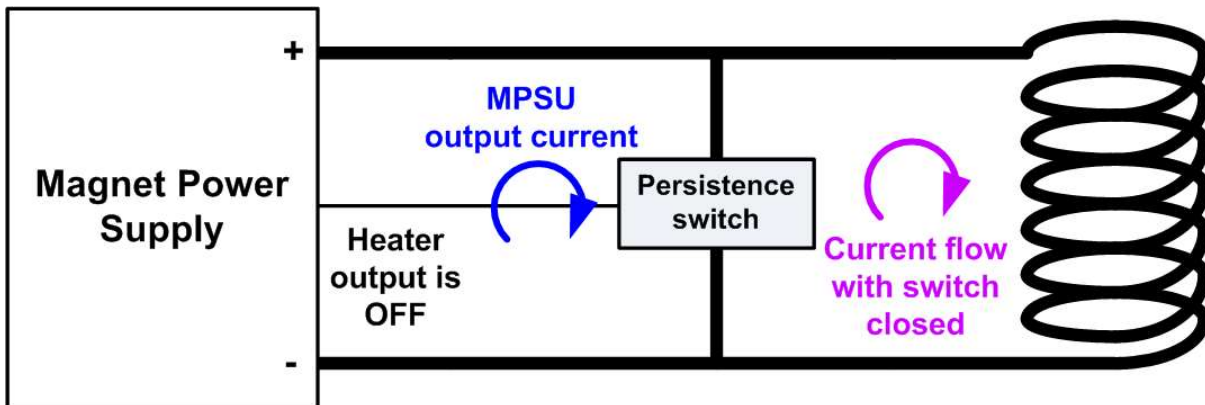


Figure 8. Diagram showing a simple solenoid magnet fitted with a persistence switch. In this example the persistence switch heater is OFF, the switch is “closed” (analogy with relay contacts), so current flows through the switch so two current loops exist. The current in the switch is the difference between the psu current and the magnet current.

At the instant when the switch opens (or closes) there will be a perturbation in the power supply output as the relatively large inductance load of the magnet is connected (or disconnected) from the psu and the control loop time constant changes.

## 4.1 Quench

In normal magnet operation this is a very unusual event. This is when the superconductor of the magnet coil(s) reverts to its normal resistive state. For low-temperature superconductors such as NbTi and Nb<sub>3</sub>Sn the propagation of the normal state is very fast and the electrical resistance rise is large. The results of this transition is a rapidly rising voltage transient across



## MercuryIPS

the coil(s) terminals, fast current transients in the coils, a large power dissipation in the coil(s) due to resistive heating  $R_{\text{coil}}(t) \cdot I_{\text{coil}}^2(t)$ , a large rise in temperature in the coil(s) and fast  $I_{\text{coil}}(t) \times B(t)$  stress transients. To prevent the coils from damage and to prevent dangerously large voltages appearing at the cryostat terminals, the coil(s) are fitted with protection circuits. These circuits consist of power resistors and high-power diodes. The diodes prevent current leaking through the protection circuit during normal magnet ramping and ensure that the protection circuit only conducts when the voltage across it rises to a specified level. Design of the protection circuit is a key part of the magnet design and quench modelling process.

The power supply will see the voltage transient at its output terminals. Once this voltage has exceeded the voltage limit set in the configuration table for a period greater than the transient time set in the configuration table the psu is tripped into quench mode. Initially the psu will try to hold the voltage level by switching in the rundown resistors to dump excess current but if the magnet has actually quenched the terminal voltage will continue to rise.

For some magnets there is a possibility that a small winding (for example a cancellation coil) may quench but not the bulk of the magnet, the small part absorbs most of the magnet's stored energy and causes damage to the wire. Also, damage may occur to a persistent magnet switch if after the quench the power supply outputs a large voltage which heats up the switch while there is no liquid helium left to cool it.

For these reasons a quench event will cause the power supply to go to zero amps. Approximately 20 seconds after the magnet has settled at zero current, the power supply will clamp the output and turn off the switch heater. When a quench is detected, the power supply current will be recorded as the "Magnet Trip Current" and will appear in red in the display in the Magnet current location as well as being recorded in the Alarms log. To clear the QUENCH state and regain control at any time, the operator should press the HOLD button.

## 4.2 Slaves Detected

The Slaves detected value is the number of iPS-S units detected by the iPS-M during its boot sequence. As the iPS system boots each slave will be booted in turn and allocated a number "PSU.Mx" (where x=1 is the master unit, x=2 is the first slave etc) as it is discovered based on

## MercuryIPS

its position on the RS485 modbus. So for example, an iPS 240-10 is will consist of 1 x iPS-M plus 3 x iPS-S units. The slaves detected should equal 3, the units will be labelled PSU.M1, PSU.M2, PSU.M3 and PSU.M4. The slaves detected parameter (Figure 9) is updated every time the iPS system is booted.

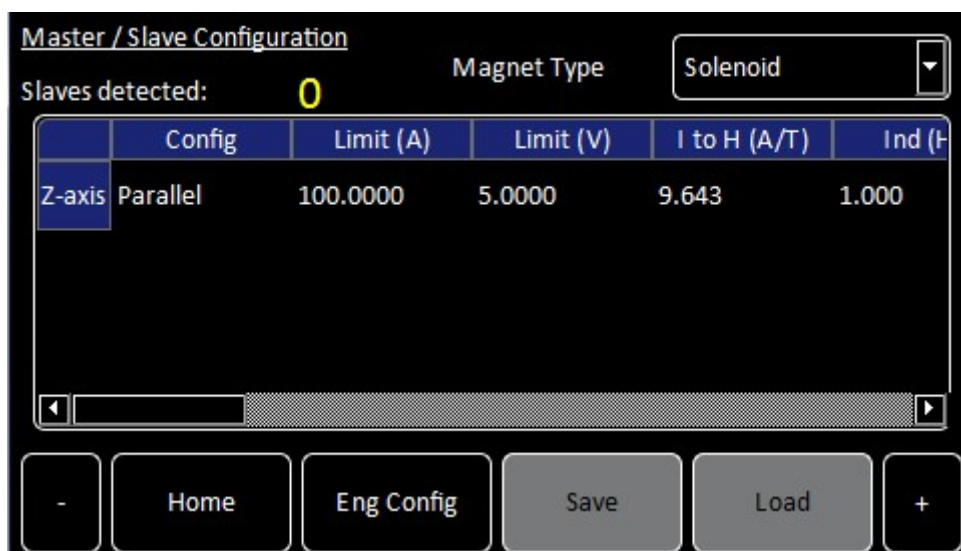


Figure 9. Magnet configuration screen of the Mercury iPS

### 4.3 Magnet Type

The “Magnet Type” drop down box allows the choice of three magnet types “Solenoid”, “Split Pair” and “Vector Rotate” (Figure 9). At the time of writing there is no operational difference between Solenoid and Split Pair, these are just single axis current supply systems. A “Vector Rotate” magnet however, is a set of 2 or 3 coil split-pairs arrange orthogonally to form a Z-axis and an X-axis (2 coil pairs), or a Z-axis, X-axis and a Y-axis (3 coil pairs). Putting the Mercury iPS into “Vector Rotate” mode will add Y-axis and X-axis rows to the “Config” table, will add Y-axis and X-axis groups to the “Eng Config” pages and will add X-axis and Y-axis control panels to the iPS Home screen.

## MercuryIPS

### 4.4 The Configuration Table (Figure 9)

#### 4.4.1 Config

The value of the “Config” parameter defines the configuration of the power supply units in the control loop architecture. The Mercury control architecture uses “groups” to define how the individual power supply units are being used in the power supply system. The most common configuration is Z-axis only (Solenoid) and “Parallel”. This means that the high-current outputs of the iPS-M (master) unit and iPS-S (slave) unit(s) are connected in parallel to form a higher current  $\pm 10V$  power supply. For example, 1 x iPS-M ( $\pm 62.5A$ ,  $\pm 10V$ ) plus 1 x iPS-S ( $\pm 62.5A$ ,  $\pm 10V$ ) connected in parallel to form a ( $\pm 125A$ ,  $\pm 10V$ , nominally an iPS120-10) power supply.

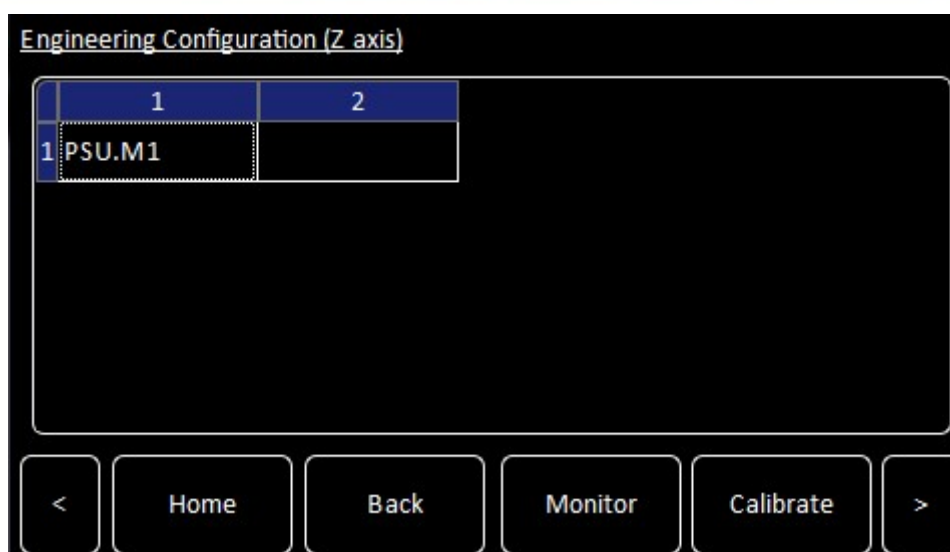
To configure the Z-axis as series units select “Series”. In the above example 1 x iPS-M ( $\pm 62.5A$ ,  $\pm 10V$ ) plus 1 x iPS-S ( $\pm 62.5A$ ,  $\pm 10V$ ) connected in series to form a ( $\pm 62.5A$ ,  $\pm 20V$ , nominally an iPS60-20) power supply.

It is also possible to configure units as a series-parallel, or “Matrix” combination (see below). For example 1 x iPS-M ( $\pm 62.5A$ ,  $\pm 10V$ ) plus 5 x iPS-S ( $\pm 62.5A$ ,  $\pm 10V$ ) connected in 3 parallel sets of series pairs to form a ( $\pm 187.5A$ ,  $\pm 20V$ , nominally an iPS180-20) power supply. More details on how to configure this are listed below.

##### 4.4.1.1 Eng Config

Having selected the “Config” parameter for each axis (Z only for Solenoid and Split Pair. Z, Y and X for Vector Rotate) tap “Eng Config” to allocate the Mercury units to the correct configuration groups so that the system will function correctly. If the “Parallel” configuration has been selected for the Z-axis the Z-axis grouping table will be a row. Tap on the left cell of the table row to bring up a list of the available unit. Select the unit from the list (e.g. PSU.M1 for the master) and tap OK. The name “PSU.M1” will now appear in the cell (Figure 10). Tap the next cell to the right and select the next unit for the Z-axis group (named “GRPZ”). There will always be a blank box on the right-hand end of the row.

## MercuryIPS



The screenshot shows a software interface titled "Engineering Configuration (Z axis)". It features a table with two columns labeled "1" and "2". The first row of the table contains the text "1 PSU.M1" in the first column and is empty in the second. Below the table is a navigation bar with six buttons: a left arrow, "Home", "Back", "Monitor", "Calibrate", and a right arrow.

	1	2
1	PSU.M1	

Figure 10. Engineering Configuration table for “Parallel” configuration showing only 1 unit.

Repeat this for the Y-axis group and X-axis group as required. To access the Y-axis and X-axis grouping tables use the “<” and “>” arrow buttons in the bottom corners of the “Engineering Configuration” page.

If the “Series” configuration has been selected for the Z-axis the Z-axis grouping table will be a column. Tap on the top cell of the column and populate the column as above. There will always be an empty cell at the bottom of the column. Again repeat for the Y-axis group and X-axis group as required.

Tap on the top cell of the column and populate the column as above. There will always be an empty cell at the bottom of the column. Again repeat for the Y-axis group and X-axis group as required.

MercuryIPS

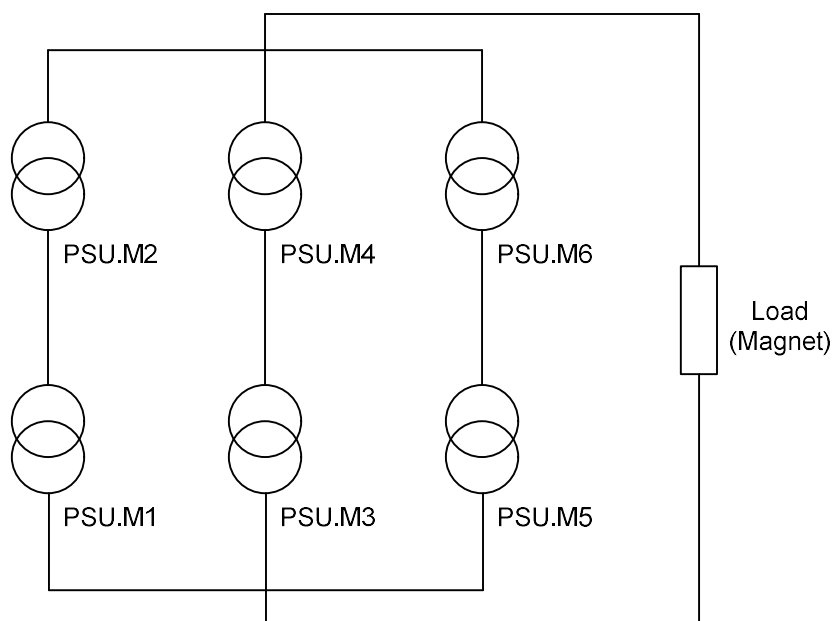


Figure 11. Schematic circuit for an iPS180-20 showing the 6 current source units.

If the “Matrix” configuration has been selected for the Z-axis the Z-axis grouping table will be a table. The matrix combination will be used for power supplies which require high-current and high-voltage such as an iPS180-20. The iPS will be configured as parallel sets of series units. So in the example case of the iPS180-20 this 6 units, 1 x master and 5 x slaves configured as 3 parallel sets of series pairs. So PSU.M1 and PSU.M2 in a 60A, 20V series pair in parallel with PSU.M3 and PSU.M4 as a 60A, 20V series pair and theses in parallel with PSU.M5 and PSU.M6 as a 60A, 20V series pair. The 3 pairs in parallel give 180A (see Figure 11).

In this case, to populate the grouping table tap on the top left cell first and select the unit e.g. PSU.M1 from the drop-down list. Continue to populate the other cells as required remembering that columns are series combinations and rows are parallel combinations. For the iPS180-20 example shown in Figure 11 the table would look like

PSU.M1	PSU.M3	PSU.M5	
PSU.M2	PSU.M4	PSU.M6	

Figure 12. Engineering Configuration grouping table for an iPS180-20. PSU.M1 is in series with PSU.M2. PSU.M3 is in series with PSU.M4. PSU.M5 is in series with PSU.M6. These 3 series pairs are in parallel with each other.

## MercuryIPS

## UNIT CONFIGURATION

*It is very important for normal operation of a Mercury iPS power supply system that the configuration defined in the Config table and Eng Config grouping tables correctly represents the actual connections of the units. Incorrect operation and/or unit damage may result if the configurations are incorrect.*



## UNITE CONFIGURATION

*Il est très important pour le fonctionnement normal d'un système d'alimentation Mercury iPS que la configuration définie dans le tableau Config et Eng Config tables de regroupement représente correctement les connexions réelles des unités. Une utilisation incorrecte et / ou des dommages appareil peut entraîner si les configurations sont incorrects.*

#### 4.4.2 Limit(A)

This is the current limit for the group of power supply units configured in the group. It is the total limit not the unit limit. For example, if the Z-axis group (GRPZ) is configured as a 180-10, (3 units in parallel) and if the limit current was set to 169.00A this would be a total limit of 169A which would be  $169/3 = 56.3333A$  limit for each unit. The group cannot ramp beyond 169A, so if a demand set point was above this value the ramp would stop at 169A. If your magnet needed 169A the current limit should be set slightly above this to compensate for slight over shoots at the end of fast ramps. For example 169.1A or possibly even 169.5A.

#### 4.4.3 Limit(V)

This is the voltage limit for the group of power supply units configured in the group. It is the total limit not the unit limit. If the power supply measures a voltage greater than this limit at the output terminal for a time period longer than the "Transient Time" (see below) the group will enter QUENCH mode. The voltage limit should be set at a value above the maximum expected output terminal voltage in normal use. So if the iPS was being used to energise a magnet with a self-inductance of 35H to a current of 169A with a target ramp rate of 6A per minute and a lead resistance of 10mΩ the maximum operational voltage would be  $35 \cdot 6/60 + 169 \cdot 0.01 =$  an

## MercuryIPS

inductive voltage of 3.5V plus a resistive voltage of 1.69V giving an estimate maximum operational voltage of 5.2V. So the voltage limit should be set to between 5.5 and 6V.

### 4.4.4I to H (A/T)

This is the current to field ratio which is a design parameter from the magnet geometry. The Mercury uses this value to display equivalent applied field in Tesla. So if this value were 8.6A/T and the magnet current was 100A the central field would be 11.628T. If the home screen was set to display "Field (T)" it would display 11.628T in this example.

### 4.4.5Ind (H)

This is the self-inductance value of the magnet the unit group is driving. This value is used in the Mercury iPS to set the damping factors in the current drive control loops based on an estimate of the load time constant.

### 4.4.6Trans (ms)

This "Transient Time" is used in conjunction with the "Voltage Limit" (see above) as a mechanism of magnet QUENCH detection. If the measured voltage at the group output terminals exceeds the voltage limit for longer than this transient time then the power supply group enters QUENCH mode. However, if the measured voltage at the group output terminals exceeds the voltage limit for less than this transient time then the power supply continues in normal operation mode. This parameter is used to prevent false trips of the iPS due to noise voltage spikes or spikes due to flux jumps.

It is not recommended to set the transient time to less than 300ms, typical values could be between 500ms to 3000ms.

### 4.4.7Switch

Each Mercury unit, iPS-M or iPS-S has a switch heater drive output. This parameter specifies which one of the group is the unit being used for the switch heater current output (e.g. PSU.M1 for the master unit).

### 4.4.8Sw Cur (mA)

This parameter specifies the value of the switch heater current required to raise the switch temperature up to a level where the switch is open (superconducting wire in the switch coil

## MercuryiPS

heated to its “normal” i.e. non-superconducting state). For “wet” systems where the magnet is immersed in a liquid  $^4\text{He}$  bath typical switch heater current values are 60 – 65mA. For cryocooled systems where the magnet is in vacuum typical switch heater current values are 20 – 25mA.

### 4.4.9 Mode

This parameter is either “Bipolar” or “Unipolar”. In Bipolar mode the power supply group will ramp in both positive and negative directions up to the current limit specified above. In Unipolar mode the power supply group will only ramp in the positive direction.

### 4.4.10 Safety

This parameter specifies the device and signal which will be used to check it is safe to run the magnet, or if the magnet is already energised will put the power supply group in auto-rundown mode. Typical values are “None”, MB1.T1, DBx.T1, DBx.L1 or DBx.G1.

- None = no safety is applied. The magnet running will not be inhibited.
- MB1.T1 or DBx.T1. The magnet temperature is used as a safety threshold for safe running of the magnet. The threshold value for safe operation is defined by the “Limit(K)” value (see below). If the magnet temperature signal is coming in via the iPS-M motherboard temperature sensor circuit then MB1.T1 should be chosen. If the magnet temperature signal is coming in via a temperature daughter card installed in the iPS-M then DBx.T1, where x is the slot number the daughter board is installed in, should be chosen.
- DBx.L1. The Helium level is used as a safety threshold for safe running of the magnet. The threshold value for safe operation is defined by the “Limit(L)” value (see below). As the signal is coming in via a level meter daughter card installed in the iPS-M then DBx.L1, where x is the slot number the daughter board is installed in, should be chosen.
- DBx.G1. An external signal is used as a safety threshold for safe running of the magnet. As the signal is coming in via an Auxiliary (labelled Gas flow hence “G1”) daughter card installed in the iPS-M then DBx.G1, where x is the slot number the daughter board is installed in, should be chosen. This is primarily for backward compatibility so that Mercury iPS units can be used with old style ILM2xx series cryogen level meters.



## MercuryIPS

### 4.4.11 Limit (K)

This is the temperature threshold below which it is safe to run the magnet (see above). If the magnet temperature signal is above this value the iPS group will not ramp up. If the magnet is already energised the iPS group will enter auto-rundown mode. This will ramp the magnet to 0A at a safe slow rate. If the magnet is persistent, the iPS group will ramp up to the last known magnet current, turn on the switch heater to 'pick-up' the magnet, ramp the magnet to zero, then turn off the switch heater.

### 4.4.12 Limit (L)

This is the level threshold above which it is safe to run the magnet (see above). If the magnet Helium level signal is below this value the iPS group will not ramp up. If the magnet is already energised the iPS group will enter auto-rundown mode. This will ramp the magnet to 0A at a safe slow rate. If the magnet is persistent, the iPS group will ramp up to the last known magnet current, turn on the switch heater to 'pick-up' the magnet, ramp the magnet to zero, then turn off the switch heater.

### 4.4.13 Sw Intel

This parameter switches ON/OFF the Intelligent Switch function.

- In the "Sw Intel" = OFF state the switch heater current is either 0mA, when the switch heater is OFF, or a constant value determined by the "Sw Cur" parameter (see above), when the switch heater is ON.
- In the "Sw Intel" = ON state, when the switch heater is also ON, the total power dissipated in the switch is kept constant based on the equation:-

$$P_{SwitchTotal} = I_{SwHtr}^2 * R_{SwHtr} + \frac{(V_{op} - (I_{op} * R_{leads}))^2}{R_{Switch}}$$

where  $R_{SwHtr}$  is the resistance of the switch heater entered in the table (see below),  $R_{Switch}$  is the resistance of the superconducting element of the switch when it's in its "normal" state, a value entered in the table (see below),  $V_{op}$  is the iPS group output voltage,  $I_{op}$  is the iPS group output current,  $R_{leads}$  is the lead resistance a value entered in the table (see below) and  $P_{SwitchTotal}$  is the target total power dissipated in the switch.

## MercuryIPS

This value can be defined from the state of the switch when the switch is in its superconducting state and the second term of the above equation is zero. In this case

$$P_{SwitchTotal} = I_{SwHtr0}^2 * R_{SwHtr}$$

where  $I_{SwHtr0}$  is the switch heater current required to keep the switch in the normal state when the magnet current is zero (i.e.  $I_{op} = 0$  and  $V_{op} = 0$ ). This is defined in the configuration table for non-intelligent switch operation (section 4.4.8). So, in intelligent switch mode the switch heater current is calculated as

$$I_{SwHtr} = \sqrt{I_{SwHtr0}^2 - \frac{(V_{op} - I_{op} * R_{leads})^2}{R_{Switch} * R_{SwHtr}}}$$

Therefore the iPS system adjusts the switch heater current based on the variation of the voltage across the switch ( $V_{op} - I_{op} * R_{leads}$ ) to keep  $P_{SwitchTotal}$  constant.

When the switch heater is switched OFF the switch heater current reverts to its 0mA value.

### 4.4.14 Htr Res ( $\Omega$ )

Parameter used as above. This value is an estimate of the switch heater resistance.

### 4.4.15 Sw Res ( $\Omega$ )

Parameter used as above. This value is an estimate of the switch superconducting element resistance when it's in its "normal" (non-superconducting) state.

### 4.4.16 Lead ( $\Omega$ )

Parameter used as above. This value is an estimate of the main current leads total resistance. The power supply can also calculate this value and may update this value in its normal operating cycle. From firmware version 2.5.05.xxx onwards, a routine is included to accurately calculate the lead resistance.

## MercuryIPS

### 4.4.17 SW on (ms)

A parameter to define the time it takes for the switch to OPEN after the switch heater is turned ON. The magnet should not be ramped during this time.

### 4.4.18 SW off (ms)

A parameter to define the time it takes for the switch to CLOSE after the switch heater is turned OFF. The magnet should not be ramped during this time.

### 4.4.19 Catch

Firmware package 2.3.0.0 includes magnet firmware 2.5 which now includes faster voltage readings internally making the Catch trigger robust. The Catch routine can now be used reliably.

The “Catch” routine is a routine designed to catch the magnet if the switch breaks open while setting the magnet persistent. So, if when ramping the leads to 0A after having energised the magnet the switch quenches (breaks open) the iPS group detects this and rapidly ramps the current up to match the magnet current. It will then turn on the switch heater to HOLD the magnet current at the caught value. Then a current balancing routine will run to ensure each unit in the group is supplying an equal proportion of the current while keeping the total current constant. Once this is complete, the current is ramped back to the previous set point and held there.

### 4.4.20 Current Epsilon (A)

Defines a band around the target current specified as  $EpsilonBand = TargetCurrent \pm Epsilon$ .

Within the band the control mode of the iPS drops into “fine trim” which is considered to be the end of a magnet ramp task. This value is typically 100mA but can be any value from 5mA up to 1A. In fine trim mode the iPS will make small (20µA) adjustments to the output current on every control loop iteration (100ms) to ensure the output does not drift from the target current. It can be useful to set the epsilon band to 1A if there is a concern over ramp overshoot.

## MercuryIPS

### 4.4.21 Voltage Epsilon (V)

Defines a band around the target voltage specified as

$$EpsilonBand = TargetVoltage \pm Epsilon_{Voltage}$$

This parameter is only active in series or matrix configuration modes (i.e. not parallel configuration).

This parameter defines the limits by which the slave unit, acting as a voltage follower, is allowed to lag behind its companion master unit (see section 4.4.1.1).

For a series configuration of a MercuryIPS-M (master) and a MercuryIPS-S the (slave) the master will try to ramp at the requested ramp rate. This will require a drive voltage which is the sum of the voltage drop on the current leads plus the inductive voltage of the magnet. At the start of the ramp, as the master output voltage rises the slave voltage will rise to track it within  $2 * Epsilon_{Voltage}$ . The drive voltage is shared between the master and slave units thus allowing 20V drive voltages to be achieved from 10V units.

The default value for  $Epsilon_{Voltage}$  is 5mV. In some cases it may be necessary to increase this value. For very high inductive loads the drive time constant is long and the slave output may oscillate because its target output is being adjusted too often. In general the  $Epsilon_{Voltage}$  (and  $Epsilon_{Current}$ ) values will need to be set empirically on system test with the current leads and magnet the power supply is intended to be used with.

For matrix configurations (e.g. 180-20) consisting of 1 \* MercuryIPS-M (master) and  $n$  \* MercuryIPS-S (where  $n = 3, 5, 7$  or  $9$ ) units, some of the MercuryIPS-S will be "local masters" (current sources) while others will be voltage followers (slaves). For the 180-20 example, this consists of 3 parallel, series pairs (see Figure 11). Each series pair is one local master current source plus a voltage follower slave. For the first series pair the local master current source is a MercuryIPS-M, but for the other 2 series pairs the local master current sources are MercuryIPS-S's. For all 3 series pairs the voltage followers are MercuryIPS-S's.

For each series pair the voltage follower must track its local master within  $2 * Epsilon_{Voltage}$ . The local master will ramp at 1/3 of the target ramp rate to ensure each parallel branch of the 180-20 supply contributes correctly to the target current and total current.

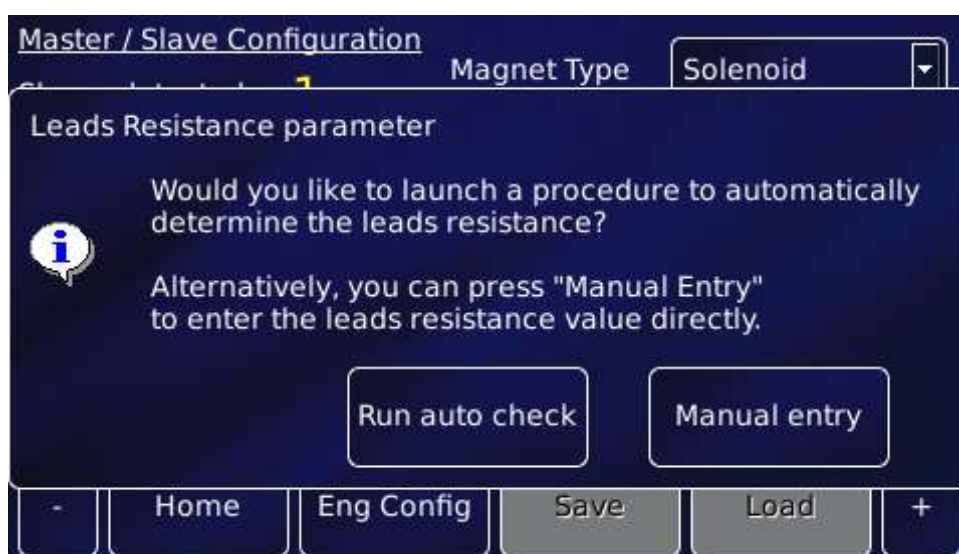
## MercuryIPS

### 4.4.22 Lead Resistance and Load Inductance determination

From Cryosys firmware version 2.5.05.xxx onward a new function has been added to accurately determine the lead resistance and load inductance connected to the power supply output. The process is axis (i.e. Group) dependent so it can be run for each axis for a Vector Rotate magnet.

#### 4.4.22.1 Lead Resistance Check

To start the process of checking the total current lead resistance, the iPS unit must be in engineering mode (see section 9.7). Go to the Config table (from the Home screen tap “Config”) and scroll across the table to the “Lead ( $\Omega$ )” column. Tap the cell of the axis (Group) that you want to check. This will bring up the dialog below.



If the lead resistance is already known, you can tap “Manual entry” which will open the keypad and value can be entered in ohms. Alternatively you tap the “Run auto check” button and the 13 stage test sequence will begin. It is a simple ramp to a positive current based on system parameters, wait for a short settling time, take a set of voltage measurements, then ramp to a negative current and repeat. The positive and negative results are compared to check for offsets and combined to produce an averaged value. While the process is running the dialog below will show the progress. The sequence takes about 20 minutes during which time the power supply will not be available for magnet energisation. If the sequence needs to be terminated early, tapping the “Abort” button will exit the sequence without making any changes.

## MercuryIPS



Once the process has terminated the dialog will disappear and the value in the Config table will be updated. If, however, the checking process fails, the dialog will appear as below. The message will state why the process failed. Tap “Close” to finish the process. No parameters will be modified. Check the rear connections of the power supply and run the sequence again.

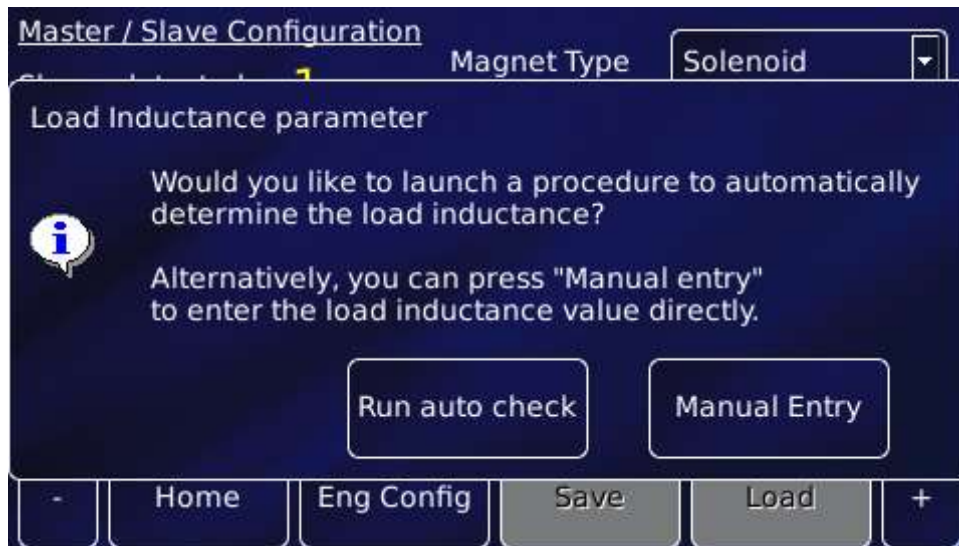


### 4.4.22.2 Load Inductance Check

A very similar sequence to the Lead Resistance Check is run with a similar set of dialogs. Again to start the sequence the iPS unit must be in engineering mode (see section 9.7). Go to the Config table (from the Home screen tap “Config”) and scroll across the table to the “Ind (H)” column. Tap the cell of the axis (Group) that you want to check. Similar to the resistance check,

## MercuryIPS

this opens a dialog shown below. Again if the value is known tapping on “Manual Entry” allows the value to be entered directly in units of Henries.



The sequence will run through in the same way the resistance check does. In this sequence voltage measurements are made during ramping and at the holding currents. There are pauses in the voltage measurement periods to allow for settling at the beginning and end of the ramps.

## MercuryIPS

## 5 OPERATING THE MAGNET

Standard **MercuryIPS**'s home screen in single axis solenoid (or split-pair) mode is shown below (Figure 13). This screen has the principle controls required to energise the superconducting magnet attached to the output terminals of the power supply group. These controls are described in section 3.5.1.

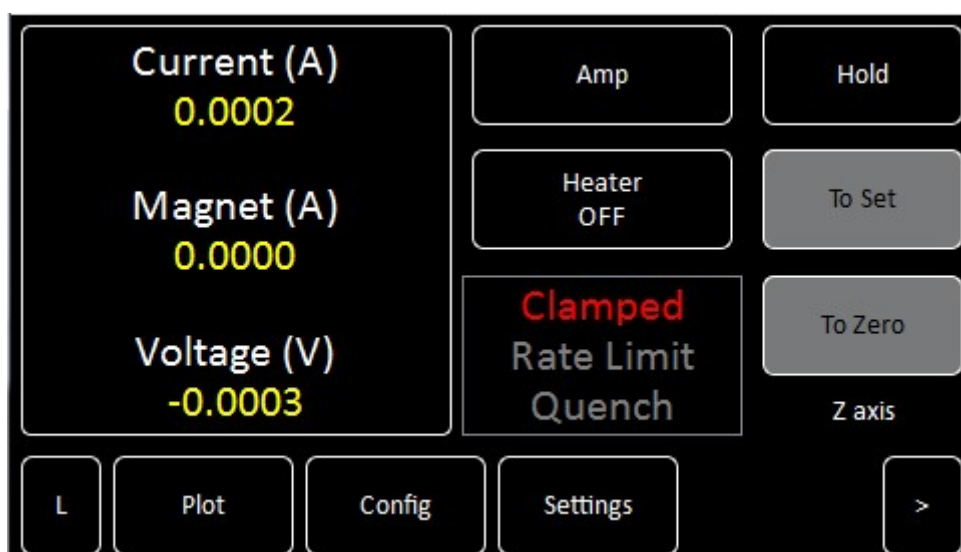


Figure 13. Magnet Home screen in “Solenoid (or Split Pair) mode”

To energise the magnet it is necessary to enter a set point (target current or target field) and a set ramp rate at which to ramp the magnet current. To do this, tap on the “Current (A)” display of the Home page (Note: if the Home page is in “Tesla” mode, tap on the “Field (T)” display). This will bring up the “Set Point / Set Rate” page show below (Figure 14).

To enter a set point tap on the “Set Point” box to open the numeric keypad. Enter the value of the current (or field) you want to ramp to and tap OK. The value will appear in the box. Take care to note which mode the iPS is in which is defined by the Amp/Tesla button on the Home screen. If you enter the “Set Point / Set Rate” page in Amp mode the settings will be in Amps and Amps/minute. If you enter the “Set Point / Set Rate” page in Tesla mode the settings will be in Tesla and Tesla/minute.

Similarly, to enter a set rate tap on the “Set Rate” box to open the numeric keypad. Enter the value of the current rate (or field rate) you want to ramp at and tap OK. The value will appear in the box. Tap Home to return to the Home screen.



## MercuryiPS

To execute the ramp tap “Hold” on the Home screen to unclamp the power supply outputs and to start the PWM output stages. You will hear some clunking as the crow-bar relay(s) open.

If the magnet is fitted with a switch, tap the “Heater” button to turn on the switch heater. Wait for the heat switch to activate to be sure it is open. Now tap “To Set” to start the ramp to the output at the pre-entered set point at the pre-entered set rate.

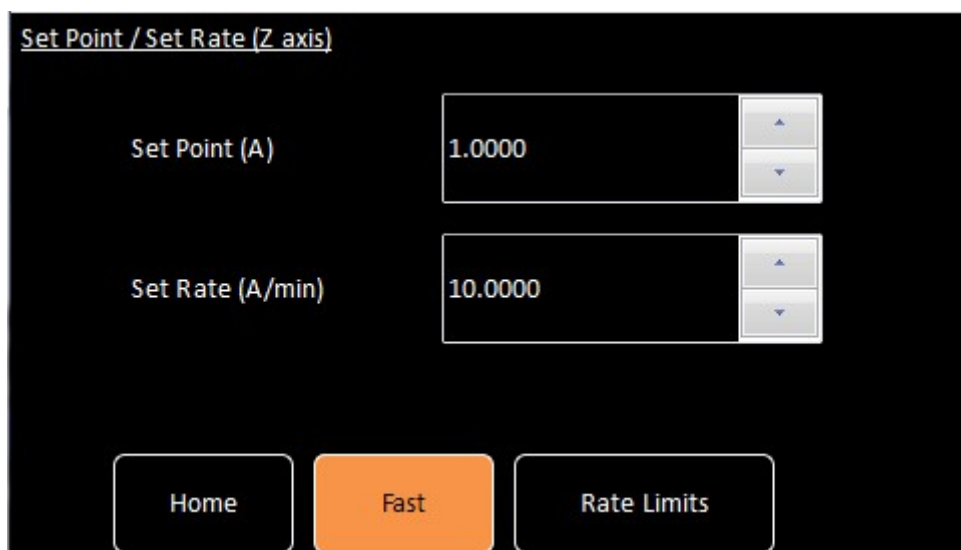


Figure 14. Set Point / Set Rate screen

The Mercury iPS-M will distribute the set points and set rates to each unit in the group configuration. So, for example, if the group were a 180-10 which would be a parallel group of 1 x iPS-M plus 2 x iPS-S's and if a set point of 150A were entered the target currents would be distributed as 50A for each of the 3 parallel units (iPS-M, iPS-S<sub>1</sub> and iPS-S<sub>2</sub>). Similarly if a set rate of 9A/minute were entered, the target rates would be distributed as 3A/min for each of the 3 parallel units (iPS-M, iPS-S<sub>1</sub> and iPS-S<sub>2</sub>). When “To Set” is tapped, each unit starts its own controlled ramp to achieve the group requirement of 150A at 9A/min.

At the end of the ramp the units drop back into “Hold” mode. In this mode there is a fine trim function running which ensures the output is held constantly and precisely at the set point.

## 5.1 Rate Limits

As an additional form of operational protection for the magnet, the power supply can be pre-programmed with sets of ramp rate limits to avoid ramping the magnet too quickly or dumping current in the switch too quickly. There are 4 types of rate limit:-

## MercuryIPS

- LRMZ = Lead Rate, Magnet at Zero
- LRMF = Lead Rate, Magnet at Field
- MRFa = Magnet Rate – Fast
- MRSI = Magnet Rate – Slow

Lead Rate limits are effective when the switch heater is OFF for power supplies that have been configured with a persistent switch. Under these conditions the power supply is ramping its output current but not the magnet current. In general the LRMZ and LRMF table entries will be the same (Figure 15). Only some special case NMR magnets will have different values for LRMZ and LRMF.

Type	From (A)	To (A)	Rate Limit (A/min)
1 LRMZ	0	120.5	70
2 LRMF	0	120.5	70
3 MRFa	0	70	10

Figure 15. Rate limits table showing example lead rate (LR) entries.

The rate limit table has 4 columns. Column 1, “Type” on the left specifies the type of rate limit that is being defined. Column 2, “From (A)” specifies the lower current at which the limit will be applied. Column 3, “To (A)” specifies the upper current at which the limit will be applied. Column 4, “Rate Limit (A/min)” is the limit value which will be applied to the ramp for all output current values between the “From” and “To” values. The limit is applied to the group output (e.g. GRPZ) not the individual power supply device outputs.

The rate limit should be specified for the entire expected operational range of the system, i.e. from 0A up to the current limit specified in the configuration table (section 4.4). It is possible to set different limits for different ranges but the ranges must form a continuous set so that the entire current range has a defined limit, to a range resolution of 0.1mA. If there is a gap in the limit range a default value of 0.1A/min will be applied and this will cause operational problems.

## MercuryIPS

The “Magnet Rate” MRFa example (Figure 16) shows how to split the range. In this example a fast magnet rate limit of 10A/min is being applied for output currents from 0A to 70.0000A, then fast magnet rate limit of 8A/min is being applied for output currents from 70.0001A to 120.5000A.

Type	From (A)	To (A)	Rate Limit (A/min)
3 MRFa	0	70	10
4 MRFa	70.0001	120.5	8
5 MRSI	0	70	5

Figure 16. Rate limits table showing example magnet rate (MR) entries.

The “magnet rate” limits are applied when the switch heater is ON for systems configured with a persistent switch, or all the time for systems configured without a persistent switch because for systems without a switch, ramping the output will always be ramping the magnet.

The rates are applied as a coercive limit. If the operator sets a target ramp rate which is greater than the limit being applied the magnet will ramp at the limit rate NOT the requested target rate. The “Rate Limit” indicator on the Home screen will be asserted to inform the operator that the requested ramp rate is not being delivered.

In the above MRFa example, if a magnet ramp rate of 9A/min were requested from 0A to 120A, the ramp would proceed at 9A/min up to 70.0001A, then the limit would restrict the rest of the ramp to 120A to 8A/min and the “Rate Limit” indicator on the Home screen is asserted for the rest of the ramp.

## MercuryIPS

### 5.2 Fast Rates / Slow Rates

The Fast/Slow button on the “Set Point / Set Rate” page (Figure 14) defines whether fast magnet rate limits, or slow magnet rate limits will be applied. In general fast rate limits should be used. The slow rates are usually only used for training magnets or after a major quench.

### 5.3 Editing the Rate Limits table

To add a row to the rate limit table, tap the “+” button in the bottom right corner (Figure 16). This will add a row of the same rate limit type as the previous row with the “From” value set to 0.1mA greater than the “To” value of the previous row. To edit any of the values tap on the value to open either a drop-down list to set the type or the numeric keypad to enter a value.

It is necessary that a limit type is specified over the complete current range (to 0.1mA resolution) but it is not necessary that the rows of the same limit type are consecutive in the table.

To remove a row from the table, tap the row number on the left-hand side, then tap the “-“ button in the bottom-left corner. A dialogue box will show a message indicating which row you are about to remove. Tap OK to remove it.

### 5.4 Quench

See section 4.1 for a description of a quench event. The effect at the magnet terminals will be a fast voltage transient which will appear at the power supply group terminals. When the voltage exceeds the voltage limit defined for the group (e.g. GRPZ) in the configuration table (section 4.4.3), the Mercury starts an internal timer. The timer keeps running while the terminal voltage is above the threshold. During this time the rundown resistors of each magnet device will switch in to dissipate some of the energy from the magnet to try to get the terminal voltage below the limit (in case the quench is a false quench). However, when the timer exceeds the transient time defined in the configuration table (section 4.4.6) the power supply stops trying to dissipate the energy and drops into Quench mode. The “Quench” indicator on the Home screen will be asserted in red. Typically one power supply device will enter Quench mode before the others in the same group. At this point its Quench status is broadcast to all the other units in

# MercuryiPS

the group and they also enter quench mode. These units may have already quenched as their terminal voltages will also have been high for a time close to the transient time.

In quench mode the PWM of each magnet device trips to zero so that the output of each device is 0A. Once the terminal current has decayed below 1A a 20 second delay is initiated after which the device outputs are clamped and the “Clamped” indicator on the Home screen will also be asserted in red.

To clear the Quench mode, unclamp and reset the power supply group, tap “Hold”.

## 5.5 Vector Rotate mode

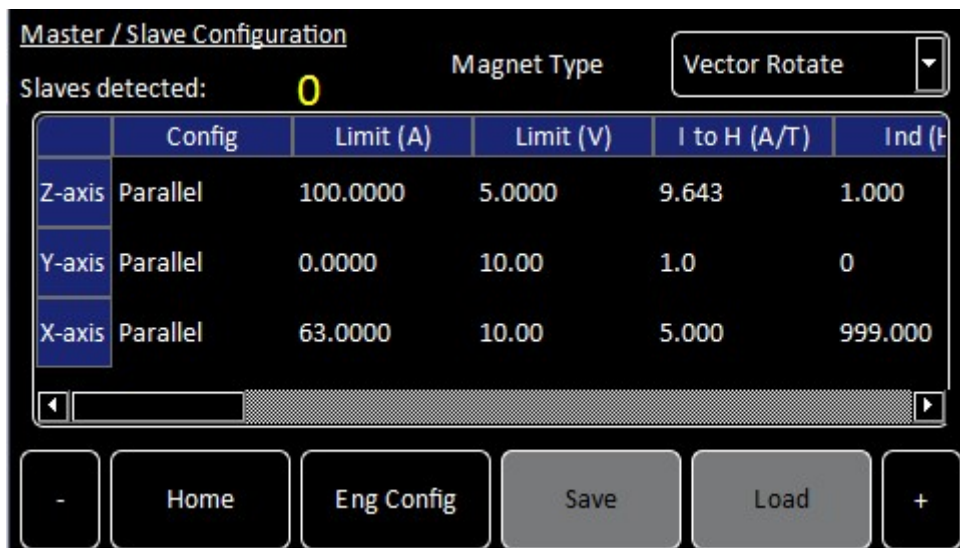


Figure 17. Configuration Screen in Vector Rotate mode.

The Mercury iPS-M is capable of controlling up to 3 independent axes. To do this, set the “Magnet Type” to “Vector Rotate” (Figure 17) mode. Now the configuration table has 3 rows “Z-axis”, “Y-axis” and “X-axis” so that configuration parameters can be set for each axis.

There are now 3 magnet groups (“GRPZ”, “GRPY” and “GRPX”). Each magnet group has an “Engineering Configuration” table so that individual power supply devices (PSU.M1, PSU.M2...) can be added to the relevant axis group.

## MercuryIPS

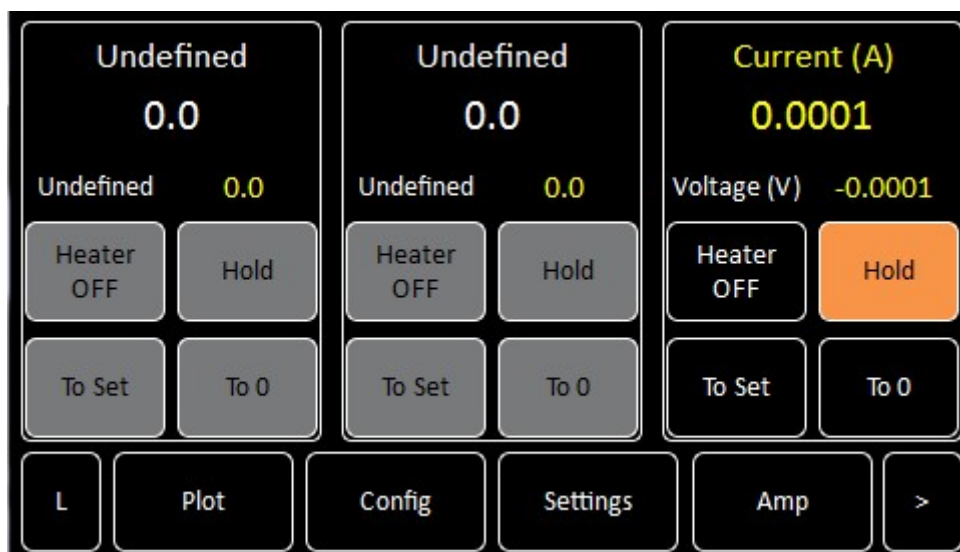


Figure 18. Vector Rotate Home screen. The left panel controls the X-axis, centre the Y-axis and right the Z-axis.

In Vector Rotate mode the Home screen now has 3 panels (Figure 18). In this example the X-axis and Y-axis are showing undefined. This is because there are no power supply devices configured in the axis groups of GRPX or GRPY. The panels, whilst cut down still have the essential controls which function in the same way as the standard “solenoid” Home screen. To see the detailed “Home” screen for each axis tap the “>” button at the bottom-right corner.

Tapping on the “Current (A)” (or “Field (T)”) indicator brings up an axis dependent “Set Point / Set Rate (?-axis)” (where ? = X or Y or Z) screen, so that the target current (or field) and target ramp rates can be set for each axis. Each screen also has a “Rate Limits” button so that a rate limit table can be defined for each axis.

## MercuryIPS

# 6 TEMPERATURE MEASUREMENT

Standard **MercuryIPS**'s are fitted with one temperature board. The temperature board will typically be used to measure the magnet temperature but may also be used to measure the switch temperature.

The iPS 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 4Hz. The iPS can detect short-circuit inputs and open-circuit inputs. The iPS 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
- Using a generic calibration file (if applicable) + generic sensor adjustment
- More about thermocouples

See chapter 12 for a description of the temperature sensor circuit.

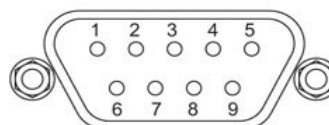
## 6.1 Sensor connections

The temperature sensor input is connected via the 9-way D-connector on the rear panel of the iPS marked "Sensor".

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	

## MercuryIPS

6	NC
7	NC
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-

### 6.1.1 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 iPS. 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 thermocouple even if the equipotential isothermal junction is grounded, as the iPS 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 iPS's internal reference temperature.

## 6.2 Configuring a temperature sensor

The home page shows six widgets and four buttons. If the iPS 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.

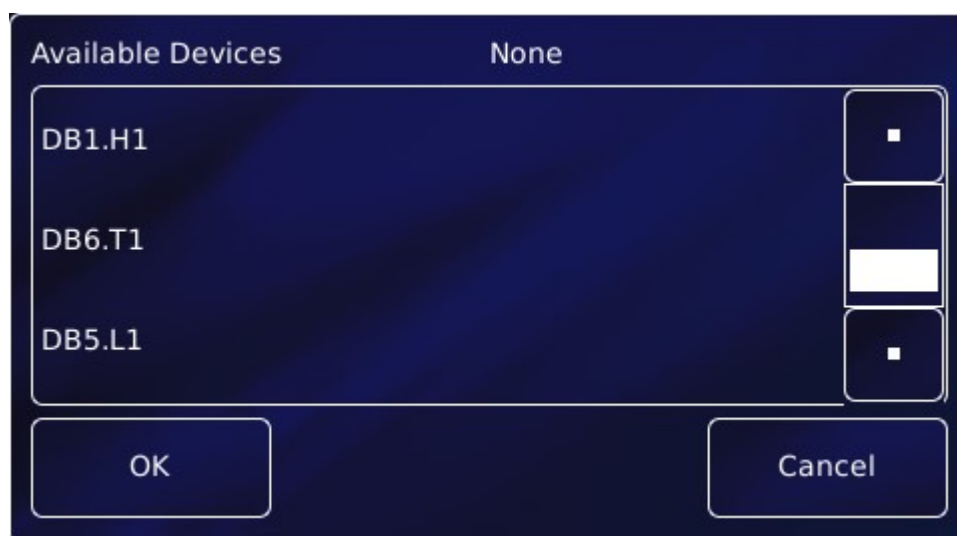


## MercuryIPS

- 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**.



- 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.

### 6.2.1 Configuring the sensor details

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

## MercuryIPS

**Sensor Details**

Example

• **Sensor Readings**

I (µA)	100.0000
P (µW)	1.0612
R (Ω)	106.1198
S (Ω/K)	0.3597
T (K)	295.0027
V (mV)	10.6120

Sensor Type: PTC

Calibration: RP51.DAT

Interpolation: Linear

Excitation: Unipolar

Magnitude (µA): 100.00

Home Cal Adj Calibrate

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.
- 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 6.5.

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 6.4).

4 **Interpolation**

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

## MercuryIPS

- 5 Tap the **Excitation** parameter box and select an excitation mode from the drop-down menu (see section 6.5.5).
- 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 6.4.2). This allows the user to adjust the scale and offset of a generic calibration curve to suit a particular sensor.
- 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.

### 6.2.2 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.

## 6.4 Using a generic calibration-file

### 6.4.1 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.

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.

### 6.4.2 Adjusting a generic calibration file

You need a method of maintaining the temperature sensor at two known temperatures ( $T_1$  and  $T_2$ ) 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.

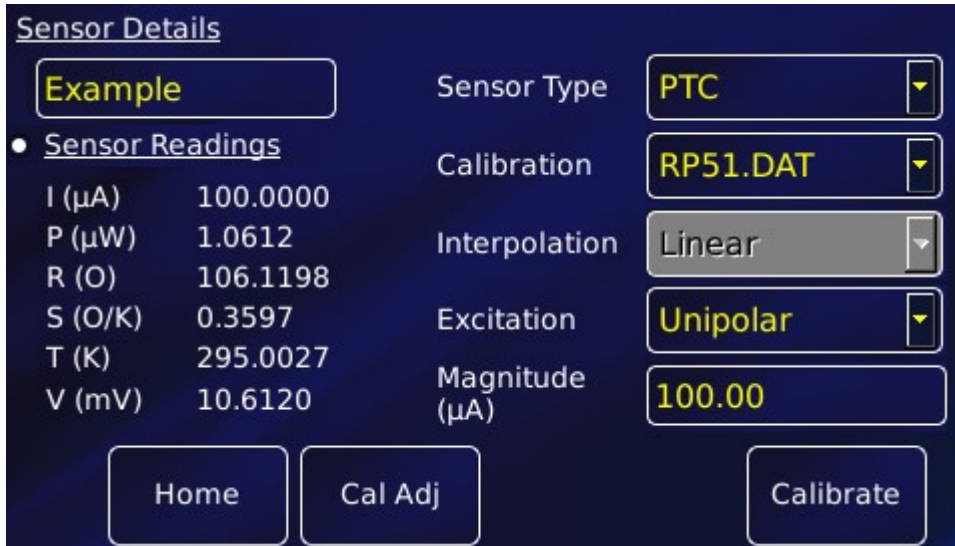
For this procedure,  $T_1$  produces a lower sensor-resistance than  $T_2$ :

- For a PTC sensor,  $T_1 < T_2$

# MercuryiPS

- 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.



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**.

## MercuryiPS

- 8 Tap **Calculate** to request the iPS 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.

## 6.5 Types of temperature sensor

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

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

### 6.5.2 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 iPS 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.

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

Semiconductor resistance thermometers (negative temperature coefficient)

The resistance of semiconductor resistors decreases with increasing temperature. The

## MercuryiPS

relationship is non-linear. The iPS uses a 4-wire connection, applying a constant voltage across the resistor. The iPS 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.

### 6.5.4 Semiconductor diodes

These devices produce a voltage that decreases as the temperature increases. The iPS passes a constant current through the diode and measures the voltage produced. Resolution to 1mK is possible at low temperatures.

### 6.5.5 Excitation current

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

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

When the circuit is configured to measure negative temperature coefficient (NTC) sensors, such as CERNOX ceramic oxi-nitride or 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.

## MercuryIPS

- 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.

### 6.5.6 Calibration for different sensors

The iPS 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 MercuryIPS 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.
- .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 iPS calculates set point limits and sensor limits from the chosen calibration file.



## MercuryiPS

### 6.5.7 Available generic calibration files

The **MercuryiPS** 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 **MercuryiPS** 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.

## MercuryiPS

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

## 6.6 More about thermocouples

### 6.6.1 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.

### 6.6.2 Configuring for thermocouples

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

## MercuryIPS



- 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 6.2), 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 6.5.7.

## MercuryIPS

**Sensor Details**

**MB1.T1**

• **Sensor Readings**

T (K)	298.1752
S (O/K)	0.0000
T (K)	308.0686
V (mV)	0.4034

Sensor Type: **Thermocouple**

Calibration: **TT5.DAT**

Interpolation: **Linear**

Reference: **Internal**

Home    Cal Adj    Calibrate

### 6.6.3 Reference junction compensation

The MercuryIPS configuration options permit an internal or external reference junction to be used. Each iPS 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.

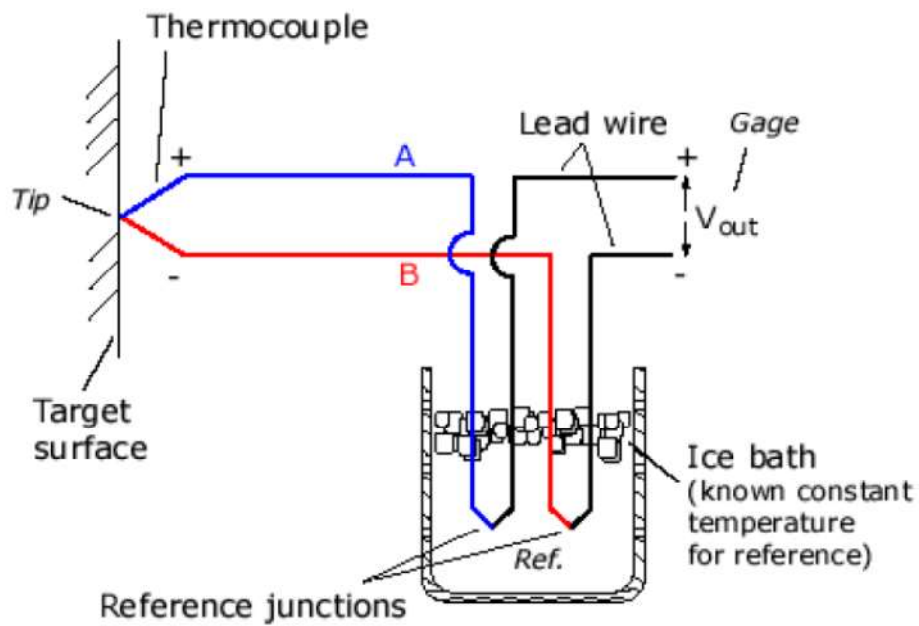
an assumption that the internal reference chip is 2.0C warmer than pins 1 and 3 in the 9 way D-connector. This figure, derived from tests, is also limited by the accuracy of the ADT7310 chip.

### 6.6.4 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.

## MercuryiPS



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.

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

## 7 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 level sensor probe (bottom connector) and one for a helium level sensor probe (top connector).

### 7.1 Principles of operation

#### 7.1.1 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

## MercuryIPS

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.

### 7.1.2 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.

### 7.1.3 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.

## 7.2 Installing the level-meter board

### 7.2.1 Removing the top cover

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

## MercuryIPS

- 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 iPS.
- 6 Slide the top cover back (it can be quite tight) and lift it off.

### 7.2.2 Fitting the board

The level-meter board can be fitted in any expansion slot. Only one level meter board can be fitted in a **MercuryIPS**, 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 19). Remove the board clamp.



Figure 19 MercuryIPS daughter board clamp

- 3 Knock out the blanking plate (Figure 20) 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 iPSs).
  - For the 2 tongue iPS, gently swivel the blanking plate back and forward until the retaining tongues break.
  - For the 4 tongue iPS, 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.



## MercuryiPS

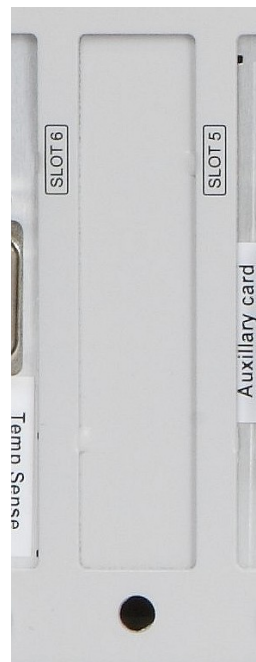


Figure 20 MercuryiPS daughter board blanking plate

- 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 iPS back plane. Lower the board into the iPS 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 iPS, insert the retaining screw to hold the card. Do not tighten at this time.
- 7 From the top of the iPS, 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.

## MercuryIPS

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

### 7.2.3 Basic check of board operation

- 1 Power up the **MercuryIPS**. If fitted correctly, the iPS will detect the board and may request permission to use it (depending on firmware version).
- 2 Put the iPS in Local mode by tapping the local/remote toggle button on the iPS **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.

## 7.3 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

## 7.4 Configuring MercuryIPS 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).

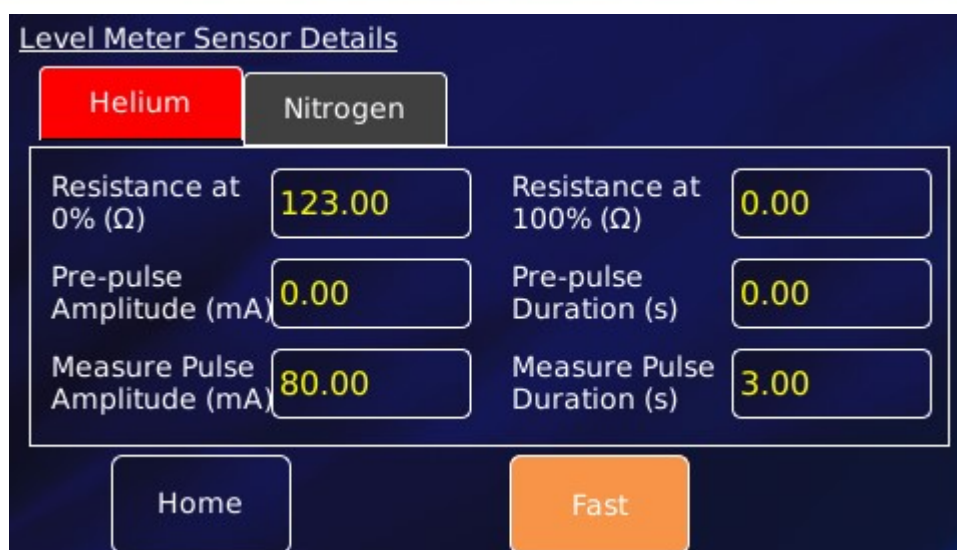
## MercuryIPS

- 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 iPS 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.

## MercuryiPS



- 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 (%).



## 7.5 Configuring MercuryiPS 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**

## MercuryiPS

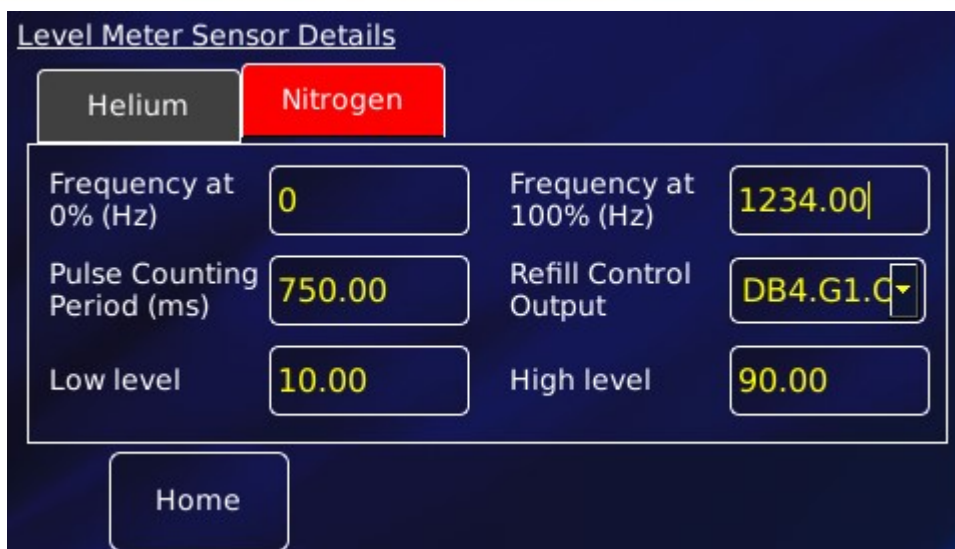
- 4 Tap **Assign** to save the changes and return to the Home page.

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 iPS 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.

## MercuryiPS



- 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.

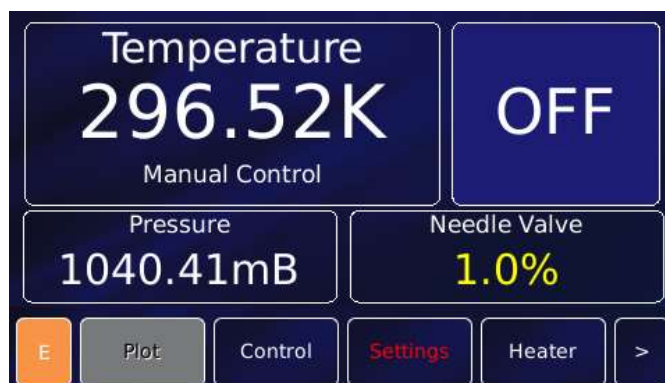
## MercuryIPS

## 8 LAMBDA MODE

It is possible to configure the Mercury iPS 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 iPS. Lambda mode can be invoked by loading the “lambda” template. This can be run in parallel with normal iPS 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.

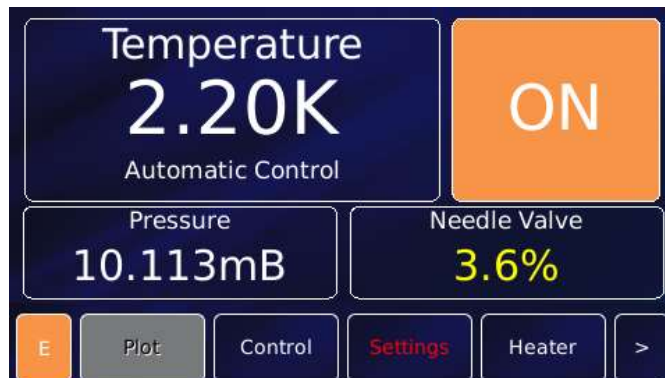
When the lambda mode is invoked, one of the unit's home screens will become the LPC home screen.



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.

## MercuryIPS

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.

### 8.1 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.



## MercuryIPS

### 8.2 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.

#### 8.2.1 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.

## 8.2.2 Remote Commands

See section 11.3.6 “Addressing in Lambda mode”

## MercuryiPS

# 9 MANAGING YOUR MERCURY

This chapter describes

- general operation of the **MercuryiPS**, 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 9.1 to 9.8 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 10 below.

## 9.1 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

## MercuryIPS

all GUI controls are disabled. Set Remote Lock to Off to allow (normal) GUI control of the iPS. 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 iPS 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 Application version number**

The number in the lower-left corner of the screen is the “Cryosys” Application version number. “Cryosys” is the main application running on any Mercury unit providing the control logic of the unit, the GUI and the remote interfaces. The version number has the form x.x.xx(.x). The first number is a major release revision, the second is a minor release update revision. The third and possibly fourth revision numbers are for small bug fixes or feature request updates.

- **The Application update rate**

The number in the lower-right corner of the screen is the Cryosys application refresh rate, typically 4Hz for iTC's and 1Hz for iPS systems, but this may vary.

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.

## MercuryiPS

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

### 9.2 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 (%)**.

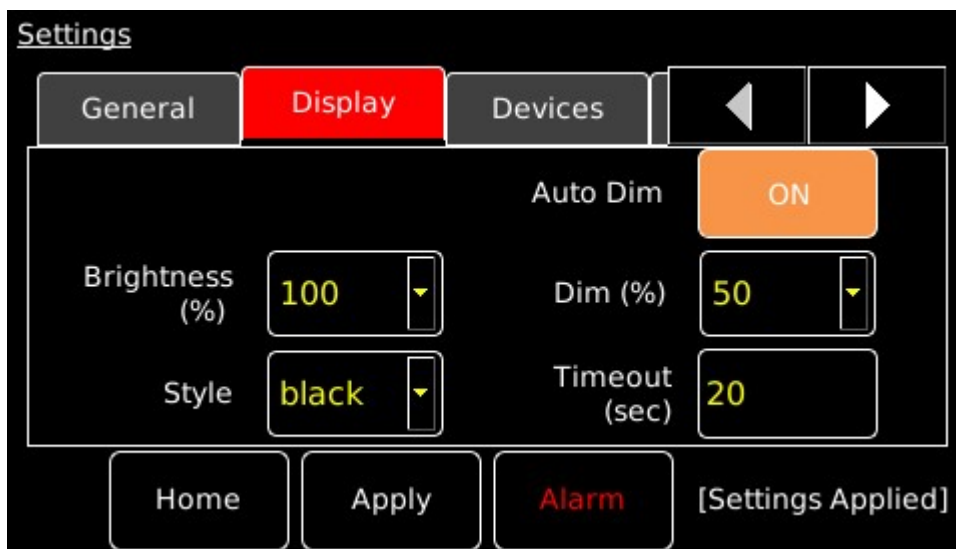
- **Style**

There are two choices for the display colours.

## MercuryiPS

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

**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.

# MercuryIPS

## 9.3 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 iPS. 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.

# MercuryIPS

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

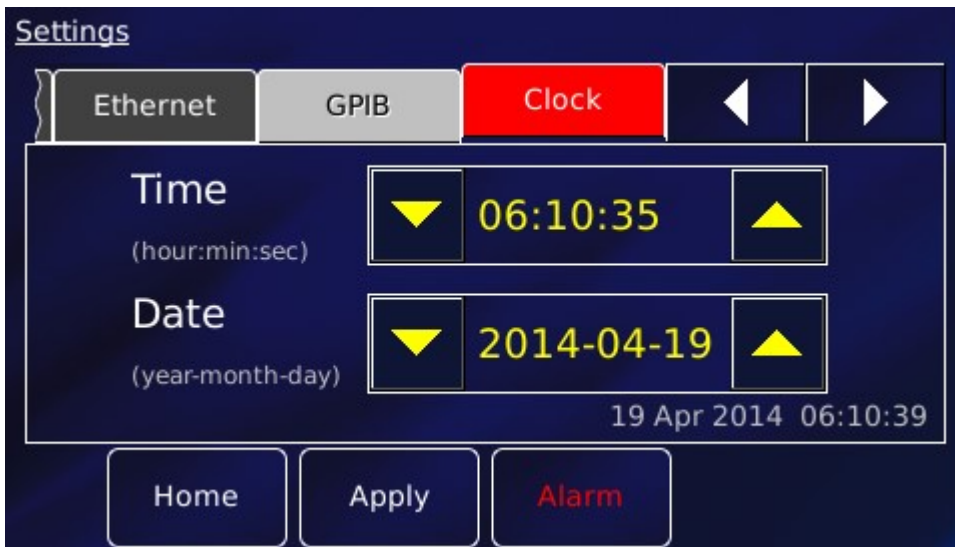
The page contains the following buttons:

- **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.



## 9.4 Clock

Select the **Clock** tab to reset the **MercuryIPS** 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.



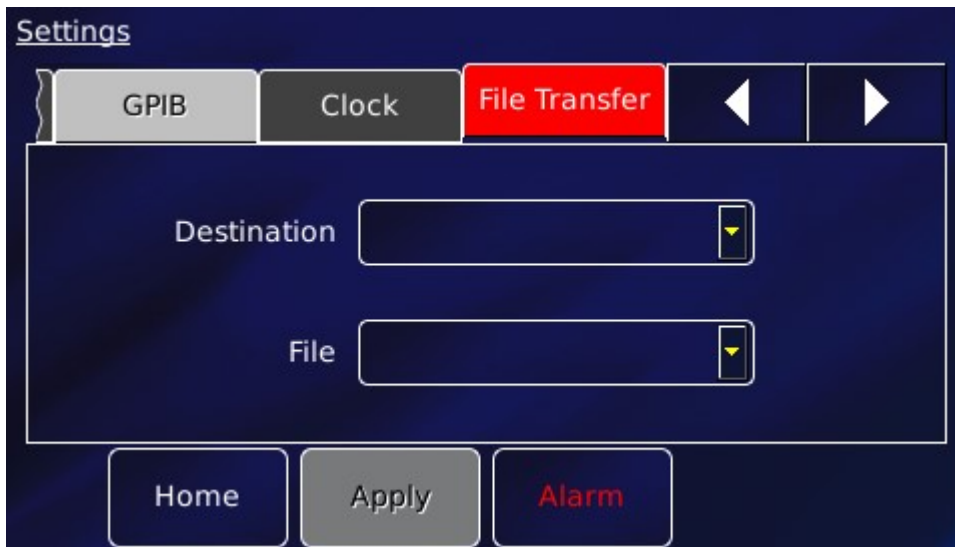
## MercuryiPS

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.

## 9.5 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 iPS.



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.

## MercuryIPS

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.

## 9.6 Updates

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

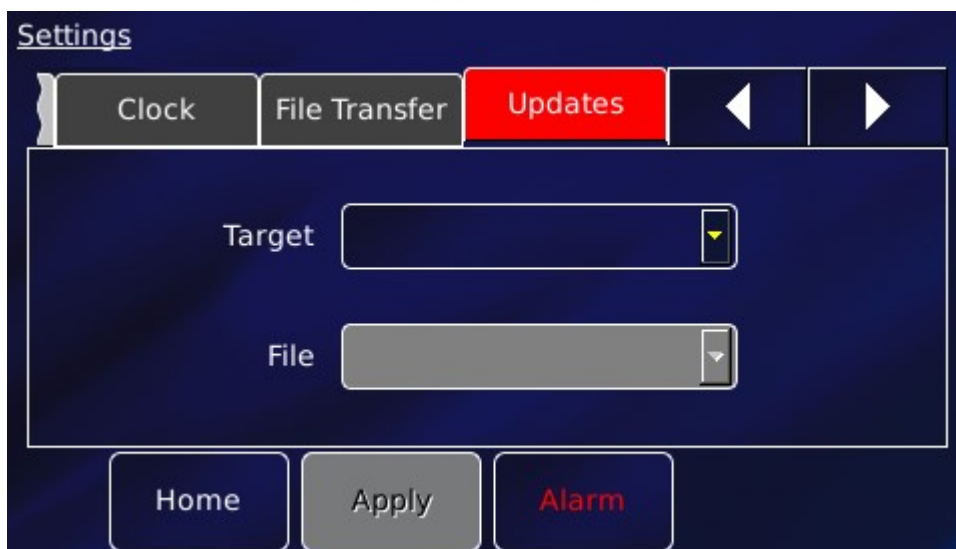
The Mercury **application** is software that runs on the **MercuryIPS** and allows the user to interact with the instrument using the touch screen GUI. It translates and communicates user commands to the appropriate device (board).

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 9.8 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 iPS. Allow a few seconds for the flash drive to be detected and scanned.
- 5 Select the **Updates** tab.

## MercuryIPS



- 6 With the iPS 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!

## MercuryIPS

- 9 Run some standard procedures to test that the iPS is working as expected.
- 10 With the iPS 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 iPS 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.

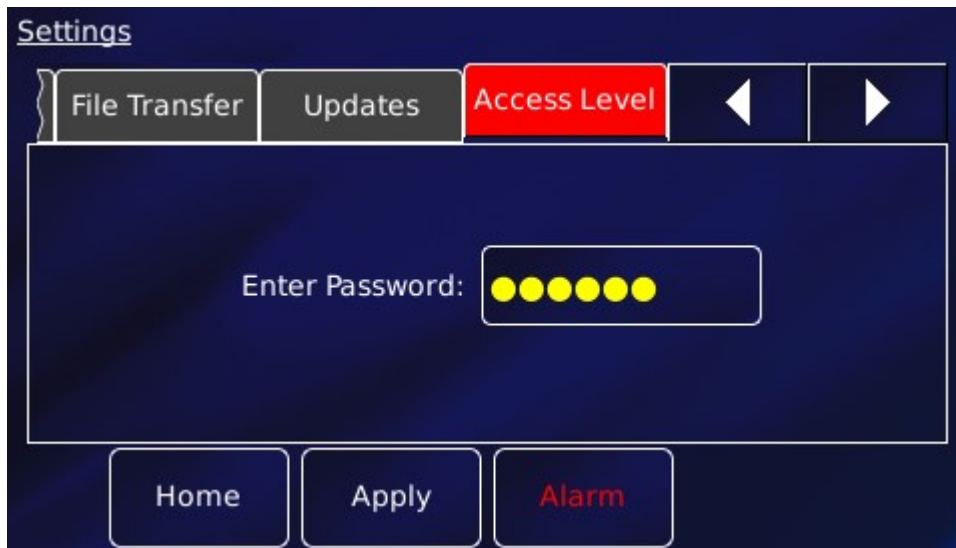
## 9.7 Access Level

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.

## MercuryIPS



- 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.

## MercuryIPS

- 3 Tap **Access Level**. The engineering mode page opens with the message “Engineering mode is enabled”, as shown above.
- 4 Tap **Exit Mode**. The iPS is no longer in engineering mode. The previous page reappears with the prompt for password.

### 9.8 Factory

This page allows the user to save the configuration of the **MercuryIPS**. 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 iPS'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 **MercuryIPS**.

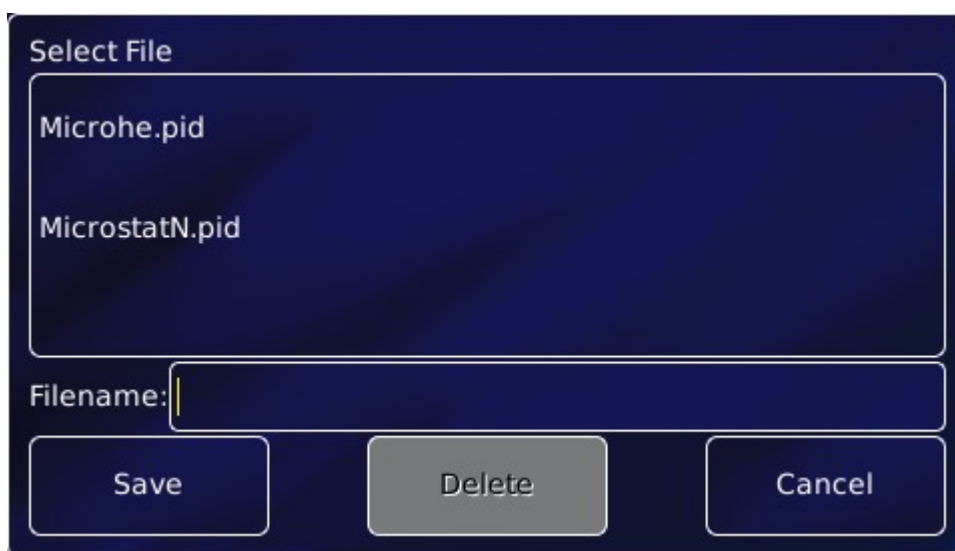
## MercuryiPS

- **Delete**

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

## 9.9 Save File pages

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.

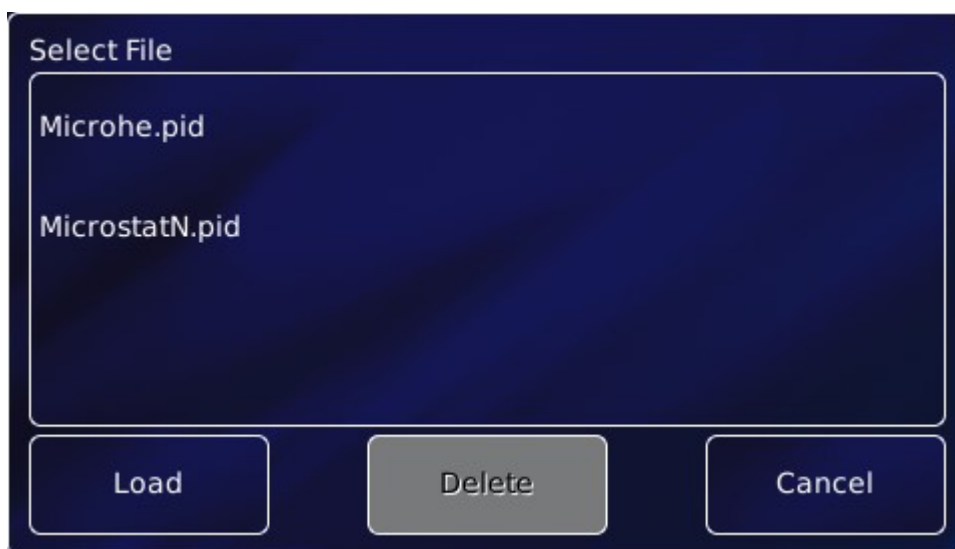
- **Cancel**

Tap once to exit this page without saving the file.

## MercuryiPS

### 9.10 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.



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.



## 10 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 **MercuryiPS** can be remotely operated using any of the following interfaces:

- RS232 or ISOBUS
- GPIB (IEEE-488) (optional)
- Ethernet 10/100 IEE802.3
- USB 2.0

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

## 10.1 Remote operation using RS232 or ISOBUS

### 10.1.1 Configuring RS232 and ISOBus

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

## MercuryIPS



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.

## MercuryIPS

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

### 10.1.2 Serial RS232 cabling requirements

The RS232 interface is connected via a 25-way D-socket on the rear page. The iPS 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 iPS.
2	TD	Data from the computer to the iPS.
3	RD	Data from the iPS to the computer.
4	RTS	Linked to Pin 5 inside the iPS.
5	CTS	Linked to Pin 4 inside the iPS.
6	DSR	Linked to +5 V when the iPS is powered.
7	SG	Linked to digital ground inside the iPS.
8	DCD	Linked to +5 V when the iPS is powered.
9 to 25	Open circuit	

The iPS 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 iPS 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

# MercuryIPS

Max Rx input voltage     $\pm 30$  V

## 10.2 Remote operation using GPIB

### 10.2.1 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 iPS 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:

## MercuryIPS

- **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.

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

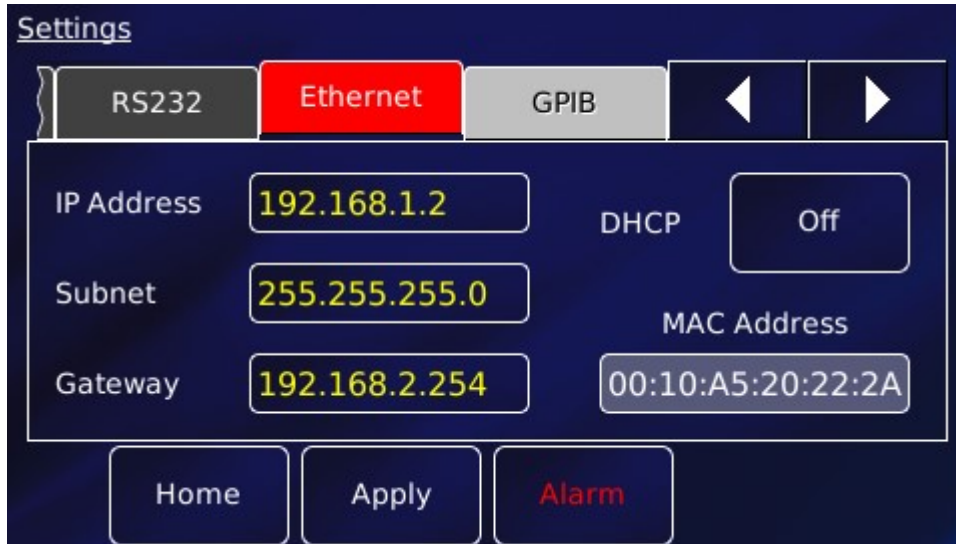
## 10.3 Remote operation using Ethernet

### 10.3.1 Configuring Ethernet

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

## MercuryIPS

- 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 iPS 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 iPS ethernet connection.

- **Subnet**

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

- **Gateway**

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

- **MAC Address**

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

- **Port**

## MercuryIPS

Not shown on the details page, but 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.

### 10.3.2 Ethernet cabling requirements

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

## 10.4 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. The USB port is configured to emulate a serial port.

### 10.4.1 Configuring USB

Since USB is a one-to-one connection, no addresses are required. The baud rate is preset to 115200, data bits to 8, stop bits to 1, parity to none and flow control to none.

### 10.4.2 USB Cabling requirements

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

### 10.4.3 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 **MercuryIPS** over the USB port. Instructions are included in the download.

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

## 10.5 Switching MercuryiPS 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 iPS.

A quicker way to switch off (disable) the remote interface is from the Home screen. The virtual button in the bottom left corner (see Figure 13). If the virtual button is orange/red the remote interface is enabled, if it is blue/black it is disabled. Tap it to toggle its state. The character displayed in the button indicates which remote interface is selected (I = Isobus/Serial, U = USB, G = GPIB and E = Ethernet).

## 10.6 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 **MercuryiPS** via RS232/Isobus, USB, Ethernet or GPIB.

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

## 10.7 Programming examples



## MercuryiPS

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 LV VIs. This is a library of Vi's for National Instruments LabView version 8.6 and later.
- Communication with MagLab over ISOBUS. This document is a guideline on how to establish communication between MagLab software and MercuryiPS over the serial ISOBUS interface.
- Teslatron (OxSoft) Installer. This is an installation package including executable installer, source code, **MercuryiPS** driver and an operation manual.

# 11 COMMAND REFERENCE GUIDE

## 11.1 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]).

## 11.2 SCPI and legacy command sets

The iPS supports two separate sets of remote commands:

- SCPI commands are based on the SCPI command set, although the iPS may not be fully compliant with SCPI.
- Legacy commands were used in previous power supply models (e.g. IPS120-10).

The user configures the iPS 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 iPS is compatible with any existing remote applications that have been written to drive earlier Oxford Instruments equipment.

## 11.3 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:-

## MercuryiPS

- \*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

### 11.3.1 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).

### 11.3.2 Reading the instrument identity

Send the command:

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

## MercuryIPS

The format of the reply is:

IDN:OXFORD INSTRUMENTS:MERCURY dd:ss:ff

Where:

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

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

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

### 11.3.3 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 11.3.6). This appears immediately after the term that cannot be interpreted.

### 11.3.4 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 iPS 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')

## MercuryIPS

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')

### 11.3.5 Nouns

Elements within the iPS 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

m# - milli

# - none

k# - kilo

M# - mega

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

## MercuryIPS

A – Amps, V – Volts or W – Watts.

### 11.3.5.1 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
SYS DISP	DIMT 0 - 10	R/W	Sets the time for the automatic dimming
SYS DISP	BRIG 0 - 100	R/W	Sets the brightness
SYS MAN	HVER	R	Reads Hardware version of the Box
SYS MAN	FVER	R	Cryosys version
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
SYS CUTOFF	OFF:ON	R/W	Sets the shutdown mode of Cryojet

To enter engineering mode, send the following command:

## MercuryIPS

```
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 set 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 iPS configuration:

```
READ:SYS:CAT (meaning 'read system catalogue')
```

A power supply system with no daughter boards would return the following:

```
STAT:DEV:MB1.T1 :TEMP:DEV:GRPZ :PSU.M1:PSU (meaning 'status device  
motherboard1, temperature1 is a temperature board device, Group Z power supply magnet1 is  
a power supply board device')
```

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:MB1.T1 :TEMP:DEV:GRPZ :PSU.M1:PSU:DEV:DB3 :AUX:DEV:DB4 :LVL
```

(meaning 'status device motherboard1, temperature1 is a temperature board device, Group Z power supply magnet1 is a power supply board device, device daughter board3 is an auxiliary board device, device daughter board4 is a level board device')

### 11.3.5.2 Addressing a magnet power supply device

To address a magnet power supply, use the following structure:

```
DEV:<UID>:PSU
```

## MercuryIPS

where <UID> is a unique identifier that is allocated to each power supply. The power supplies are special cases as they are configured in axis groups, GRPZ, GRPY and GRPZ. So the UID can be, for example "GRPZ" or the device name, for example "PSU.M1". So for example READ:DEV:PSU.M1:PSU:SIG:CURR would return the output current of the PSU.M1 magnet board. But READ:DEV:GRPZ:PSU:SIG:CURR would return the sum of the output currents of all the magnet devices configured in GRPZ (e.g. PSU.M1 + PSU.M2 for a 120A single axis unit). Not all the parameters are consistent with devices and not all are consistent with groups.

The configuration settings for an individual power supply device (e.g. UID = PSU.M1) are DEV:<UID>:PSU 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
VRTT	0 - 60000	R/W	Reads/Sets the transient time for ignoring the over voltages at the psu terminals
BIPL	OFF ON	R/W	Reads/Sets the bipolar mode to ON or OFF
SHTC	0 - 125	R/W	Reads/Sets the static switch heater current
VLIM	0-100	R/W	Reads/Sets the maximum normal operation voltage (quench threshold)
IND	0 - 1000	R/W	Reads/Sets the self-inductance to match the magnet, used for control loop stability.
CLIM	0 - 630	R/W	Reads/Sets the maximum current for a group of power supplies

The signals for an individual power supply device are DEV:<UID>:PSU followed by:

COMMAND	Read/Write	DESCRIPTION
SIG VOLT	R	Magnet device output voltage
SIG CURR	R	Magnet device output current
SIG PCUR	R	Magnet device output persistent current
SIG CSET	R	Target current in A
SIG FSET	R	Target field in T
SIG RCST	R	Target ramp rate in A/min
SIG RFST	R	Target ramp rate in T/min
SIG FLD	R	Field in T
SIG PFLD	R	Persistent field in T

The configuration settings for a power supply group (e.g. UID = GRPZ) are DEV:<UID>:PSU followed by:



## MercuryIPS

COMMAND	OPTIONS	Read/Write	DESCRIPTION
NICK		R/W	Sets the name of the device
STAT		R	Reads the alarm flags for the device (Hex Format)
VRTT	0 - 60000	R/W	Reads/Sets the transient time for ignoring the over voltages at the psu terminals
BIPL	OFF ON	R/W	Reads/Sets the bipolar mode to ON or OFF
ATOB	0 - 1000	R/W	Reads/Sets the current to field ratio
SWPR	UID	R/W	Reads/Sets which units drives the switch heater
SHTC	0 – 125	R/W	Reads/Sets the static switch heater current
VLIM	0-100	R/W	Reads/Sets the maximum normal operation voltage (quench threshold)
IND	0 - 1000	R/W	Reads/Sets the self-inductance to match the magnet, used for control loop stability. Reads/Sets the maximum current for a group of power supplies
CLIM	0 - 630	R/W	
SWHR	0 - 10000	R/W	Set the switch heater resistance
SWR	0 - 10000	R/W	Sets the switch resistance
LEAD	0 - 100	R/W	Sets the Lead resistance value
SFTY	<UID>	R/W	Sets the UID of the safety device
TLIM	0 - 999	R/W	Sets the temperature safety limit
LLIM	0 - 100	R/W	Sets the level safety limit
SWONT	0 – 60000	R/W	Sets the switch on time
SWOFT	0 – 60000	R/W	Sets the switch off time

The signals for a power supply group are DEV:<UID>:PSU followed by:

COMMAND	OPTIONS	Read/Write	DESCRIPTION	
SIG	VOLT	R	Magnet device output voltage	
SIG	CURR	R	Magnet device output current	
SIG	PCUR	R	Magnet device output persistent current	
SIG	CSET	R/W	Target current in A	
SIG	FSET	R/W	Target field in T	
SIG	RCST	R/W	Target ramp rate in A/min	
SIG	RFST	R/W	Target ramp rate in T/min	
SIG	FLD	R	Field in T	
SIG	PFLD	R	Persistent field in T	
SIG	RCUR	R	Actual Current rate in A/min	
SIG	RFLD	R	Field rate in T/min	
SIG	SWHT	OFF:ON	R/W	Switch heater status (check before set)
SIG	SWHN	OFF:ON	R/W	Switch heater status (forced on set)
ACTN	HOLD:RTOS:RTOZ:CLMP	R/W	Ramp status (Hold, to set, to zero, clamp)	

## MercuryIPS

### 11.3.5.3 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:

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 for the device (Hex Format)
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)
RSMP		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 RTMP	R	Raw temperature
SIG POWR	R	Sensor power dissipation
SIG RES	R	Measured resistance (PTC/NTC)

# MercuryiPS

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:

```
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
```

### 11.3.5.4 Addressing a level meter sensor

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

```
DEV:<UID>:LVL
```

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

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

COMMAND	OPTIONS	Read/Write	DESCRIPTION
---------	---------	------------	-------------

## MercuryIPS

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)
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
NIT	LOW		0-100	R/W	Sets/reads the threshold for low Nitrogen level that starts a refill
NIT	HIGH		0-100	R/W	Sets/reads the threshold for high Nitrogen level that stops a refill
NIT	RFL		OFF:ON	R/W	Sets/reads whether autofill is activated
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
SIG	NIT FREQ	R	Nitrogen sensor measured frequency
SIG	NIT LEV	R	Nitrogen sensor level

## MercuryIPS

### 11.3.5.5 Addressing an auxiliary I/O daughter board

To address an auxiliary board, use the following structure:

DEV:<UID>:AUX

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

The configuration settings for an auxiliary board are 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	Input state
SIG	On	OFF:ON	Output state

### 11.3.5.6 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:

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

## MercuryiPS

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	HIGHL	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

### 11.3.5.7 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	AUX UID	R/W	Assign Auxiliary device to Temperature
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	TSET 0 - 2000	R/W	Sets the pressure set point
LOOP	FSET 0 - 100	R/W	Sets the flow percentage (Manual flow)
LOOP	FAUT OFF:ON	R/W	Enables/Disables flow control

## MercuryIPS

LOOP	P		R/W	Set the P Value
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

### 11.3.6 Addressing in Lambda mode

To address an iPS 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 iPS. The template requires the iPS 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

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.

## MercuryiPS

### 11.3.7 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.

## 11.4 Legacy commands

### 11.4.1 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)

### 11.4.2 Legacy monitor commands

#### 11.4.2.1 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	Output Current	A
R1	Output voltage	V
R2	Output Current	A
R3	Unused	
R4	Output Current	A
R5	Set point (Target current)	A
R6	Target current sweep rate	A/min
R7	“Output” Field	T
R8	Set point (Target field)	T
R9	Target field sweep rate	T/min



## MercuryIPS

R10	Temperature**	K
R11	Liquid Nitrogen level†	%
R12	Liquid Helium level†	%
R13	Unused	
R14	Output Current	A
R15	Voltage limit	V
R16	Magnet current	A
R17	Unused	
R18	Magnet field strength	T
R19	Unused	
R20	Switch heater current	mA
R21	Negative current limit	A
R22	Positive current limit	A
R23	Unused	
R24	Magnet Inductance	H

Note: \*\* The temperature measured by the MB1.T1 sensor input channel. This will typically be the magnet temperature or lambda plate temperature.

† Assuming a cryogen level meter card is fitted in the iPS-Master.

### 11.4.2.2 V command - Read Version

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

### 11.4.2.3 X command - Examine Status

The EXAMINE command allows the computer to read the present iPS STATUS. The command requires no parameters and returns a message string with a fixed length of 13 characters.

The returned string is of the form `XmnAnCnHnMmn` where

Xmn	System Status
m=0	Normal
m=1	Quenched
m=2	Over heated
m=4	Warming up
m=8	Fault
n=0	Normal

## MercuryIPS

	n=1	On positive voltage limit
	n=2	On negative voltage limit
	n=4	Outside negative voltage limit
	n=8	Outside positive voltage limit
<b>An</b>		<b>Activity</b>
	n=0	Hold
	n=1	To Set
	n=2	To Zero
	n=4	Clamped
<b>Cn</b>		<b>Local/Remote Status</b>
	n=1	Remote and unlocked
	n=2	Remote and locked
<b>Hn</b>		<b>Switch Heater Status</b>
	n=0	OFF, magnet at zero (N/A)
	n=1	ON
	n=2	OFF, magnet at field
	n=5	Heater fault
	n=8	No Switch
<b>Mmn</b>		<b>Mode: Display   Magnet Sweep</b>
	m=0	Fast
	m=1	Slow
	n=0	At rest (Hold)
	n=1	Sweeping

## 11.4.3 Legacy control commands

### 11.4.3.1 An command - Activity

The ACTIVITY command sets control of the magnet output to either HOLD, To SET, To ZERO or CLAMPED (note: the output will only be clamped if the output current is less than 1A).

Allowed values are:

n=0	Hold
n=1	To Set
n=2	To Zero
n=4	Clamped (will only clamp the psu if the output is <1A)

## MercuryiPS

### 11.4.3.2 Hn command - Set Switch Heater State

The Set Switch Heater command turns on/off the switch heater.

H0	Turns the switch heater OFF.
H1	Turns the switch heater ON if the difference between the magnet current and power supply output current is < 0.1A.
H2	<b>CAUTION!!</b> Turns the switch heater ON without making any checks of the magnet current and psu current.

### 11.4.3.3 Innnn command - Set Target Current (A)

The Set Target Current command format can have up to 3 digits before the decimal point (e.g. Innn.nnnn) and has 4 digits of precision after the decimal point.

### 11.4.3.4 Jnnnn command - Set Target Field (T)

The Set Target Field command format can have up to 2 digits before the decimal point (e.g. Jnn.nnnnn) and has 5 digits of precision after the decimal point.

### 11.4.3.5 Snnnn command - Set Target Current Ramp Rate (A/min)

The Set Target Current Ramp Rate command format can have up to 3 digits before the decimal point (e.g. Snnn.nnnn) and has 4 digits of precision after the decimal point.

### 11.4.3.6 Tnnnn command - Set Target Field Ramp Rate (T/min)

The Set Target Field command format can have up to 3 digits before the decimal point (e.g. Tnnn.nnnnn) and has 5 digits of precision after the decimal point.

## 11.4.4 Legacy system commands

### ! command - Set ISOBUS Address

This is equivalent to setting the ISOBUS address using the RS232 Settings page (section 10.1.1).

MercuryiPS

## 12 TEMPERATURE SENSOR DAUGHTER BOARD

This chapter describes the single and dual temperature sensor boards.

### 12.1 Overview of the temperature sensor board

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

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

### 12.2 Installing a temperature sensor board

#### 12.2.1 Fitting the board

A temperature sensor board can be fitted in any expansion slot. It is preferable to locate temperature boards in the higher numbered slots. The procedure for fitting a daughter board has already been described in section 7.2.

#### 12.2.2 Basic check of board operation

- 1 Power up the **MercuryIPS**. If fitted correctly, the iPS will detect the board and may request permission to use it.
- 2 Put the iPS in Local mode by tapping the local/remote toggle button on the iPS **Home** page.
- 3 Tap **Settings**, scroll to and tap the **Devices** tab.

## MercuryIPS

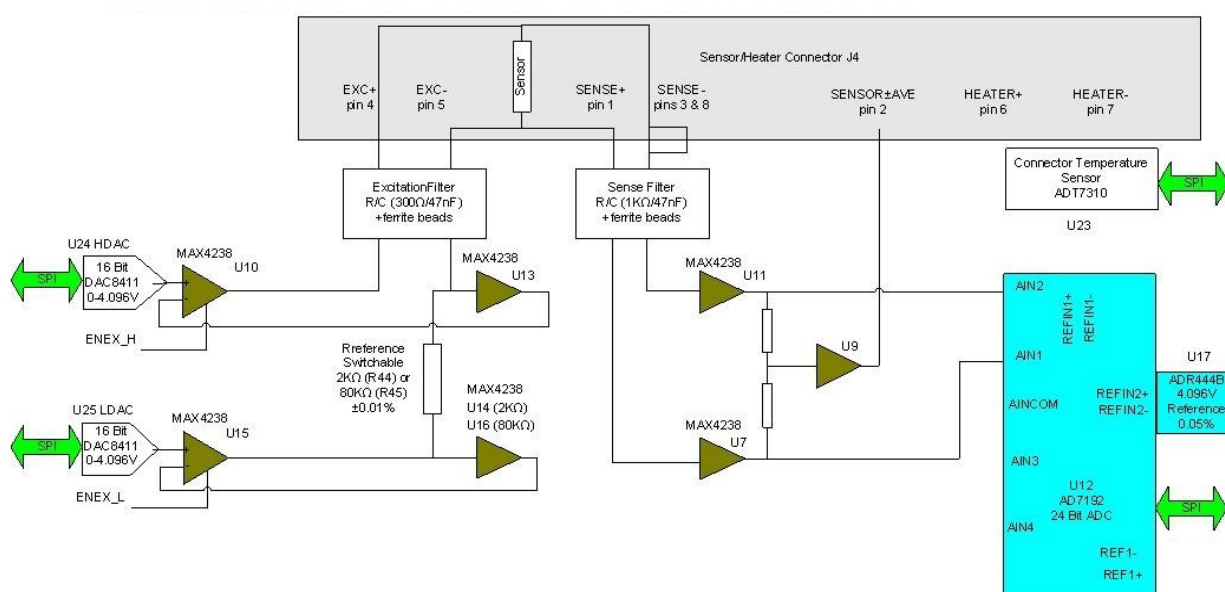
- 4 Scroll down the list of devices and find the level meter board. Also, scroll to the right to read the firmware version.

## 12.3 Circuit description of the temperature sensor board

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

### 12.3.1 Voltage measurement mode

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



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.

## MercuryIPS

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.

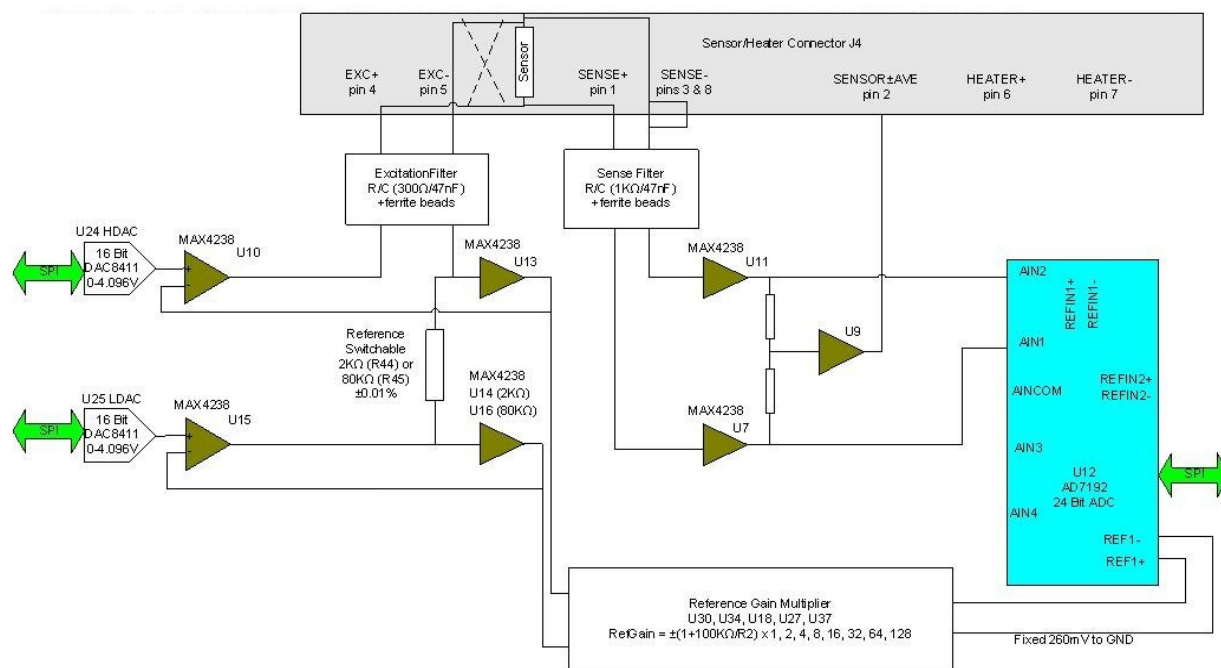
The temperature of the sensor to heater connection is measured to provide thermocouple correction.

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.

## MercuryIPS

## 12.3.2 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:



# MercuryIPS

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

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.

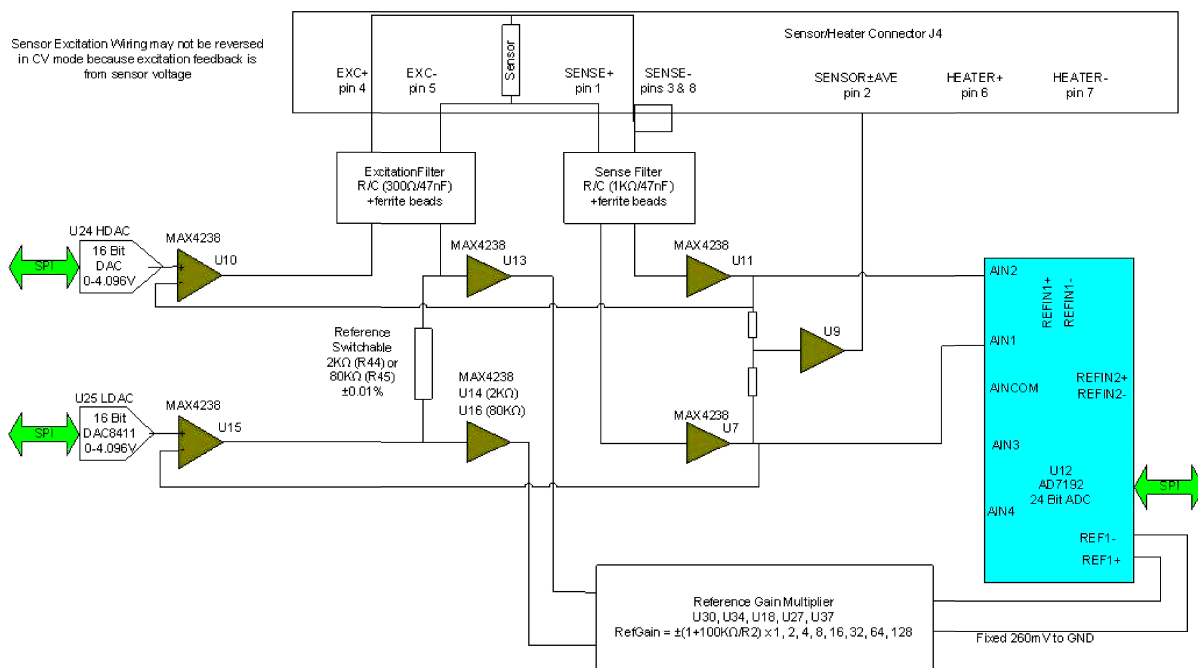
**RefGain** is the interpolated gain from the calibration tables.

**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.

### 12.3.3 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

## MercuryiPS

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.

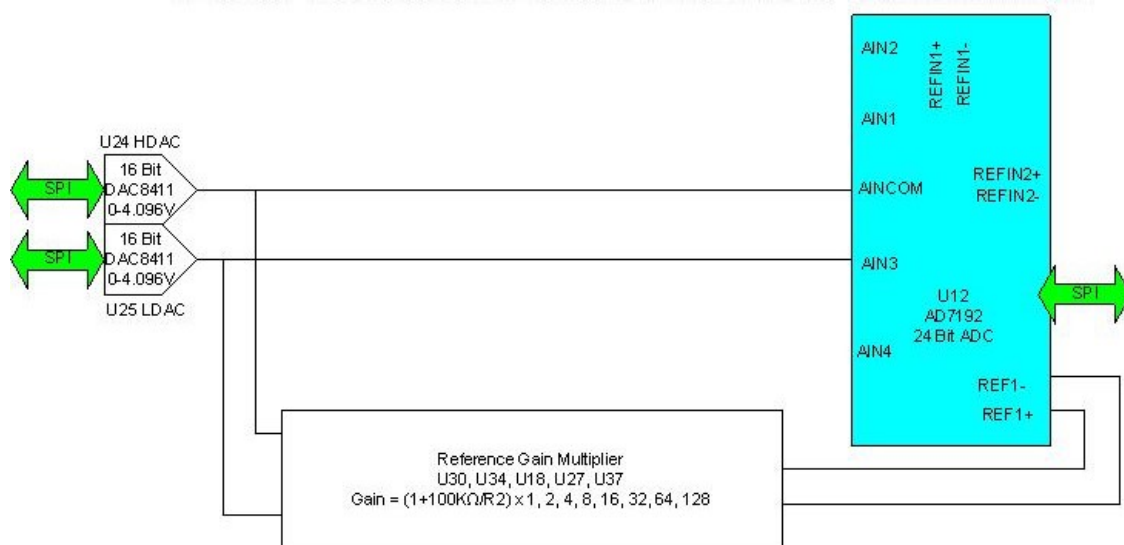
**ADCgain** is the gain setting of the ADC.

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.

### 12.3.4 Calibrating the temperature measurement circuit

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

## MercuryIPS



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.

## 13 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.

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

#### 13.1.1 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 iPS 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 iPS 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.

## MercuryIPS

### 13.1.2 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 **Error! Reference source not found.** for a full description of gas-flow control.

## 13.2 Installing an auxiliary I/O board

### 13.2.1 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 7.2.

### 13.2.2 Basic check of board operation

- 1 Power up the **MercuryIPS**. If fitted correctly, the iPS will detect the board and may request permission to use it.
- 2 Put the iPS in Local mode by tapping the local/remote toggle button on the iPS **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.

## MercuryiPS

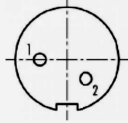
### 13.2.3 Connecting to the auxiliary I/O board

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.

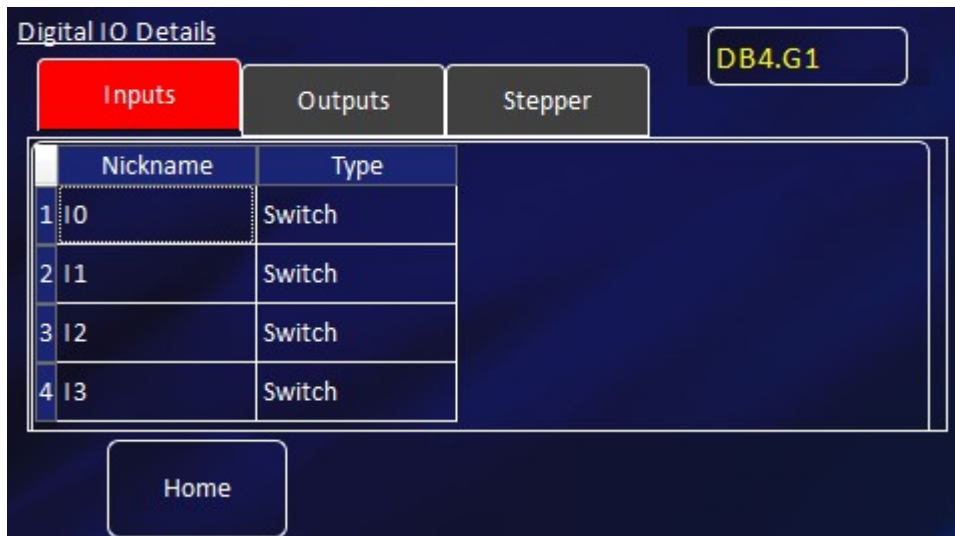
Pin	Function
1	+ve
2	ground



### 13.2.4 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.

## MercuryIPS



- 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.

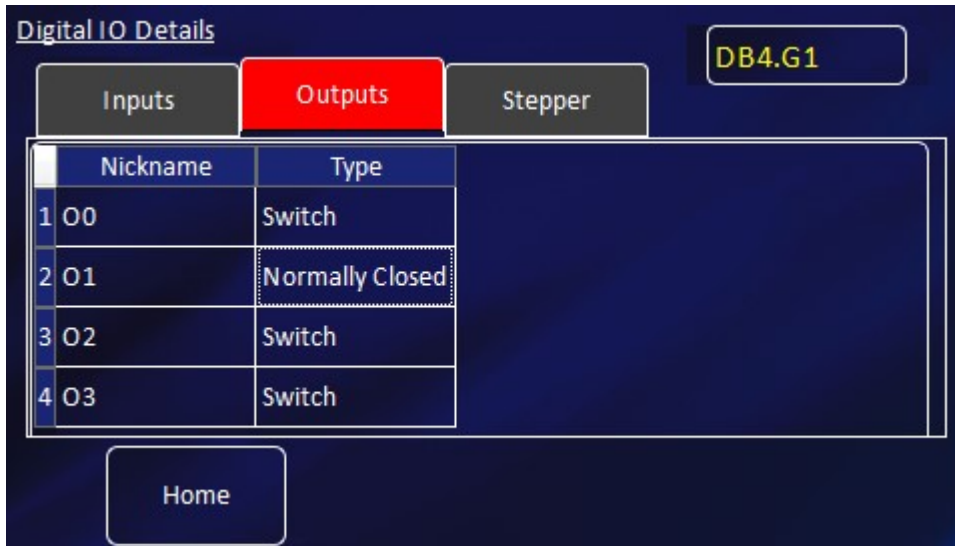
**NORMALLY OPEN** - The Home page displays OPEN when the input is high and CLOSED when the input is low.

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

### 13.2.5 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.

# MercuryIPS



- 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.



## 14 PRESSURE BOARD

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

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

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

### 14.1 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.

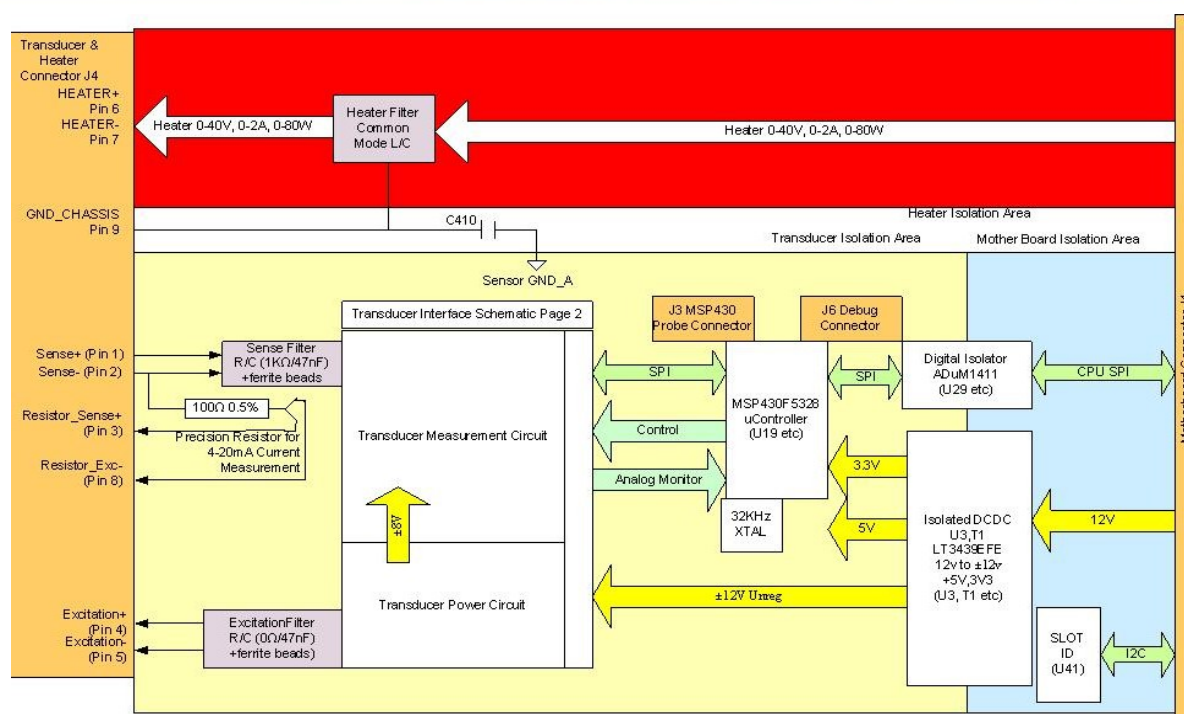
4-20mA current and 0-10 volt transducer outputs are measured on an auto-ranging 24 bit sigma delta ADC with a 0.04% accurate voltage reference. Together with other high precision components and automatic self-calibrating, this results in high accuracy and stability and low noise measurements. The pressure sensor input is via 9-way D-connector on the rear panel of the iPS.

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.

#### 14.1.1 Description of the pressure board circuit

A block diagram of the pressure board is given below.

## MercuryIPS



The circuit is powered from the CPU board 12 Volt supply. This enables the board to be used in both **MercuryIPS** 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.

## MercuryIPS

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.
- 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

## MercuryIPS

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.

## 14.2 Installing a pressure board

### 14.2.1 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 7.2.

### 14.2.2 Basic check of board operation

- 1 Power up the **MercuryIPS**. If fitted correctly, the iPS will detect the board and may request permission to use it.
- 2 Put the iPS in Local mode by tapping the local/remote toggle button on the iPS **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.

### 14.2.3 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	NC	
7	NC	
8	Resistor_Exc-	4-20mA current Sense Resistor Supply(-)
9	(Chassis)	

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

## MercuryiPS

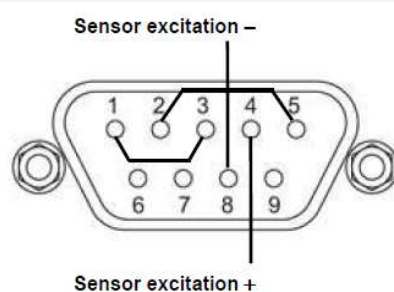
## Sensor and energisation options

## 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.

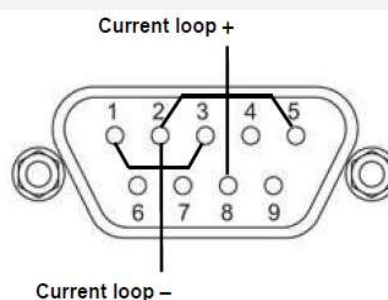
Pins 2 and 3 are not interchangeable.



**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.

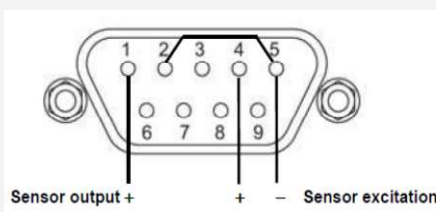
Pins 2 and 3 are not interchangeable.



**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

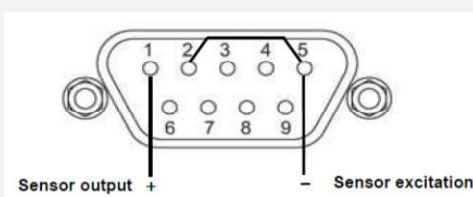


**Absolute Voltage Output (3 wire) sensors** using external excitation to energise the sensor.

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

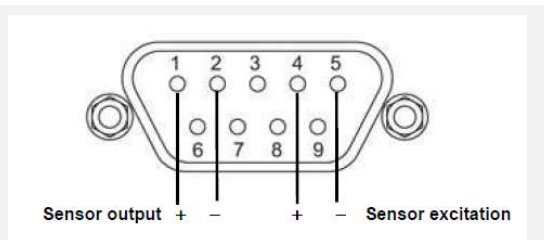


## MercuryiPS

**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.



### 14.2.4 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.

### 14.2.5 Configuring the pressure sensor details

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

## MercuryIPS

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

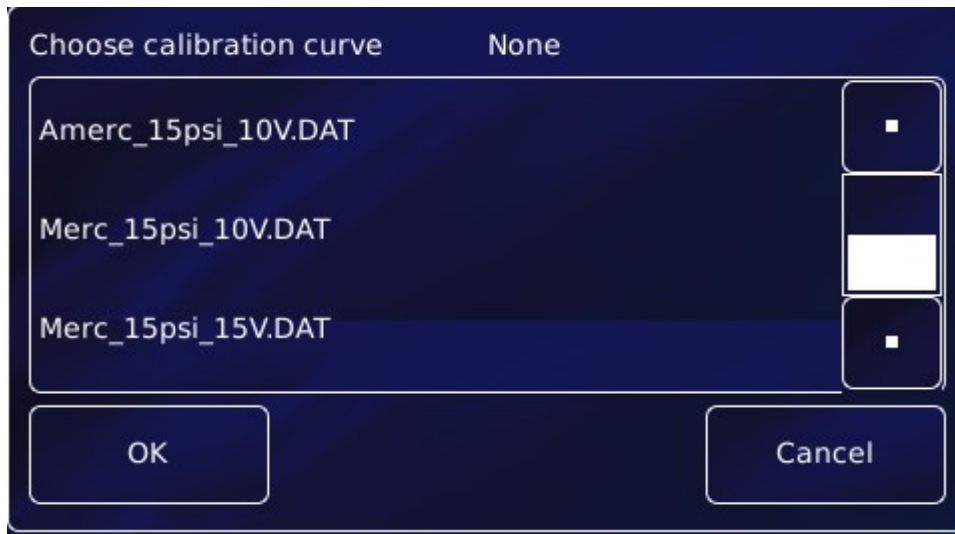
Ratiometric

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:

## MercuryIPS



- 4 Tap the **Excitation** parameter box and select None, 10V or 15V depending on the type of sensor (and advice give in section 14.2.3).
- 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 **Cal Adj**  
Tap once to access the Generic Sensor Adjustment page (see section 6.4.2). This allows the user to adjust the scale and offset of a generic calibration curve to suit a particular sensor.
- 7 **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. It is recommended that the user calibrates at least once a year with the iPS 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.
- 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.



## 15 GPIB DAUGHTER BOARD

### 15.1 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 iPS 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, is able to generate service requests and services device clear commands but does not respond to serial poll. 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

### 15.2 Installing a GPIB board

#### 15.2.1 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 7.2.

#### 15.2.2 Basic check of board operation

- 1 Power up the **MercuryIPS**. If fitted correctly, the iPS will detect the board and may request permission to use it.
- 2 Put the iPS in Local mode by tapping the local/remote toggle button on the iPS **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.

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

## 16 PREVENTIVE MAINTENANCE

The **MercuryIPS** 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 **MercuryIPS**.
- 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 iPS. 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 iPS, the **Settings** and **Alarm** 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.

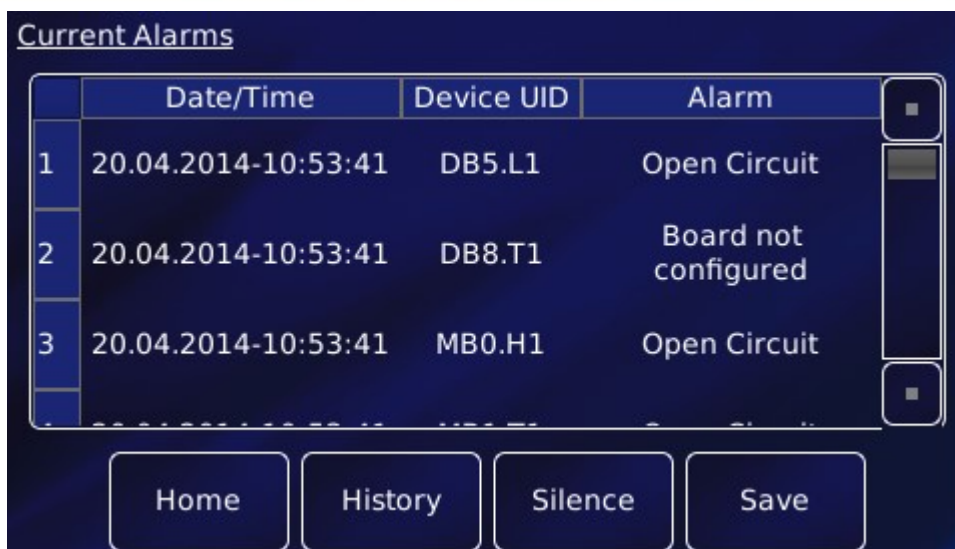
Safety interlocks are also registered in the alarms log.

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.

## MercuryIPS



	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.

## MercuryIPS

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.

## MercuryIPS

### 17.2 Troubleshooting

It is useful to distinguish between internal and external alarms. Some alarms arise because of an event internal to the **MercuryIPS**; 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>MercuryIPS</b> OFF then ON.
2	Update board firmware (section 9.6)
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>MercuryIPS</b> and securely fastened. The connector should be flush with the iPS and the locking screws tightened.
2	Check the cable between the iPS 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.



## MercuryIPS

## 17.3 Directory of alarms

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

Alarm	Interlock/ description	What to do
<b>Magnet board</b>		
Quench detected	Board has triggered in Quench mode.	If the board is tripping into quench mode when no actual magnet quench is occurring, try increasing the transient time and/or raising the voltage limit. If the problem persists contact Oxford.
Catch detected	A group Catch sequence has been triggered.	If the group is tripping into Catch mode incorrectly, try disabling the Catch function in the Config table (requires Application firmware 2.2.6.5 or later).
PWM Cutoff	PWM output OFF.	Check the cause – see below. Re-start the unit. If this persists contact Oxford.
Over temp Rundown Resistors	Run down resistors are too hot, PWM stops.	Re-start the unit. Check rundown resistor fan starts (loud airflow noise for 2 seconds on start up). If the run-down fan does not pulse or the problem persists contact Oxford.
Over temp Sense Resistor	Sense resistor is too hot PWM stops.	Re-start the unit. If the problem persists contact Oxford.
Overt temp PCB	PCB is too hot, PWM stops.	Re-start the unit. If the problem persists contact Oxford.
Overt temp Sense amplifier	Error amplifier circuit is too hot, PWM stops.	Re-start the unit. If the problem persists contact Oxford.
Overt temp Amp 1	Amplifier 1 is too hot, PWM stops.	Re-start the unit. If the problem persists contact Oxford.
Overt temp Amp 2	Amplifier 2 is too hot, PWM stops.	Re-start the unit. If the problem persists contact Oxford.
MSP430 firmware error	Firmware update did not complete correctly or firmware is corrupt.	Re-install magnet board firmware.
MSP430 RS-485 failure	Bus error.	Re-start the unit. If the problem persists contact Oxford.
Rundown resistors failed	Boot check of rundown resistor values is out of range.	Re-start the unit. If the problem persists contact Oxford.
Calibration failure	Board calibrations either corrupt or missing.	Re-start the unit. Try re-calibrating the board. If the problem persists re-load board firmware.
Voltage ADC error	V-ADC comms error.	Board will automatically reset. If the problem persists contact Oxford.
Current ADC error	C-ADC comms error.	Board will automatically reset. If the problem persists contact Oxford.
Voltage ADC not configured	V-ADC configuration error.	Board will automatically reset. If the problem persists contact Oxford.
Voltage out of bounds	Voltage error (may happen during Quench).	If the problem persists contact Oxford.
<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

## MercuryIPS

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

If you are experiencing difficulties, please

- check the relevant sections of this manual

## MercuryiPS

- upgrade application/firmware to the latest versions, as described in section 9.6.
- 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>MercuryiPS</b>
Serial number	A 9 character alphanumeric code (starting with “MM” or “MS” located on the iPS 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 2.2.6.6. 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. 1.26. This is the Device (e.g. magnet 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.

## MercuryiPS

## 18 TECHNICAL SPECIFICATIONS

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

### 18.1 Physical specification

Item	Specification
Width	426 mm
Depth	481 mm
Height	131 mm
Weight	14.0 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	800 W
Maximum mains voltage fluctuation	±10% of nominal voltage
Compliance Standard	CE, cETLus (UL and CSA recognised standard)
Over current protection	Internal – no user changeable fuses inside.
Category II transient overvoltages can typically be present on the mains supply.	

### 18.3 Magnet outputs

Item	Specification
Main output current range	±60.0A nominal ±62.5A peak per Mercury unit (up to ±600A (10V))
Main output current resolution	< 9µA per Mercury unit
Main output current stability	< ±2mA per Mercury unit
Main output current drift	< 0.1mA/Hr/degC (Temperature controlled sense resistor and error amplifier)
Main output current accuracy	Error < ±0.13%
Main output current ripple	PWM output control prevents supply ripple reaching the current output
Typical output current noise (at 60A)	-48.4dBm (0.51mA)

## MercuryiPS

Main output voltage range	$\pm 10.0V$
Main output voltage resolution	$< 20\mu V$
Main output voltage stability	$< \pm 0.2mV$
Main output voltage drift	Depends on output current drift and size of the inductive load
Line regulation	$< \pm 0.005\%$ (SMPS supply unit backed by a PWM driven class D amplifier prevents supply voltage ripple reaching output).
Maximum current ramp rate	1200A/min
Minimum current ramp rate	0.005A/min
Maximum load inductance	1000H
Maximum persistent switch heater current	120mA (11.5V compliance limit)
Persistent switch heater current stability	$< \pm 0.01mA$

## 18.4 Sensor inputs

Item	Specification
Basic iPS – single sensor input	Upgradeable to 9 sensor inputs
NTC resistance range	5 ohms to 200 kohms
Constant voltage	Typically $< 10\text{ mV}$
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 iPS. 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.

### The MercuryiPS

- 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.

## MercuryiPS

### 18.5 PC interfaces

Item	Specification
Serial interface	RS232 + ISOBUS
Serial interface 2	USB 2.0
GPIB	IEEE-488 (optional)
Ethernet	10/100 IEE802.3

### 18.6 Electrical isolation

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

## MercuryIPS

## 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%
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	±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±5% or 15V±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

## MercuryIPS

# 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 and Switzerland Oxford Instruments GmbH - NanoScience

Borsigstr. 15a, Wiesbaden, 65205, Germany  
Tel: +49 6122 937-0  
Fax: +49 6122 937-100  
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)

### USA

300 Baker Avenue, Suite 150  
Concord, MA 01742  
Telephone: +1 800 447 4717  
E-mail: [service.nanoscience@oxinst.com](mailto:service.nanoscience@oxinst.com)  
Web: [www.oxford-instruments.com](http://www.oxford-instruments.com)

### Japan

Oxford Instruments K.K.  
Haseman Building  
2-11-6 Tomioka  
Kotoku, Tokyo 1350047  
Telephone: +81 (0)3 5245 3871  
Email: [nanoscience.jp@oxinst.com](mailto:nanoscience.jp@oxinst.com)  
Web: [www.oxford-instruments.com](http://www.oxford-instruments.com)

### China

Oxford Instruments China  
Room 14F, No. 1 Plaza No. 800,  
Nanjing East Road,  
Shanghai 200001  
Telephone: +86 21 63608530/1/2/3  
E-mail [info@oxford-instruments.com.cn](mailto:info@oxford-instruments.com.cn)  
Web: [www.oxford-instruments.com](http://www.oxford-instruments.com)