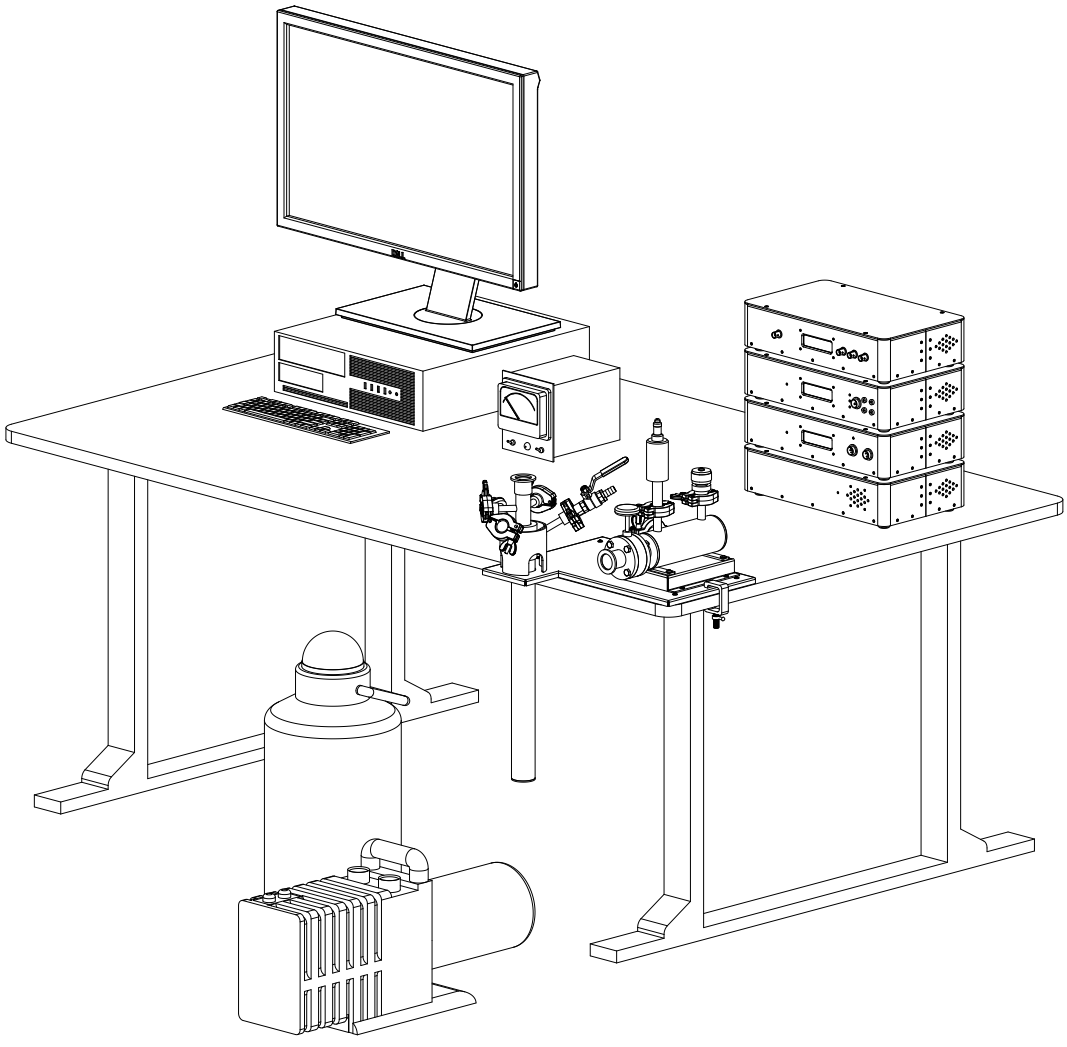
XPLORE 1.1™

Physical Quantities Measurement System (PQMS)

User Manual



Precision-Quazar Tech Pvt. Ltd.
New Delhi, India

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Chapter 1

Introduction to XPLORE 1.1™ System

1.1 XPLORE 1.1™ System Components

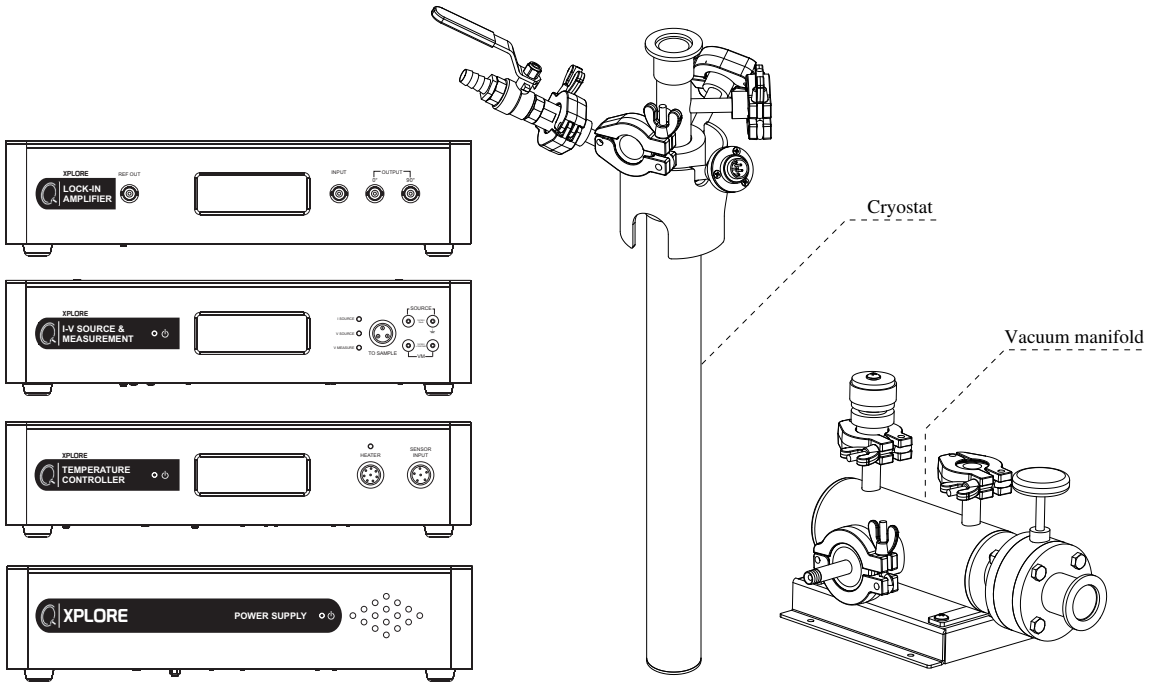


Figure 1.1: Major sub-units of XPLORE 1.1™ setup

Component	Description
Mechanical	
Cryostat	Non-magnetic double walled construction.
Vacuum manifold	To evacuate the cryostat to reduce evaporation of liquid N_2.
Electronics	
Power supply	Powers up all XPLORE 1.1™ electronics modules.
Temperature controller	Controls temperature of cryostat heater and reads sample temperature.
I-V source & measurement unit	Measures resistance of the sample under constant voltage or constant current mode.
Lock-in amplifier	Measures output from secondary winding of magnetic AC susceptometer coil.

1.2 Cryostat and Vacuum Manifold

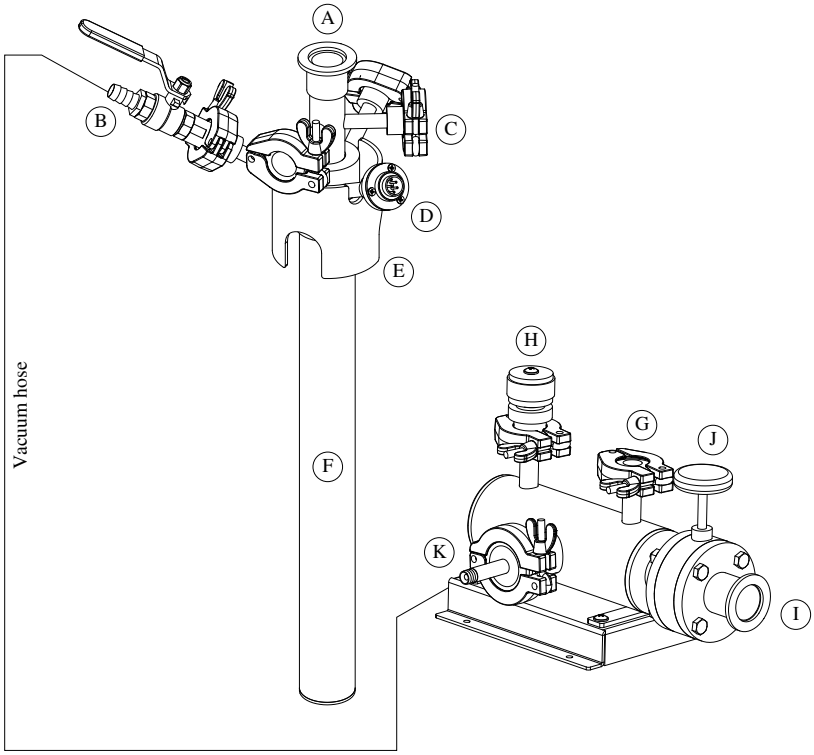


Figure 1.2: Cryostat and vacuum manifold

Item	Description	Port	Remark
A	Sample insertion port.	KF-25	Supplied
B	Heater chamber evacuation port.	KF-16	Supplied
C	Sample chamber evacuation port.	KF-16	Not supplied
D	Heater electrical connection feed-through.	8-pin BNC	Supplied
E	Cryostat stand.		
F	Non-magnetic double-walled cryostat.		
G	Pirani gauge mounting port.	KF-10	Supplied
H	Release valve.	KF-10	Supplied
I	Vacuum pump connection port.	KF-25	Not supplied
J	Butterfly valve.		
K	Cryostat vacuum hose connection port.	KF-25	Supplied

1.3 Inserts

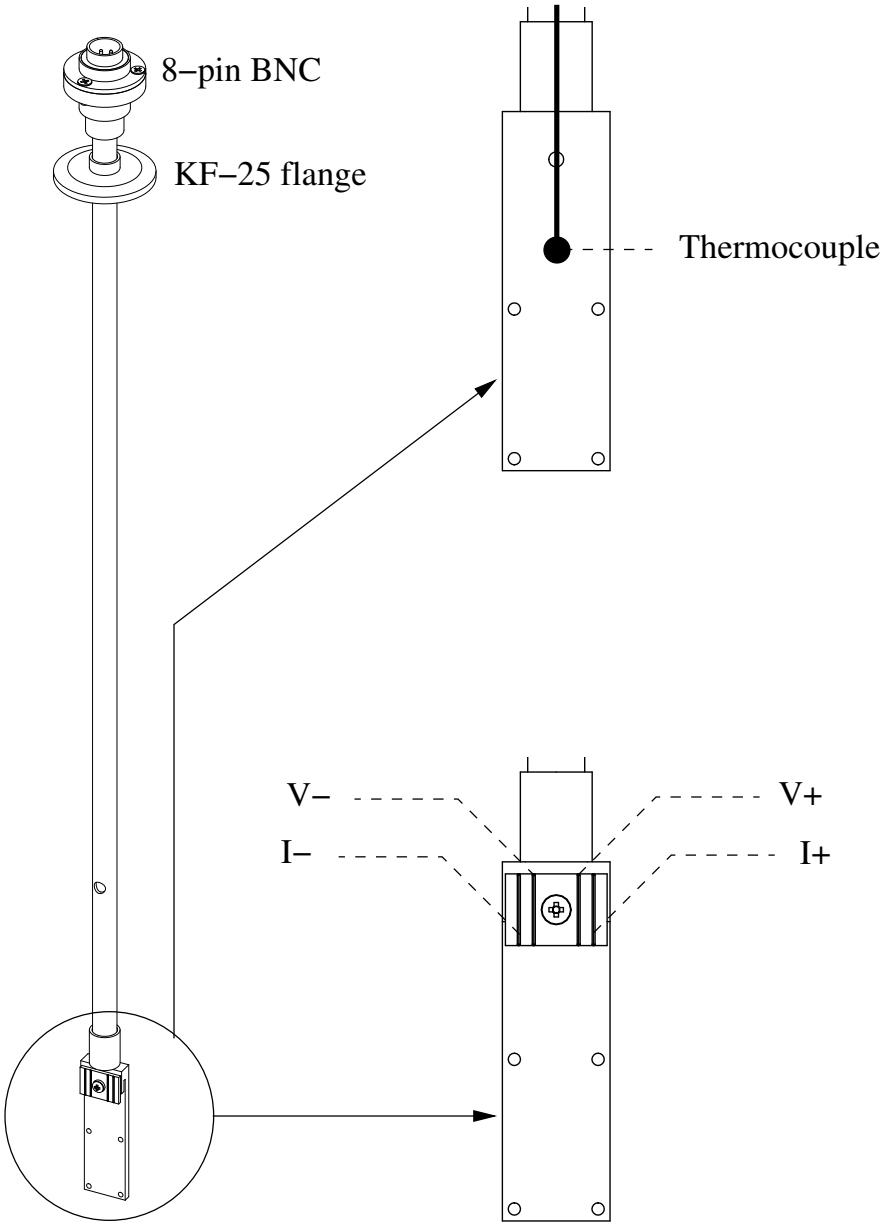


Figure 1.3: Four-probe I-V and R-T measurement insert

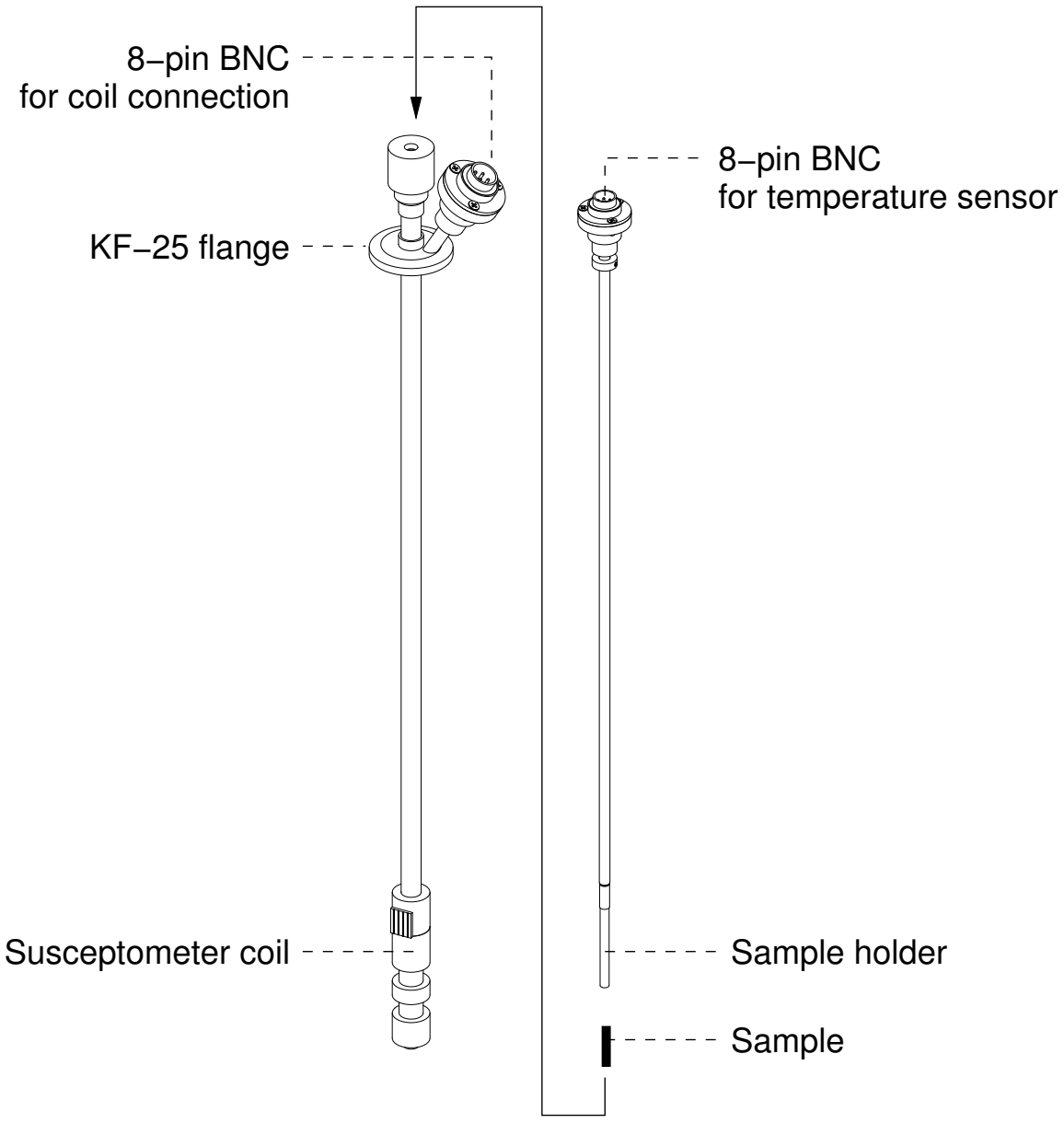


Figure 1.4: AC susceptibility measurement insert

1.4 Power Supply Module (XPS)

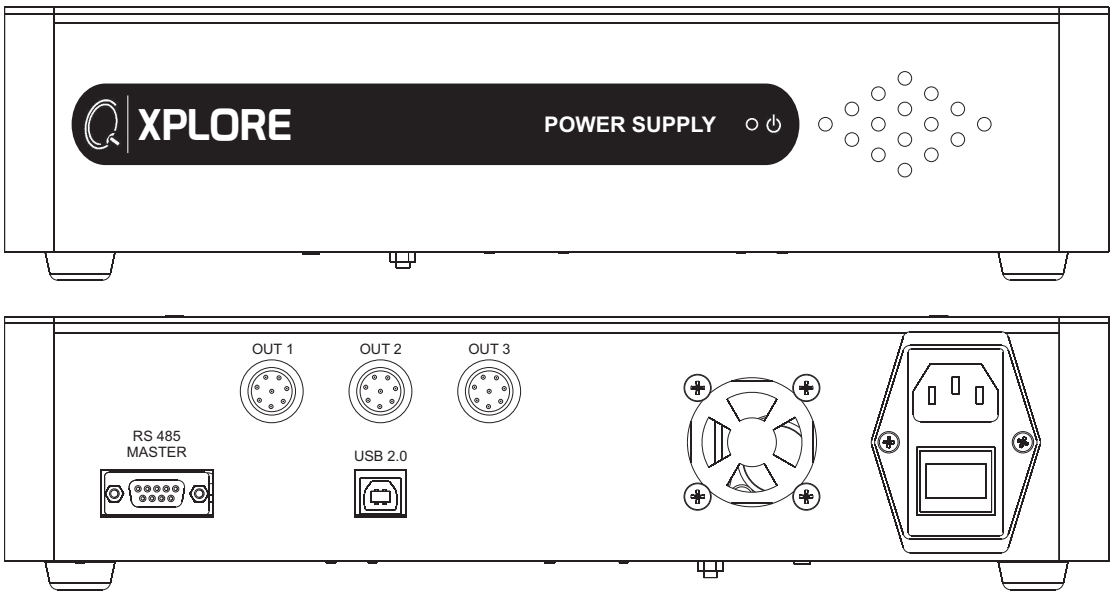


Figure 1.5: XPLORE 1.1™ power supply front & rear view

1.5 Temperature Controller Module (XTCON)

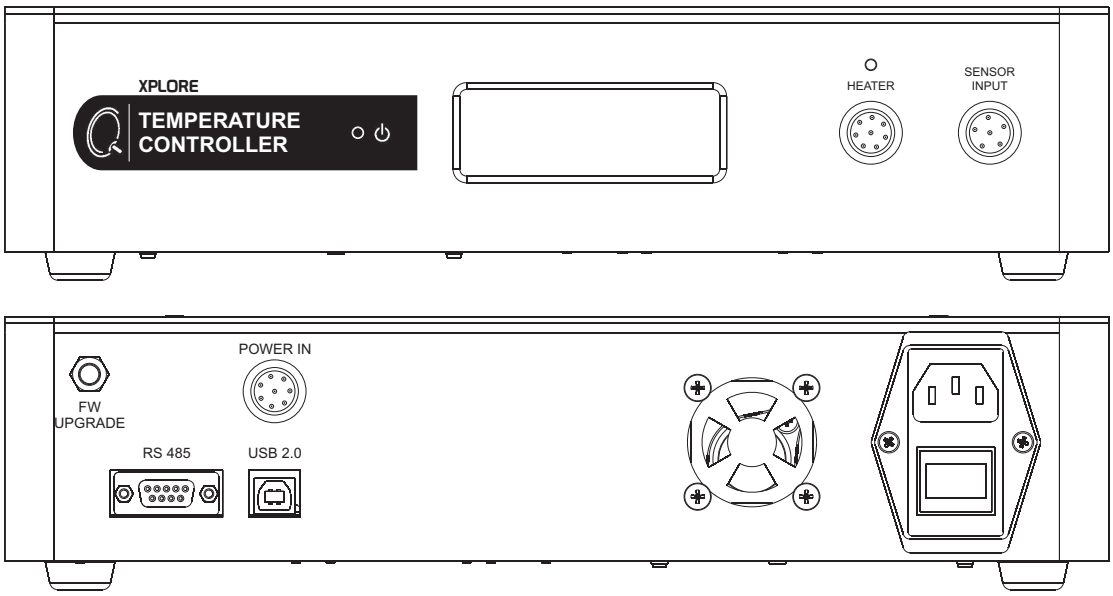


Figure 1.6: XPLORE 1.1™ temperature controller front & rear view

Parameter	Value
Temperature measurement and control	
Temperature range	77 K – 450 K
Sensors	Pt100 and K-type thermocouple
Temperature resolution	0.01 K
Temperature stability	Better than $\pm$0.1 K in isothermal mode
Temperature ramp-rate	1 K/min – 10 K/min in steps of 0.1 K/min
Control algorithm	PID
PID parameters	User configurable
Heater	
Heater power	40 Watt
Others	
Computer connectivity	USB

1.6 Source & Measurement Module (XSMU)

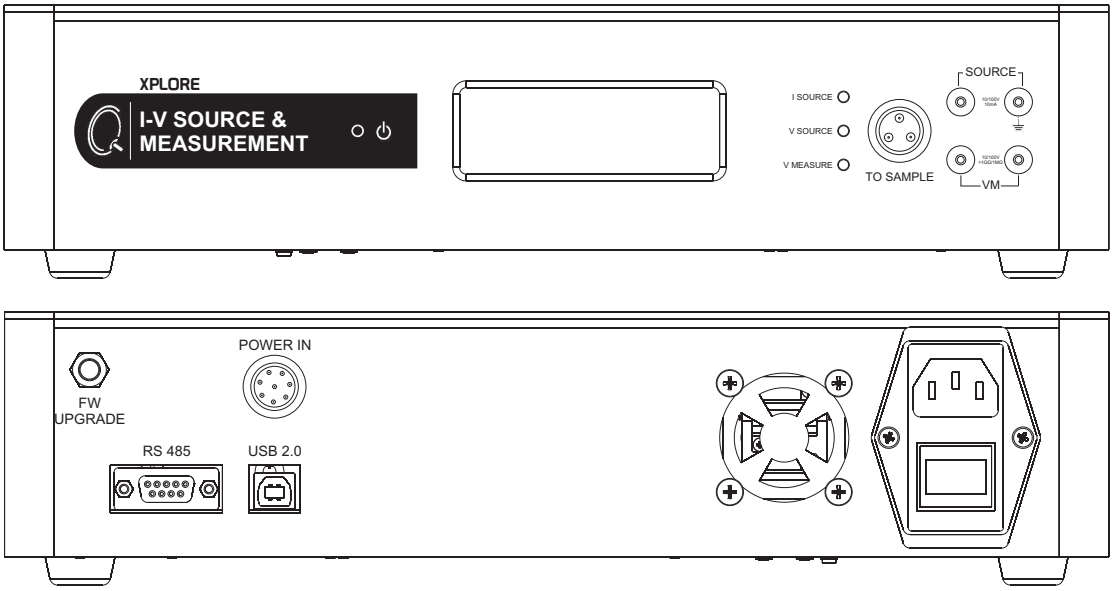


Figure 1.7: XPLORE 1.1™ source & measurement unit front & rear View

Parameter	Value
Source mode	Current or voltage
Current source specification	
Current source range(s)	100 μA, 1 mA, 10 mA
Current set-point resolution	Better than 0.05 % of full-scale
Voltage compliance	10V
Voltage source specification	
Voltage source range(s)	10 V
Voltage set-point resolution	Better than 0.005 % of full-scale
Current compliance	10 mA
Ammeter specification	
Current measurement range(s)	100 μA, 1 mA, 10 mA
Current measurement resolution	6½ digit
Voltmeter specification	
Voltage measurement range(s)	100 mV, 1 V, 10 V

I-V source and measurement unit specification continued on next page ...

... I-V source and measurement unit specification continued from previous page

Parameter	Value
Voltage measurement resolution	6½ digit
Input impedance	$> 10^{12}\,\Omega$
Ohmmeter specification	
Resistance measurement range(s)	$10\,\Omega$, $100\,\Omega$, $1\,\text{k}\Omega$, $10\,\text{k}\Omega$, $100\,\text{k}\Omega$, $1\,\text{M}\Omega$, $10\,\text{M}\Omega$
Resistance measurement resolution	6½ digit
Others	
Computer connectivity	USB

1.7 Lock-in Amplifier Module (XLIA)

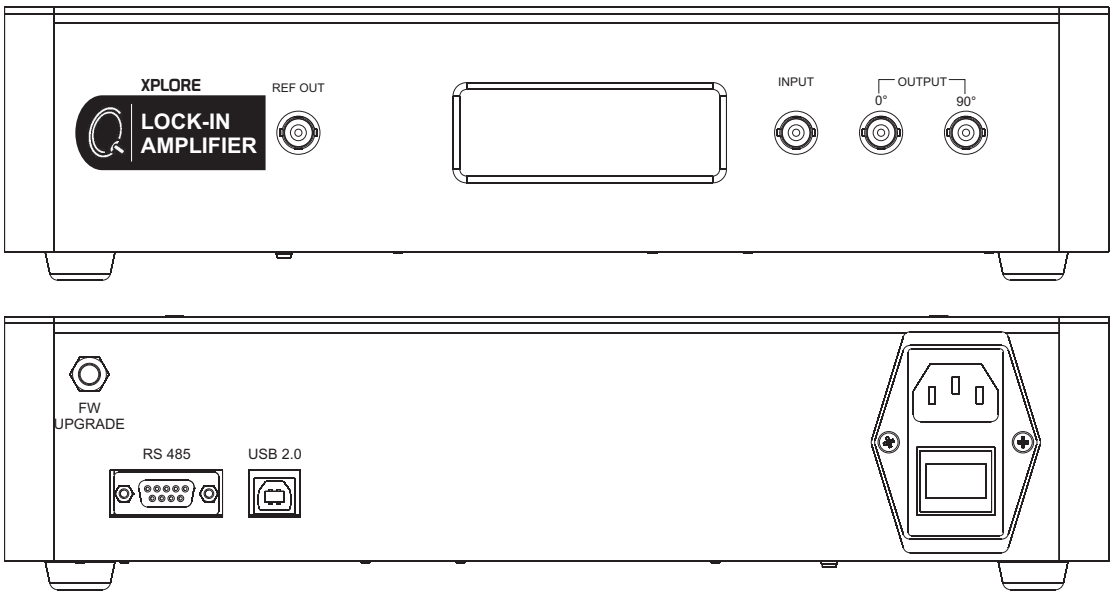


Figure 1.8: XPLORE 1.1™ lock-in amplifier front & rear view

Parameter	Value
Primary driver	
Frequency range(s)	10 Hz – 10 KHz
Reference output	2V peak-to-peak
Reference generation	Direct digital synthesis
Lock-in detection	
Integration time	1 sec
Pre-amp gain(s)	1, 10, 100
Post-amp gain(s)	1, 10, 100
Measurement	
Measurement resolution	5½ digit
Measured quantities	In phase, quadrature phase, amplitude, and phase.
Others	
Computer connectivity	USB

1.8 Electrical connections

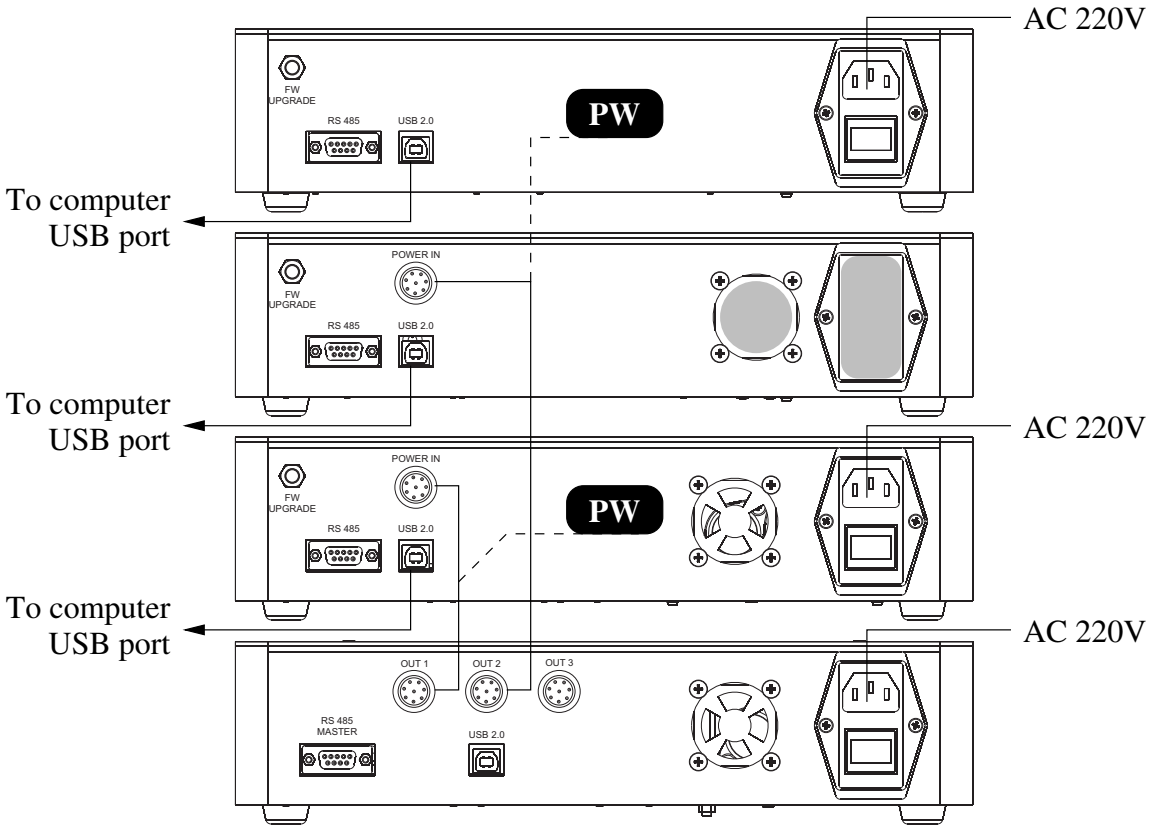


Figure 1.9: XPLORE 1.1™ electronics power supply and computer interface connection

Figure no.	Description
Figure 1.9	Shows basic power supply and computer interface connection irrespective of the nature of the experiment.
Figure 1.10	Shows connections between electronics modules, and cryostat and inserts for I-V and R-T experiments.
Figure 1.11	Shows connections between electronics modules, and cryostat and inserts for χ-T experiment.

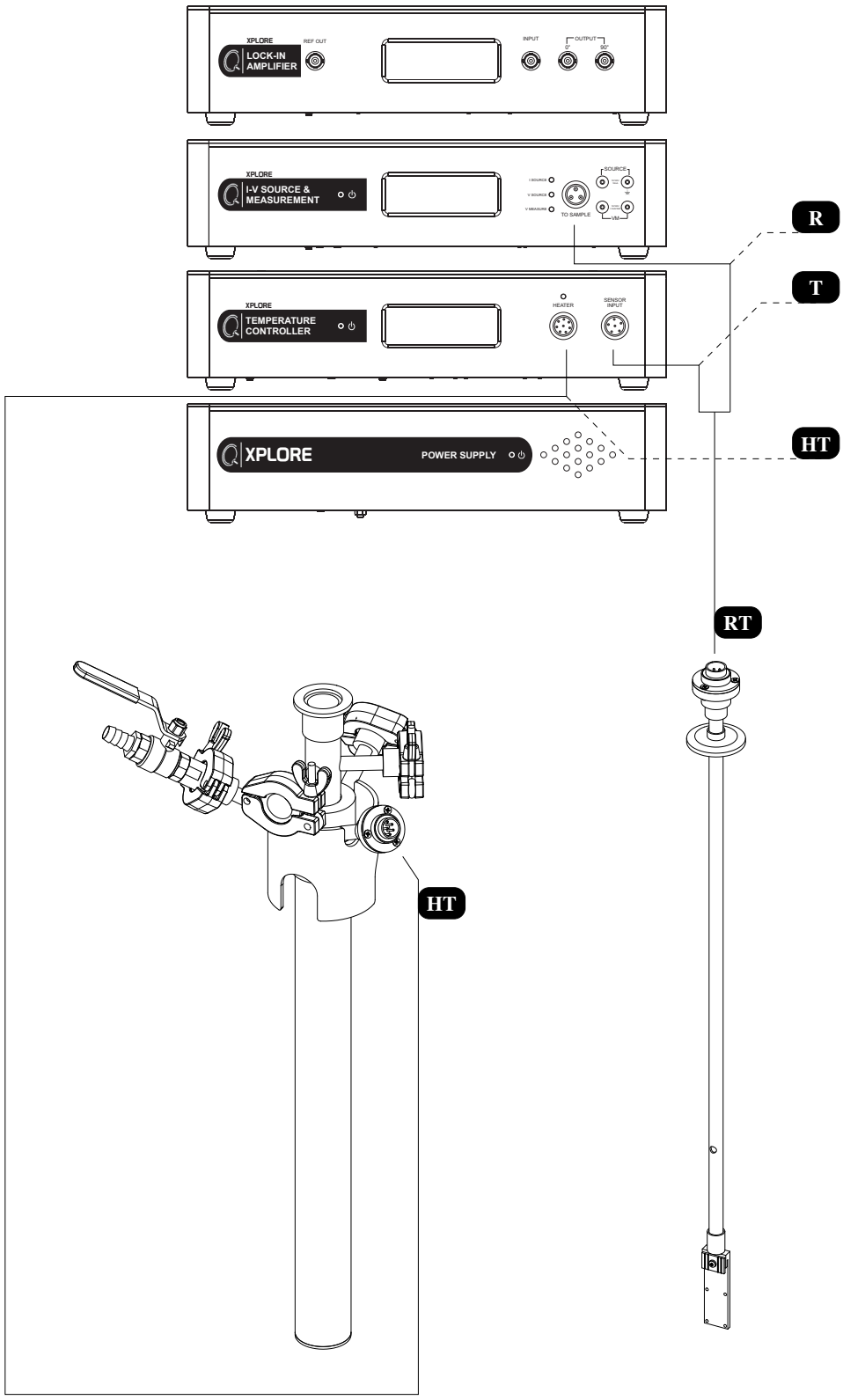


Figure 1.10: XPLORE 1.1™ electronics to cryostat connection for R-T measurement

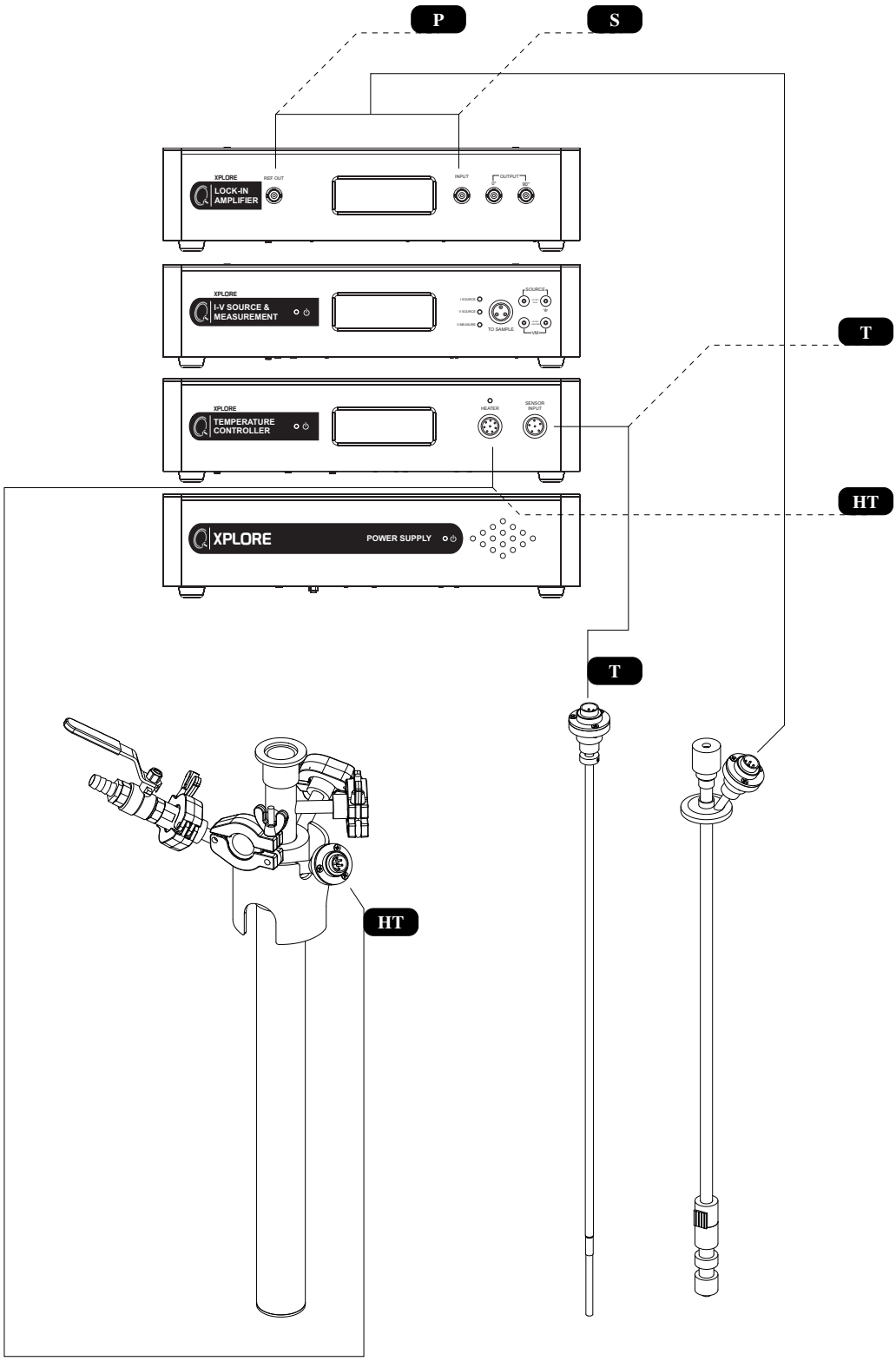


Figure 1.11: XPLORE 1.1™ electronics to cryostat connection for χ-T measurement

Chapter 2

4-Probe Resistance Measurement

2.1 Mounting sample

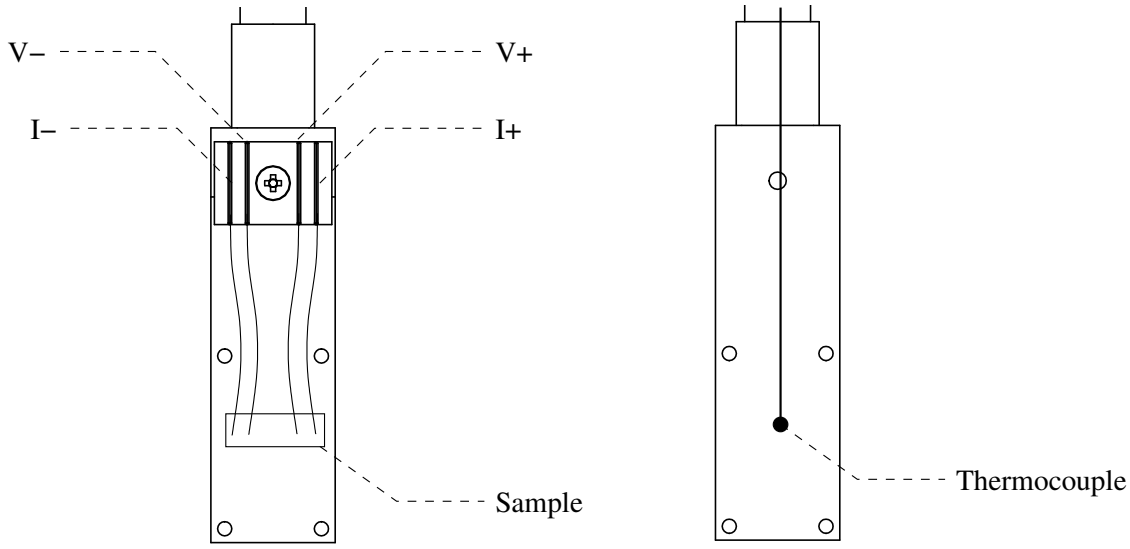


Figure 2.1: Sample mount for I-V and R-T measurement

- Paste the sample on the sample mount as shown in Figure 2.1. Position it as close to the thermocouple as possible to avoid lag in temperature readout.
- Solder four thin wires to the contact pads I+, I-, V+, and V-.
- Connect their other ends to the sample using silver epoxy, indium solder or any other technique, which ensures a good electrical contact of the wires to the sample.
- Gently slide down the four-probe measurement insert in the cryostat and clamp it using its top flange (KF-25).
- Connect the insert with the XSMU and XTCON as described in Section 1.8.

2.2 Acquiring I-V data

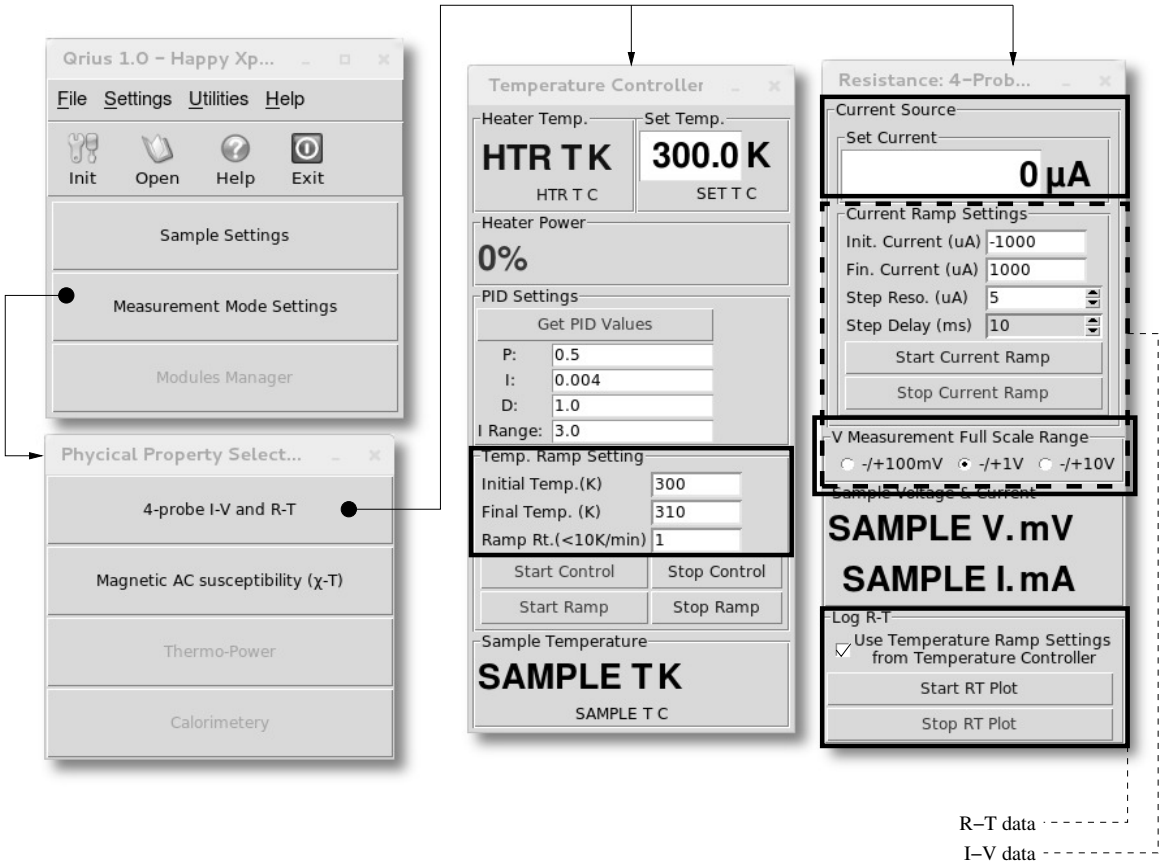


Figure 2.2: Settings to acquire I-V data.

- Launch Qrius and open 4-probe I-V and R-T module as shown in Figure 2.2. Consider the dotted rectangle.
- In the Current Ramp Settings frame on the four-probe window, enter the initial and final values of the current with the step increment in current value.
- Select the V Measurement Full Scale Range in order to ensure that the measurement does not saturate during the sweep.
- Start I-V data logging by pressing the Start Current Ramp button.
- Check if the data obtained shows the expected curve.
- If the curve is a flat-line (saturated measurement inputs), then increment the V Measurement Full setting.
- Restart the I-V log by again pressing the Start Current Ramp button.

2.3 Acquiring R-T data

Note: Before taking an R-T plot, log I-V data to ensure that the contacts are fine, and current and voltmeter settings are within range.

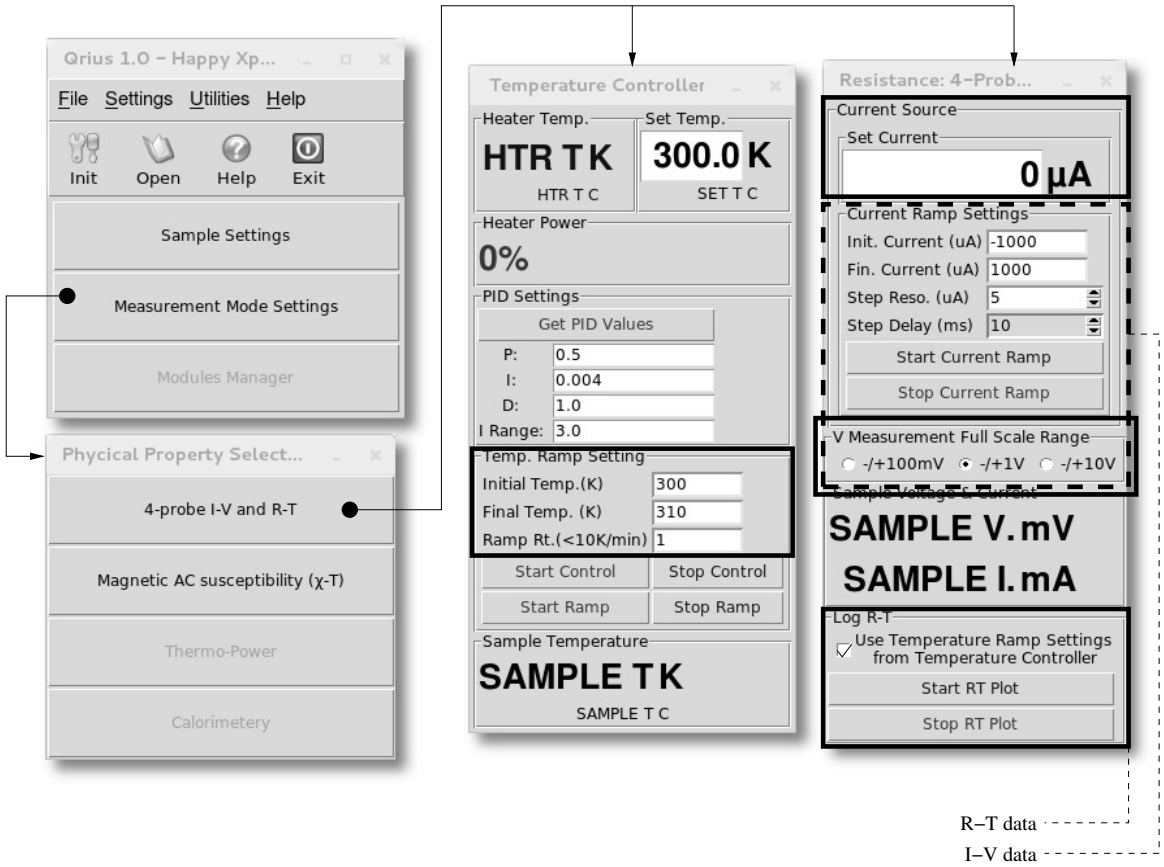


Figure 2.3: Settings to acquire R-T data.

- Launch Qrius and open 4-probe I-V and R-T module as shown in Figure 2.3. Consider the solid rectangles.
- Enter the current to be supplied to the sample in the Set Current entry box & Press return key. The box turns yellow to indicate that the specified current has been set.
- Select the (optimal) V Measurement Full Scale Range.
- Enter the final temperature and ramp rate values on the XTCON interface. Press return key to transmit these settings to the XTCON hardware.
- On the four-probe interface, tick on the box which directs it to use the temperature ramp settings provided in the XTCON interface.
- Click on the Start R-T Plot button to initiate R-T data logging.

- The final temperature and ramp rate can be modified on-the-fly during an experiment.
- To stop R-T data logging, click on Stop R-T Plot button.

Please note

- A negative ramp can also be entered as long as the final temperature is lower than the current temperature.
- The initial temperature setting is ignored. Current temperature is used as the initial temperature in a ramp.
- Apply a lower ramp rate ($< 2\,^{\circ}$C/min) to avoid temperature sensor lag.

Chapter 3

Magnetic AC Susceptibility Measurement

3.1 Mounting Sample

- Encapsulate the sample in a butter-paper wrapping and insert it into the sample holder pipe sleeve.
- Ensure that the sample position in the sleeve is such that it can traverse freely on either side, from the middle of the primary coil.
- See to it that no other magnetic material is introduced in the coil except the test sample.
- Slowly lower the sample into the coil while observing the amplitude output of the XLIA module on its LCD display.
- Fix the position of the sample when the maximum value on the amplitude is observed.
- Position the cryostat and the susceptibility insert in a position that the sample location remains undisturbed throughout the experiment.

3.2 Lock-in amplifier settings

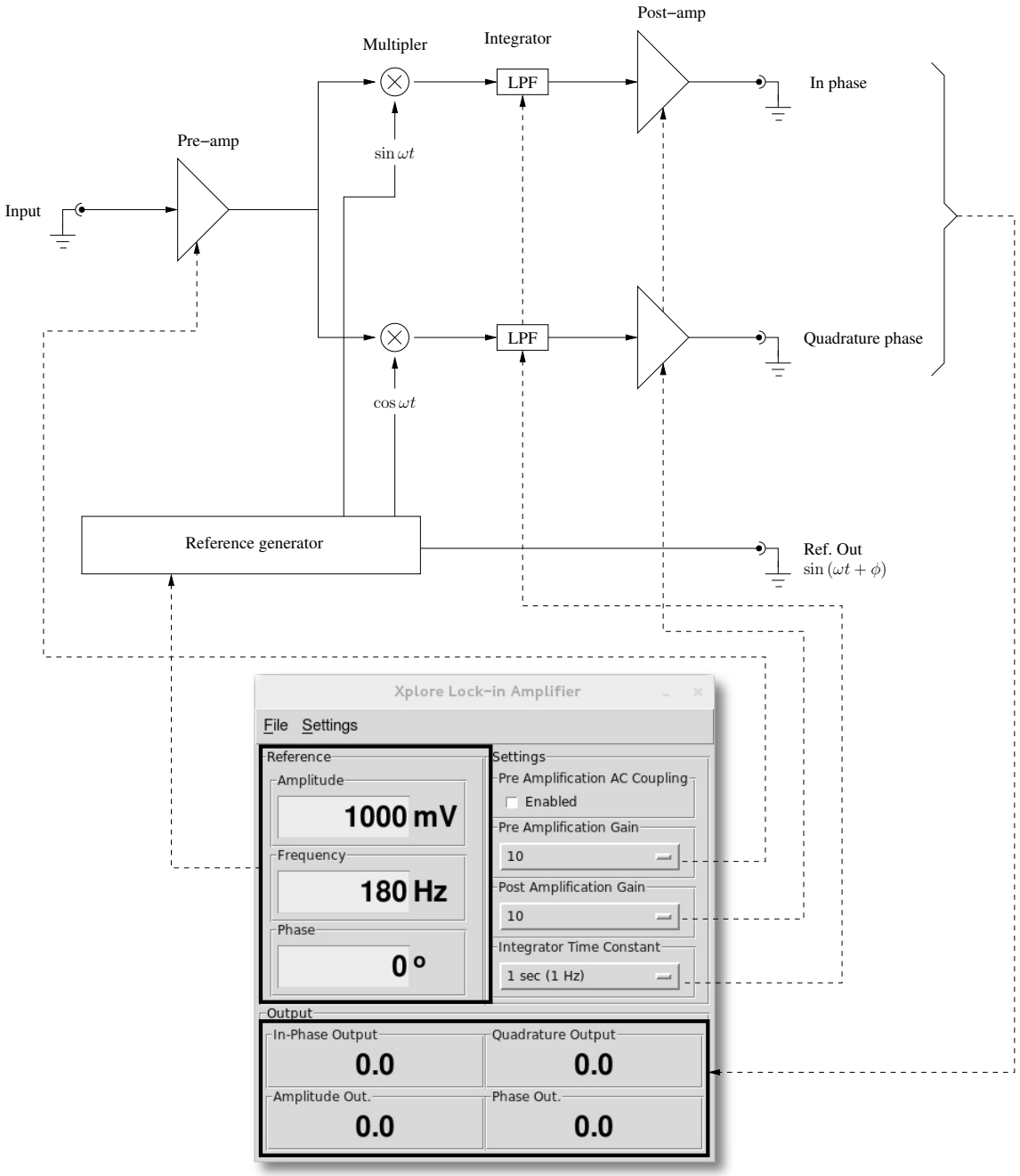


Figure 3.1: Lock-in amplifier block diagram

3.3 Acquiring χ-T data

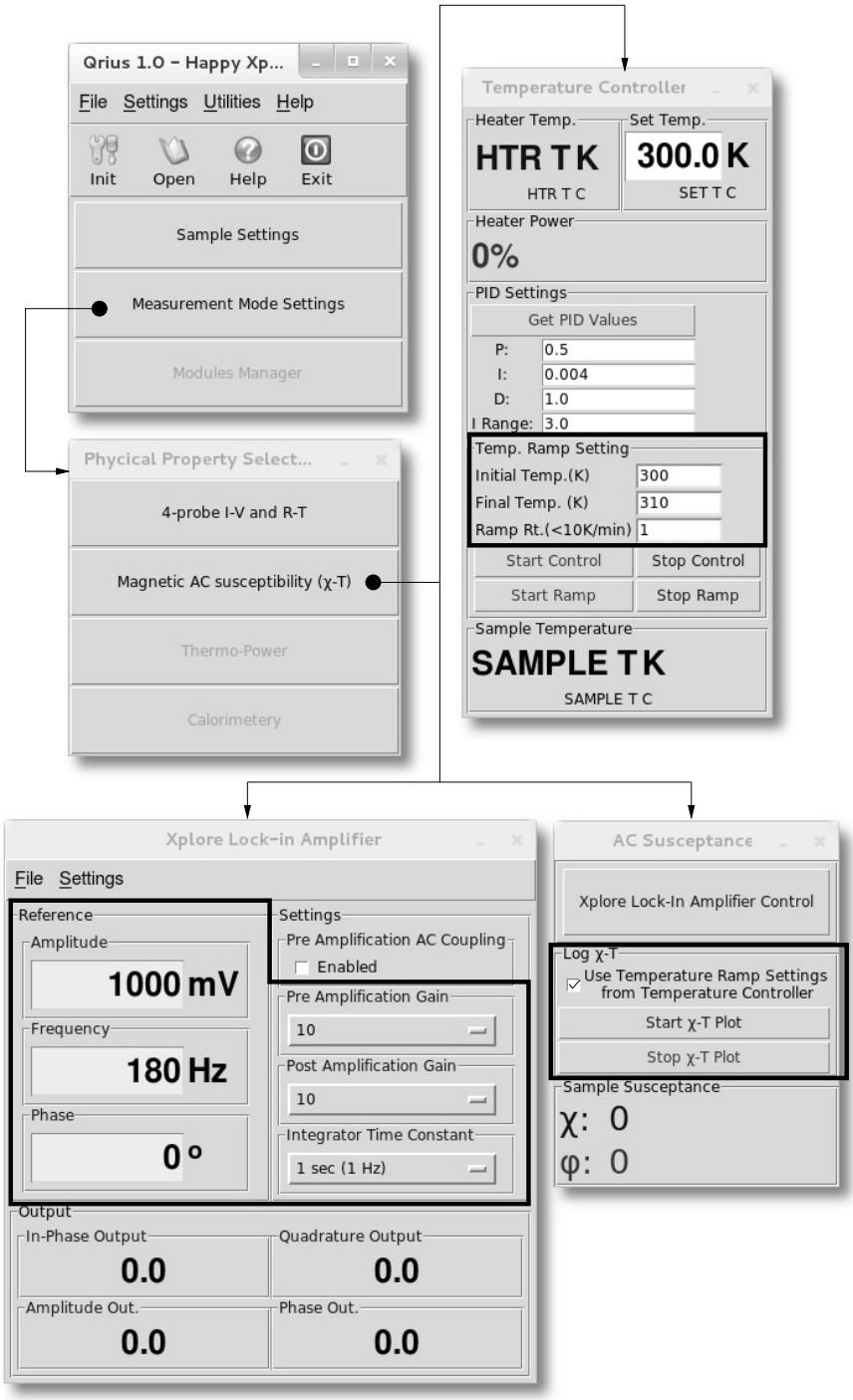


Figure 3.2: Launching Qrius χ-T module

- Launch Qrius and open Magnetic AC susceptibility (χ-T) module as shown in Figure 3.2. Consider the solid rectangles.
- Enter the final temperature and ramp rate values on the XTCON interface. Press return key to transmit these settings to the XTCON hardware.
- Set lock-in amplifier parameters, as shown in Figure 3.1.
- On the AC susceptance window, tick on the box which directs it to use the temperature ramp settings provided in the XTCON interface.
- Click on the Start χ-T Plot button to initiate data logging.
- Click on the Stop χ-T Plot to terminate an ongoing run.

Appendix A

Installation requirements

Power supply

1 8 nos. 240 VAC 5 A 3-pin sockets.
2 Ground should not be more than 5 V w.r.t neutral.
3 3 KVA UPS back-up of all sockets if power failure is frequent.

Space

1 One 5 ft $\times$ 3 ft dedicated table for comfortable accommodation of electronics, vacuum manifold, and computer.

Computer Requirements

1 DVD drive
2 2 GB RAM
3 3 free USB ports
4 30 GB free partition on hard disk
5 1024x768 (or better) monitor
6 We would recommend a dedicated PC for XPLORE 1.1 system.

Additional Requirements

1 3 liter Liquid N_2 for experiments where cooling is required.
2 Soldering iron, GE-varnish, silver paste, laminated copper wire, etc. for mounting samples.

Appendix B

Component checklist

Electronics boxes

1	Power supply	1
2	Temperature controller	1
3	I-V source & measurement unit	1
4	Lock-in amplifier	1
5	Pirani gauge readout unit	1

Electrical cables

1	Power cord	4
2	Cryostat heater cable	1
3	4-probe I-V and R-T insert cable	1
4	AC susceptometer coil insert cable	1
5	AC susceptometer sample insert cable	1
6	Power supply inter-connects	2
7	Pirani gauge inter-connect	1
8	USB cable	3

Cryostat, inserts, and vacuum accessories

1	Cryostat	1
2	Cryostat stand	1
3	Vacuum manifold	1
4	Vacuum manifold base	1
5	Cryostat vacuum hose	1
6	Pirani gauge	1
7	Mounting base	1
8	C-clamp (3 inch)	2

XPLORE 1.1™ component checklist continued on next page ...

... XPLORE 1.1™ component checklist continued from previous page

9	KF-10 clamp and center-ring	2
10	KF-16 clamp and center-ring	4
11	KF-25 clamp and center-ring	2
12	4-probe I-V and R-T insert	1
13	AC susceptometer coil insert	1
14	AC susceptometer sample insert	1
15	Liquid nitrogen dewar	1

Sample toolkit

1	Tool box	1
2	Kapton tape reel	1
3	Teflon tape reel	1
4	size-4 brush	1
5	GE-varnish	5 ml
6	Silver paste	2 ml
7	Copper wire	5 m
8	Screw driver set	1
9	Scissor	1
10	Wire cutter	1
11	Tweezers	1
12	Test samples	5
13	AC susceptometer sample holder sleeve	10

Vacuum pump and accessories

1	Vacuum pump	1
2	Bellow 1 meter, KF-25	1
3	KF-25 clamp and center-ring	2

Appendix C

System specification

C.1 Cryostat and temperature controller

Parameter	Value
Sample chamber	
Dimension	21 mm (dia) $\times$ 100 mm (length), top loading
Construction	Non-magnetic, double walled
Temperature range	
Temperature range	80 K – 450 K
Cryogen	Liquid N_2
Exchange gas	Air, port available for evacuation/flushing
Temperature measurement and control	
Sensors	Pt100 and K-type thermocouple
Temperature resolution	0.01 K
Temperature stability	Better than $\pm$0.1 K in isothermal mode
Temperature ramp-rate	1 K/min – 10 K/min in steps of 0.1 K/min
Control algorithm	PID
PID parameters	User configurable
Heater	
Heater power	40 Watt
Winding type	Non-magnetic
Others	
Computer connectivity	USB

C.2 I-V source and measurement unit for 4-probe R-T

Parameter	Value
Source mode	Current or voltage
Current source specification	
Current source range(s)	100 μA, 1 mA, 10 mA
Current set-point resolution	Better than 0.05 % of full-scale
Voltage compliance	10V

I-V source and measurement unit specification continued on next page ...

... I-V source and measurement unit specification continued from previous page

Parameter	Value
Voltage source specification	
Voltage source range(s)	10 V
Voltage set-point resolution	Better than 0.005 % of full-scale
Current compliance	10 mA
Ammeter specification	
Current measurement range(s)	100 μA, 1 mA, 10 mA
Current measurement resolution	6½ digit
Voltmeter specification	
Voltage measurement range(s)	100 mV, 1 V, 10 V
Voltage measurement resolution	6½ digit
Input impedance	$> 10^{12}\,\Omega$
Ohmmeter specification	
Resistance measurement range(s)	10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, 10 MΩ
Resistance measurement resolution	6½ digit
Others	
Computer connectivity	USB

C.3 Lock-in amplifier for AC-susceptibility (χ-T) measurement

Parameter	Value
Sample	
Sample size	5 mm (dia) × 10 mm (length)
Field strength	4 Oe RMS field at 80 Hz
Primary driver	
Frequency range(s)	10 Hz – 10 KHz
Reference output	2V peak-to-peak
Reference generation	Direct digital synthesis

AC-susceptometer specification continued on next page ...

... AC-susceptometer specification continued from previous page

Parameter	Value
Lock-in detection	
Integration time	1 sec
Pre-amp gain(s)	1, 10, 100
Post-amp gain(s)	1, 10, 100
Measurement	
Measurement resolution	16-bit
Measured quantities	Both amplitude and phase
Others	
Computer connectivity	USB

C.4 Data acquisition and control software: Qrius 1.1

Computer automation of R-T and χ-T measurements using above mentioned modules have been provided by Qrius 1.1 software. It allows easy control of all experimental parameters and real time recording and plot of physical quantities. The software runs on Ubuntu 12.04.

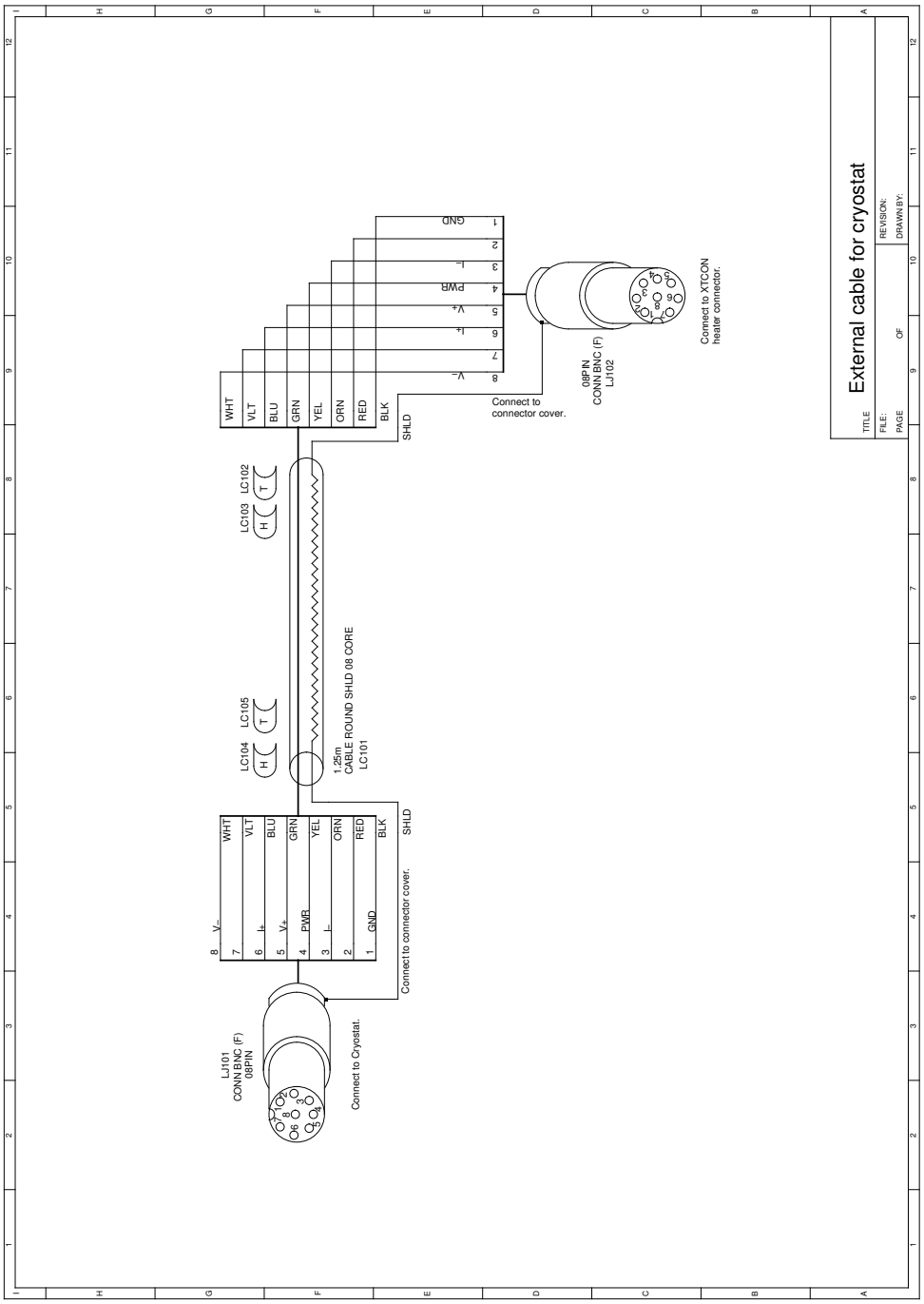
C.5 Other user provided accessories required to run the system

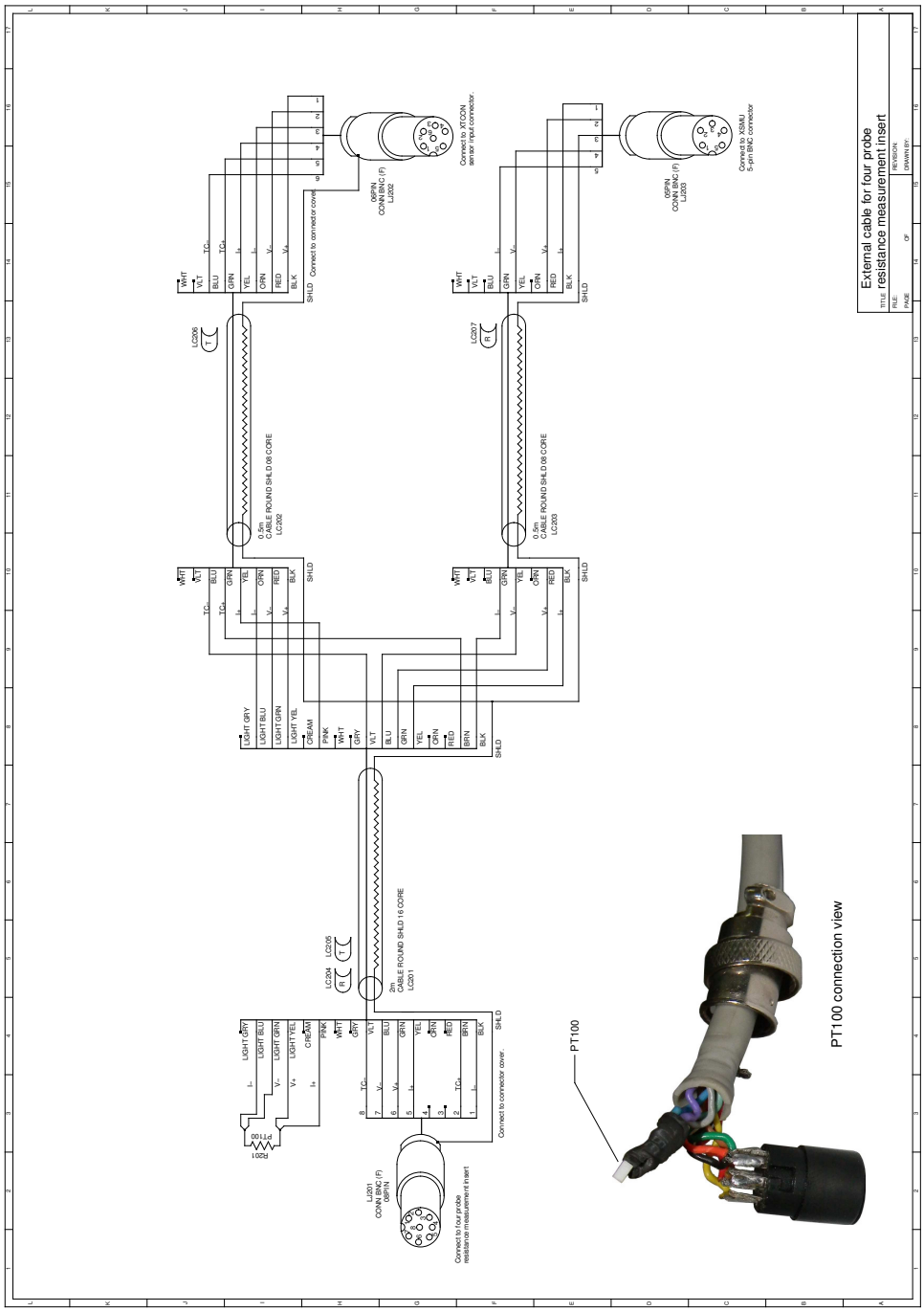
The following is a list of accessories that *need to be provided by the user* for proper operation of XPLORE-1.1 PQMS setup.

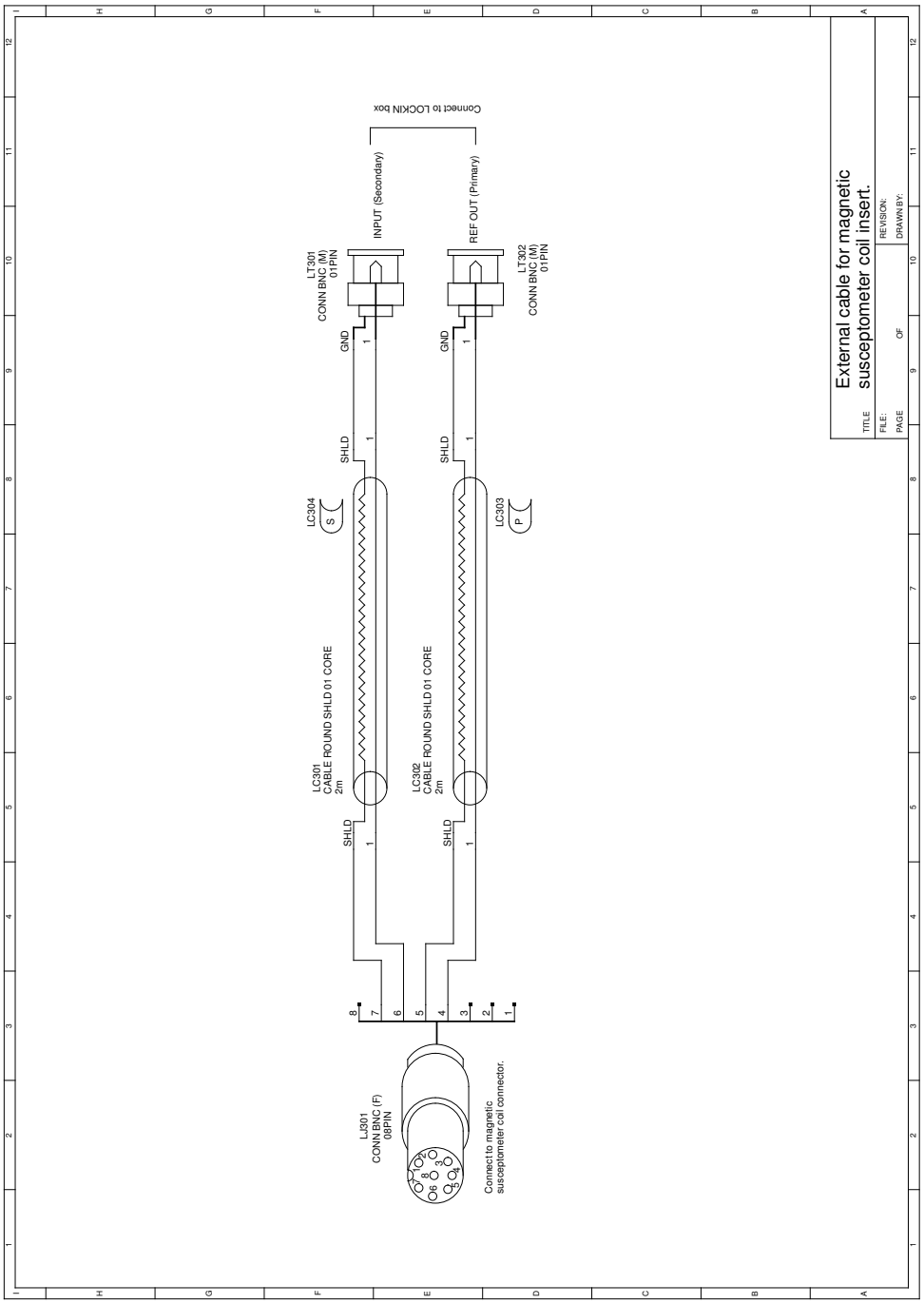
- Rotary vacuum pump.
- Minimum of 3 liters of liquid nitrogen.
- Computer with DVD drive, USB 2.0 port, 2GB RAM, 100GB of hard-disk space and Pentium dual core or above processor.

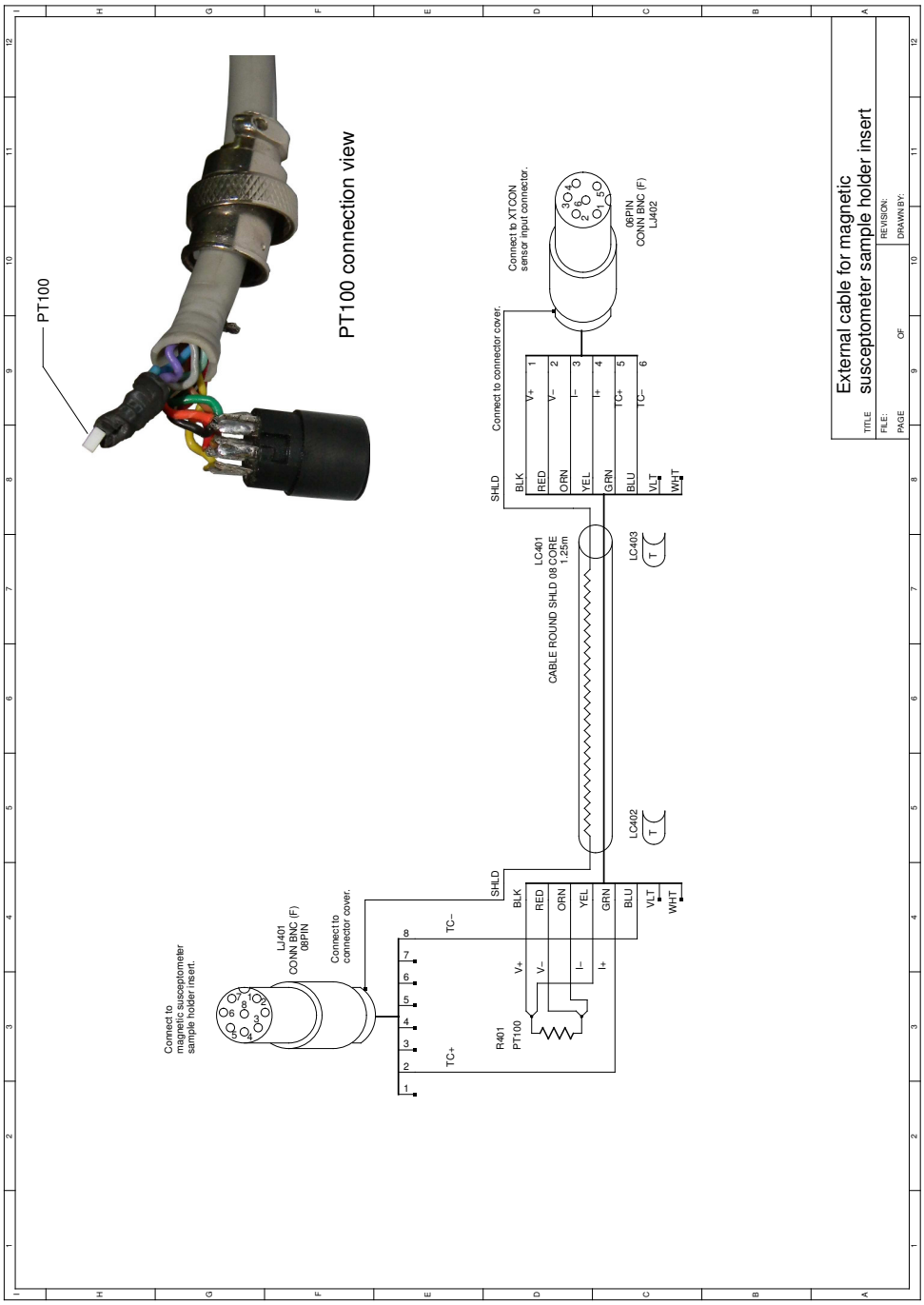
Appendix D

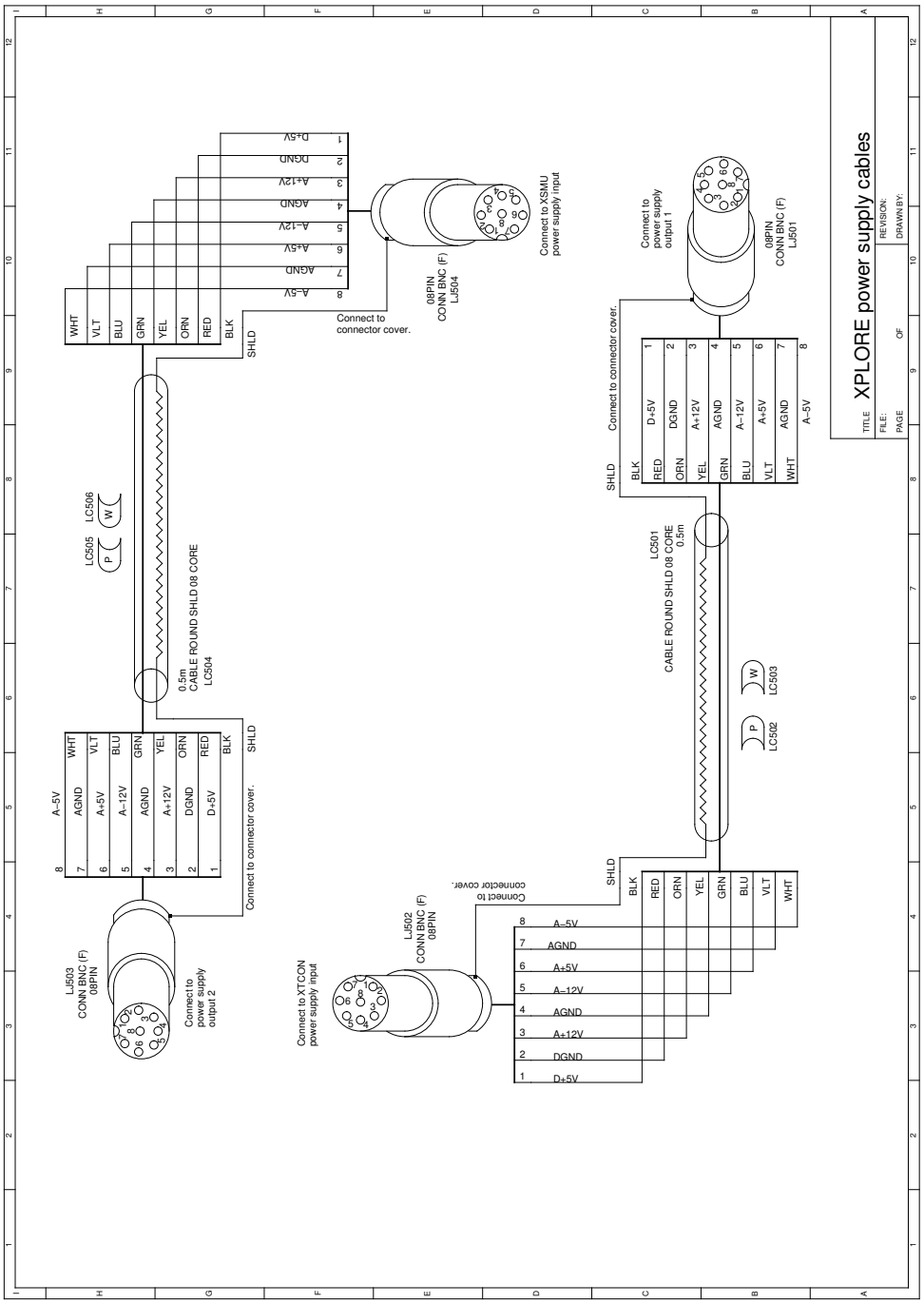
Cable details


External cable for cryostat
TITLE
FILE:
PAGE
OF
REVISION:
DRAWN BY:
LJ101
CONN BNC (F)
08PIN
Connect to Cryostat.
Connect to connector cover.
SHLD
WHT
VLT
BLU
GRN
YEL
ORN
RED
BLK
LC104
LC105
LC103
LC102
1.25m
CABLE ROUND SHLD 08 CORE
LC101
08PIN
CONN BNC (F)
LJ102
Connect to
connector cover.
Connect to XTCON
heater connector.
GND
PWR


External cable for four probe
resistance measurement insert
PT100 connection view
PT100
Connect to connector cover.
Connect to four probe resistance measurement insert
Connect to XTCON sensor input connector.
Connect to XSMU 5-pin BNC connector
0.5m CABLE ROUND SHLD 08 CORE LC202
0.5m CABLE ROUND SHLD 08 CORE LC203
2m CABLE ROUND SHLD 16 CORE LC201


External cable for magnetic susceptometer coil insert.
TITLE
FILE:
PAGE
OF
REVISION:
DRAWN BY:
Connect to LOCKIN box
INPUT (Secondary)
REF OUT (Primary)
LT301 CONN BNC (M) 01PIN
LT302 CONN BNC (M) 01PIN
GND
SHLD
LC304 S
LC303 P
LC301 CABLE ROUND SHLD 01 CORE 2m
LC302 CABLE ROUND SHLD 01 CORE 2m
LJ301 CONN BNC (F) 08PIN
Connect to magnetic susceptometer coil connector.


PT100
PT100 connection view
External cable for magnetic
susceptometer sample holder insert
TITLE
FILE:
PAGE
OF
REVISION:
DRAWN BY:
Connect to XTCON
sensor input connector.
06PIN
CONN BNC (F)
LJ402
Connect to connector cover.
SHLD
BLK
RED
ORN
YEL
GRN
BLU
VLT
WHT
V+
V−
I−
I+
TC+
TC−
LC401
CABLE ROUND SHLD 08 CORE
1.25m
LC403
LC402
LJ401
CONN BNC (F)
08PIN
Connect to
magnetic susceptometer
sample holder insert.
R401
PT100


XPLORE power supply cables
TITLE
FILE:
PAGE
OF
REVISION:
DRAWN BY:
LC501
CABLE ROUND SHLD 08 CORE
0.5m
LC502
LC503
LC504
0.5m
CABLE ROUND SHLD 08 CORE
LC504
LC505
LC506
LJ501
08PIN
CONN BNC (F)
Connect to
power supply
output 1
LJ502
CONN BNC (F)
08PIN
Connect to XTCON
power supply input
LJ503
CONN BNC (F)
08PIN
Connect to
power supply
output 2
LJ504
CONN BNC (F)
08PIN
Connect to XSMU
power supply input
Connect to
connector cover.
Connect to connector cover.
SHLD
BLK
RED
ORN
YEL
GRN
BLU
VLT
WHT
D–5V
DGND
A+12V
AGND
A–12V
A+5V
AGND
A–5V
D+5V
DGND
A+12V
AGND
A–12V
A+5V
AGND
A–5V