DXTC-290

Temperature Controller

Operating Manual

V 1.1

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   d) Unauthorized modification or misuse;
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   f) Inappropriate site preparation or environment.

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Catalogue

Chapter 1 Introduction

Figure 1-1 Front view of TC290

1.1 Product Description

Feature:

- **With the appropriate NTC RTD sensor,the measurement and control range can be as low as 300 mK**
- **Two standard sensor inputs and eight expansion inputs and three independent control outputs**
- **Two PID control loops:2-way 100W or 1-way 200W and 1-way 1W power output can be realized**
- **Automatically adjust and set PID parameters**
- **Zone function automatically switches sensor inputs for continuous measurement and control from 300mK to 1505K**
- **5"color capacitive touch screen,Chinese and English display,multiple display modes,flexible and convenient operation,clear display**
- **Allows you to tag each sensor input name,and display on the screen;10 inputs can be displayed on one screen**
- **Supports Ethernet,RS485 and USB interfaces**
- **Multiple temperature monitors can be run in a network,and one network can support up to 255 monitors running at the same time**

- **In addition to the DEXIN custom protocol,it also supports the standard MODBUS protocol**
- **Supports Diode,RTD and Thermocouple temperature sensors**
- **Allows storage of up to 64 temperature curves,including 20 standard temperature curves for internal curing**
- **Supports thermoelectric compensation for resistance sensors**
- **Supports ±10 V analog voltage output,alarm and relay control**

The TC290 temperature controller is designed by our company using the most advanced electronic technology.It has extremely high resolution,accuracy and stability characteristics.The temperature measurement accuracy can be as low as 10 mK.TC290 supports the connection of diodes,platinum resistance and negative temperature coefficient resistance sensors,and can also be expanded to connect ten temperature sensors at the same time,or expand the function of supporting thermocouples or capacitance sensors,it is very convenient for users who need multi-point measurement.The sensor adopts a dual constant current source mode with balanced output.The constant current source can automatically shift gears at extremely low temperatures,reducing the injected energy of the sensor,ensuring accurate measurement of the sensor and stable and reliable operation.

The TC290 temperature controller has two control loops,the input of each loop can be associated with any one of ten sensors,the output of loop 1 can be 100W or extended to 200W low noise heater power supply,the output of loop 2 can be 1W or extended to 100W low noise heater power supply,and closed-loop temperature control in proportional,integral,derivative (PID) mode can be achieved through these two control loops.The TC290 temperature controller also has the function of self-tuning,which can automatically adjust the PID control parameters,which allows you to reduce the adjustment time of the PID control parameters,so that you have more time to do the test work.

TC290 temperature controller supports Ethernet,RS -485,USB multiple communication methods,supports multiple network operation,long data transmission distance,convenient and flexible data acquisition.5"color capacitive touch screen,built-in Chinese and English dual menu,friendly human-computer interaction interface,similar operation mode to mobile phone,making it easier to use.

TC290 temperature controller allows you to seamlessly measure and control temperatures from 300mK to over 1500K by automatically switching the temperature sensor input when the temperature range is out of the available range of a given sensor.You no longer have to worry about temperature sensor errors and measurement continuity issues.Alarms,relays and ±10v analog voltage output functions can help you automate secondary control functions.

In many applications,the unmatched capabilities of the TC290 allow you to replace multiple instruments with one,saving time,money and valuable lab space.It can provide more feedback,tighter control,and faster cycle time,and it keeps pace with increasingly complex temperature measurement and control applications.It is the ideal solution for advanced laboratory applications.Please put the TC290 temperature controller in your laboratory and let it control your measurement environment.

1.1.1 Sensor Input

TC290 temperature controller supports 2 standard sensor inputs,compatible with diode and RTD temperature sensors.By adding a TC2901 type 8-channel expansion card,the number of sensor inputs can be increased to 10.The first four and the last four of the added 8-channel sensors can be different types of sensors,but the adjacent four must be of the same type.For the thermocouple sensor,you can install the thermocouple expansion card,and set the C and D channel sensor types to thermocouple,and then enable the thermocouple function,which supports up to 2 thermocouple sensor inputs.

The sensor inputs have 24-bit high-resolution analog-to-digital converters;each input has its own current source,providing fast settling times.And both sensor inputs are optically isolated from other circuits to reduce noise and provide repeatable sensor measurements.Current reversal eliminates thermal electromotive force (EMF) errors in resistive sensors.Nine levels of excitation current can easily enable temperature measurement and control down to 300 mK using a suitable negative temperature coefficient (NTC) RTD.The auto-ranging mode can automatically adjust the excitation current,and the NTC RTD can effectively reduce self-heating when the sensor resistance changes by many orders of magnitude in a low temperature environment.Temperatures below 1.4 K can be measured and controlled using silicon or gallium arsenide diodes.When the sensor type is entered through the instrument's front panel,the software selects the appropriate excitation current and signal gain levels.The unique zone setting feature automatically switches sensor inputs,enabling you to measure temperatures from 300 mK to over 1500 K without interrupting your experiments.

TC290 temperature controller has built-in standard temperature sensor response curve of silicon diode,platinum resistance temperature detector and ruthenium oxide resistance temperature detector.The non-volatile memory can store up to 64 temperature sensor curves with 250 points each,the first 20 are standard curves cured inside the system,and the last 44 are user-defined curves.Using the TC290 temperature controller curve processing software,the temperature sensor curve data can be easily uploaded and manipulated.

1.1.2 Temperature Control

TC290 temperature controller is the most powerful temperature controller,providing a total of 200 W of heater power.Providing a very clean heater power supply,it precisely controls temperature over the full full-scale temperature range for superior measurement reliability,efficiency and productivity.Two independent PID control loops,providing two outputs of 100 W or one 200 W and one 1W heater power supply,which can be linked to any of the standard sensor inputs.The precise control output is calculated based on the temperature set point and feedback from the control sensor.Wide adjustment parameters are suitable for most low temperature cooling systems and many high temperature furnaces commonly used in laboratories.PID values can be set manually for fine control,or the process can be automatically tuned using the advanced auto-tuning feature.Autotune collects PID parameters and provides information to help build the zone table.The Setpoint Ramp function provides smooth,continuous setpoint changes and a predictable setpoint approach without worrying about overshoot or excessive settling time.When combined with the zone setting function,the TC290 is able to automatically switch sensor inputs and scale current excitation through 10 different preloaded temperature zones,providing continuous measurement and control from 300 mK to 1505 K.

Control outputs 1 and 2 are variable DC current sources that are internally referenced.Output 1 provides 100 W of continuous power output for a 25 ohm load.Output 2 also provides 100 W of continuous power output for a 25 ohm load.Output 3 is a variable DC voltage source output that provides a ±10 V analog output that can be used as a manually controlled voltage source when not used to extend the temperature controller heater power supply.

A temperature limit setting can be provided for the input to prevent system damage.Each input has a temperature limit,and if any input exceeds that limit,all control channels are automatically disabled.

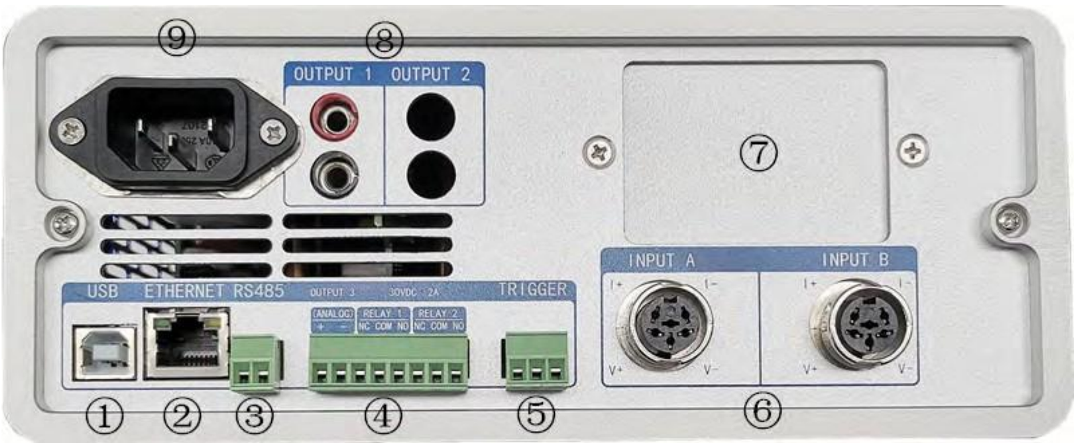
1.1.3 Interface

TC290 temperature controller has standard configuration Ethernet,RS-485,USB interface.In addition to acquiring data,almost all instrument functions can be controlled through a computer interface.You can download the TC290 curve processing software to your computer for easy entry and manipulation of sensor calibration curves for storage in the instrument's non-volatile memory.

Ethernet provides the ability to access and monitor instrument activity over the Internet from anywhere in the world.The USB interface emulates an RS-232 serial port at a fixed 115200 baud rate,but uses a physical plug-in for USB.It also allows you to download firmware upgrades,ensuring the latest firmware version is loaded into your instrument without any physical changes.

Each sensor input has a high and low alarm,providing latching and non-latching operation.2 relays can be used with alarms to alert you to fault conditions and perform simple on/off control.Relays can be assigned to any alarm or manual operation.

The ±10 V analog voltage output on Output 3 can be configured to send a temperature proportional voltage to a bargraph recorder or data acquisition system.You can select the starting and ending temperature or the corresponding value of the sensor to control the starting voltage of the output.



① USB interface,② Ethernet interface,③ RS485 interface,④ Output 3 and 2 relays, ⑤Trigger signalInput,⑥ two standard inputs,⑦ 8 expansion inputs,⑧ two 100W outputs,

⑨ AC220V powerinput

Figure 1-2 TC290 rear panel

1.1.4 Display Settings

The TC290 temperature controller offers a bright color LCD touch screen with LED backlighting that simultaneously displays up to 10 readings number.You can set the display mode as monitoring display or temperature control display.The monitoring display can display 2,4,and 10 sensor input data on a single page,and the temperature control display can display 1,2,4,and 10 on the upper half of a single page.The input data of each sensor,the lower part displays the control parameters of temperature control loop 1,loop 2,loop 1 and 2 respectively.For convenience,you can also customize the name of each sensor input to remember the actual location of each sensor input.

Figure 1-3 Display mode setting,monitoring display,temperature control display loop 1 and loop 2

1.1.5 Expansion Cards

Install an 8-way expansion card to expand your sensor selection,including silicon diodes (such as DT-670),capacitive sensors or thermocouple.Once installed,option inputs can be selected and named from the front panel like other input types.The 8 -way expansion card further expands the application versatility of the TC290 temperature controller,allowing specialized sensor switching to achieve specific measurement goals.

For example,adding a thermocouple expansion card enables continuous measurements to 1000 K or over.Alternatively,Capacitive Sensor Option Card switching of the magnetically impermeable capacitive temperature sensor to eliminate magnetoresistive effects when measuring low temperature samples at high temperatures or in changing magnetic fields.The 8-channel scan expansion card allows supplementary monitoring with additional sensors.

1.2 Sensor selection

Silicon diodes are the best choice for general low temperature applications,from 1.4 K to above room temperature.The use of diodes is economical because they are interchangeable in many applications as they follow a standard curve.They are not suitable for ionizing radiation or magnetic fields.

Cernox™ Thin Film RTDs offer high sensitivity and low magnetic field induced errors over a temperature range of 0.3 K to 420 K.Cernox sensor needs to be calibrated.

Platinum resistance temperature detectors offer high uniform sensitivity from 30 K to 800 K. have excellent reproducibility,they can be used as a temperature measurement standard.They follow a standard curve of 70 K and are interchangeable in many applications.

		Model	Effective range	Magnetic field
Diode	Silicon Diode	DT-670-SD	1.4K to 500K	T ≧ 60 K & B ≦ 3 T
	Silicon Diode	DT-670E-BR	30K to 500K	T ≧ 60 K & B ≦ 3 T
	Silicon Diode	DT-414	1.4K to 375K	T ≧ 60 K & B ≦ 3 T
	Silicon Diode	DT-421	1.4K to 325K	T ≧ 60 K & B ≦ 3 T
	Silicon Diode	DT-470-SD	1.4K to 500K	T ≧ 60 K & B ≦ 3 T
	Silicon Diode	DT-471-SD	10K to 500K	T ≧ 60 K & B ≦ 3 T
	GaAIAs Diode	TG-120-P	1.4K to 325K	T > 4.2 K & B ≦ 5 T
	GaAIAs Diode	TG-120-PL	1.4K to 325K	T > 4.2 K & B ≦ 5 T
	GaAIAs Diode	TG-120-SD	1.4K to 500K	T > 4.2 K & B ≦ 5 T
Positive Temperature Coefficient RTD	100Ω Platinum	PT-102/3	14K to 873K	T > 4 0 K & B ≦2.5 T
	100Ω Platinum	PT-111	14K to 673K	T > 4 0 K & B ≦2.5 T
	Rhodium-Iron	RF-800-4	1.4K to 500K	T > 77 K & B ≦ 8 T
	Rhodium-Iron	RF-100T/U	1.4K to 325K	T > 77 K & B ≦ 8 T
Negative Temperature Coefficient RTD	Cernox™	CX-1010	0.3K to 325K [1]	T > 2 K & B ≦ 19 T
	Cernox™	CX-1030-HT	0.3K to 420K [1,3]	T > 2 K & B ≦ 19 T
	Cernox™	CX-1050-HT	1.4K to 420K [1]	T > 2 K & B ≦ 19 T
	Cernox™	CX-1070-HT	4K to 420K [1]	T > 2 K & B ≦ 19 T
	Cernox™	CX-1080-HT	20K to 420K [1]	T > 2 K & B ≦ 19 T
	Germanium	GR-200A-100	0.3K to 100K	Not recommended
	Germanium	GR-200A-250	0.5K to 100K	Not recommended

	Germanium	GR-200A/B-500	1.4K to 100K	Not recommended
	Germanium	GR-200A/B-1000	1.4K to 100K	Not recommended
	Germanium	GR-200A/B-1500	1.4K to 100K	Not recommended
	Germanium	GR-200A/B-2500	1.4K to 100K	Not recommended
	Carbon-Glass	CGR-1-500	1.4K to 325K	T > 2 K & B ≦ 19 T
	Carbon-Glass	CGR-1-1000	1.7K to 325K [2]	T > 2 K & B ≦ 19 T
	Carbon-Glass	CGR-1-2000	2K to 325K [2]	T > 2 K & B ≦ 19 T
	Rox™	RX-102	0.3K to 40K [3]	T > 2 K & B ≦ 1 0 T
	Rox™	RX-103	1.4K to 40K	T > 2 K & B ≦ 1 0 T
	Rox™	RX-202	0.3K to 40K [3]	T > 2 K & B ≦ 1 0 T
Capacitance		CS-501	1.4K to 290K	T > 4.2 K & B ≦ 18.7 T
Thermocouple	Type K	9006-006	3.2K to 1505K	Not recommended
	Type E	9006-004	3.2K to 934K	Not recommended
	Chromel-AuFe 0.07%	9006-002	1.2K to 610K	Not recommended

1.Maximum temperature of non-high temperature version:325K 2.Low temperature limited by input resistance range 3.Low temperature specified for self-heating error ≦ 5mK.

Table 1-1 Sensor temperature range

	Sensor	Temperature	Rated resistance / Voltage	Typical Sensor Sensitivity [4]	Measurement Resolution: Temperature equivalent	Electronic accuracy: Temperature equivalent	Temperature accuracy Includes electronic accuracy,calculator and calibration sensor	Electronically controlled stability [5]:Temperature equivalent
Silicon Diode	DT-670-CO-13 with 1.4H calibration	1.4K 77K 300K 500K	1.664V 1.028V 0.5597V 0.0907V	-12.49mV/K -1.73mV/K -2.3mV/K -2.12mV/K	0.8 mK 5.8 mK 4.4 mK 4.7 mK	± 13 mK ± 76 mK ± 47 mK ± 40 mK	± 25 mK ± 98 mK ± 79 mK ± 90 mK	± 1.6 mK ± 11.6 mK ± 8.8 mK ± 9.4 mK
Silicon Diode	DT-470-SD-13 with 1.4H calibration	1.4K 77K 300K 475K	1.6981 V 1.0203 V 0.5189V 0.0906V	-13.1 mV/K -1.92mV/K -2.4mV/K -2.22mV/K	0.8 mK 5.2 mK 4.2 mK 4.5 mK	± 13 mK ± 69 mK ± 45 mK ± 38 mK	± 25 mK ± 91 mK ± 77 mK ± 88 mK	± 1.6 mK ± 10.4 mK ± 8.4 mK ± 9 mK
GaAlAs Diode	TG-120-SD with 1.4H calibration	1.4K 77K 300K 475K	5.391V 1.422V 0.8978V 0.3778V	-97.5mV/K -1.24mV/K -2.85mV/K -3.15mV/K	0.2 mK 16 mK 7 mK 6.4 mK	± 7 mK ± 180 mK ± 60 mK ± 38 mK	± 19 mK ± 202 mK ± 92 mK ± 88 mK	± 0.4 mK ± 32 mK ± 14 mK ± 13 mK

100Ω Platinum RTD 500Ω _ Full Scale	PT-103 with 14J calibration	30K 77K 300K 500K	3.660Ω _ 20.38Ω _ 110.35Ω _ 185.668Ω	0.191Ω / K 0.423Ω / K 0.387Ω / K 0.378Ω / K	1.1 mK 0.5 mK 5.2mK 5.3 mK	± 13 mK ± 10 mK ± 39 mK ± 60 mK	± 23 mK ± 22 mK ± 62 mK ± 106 mK	± 2.2 mK ± 1.0 mK ± 10.4 mK ± 10.6 mK
Cernox™	CX-1010-SD with 0.3L calibration	0.3K 0.5K 4.2K 300K	2322.4Ω _ 1248.2Ω _ 277.32Ω _ 30.392Ω _	-10785Ω / K -2665.2Ω / K -32.209Ω / K -0.0654Ω / K	8.5 µK 26 µK 140 µK 23 mK	± 0.1 mK ± 0.2 mK ± 3.8 mK ± 339 mK	± 3.6 mK ± 4.7 mK ± 8.8 mK ± 414 mK	± 17 µK ± 52 µK ± 280 µK ± 46 mK
Cernox™	CX-1050-SD-HT [6] with 1.4M calibration	1.4K 4.2K 77K 420K	26566Ω _ 3507.2Ω _ 205.67Ω _ 45.03Ω _	-48449Ω / K -1120.8Ω / K -2.4116Ω / K -0.0829Ω / K	20 µK 196 µK 1.9 mK 18 mK	± 0.3 mK ± 2.1 mK ± 38 mK ± 338 mK	± 5.3 mK ± 7.1 mK ± 54 mK ± 403 mK	± 40 µK ± 392 µK ± 3.8 mK ± 36 mK
Germanium	GR-300-AA with 0.3D calibration	0.35K 1.4K 4.2K 100K	18225Ω _ 449Ω _ 94Ω _ 2.7Ω _	-193453Ω / K -581Ω / K -26.6Ω / K -0.024Ω / K	4 µK 41 µK 56µK 6.3 mK	± 48 µK ± 481µK ± 1.8 mK ± 152 mK	± 4.2 mK ± 4.7 mK ± 6.8 mK ± 175mK	± 8 µK ± 82 µK ± 112 µK ± 12.6 mK
Germanium	GR-1400-AA with 1.4D calibration	1.8K 4.2K 10K 100K	15288Ω _ 1689Ω _ 253Ω _ 2.8Ω _	-26868Ω / K -862Ω / K -62.0Ω / K -0.021Ω / K	28 µK 91 µK 73 µK 7.1 mK	± 302µK ± 900µK ± 1.8 mK ± 177 mK	± 4.5 mK ± 5.1 mK ± 6.8 mK ± 200 mK	± 56 µK ± 182 µK ± 146 µK ± 14.2 mK
Carbon-Glass	CGR-1-500 with 1.4L calibration	1.4K 4.2K 77K 300K	103900Ω _ 584.6Ω _ 14.33Ω _ 8.55Ω _	-520000Ω / K -422.3Ω / K -0.098Ω / K -0.0094Ω / K	13 µK 63 µK 4.6 mK 16 mK	± 0.1 mK ± 0.8 mK ± 108 mK ± 760 mK	± 4.1 mK ± 4.8 mK ± 133 mK ± 865 mK	± 26 µK ± 126 µK ± 9.2 mK ± 32 mK
Rox™	RX-102A-AA with 0.3B calibration	0.5K 1.4K 4.2K 40K	3701Ω _ 2005Ω _ 1370Ω _ 1049Ω _	-5478Ω / K -667Ω / K -80.3Ω / K -1.06Ω / K	41 µK 128µK 902 µK 62 mK	± 0.5 mK ± 1.4 mK ± 8 mK ± 500 mK	± 5 mK ± 6.4 mK ± 24 mK ± 537K	± 82 µK ± 256 µK ± 1.8 mK ± 124 mK
Capacity	CS-501	4.2 77 200	6.0nF 9.1nF 19.2nF	27 pF/K 52 pF/K 174 pF/K	74 mK 39 mK 12 mK	NA	calibration not available	± 14.8 mK ± 7.7 mK ± 23 mK
Thermocouple 50mV	Type K	75K 300K 600K 1505K	-5862.9 µV 1075.3 µV 13325 µV 49998.3 µV	15.6 µV/K 40.6 µV/K 41.7 µV/K 36.006 µV/K	26 mK 10 mK 10 mK 11 mK	± 0.25K [7] ± 0.038K [7] ± 0.184K [7] ± 0.73K [7]	calibration not available	± 52 mK ± 20 mK ± 20 mK ± 22 mK

4.Typical sensor sensitivities are taken from a representative calibration of the listed sensors.

5.In an ideal thermal system,only the stability of the electronics is controlled.

6.Maximum temperature for non-high temperature version:325 K.

7.Accuracy specifications are not include room temperature compensation errors.

Table 1-2 Typical sensor performance

1.3 TC290 Specifications

1.3.1 Input Specifications

Standard input and tc2901 Expansion card	Sensor Temperature coefficient	Input range	Excitation current	Display resolution	Measurement Resolution	Electronic precision (25°c)	Measuring temperature coefficient	Controlled stability8
Diode	Negative	0V to 2.5V	10μA±0.05% [9,10]	100μV	3 μV	± 80 μV ±0.005% of rdg	(10 μV + 0.0005% of rdg)/°C	± 20 μV
	Negative	0V to 10V	10μA ±0.05% [9,10]	100 μV	10 μV	± 320 μV ±0.01% of rdg	(20 μV + 0.0005% of rdg)/°C	± 40 μV
PTC RTD	Positive	0Ω to 10Ω _	1 mA [11]	0.1 mΩ	0.01 mΩ _ _	± 0.002Ω _ ± 0.01% of rdg	(0.01 mΩ + 0.001% of rdg)/ °C	± 0.4 mΩ
		0Ω to 30Ω _	1 mA [11]	0.1 mΩ	0.03 mΩ _ _	± 0.002Ω _ ± 0.01% of rdg	(0.03 mΩ + 0.001% of rdg)/ °C	± 0.4 mΩ
		0Ω to 100Ω _	1 mA [11]	0.1 mΩ	0.1 mΩ _	± 0.004Ω _ ± 0.01% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	± 4mΩ _
		0Ω to 300Ω _	1 mA [11]	0.1 mΩ	0.3 mΩ _	± 0.004Ω _ ± 0.01% of rdg	(0.3 mΩ + 0.001% of rdg)/°C	± 4mΩ _
		0Ω to 1kΩ _	1 mA [11]	0.1 mΩ	1 mΩ _	± 0.04Ω _ ± 0.02% of rdg	(1 mΩ + 0.001% of rdg)/°C	± 40mΩ _ _ _
		0Ω to 3kΩ _	1 mA [11]	0.1 mΩ	3 mΩ _	± 0.04Ω _ ± 0.02% of rdg	(3 mΩ + 0.001% of rdg)/°C	± 40mΩ _ _ _
		0Ω to 10kΩ _	1 mA [11]	0.1 mΩ	10 mΩ _	± 0.4Ω _ ± 0.02% of rdg	(10 mΩ + 0.001% of rdg)/°C	± 400 mΩ _ _
NTC RTD 10mV	Negative	0Ω to 10Ω _	1 mA [11]	0.1 mΩ	0.01 mΩ _ _	± 0.002Ω ± 0.06% of rdg	(0.01 mΩ + 0.001% of rdg)/ °C	± 0.3 mΩ
		0Ω to 30Ω _	300 μA [11]	0.1 mΩ	0.03 mΩ _ _	± 0.002Ω ± 0.06% of rdg	(0.03 mΩ + 0.001% of rdg)/ °C	± 0.9 mΩ _ _
		0Ω to 100Ω _	100 μA [11]	0.1 mΩ	0.1 mΩ _	± 0.01Ω ± 0.04% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	± 3 mΩ
		0Ω to 300Ω _	30μA [11]	0.1 mΩ	0.3 mΩ _	± 0.01Ω ± 0.04% of rdg	(0.3 mΩ + 0.001% of rdg)/°C	± 9 mΩ
		0Ω to 1kΩ _	10 μA [11]	0.1 mΩ	1 mΩ	± 0.1Ω ±0.04 % of rdg	(1 mΩ + 0.001% of rdg)/°C	± 30 mΩ ±0.004% of rdg
		0Ω to 3kΩ _	3 μA [11]	0.1 mΩ	3 mΩ _	± 0.1Ω ±0.04 % of rdg	(3 mΩ + 0.001% of rdg)/°C	± 90 mΩ ±0.004% of rdg
		0Ω to 10kΩ _	1 μA [11]	0.1 mΩ	10mΩ _ _ _	± 1.0Ω ± 0.04% of rdg	(10 mΩ + 0.001% of rdg)/°C	± 300 mΩ ± 0.004% of rdg
		0Ω to 30kΩ _	300nA [11]	1 mΩ _	30mΩ _	± 2.0Ω ± 0.04% of rdg	(30 mΩ + 0.001% of rdg)/°C	± 900 mΩ ± 0.004% of rdg
		0Ω to 100kΩ _	1 00 nA [11]	1 mΩ _	100mΩ _	± 10.0Ω ± 0.04% of rdg	(100 mΩ + 0.001% of rdg)/°C	± 3Ω _ ±0.01% of rdg

8.In an ideal thermal system,only the stability of the electronics is controlled.

9.The effect of current source errors on measurement accuracy is negligible.

10.Diode input excitation can be set to 1 mA.

11.Eliminates current source errors during calibration.

12.Accuracy specifications are not include room temperature compensation errors.

Table 1-3 Input Specifications

Thermocouple Expansion card	Sensor Temperature coefficient	Input range	Excitation Current	Display resolution	Measurement Resolution	Electronic precision (25°c)	Measuring temperature coefficient	Electronic control Stability [13]
TC2902	Positive	± 50mV	NA	0.1μV	0.4μV	± 1 μV ±0.05% of rdg [12]	(0.1 μV + 0.001% of rdg)/°C	± 0.8μV

13.In an ideal thermal system,only the stability of the electronics is controlled.

Table 1-4 Input Specifications of Thermocouple Expansion Card

Capacitance Expansion card	Sensor Temperature coefficient	Input range	Excitation current	Display Resolution	Measurement Resolution	Electronic precision (25°c)	Measure temperature Coefficient	Electronic control Stability [14]
TC2903	Positive Or negative	0.1nF to 15nF	3.496kHz 1 mA square wave	0.1 pF	0.05 pF	± 50 pF ±0.1% of rdg	2.5 pF/°C	0.1 pF
		1nF to 150nF	3.496kHz 10mA square wave	1 pF	0.5 pF	± 50 pF ±0.1% of rdg	5 pF/°C	1 pF

14.In an ideal thermal system,only the stability of the electronics is controlled.

Table 1-5 Input Specifications of Capacitor Expansion Card

1.3.2 Sensor Input Configuration

	Diode /RTD	Thermocouple
Measurement type	4-wire differential	2-wire differential,room temperature compensated
excitation	Constant and Reverse Current for RTDs	NA

Supported Sensors	Diodes:Silicon,GaAs RTDs:100 Ω platinum resistance,100 0 Ω platinum resistance, Germanium,Carbon-Glass,Cernox™,and Rox™	Most thermocouple types
standard curve	DT-470,DT-670,DT-500-D,DT-500-E1,PT-100,PT-1000,RX-102A,RX-202A	TypeE,TypeK,TypeT,AuFe 0.07%vs.Cr, AuFe0.03%vs.CR
input connector	6-pin DIN	Threaded terminals in ceramic temperature controlleic block

Table 1-6 Sensor Input Configuration

1.3.3 Temperature measurement

Input quantity:2 (can also add 8 input expansion cards).

Input Configuration:Inputs can be configured from the front panel,selecting the supported input types.Thermocouple and capacitive inputs require an optional input expansion card,which can be installed in the field.

Supported expansion cards:8-channel scan (TC2901),thermocouple (TC2902),capacitor (TC2903).

Slot:1

Isolation:Sensor inputs are optically isolated from other circuits,but not from each other.

A/D resolution:24 bits

Input Accuracy:Depends on the sensor.see Input specification sheet.

Measurement Resolution:Depends on the sensor.see Input specification sheet.

Maximum update rate:10 rdg/s per input,5 rdg/s when the inverted NTC RTD is configured at 100K.

Maximum update rate (scan card):10 rdg/s without scanning enabled,2.5 rdg/s with scanning enabled.

Autoranging:Automatically selects the appropriate NTC RTD or PTC RTD range.

User curve:44 user curve spaces of 250 points each.

Mathematical calculations:maximum and minimum values.

Filter:Average 2 to 64 input readings.

1.3.4 Control

1.3.4.1 Heater outputs (outputs 1 and 2)

Control type:Closed loop digital PID with manual heater output or open loop output.

Update rate:10/s

Tuning:Auto tuning (one loop at a time),PID,PID zone.

Control Stability:Depends on sensor,see input specification table.

PID control settings

Proportion (Gain):0 to 1000,0.1 sets the resolution.

Integral (reset):1 to 1000 (1000/s),0.1 sets the resolution.

Differential (rate):1 to 200% with 1% resolution.

Manual output:0 to 100%,0.01% sets the resolution.

Zone Control:10 temperature zones,heater output with PID manual control,range,channel,rate.

Fixed point rate:0.1 K/min to 100 K/min.

	25Ω setting	50Ω setting
Type	Variable DC Current Source	
D/A resolution	16 bit	
Maximum power	100W	50W
Maximum current	2A	2A
Constant current maximum voltage	50V	50V
Maximum power heater load	25Ω	50Ω
Heater load range	10Ω to 100Ω	
Tap position	3 (1/10 damping each position)	
Heater noise	0.12µA rms (mainly at line frequency and its harmonics)	
Ground	refer to the grounded output of the mainboard	
heater connector	double banana head	
safety margin	Curve temperature,heater power off,short circuit protection	

Table 1-7 Output 1

	25Ω setting	50Ω setting
Type	Variable DC Current Source	
D/A resolution	16 bit	
Maximum power	100W	50W
Maximum current	2A	2A
Constant current maximum voltage	50V	50V
Maximum power heater load	25Ω	50Ω
Heater load range	10Ω to 100Ω	
Tap position	3 (10 steps each position)	
Heater noise	0.12μA rms (mainly at line frequency and its harmonics)	
Ground	refer to the grounded output of the mainboard	
heater connector	double banana head	
safety margin	Curve temperature,heater power off,short circuit protection	

Table 1-8 Output 2

Note :Output 1 and Output 2 can be set as the output of a control loop,and the output power of 200W can be obtained at this time.

1.3.4.2 no power analog output (output 3)

Control Type:Closed Loop PID,PID Zone,Preheat Heater Mode,Manual Output or Monitored Output.

Tuning:Auto tuning (one cycle at a time),PID,PID zone.

Control Stability:Depends on sensor,see input specification table.

PID control settings

Proportion(Gain):0 to 1000,0.1 sets the resolution.

Integral (reset):1 to 1000 (1000/s),0.1 sets the resolution.

Differential (rate):1 to 200% with 1% resolution.

Manual output:0 to 100%,0.01% sets the resolution.

Zone Control:10 temperature zones,heater output with PID manual control,range,channel,rate.

Fixed point rate:0.1 K/min to 100 K/min.

Preheat heater mode setting

Warmup Percentage:0 to 100% with 1% resolution.

Preheat Mode:Continuous control or automatic shutdown.

Monitor output settings

Range:User selectable.

Data source:Temperature or sensor unit.

Settings:Input,Source,Top of Range,Bottom of Range,or Manual.

Type:Variable DC voltage source.

Update rate:10/s

Range:± 10 V

Resolution:16 bits,0.3 mV

Accuracy:± 2.5 mV

Noise:0.3 mV RMS

Minimum load resistance:1 kΩ (short circuit protected)

Connector:Detachable connector.

1.3.5 Front Panel

Display:5” color capacitive touch display,800*480 pixels.

Reading display number:1 to 8

Display unit:K,℃,V,mV,Ω

Reading Sources:Temperature,Sensor Units,Max and Min.

Display update rate:2 rdg/s

Temperature Display Resolution:0.0001° from 0° to 99.9999°,0.001° from 100° to 999.999°, 0.01° above 1000°.

Sensor unit display resolution:up to 6 digits depending on the sensor.

Other displays:Input name,set point,heater range,heater output and PID.

Set point Setting Resolution:Same as Display Resolution (actual resolution depends on sensor).

Heater output display:Digital display as a percentage of full scale power or current.

Heater output resolution:0.01%

Display Alarms:Control Inputs,Alarms,Adjustments.

Buttons:1 button to realize the Startup & Shutdown function.

Front panel functions:Front panel curve input,display contrast control and parameter setting.

1.3.6 Interface

RS485

Function:Two-wire differential signal logic to realize network communication function.

Baud rate:115200

Address:1 (default)

Connector:Detachable connector.

Readout speed:10 rdg/s per input

Software Support:LabVIEW Driver

USB

Function:Emulates a standard RS-232 serial port.

Baud rate:115200

Connector:Type B USB connector

Reading speed:10 rdg/s per input

Software Support:LabVIEW Driver

Ethernet

Features:Emulates standard RS-232 serial port,TCP/IP web interface,networking.

Connector:RJ-45

Readout speed:10 rdg/s per input

Software Support:LabVIEW Driver

Alarm

Quantity:10,high and low for each input

Data source:temperature or sensor unit

Settings:Source,High/Low Setpoint,Deadband,Latching or Non-Latching,Sound On/Off,and Visible On/Off

Actuators:Displays annunciators,buzzers and relays.

Relay

Quantity:2

Contact point:Normally Open (NO),Normally Closed (NC) and Common (C)

Contact Rating:30VDC/2 A

Operation:Any input can activate relays for high,low or both alarms,or manual mode.

Connector:Detachable connector.

1.3.7 General

Ambient temperature:15°C to 35°C at rated accuracy;

5°C to 40°C with reduced accuracy;

Power Requirements:100,120,220,240,VAC,±10%,50 or 60 Hz,250VA.

Dimensions:330 mm L × 215 mm W × 88 mm H (plus foot pads 100 mm)

Weight:2.6 kg

1.4 Safety Summary and Symbols

Follow these general safety precautions during all phases of instrument operation,maintenance,and repair.Failure to follow these precautions Specific warnings in the application or elsewhere in this manual violate safety standards for the design,manufacture,and intended use of the instrument,and MAG assumes no responsibility for the customer's failure to comply with these requirements.

The TC290 temperature controller protects the operator and surrounding area from electric shock or burns,mechanical hazards,excessive temperatures and instrument fires,the impact of the spread of the disaster.

Environmental conditions other than those below may be hazardous to the operator and surrounding area.

- indoor use
- 2000 meters above sea level
- Safe operating temperature:5°C to 40°C
- Maximum relative humidity:80% at temperatures up to 31°C,decreasing linearly to 50% at 40°C.

- The power supply voltage fluctuation does not exceed ±10% of the rated voltage
- Overvoltage Category II
- Pollution degree 2

Instrument grounding

To reduce the risk of electric shock,the instrument is equipped with a 3-conductor AC power cord.Plug the power cord into an approved 3-contact power supply receptacle,or a 3-contact adapter with a ground wire (green) securely connected to the electrical ground (safety ground) of the electrical outlet.The receptacle and matched plug of the power cord meet Underwriters Laboratory (UL) and International Electrotechnical Commission (IEC) safety standards.

ventilation

There are ventilation holes on the side cover of the instrument.Do not block these holes when the instrument is in operation.

Do not operate in explosive atmospheres

Do not operate the instrument in the presence of flammable gases or fumes.Operating any electrical instrument in this environment would constitute certain security risks.

Keep away from live circuits

The operator must not remove the instrument cover.Consult qualified maintenance personnel for parts replacement and internal adjustments.Do not replace parts with the power cord connected.To avoid injury,always disconnect power and discharge circuits before touching them.

Do not replace parts or modify the instrument

Do not install substitute parts or make any unauthorized modifications to the instrument.Return the instrument to the authorized MAG representative for repairs to ensure that safety features are maintained.

Clean

Do not immerse the instrument in water,only use a damp cloth and mild detergent to clean the outside of the instrument.

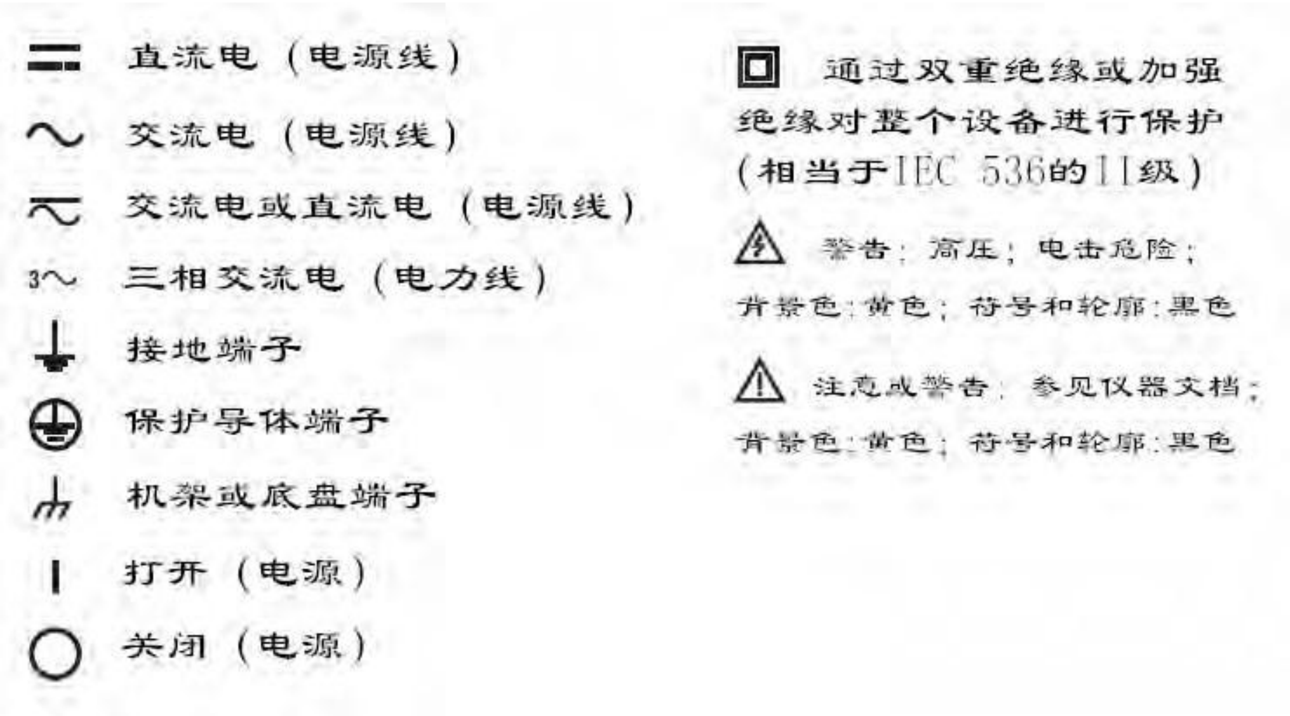


Figure 1- 4 Safety Symbols

Chapter 2 Cooling System Design and Temperature Control

2.1 Overview

Choosing the right cryostat or cooling source is probably the most important decision in designing a temperature control system.The cooling source defines the most Low temperature,cooling time and cooling power.Information on selecting a cooling source is beyond the scope of this manual.This chapter provides information on how to obtain optimum temperature measurement and control from a cooling source with proper setup,including sensor and heater installation.

2.2 Temperature sensor selection

This section attempts to answer some basic questions about temperature sensor selection.For other useful information on temperature sensor selection, Please refer to our temperature measurement and control catalogue.The catalog has a large reference section that includes sensor characteristics and sensor selection criteria.

2.2.1 Temperature range

Several important sensor parameters must be considered when selecting a sensor.One is the experimental temperature range.Some sensors may damaged by temperature being too high or too low.The manufacturer's recommendations should always be followed.

The sensitivity of the sensor varies with temperature and limits the effective range of the sensor.It is important not to specify a larger range.If experiments are performed at liquid helium temperature,very high sensitivity is required to obtain good measurement resolution at that temperature.The same resolution may not require monitoring warm-up to room temperature.Two different sensors may be required to closely cover the range from reference temperature to room temperature,but reducing the resolution requirement at warm-up may make a 1-sensor solution less expensive.

Another thing to consider when choosing a temperature sensor is that the TC290 temperature controller cannot read certain signals over the entire temperature range.The operating temperature of the calibrated sensors sold by our company is less than 20 mk,but the standard configuration of the TC290 temperature controller is limited to 300 mk and above.

2.2.2 Sensor Sensitivity

Temperature sensor sensitivity is a method to measure the change of sensor signal when temperature changes.It is a heavy sensor characteristics.because there are many measurement parameters associated with them.Resolution,accuracy,ground noise,and even control stability depend on sensitivity.Many sensors have different sensitivities at different temperatures.For example,platinum sensors have good sensitivity at higher temperatures,but their use below 30K is limited due to their sharp drop in sensitivity.In the experimental temperature range,it is difficult to determine whether the sensor has sufficient sensitivity.This manual has specifications (section 1.3) that include sensor sensitivities converted to temperature resolution and accuracy at different points.This is a typical sensor response and can be used as a guide when selecting a TC290 temperature controller sensor.

2.2.3 Environmental conditions

When choosing a sensor,the experimental environment is also important.Environmental factors such as high vacuum,magnetic fields,corrosive chemicals and even radiation

Will limit the use of certain types of sensors.Our company spent a lot of time developing sensor components to withstand the temperatures.vacuity and bonding materials found in typical cryogenic cooling systems.Experiments performed in magnetic fields are common.The field dependence of the temperature sensor used in these experiment is the important selection criterion.This manual briefly defines the field dependencies of the most common sensors in the specification (section 1.3).Detailed site-relevant tables are included in our Temperature Measurement and Control Catalog.Specific data on other environmental factors are also included in the catalog,if available.

2.2.4 Measurement accuracy

Temperature measurements have several sources of uncertainty that can reduce accuracy.When calculating accuracy,be sure to consider sensor and instrumentation leads error.The instrument has measurement errors when reading the sensor signal,as well as when calculating temperature using the temperature response curve.When comparing a sensor to a calibration standard,the sensor's temperature response will vary over time and repeated thermal cycling (from very low temperature to room temperature),leading to erroneous results.Instrument and sensor manufacturers specify these errors,but there are a few things you can do to maintain good accuracy.For example,choose a sensor with good sensitivity over the most critical temperature range,as sensitivity minimizes the effects of most error sources.Follow the guidelines in section 2.4 to properly install the sensor.Calibrate sensors and instruments regularly or otherwise invalidate time-dependent errors.Use sensor calibration suitable for accuracy requirements.

2.2.5 Sensor Package

Different types of sensors have different packages.Some types of sensors can even be purchased as bare chips without any packaging.The sensor package usually determines its size,thermal and electrical contact to the outside,and sometimes limits the temperature range.When different packages are available for a sensor.you should consider the mounting surface of the sensor and how to heat anchor the wires when selecting them.

2.3 Sensor Calibration

Sometimes choosing the right sensor,calibrating it,and converting the calibration data to a temperature response curve for TC290 temperature,and then loading the curve into the instrument can be confusing.MAG can provide a variety of calibration services to meet different accuracy requirements and budgets.

Best	Accuracy calibration	All sensors can be calibrated in different temperature ranges. Our company defines the available calibration range for each sensor type.
Better	software computing	Simplified calibration available for 400 series silicon diodes and platinum sensors (2 points:77 K and 305 K;3 points:4.2 K,77 K and 305 K; or 3 points:77 K,305 K and 480 K).
Good	Use the standard curve of the sensor	Silicon diodes follow a standard curve
		Platinum resistance follows a standard curve
		Ruthenium Oxide (Rox™) Resistors Follow Standard Curve
		Thermocouples follow a standard curve
		Gaalas Diodes,Carbon Glass,Cernox™,Germanium and Rhodiumiron Sensors can be purchased uncalibrated,but must be calibrated for accurate reading of temperature units.

Table 2-1 Sensor Calibration

2.3.1 Accuracy calibration

For calibration,MAG compares an unknown temperature response of a sensor to an acceptable standard These standards allow MAG to calibrate the sensor from 20mK to above room temperature.Calibrated sensors are more expensive than uncalibrated sensors of the same type because of the labor,refrigerant and sophisticated equipment used in the process.

Precise calibration provides the most accurate temperature sensor in MAG .The uncertainty of sensor calibration is almost always less than caused by TC290 temperature controller.The MAG 's Temperature Measurement and Control catalog has a complete specification of calibrated sensor accuracy.

Calibrating the sensor consists of printed and plotted measured test data,Chebyshev polynomial coefficients fitted to the data,and Two tables of data points to use as interpolation tables.Both interpolation tables are optimized for accurate temperature conversions.The smaller table is called the breakpoint interpolation table and Its size is suitable for TC290 temperature controller,where it is called the temperature response curve.

It is important to review the instrument specifications before ordering a calibrated sensor.If it is to be displayed at temperature,the sensor does not follow standard curve,you need to calibrate the sensor.Otherwise,the TC290 temperature controller will work in sensor units like ohms or volts.The TC290 temperature controller may not work over the full temperature range of some sensors,where the standard input is limited to operation above 300mk,even though the sensor can be calibrated to 20mk.

2.3.2 Software calculation

Software calculations are good solution for applications that do not require precise calibration accuracy.Software calculation algorithm using standard of the good characteristics of the sensor after the calibration curve to improve the accuracy of the single sensor.Several known temperature points are required to perform the software calculations.The TC290 temperature controller can also perform software calculated calibration.You need to provide one,two or three known temperature reference points.The range and accuracy of the calibration are based on these points (Section 5.10).

MAG offers two or three point software calibrated sensors,including for 400 series diodes and platinum sensors' large interpolation table and small breakpoint interpolation table.

2.3.3 Sensors using a standard curve

Some types of sensors behave so predictably that a standard temperature response curve can be created for them.The standard curve is an easy and inexpensive way to obtain reasonable temperature accuracy.When interchangeability is important,sensors with standard curves are often used.Some individual sensors are chosen for their ability to match published standard curves,but in general,these sensors do not provide the accuracy of calibrated sensors.For convenience,the TC290 temperature controller has several standard curves included in the firmware.

2.3.4 Curve Processor

MAG provides a software application called"Curve Handler"which enables the loading of temperature curves to the TC290 temperature controller becomes a very simple process.This program can copy the curve in the correct format file to the user curve position of TC290 temperature controller.You can also use this program to read the curves of the TC290 temperature controller and save them to a file.The TC290 is supplied with a CD containing all the correct formats for loading curves using the"Curve Handler"software program.

The"Curve Handler"application is a Microsoft Windows application that must be installed on a Windows computer.This version works with the USB computer interface of the TC290 temperature controller and allows you to manipulate the temperature curve directly in the program window.This version also fits all existing MAG temperature control instruments and temperature monitoring instruments.The Windows version of the Curve Processor application is available free of charge from the website at www.dexinelectronics.com.

2.4 Sensor installation

This section highlights some important elements for proper sensor installation.For more detailed information,the MAG enclosed installation instructions,which include specific sensor types and packaging.The MAG temperature measurement and control catalog also includes an installation section.To further help you properly install the sensor,MAG offers a range of cryogenic accessories.Many of the materials discussed are available by ordering MAG sensors or instruments.

2.4.1 Installation materials

In low temperature environments,it is very important to choose the right mounting material,one of the considerations is the use of high vacuum to isolate away from the cryostat.Materials used in these applications should have low vapor pressures so they do not evaporate or outgas and destroy the vacuum insulation.Metals and ceramics don't have this problem,but greases and varnishes must be checked.Another consideration is the wide temperature range to which most sensors are exposed.When the temperature changes greatly,the linear expansion coefficient of the material becomes important.Do not attempt to permanently bond materials together with coefficients of linear expansion that differ by more than three.Use a flexible mounting scheme,otherwise parts will break,potentially damaging them.Thermal expansion or contraction of rigid grips or supports can crush fragile samples or sensors that do not have the same factor.Thermal conductivity is a property of a material that changes with temperature.Don't assume that thermal anchor greases that work well at room temperature or higher will work the same at low temperatures

2.4.2 Sensor Location

Finding a good place to mount a sensor in an already crowded cryostat has never been easier.If the entire load and sample holder at the same temperature,there are fewer problems.Unfortunately,this is not the case in many systems.There are temperature gradients (temperature differences) because there is rarely a perfect balance between cooling and heat sources.Even in a well-controlled system,unwanted heat sources,such as thermal radiation and heat conducted through the mounting structure,can cause gradients.For best accuracy,place the sensor near the sample so that there is little or no heat between the sample and the sensor.However,this may not be the best location for temperature control discussed below.

2.4.3 Thermal conductivity

Heat pass through a material is called thermal conductivity.Good thermal conductivity for any part of the low temperature system at the same temperature is very important.Copper and aluminum are examples of metals that have good thermal conductivity,while stainless steel is not.Non-metallic,electrically insulating materials such as alumina and similar ceramics have good thermal conductivity,while G-10 epoxy fiberglass does not.The sensor assembly,cooling load,and sample holder should have good thermal conductivity to reduce temperature gradients.Surprisingly,connections between thermally conductive mounting surfaces often have very poor thermal conductivity (see Sections 2.4.4 and 2.4.5).

2.4.4 Contact area

Thermal contact area greatly affects heat conduction,as the larger the area,the more opportunities for heat transfer.even if the sensor dimensions of the package are fixed,and the use of sealing materials such as indium foil and low temperature grease can also improve the thermal contact area.A soft gasket material forms a rough matched surface to increase the area of the two contact surfaces.A good gasket material is soft,thin,and has good thermal conductivity.They must also withstand extreme environments.Indium foil and low temperature grease are good examples.

2.4.5 Contact pressure

When the sensor is permanently installed,the solder or epoxy used to hold the sensor acts as both a gasket and an adhesive.Permanent installation is not a good solution as it limits flexibility and can damage the sensor.Special care should be taken not to overheat or mechanically stress the sensor assembly.Less permanent installations require some pressure to keep the sensor on the mounting surface.The pressure greatly enhances the action of the gasket material to increase thermal conductivity and reduce thermal gradients.Spring clips are recommended so that different thermal expansion rates do not increase or decrease pressure with temperature.

2.4.6 Leads

Different types of sensors come with different types and lengths of wires.Typically,a phase must be added to the sensor,long leads are used for proper thermal anchoring,And connect it to the large capacity head connector at the vacuum boundary.The leads must be good electrical conductors,but should not be good thermal conductors,otherwise heat will pass down the leads and change the temperature reading of the sensor.Small wires of 30AWG to 40AWG made of alloys like phosphor bronze are much better than copper wire.It is best to use thin wire insulation.If there is interference,stranded wire should be used to reduce the influence of radio frequency noise.The wires used on the room temperature side of the vacuum boundary are not critical,so copper cables are usually used

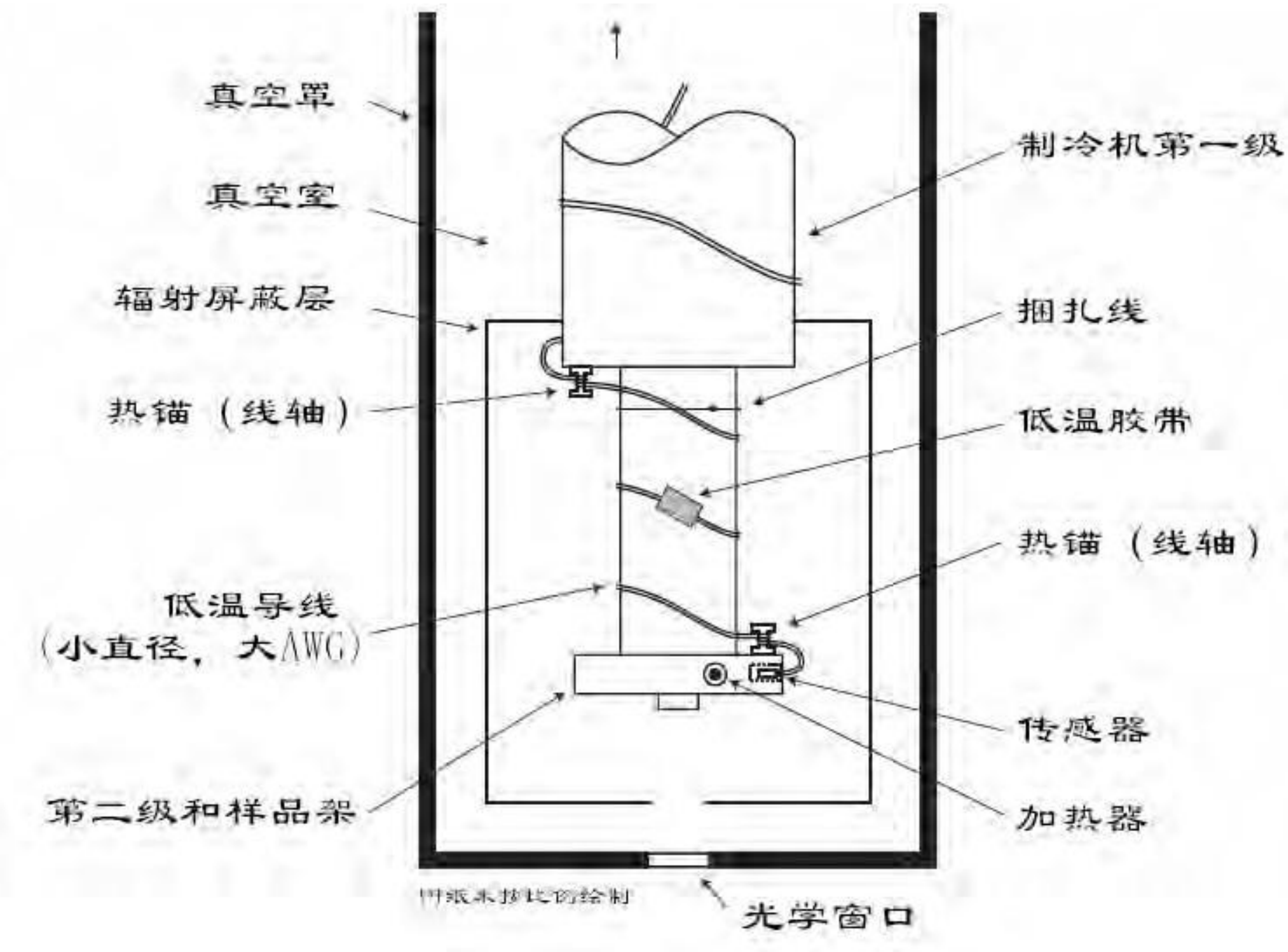


Figure 2 - 1 Typical Sensor Installation in a Mechanical Refrigerator

2.4.7 Leaded soldering

Be careful not to overheat the sensor when you solder the additional wire to the short sensor wire.Thermal anchors,such as wire clips or alligator clips will anchor the wires and protect the sensor.The wires should be tinned before connecting to reduce the amount of time heat is applied to the sensor wires.Flux cleaning after soldering to prevent corrosion or outgassing in the vacuum.

2.4.8 Thermal Anchor Leads

Sensor leads can be a significant source of error if they are not properly secured.heat will pass down,even small leads can change sensor readings.The purpose of thermal anchoring is to cool the wire to a temperature as close as possible to the sensor.This can be achieved by placing relatively long wires in thermal contact with each cooling surface between the room temperature and the sensor.You can glue lead wire to cold surfaces and varnish thin insulators,such as cigarette paper.They can also be wound on spools that are firmly attached to cold surfaces.Some sensor assemblies include a thermal anchor spool and wrapped leads to simplify thermal anchoring.

2.4.9 Thermal radiation

Thermal (black body) radiation is one of the ways of heat transfer.Warm surfaces radiate heat to cold surfaces even through the vacuum.The temperature difference between the surfaces is one factor that determines the amount of heat transfer.Thermal radiation can cause thermal gradients that reduce measurement accuracy.Many cooling systems include a radiation shield.The purpose of the shielding is to keep the surface temperature around the sample stage,sample and sensor at or near their temperature to minimize radiation.The shield is exposed to the room temperature surface of the outer surface of the vacuum enclosure,so a certain cooling power must be supplied to the shield to make it close to the load temperature.If the cooling system does not include an integrated radiation shield (if it is not easy to manufacture),another option is to loosely wrap several layers of super insulation (aluminized mylar) between the vacuum enclosure and the load.This reduces radiation transfer to the sample space.

2.5 Selection and installation of heaters

2.5.1 Heater resistance and power

The cryogenic cooling system has a wide range of cooling power.The resistance heater must be able to provide enough heating power to heat the system.The TC290 temperature controller can provide up to 100 W from output 1 and up to 100 W from output 2.Table 2-2 provides the current and voltage limits,as well as the maximum power for each output at the 25Ω and 50Ω settings,using the rated heater load values.

		25Ω setting (25Ω heater)	50Ω setting (50Ω heater)
output 1	Current limit	2A	1A
	Voltage limit	50V	50V
	Maximum power	100W	50W
output 2	Current limit	2A	1A
	Voltage limit	50V	50V

	Maximum power	100W	50W

Table 2-2 Current and voltage limits at maximum power generation

Although the outputs of the TC290 temperature controller heaters are current sources,they are limited to 50 V (called the compliance voltage).This compliance voltage also limits the maximum power.Therefore,for heater values other than 25Ω or 50Ω,calculate the maximum power using the following formulas:$P=I^2R$ and $P=V^2/R$,where P is the maximum power,I is the maximum current,V is the maximum voltage,and R is the heater resistance.Both current and voltage limits exist,so the smaller of the two calculations gives the maximum power available to the heater.

Example 1:A 20Ω heater is connected to output 1,the heater resistance is set to 25Ω and can supply up to 2 A and up to 50 V voltage.

Current Limit Voltage Limit :

$P = I^2R$ $P = V^2/R$

$P = (2A)^2 \times (20\Omega)$ $P = (50\ V)^2/(20\ \Omega)$

$P = 80W$ $P = 125W$

The power limit is the smaller of the two limits,80 W,and is limited by the current.

Example 2:A 60Ω heater is connected to output 2,the heater resistance is set to 50Ω and can supply up to 1 A and up to

50 V voltage.

Current Limit Voltage Limit :

$P = I^2R$ $P = V^2/R$

$P = (1\ A)^2 \times (60\ \Omega))$ $P = (50\ V)^2/(60\ \Omega)$

$P = 60W$ $P = 41.7W$

The power limit is the smaller of the two limits,41.7W,limited by voltage.

It is possible to choose a heater value with a maximum power greater than 100 W of output rated power,but this will cause the TC290 temperature controller not work properly.

In this case,the maximum user current setting should be used to limit power.See Section 4.5.1.1.1 for details on using the maximum user current setting.

The resistor chosen as the heater must be able to withstand the power it dissipates.Power specifications for prepackaged resistors are typically at empty

The power provided by the resistor in the air.Power may need to be reduced if used in a vacuum where convection cooling is not possible and is not sufficiently anchored to the cooling surface.The TC290 temperature controller has a current limit feature that allows you to specify the maximum output current for each heater output (section 4.5.1.1),which,if set properly,will help prevent the heater from overheating.

2.5.2 Heater Location

In order to obtain the best temperature measurement accuracy,the heater needs to be positioned to minimize temperature gradients across the sample.In order to implement optimal control,the heater should be in close thermal contact with the cooling source.The dimensional configuration of the loads may make it difficult to integrate one or both of them.This is why heaters come in several shapes and sizes.

2.5.3 Heater Type

Resistive wire like nichrome is the most flexible type of heater.This wire has electrical insulation and can be purchased together,and have a predictable resistance over a given length.This type of heating wire can be wrapped around the load to provide balance or even a heated area.Similar to the sensor leads,the entire length of the heater wire should be in good thermal contact with the load to allow heat transfer.Thermal anchoring also prevents wires from overheating and burning out.resistance heater wire is also wound around the cartridge heater.Cartridge heaters are more convenient,but bulky and difficult to fit on small loads.A typical bobbin is 6.35 mm (0.25 in) in diameter and 25.4 mm (1 in) long.The spool should be tightly seated in the hole in the load or clamped to a flat surface.Thermal anchoring for good thermal contact is also important.

Foil heaters are thin layers of resistive material attached or shielded to an electrically insulating plate.Comes in all shapes and sizes.proper sizeThe heater can evenly heat around a flat or circular load.The entire active area should be in good thermal contact with the load,not only for maximum heating,but also to prevent points in the heater from overheating and burning out.

2.5.4 Heater wiring

When wiring inside the vacuum enclosure,we recommend using 30 AWG copper wire for the heater wire.When using larger wire,the heat will be transferred too much.Similar thermal anchors to the sensor leads should be included so that any heat transfer does not heat up the load when the heater is not running.The wires should be crossed to minimize noise coupling between the heater and other wires in the system.When wiring outside the vacuum enclosure,larger gauge copper can be used,and crossover is still recommended.

2.6 Considerations for Good Control

Most of the techniques discussed in Sections 2.4 and 2.5 to improve cryogenic accuracy also apply to control.sensor location is obviously abnormal,the following section 2.6.3 proposes a compromise solution.

2.6.1 Thermal conductivity

Good thermal conductivity is important for any part of a cryogenic system that is intended to be at the same temperature.Most systems start with materials with good electrical conductivity,but as sensors,heaters,sample holders,etc.are added to increasingly crowded spaces,the connections between parts are often neglected.For the control to work well,the connections between the control loop elements must be in close thermal contact and have good thermal conductivity.Gasket materials should always be used under reasonable pressure (sections 2.4.4 and 2.4.5).

2.6.2 Thermal Hysteresis

Poor thermal conductivity can lead to thermal gradients that reduce accuracy and can also cause thermal lag,making it difficult for the controller to do its job.thermal hysteresis refers to the time it takes for a change in heating or cooling power to propagate through the load and reach the feedback sensor.Because the feedback sensor is the only thing that lets the controller know what's going on in the system,slow information to the sensor can slow down the response time.For example,if the temperature at the load is slightly below the set point,the controller will gradually increase the heating power.If the feedback is slow,the controller will put too much heat into the system before it asks to reduce the heat.Overheating can cause temperature overshoot,which reduces control stability.The best way to improve thermal hysteresis is to pay close attention to the thermal conductivity of the parts used and their joints.

2.6.3 Dual-sensor method

There is a conflict between the optimal sensor location for measurement accuracy and the optimal sensor location for control.For measurement accuracy.the sensor should be very close to the sample under test and away from heat and cooling sources to reduce heat flux and thermal gradients through the sample.Best control stability is obtained when the feedback sensor is close to the heater and cooling source to reduce thermal hysteresis.If both control stability and measurement accuracy are critical,it may be necessary to use two sensors,one for each function.Therefore,many temperature controllers,including the TC290 temperature controller,have multiple sensor inputs.

2.6.4 Thermal mass

Understandably,cryogenic designers want to reduce the thermal mass of the load as much as possible,allowing the system to cool quickly and shorten the cycle time.Small masses also have the advantage of reducing thermal gradients.Controlling a very small mass is difficult because there is no buffer to absorb small changes in the system.Without a buffer,small perturbations can produce large temperature changes quickly.In some systems,small amounts of thermal mass,such as copper blocks,need to be added to improve control stability.

2.6.5 System Nonlinearity

A system that controls a well at one temperature may not control the well well at another temperature due to nonlinearity.Although all Nonlinearity exists in all temperature control systems,but is most pronounced at low temperatures.When operating temperature changes the behavior of the control loop,the controller must be readjusted.For example,thermal mass acts differently at different temperatures.The specific heat of the loaded material is a major factor in thermal mass.The specific heat of materials such as copper changes by three orders of magnitude when cooled from 100K to 10K.Variations in cooling power and sensor sensitivity are also sources of nonlinearity.

The cooling power of most cooling sources also varies with load temperature.This is important when operating at temperatures close to the highest or lowest temperature the system can reach.Nonlinearities within a few degrees of these high and low temperatures make it difficult to configure them for stable control.If you get stuck,it is advisable to gain experience with the system at temperatures a few degrees away from the limit and gradually approach the system in small steps.

Be aware of temperature sensitivity.Sensitivity not only affects the stability of the control,but also affects the gain of the entire control system.The large changes in sensitivity that make some sensors very useful,this may require more frequent readjustment of control loops.

2.7 PID control

For closed loop operation,the TC290 temperature controller uses an algorithm called PID control.There are three control equations of PID algorithm Variable terms:Proportional (P),Integral (I) and Derivative (D).See Figure 2-2.Changing these variables to achieve the best control over the system is called tuning.The PID equation in the TC290 temperature controller is:

heater output = $P\left[e + I\int(e)\ dt + D\ \frac{de}{dt}\right]$

where error (e) is defined as:e = set point - feedback reading.

Scale is discussed in Section 2.7.1.Integration is discussed in Section 2.7.2.Differentiation is discussed in Section 2.7.3.Finally,the first Section 2.7.4 discusses the manual heater output.

2.7.1 Proportion (P)

The proportional term (also called gain) must have a value greater than 0 for the control loop to work.The value of the proportional term is multiplied by the error (e),which is defined as the difference between the set point and the feedback temperature,to produce a proportional contribution to the output:output(p) = pe.If proportional acts alone,without integration,there must always be an error,otherwise the output will go to 0.In order to calculate the proportional setpoint (P),a lot must be known about the load,sensor and controller.Typically,scale settings are determined by trial and error.The proportional setting is part of the overall control loop gain,as is the heater range and cooling power.If one of them changes,you need to change the scale settings.

2.7.2 Points (I)

In the control loop.the integral term.also called reset.reduces the error over time to establish the integral contribution to the output :

output(i) = $PI\int(e)dt$

By adding the integral and proportional contributions,the error required in a proportional-only system can be eliminated.When the error is 0,Control at the set point,the output is kept constant by the integral contribution.The integral setting (i) is more predictable than the gain setting.It is related to the dominant time constant of the load.As described in Section 2.8.3,measuring this time constant allows a reasonable calculation of the integral setting.In the TC290 temperature controller,the integral term is not set in seconds like in other systems.The integral setting can be obtained by dividing 1000 by integral seconds:Isetting=1000/Iseconds.

2.7.3 Differentiation (D)

The differential term,also called the rate,acts on the variation of the error over time to contribute to the output : $PD\frac{de}{dt}$

output(D) =

reacting to rapidly changing error signals,differentiation increases the output when the setpoint changes rapidly,thereby reducing short time required for temperature to reach set point.It also sees that the error decreases rapidly as the temperature approaches the set point and reduces the overshoot of the output.The derivative term is useful in rapidly changing systems,but it is often turned off in steady-state control because it reacts too strongly to small perturbations.The derivative setting (d) is related to the dominant time constant of the load,similar to the I setting,and is therefore set relative to the I setting when used.

2.7.4 Manual output

TC290 temperature controller is not a standard part of the PID control loop.Manual output can be used for open loop control,ignore the feedback,the heater output remains at the user manual setting.This is a great way to put constant heating power into the load when needed.Manual output terms can also be added to the PID output.Some users prefer to set the power close to the set point in order to control the set point and let the closed loop system make up for small differences.Manual output is set as a percentage of full scale current or power for a given heater range.(Section 4.5.1.5.5)

Note: Manual output should be set to 0% when not in use.

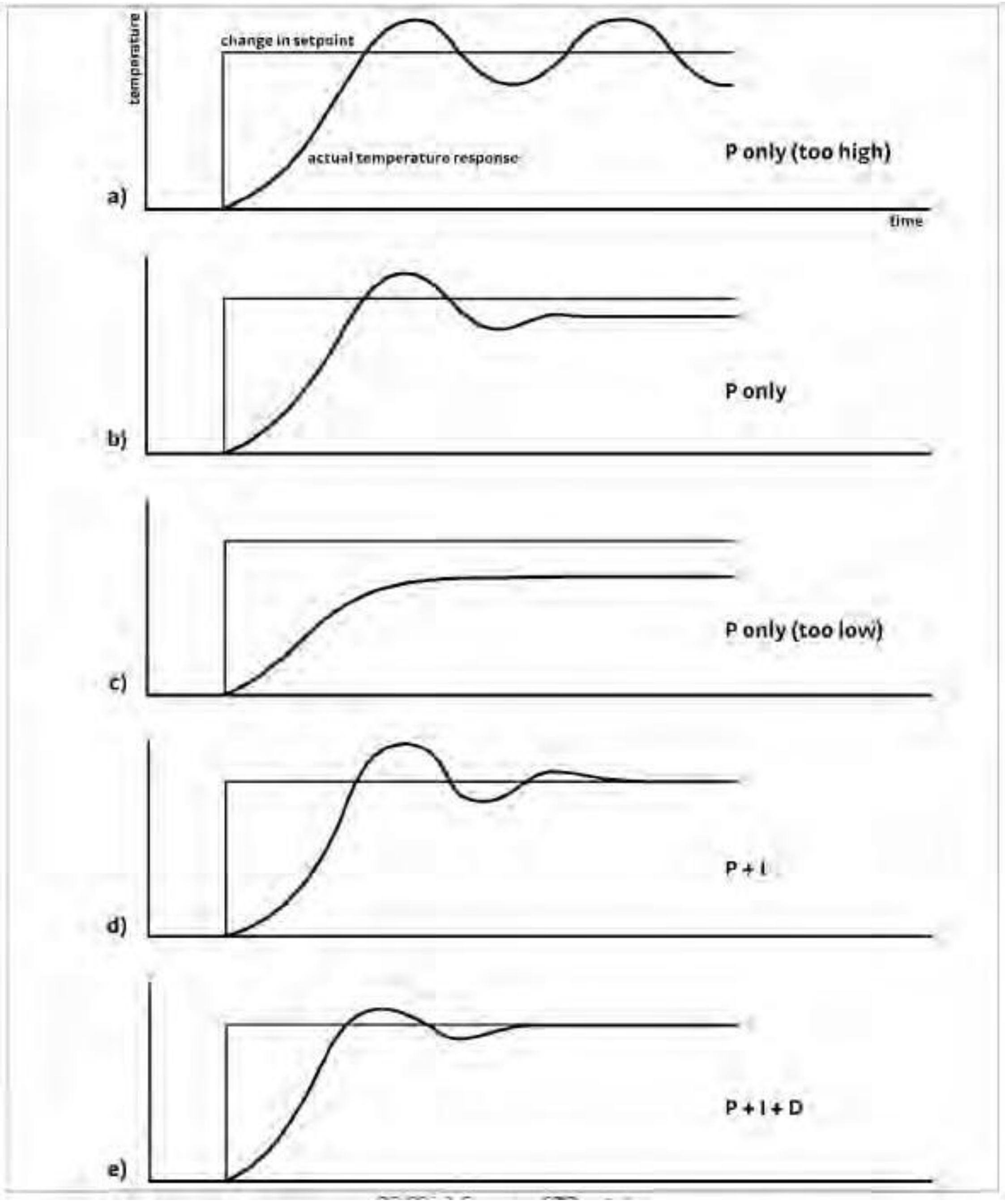


Figure 2 - 2 PID control example

2.8 Manual tuning

There have been a lot of literature reports on the tuning of the closed-loop control system,especially the tuning of the PID control loop.and this section does not attempt to compete with experts in control theory.It describes some basic rules of thumb to help inexperienced users get started.This technology doesn't solve all problems,but it has worked in many other areas of the field.This section assumes that you have completed the operating portion of this manual,have obtained good temperature readings from the sensor selected as the control sensor,and are operating Loop 1.It's best to start at the center of the cooling system's temperature range (not near its maximum or minimum temperature).Autotune (section 2.9) is another good place to start,don't forget the power of trial and error.

2.8.1 Setting the heater range

Setting the proper heater output range is an important first part of the tuning process.The heater range should allow enough heater power to comfortably overcome the cooling power of the cooling system.If the heater range does not provide enough power,the load will not reach the set temperature.Conversely,if the range is set too high,the load can have large temperature changes and take a long time to stabilize.Fragile loads can even be damaged by excessive power. Generally,there is very little information about the cooling power of the cooling system at the desired set point.If under this condition,try do the following:Allow the load to cool completely with the heater turned off.In open loop control mode,set the manual output to 50%.Turn the heater to the lowest setting and note the temperature rise (if any).Select the next slightly higher heater gear and continue the process until the load warms up to room temperature.Do not leave the system unattended;the heater may need to be turned off manually to prevent overheating.If the load never reaches room temperature,some adjustments to the heater resistance or load may be required.

The list of heater ranges and load temperatures is a good reference for selecting the appropriate heater range.The system usually requires two or more heater ranges are required for good control over their full temperature.Lower temperatures generally require lower heater ranges.The TC290 temperature controller cannot control the temperature or the temperature will get lower and lower when the heater is turned off.Many systems can be adjusted to a degree or two above the control temperature.

2.8.2 Adjustment ratio

The scale setting is closely related to the heater range and can be considered as fine-tuning and stroke adjustment of the same setting.Before proceeding with the scale setting.the appropriate heater range must be known.

1.With the heater turned off,allow the cooling system to cool down and stabilize.

2.Set the TC290 temperature controller into closed-loop PID mode for tuning.

3.Set the Integral,Derivative and Manual output settings to 0.

4.Enter a setpoint a few degrees above the minimum temperature of the cooling system.

5.Enter a low ratio setting of about 5 or 10 and enter the appropriate heater setting as described in Section 2.8.1.

6.The load temperature should be stabilized at a temperature lower than the set value.The heater display value should be greater than 0% and less than 100%.If the load temperature is unstable below the setpoint,do one of the following:

a.If the load temperature and heater display readings swing rapidly,the ratio setting or heater gear may be set too high.Decrease ratio setting or heater gear and return to step 6.

b.If the load temperature and heater display readings change very slowly,i.e.drift conditions,it means that the scale setting is too low.Increase the scale setting and return to step 6.

7.Gradually increase the scale setting by doubling each time.Allow time for the load temperature to stabilize at each new setting.

8.Repeat step 7 until the setpoint is reached where the load temperature begins to oscillate continuously and predictably,rising and falling in consistent time periods.See Figure 2-2(a).

NOTE: The goal is to find the proportional value at which oscillation starts,do not set the setpoint so high that the temperature and heater output changes become extreme.

9.If step 8 is achieved,complete steps 10 and 11,if not,skip to step 12.

10.Record the ratio setting and the time it takes for the load to change from one temperature peak to the next.This time is called the oscillation period of the load.It helps to describe the dominant time constant of the load and is used for tuning the integral.

11.Reduce the scale setting in half.The proper scale setting is half of the value required for continuous oscillation in step 8.See

Figure 2-2(b).Continue to adjust points section 2.8.3.

12.There are several systems that need to be stable and not oscillating at very high ratio settings and proper heater range settings.For these systems,setting the scale to half of the highest setting is a good starting point.Continue with the tuning integral in Section 2.8.3.

2.8.3 Setting integral

When the proportional setting is selected and the integral is set to 0 (off),if the TC290 temperature controller controls the load temperature to be lower than the set value.By setting the integral,the TC290 temperature controller control algorithm can gradually eliminate the temperature difference through the error integral over a period of time.See Figure 2-2(d).Setting the integral too low will cause the load to adjust for too long to reach the setpoint.Setting the integral too high can cause instability and may cause the load to oscillate over temperature.

1.Start this part of the adjustment process after only turning on the proportional mode from the system control.

2.Use the load oscillation period (seconds) measured in Section 2.8.2.Divide 1000 by the oscillation period to get the integral setting.

3.Input the integral setting into the TC290 temperature controller and observe that the load temperature is close to the set value.

4.Adjust the integral settings if necessary:

a.If the temperature is unstable and starts to oscillate around the set point,the integral is set too high and should be reduced by half.

b.If the temperature stabilizes but never reaches the set point,the integral is set too low and should be doubled.

5.Verify the integral setting by making some small (2 K to 5 K) changes in the set point and observe the response of the load temperature.

The trial-and-error approach helps to improve the integration setup by optimizing for experimental needs.For example,faster integration is replaced by larger overshoot,the price reaches the set point faster.In most systems,set point changes that increase temperature act differently than changes that decrease temperature.

If the oscillation period of the load cannot be measured during the proportional setting,start with the integral setting of 20.If the load becomes not to stabilize,lower the setting in half.If the load is stable,make a series of small,2 to 5 degree changes in the set point and watch the load react.Continue to increase the integral setting until the desired response is achieved.

2.8.4 Tuning Derivatives

Derivatives should be considered if the experiment requires frequent set point changes.See Figure

2-2(e).When the control system is rarely changed,It is recommended to set the derivative to 0 (off) and take the data when the load is in a steady state.

The derivative setting is entered into the TC290 temperature controller as a percentage of the integral time constant.The setting range is 0–200%,where 100%=1/4 second.Start with a setting of 50% to 100%.

Again,don't worry about making some small set point changes ;halve or double this setting to see the impact.Positive set-point changes are expected to respond differently than negative set-point changes

2.9 Autotuning

Selecting the appropriate PID control settings can be tedious.The system may take several minutes to complete the setpoint change,making it very difficult to difficult to observe the display's oscillation period and signs of instability.The TC290 temperature controller has an auto-tuning function that automatically adjusts the tuning process and calculates the setpoints of P,I,and D by measuring system characteristics,as well as some assumptions about a typical cryogenic system.Autotune works with only one control loop at a time and does not set manual outputs or heater ranges.Setting an inappropriate heater range is potentially dangerous for some loads,so the TC290 temperature controller cannot automatically adjust this step of the process.

When autotune is initiated,a step change is applied to the setpoint and the system response is observed to determine the best tuning parameters.

The auto-tuning prompt appears during auto-tuning,and the status bar at the top of the screen displays"PID tuning".If the tuning process is completely successful,the prompt message is cleared and new PID parameters are configured.If the algorithm fails,the message"PID error"will be prompted and will remain displayed,indicating that the auto-tuning process has failed.It can be cleared in Alarm Settings - Alarm Reset.

In some cases.auto-tuning is not the answer. When the cooling system is fast or slow.the thermal lag is large.or there is a nonlinear relationship between the heater power and the load temperature.the algorithm can be fooled easily..If a load can reach a new set point (proper I-set value > 500) within 10 seconds,then the cooling system is too fast for auto-tuning.The system can be this fast with very little heat.Adding mass is a solution,but not for users who need speed.Manual tuning is not difficult in these systems,as new settings can be tested quickly.Some systems are too slow for the autotune algorithm.Any system that takes more than 15 minutes to stabilize at the new setpoint is too slow (appropriate i-setpoint < 5).

Thermal hysteresis can be improved by using the sensor and heater mounting techniques discussed in Sections 2.4 to 2.6.the time should be a few seconds;too much lag time can be a problem.System nonlinearity is an issue with both auto-tuning and manual tuning.It is most often noticed when controlling temperature control systems near maximum or minimum temperatures.This is not uncommon;however,it is for the user to purchase a cryogenic cooling system designed to operate near the minimum temperature.If this is the case,try turning the system 5 degrees above the minimum temperature and gradually lower the setpoint,manually adjusting the control settings at each step.Any time the mechanical cooling action of a cryocooler can be seen as periodic temperature fluctuations,the mass is too small or the temperature is too low to automatically tune.

2.10 Zone Tuning

Once a PID tuning parameter is selected for a given set point.the entire process may need to be redone for other set points with different setting requirements.Trying to remember which set of optimization parameters to use when can be difficult.The TC290 temperature controller has a zone function as one of its adjustment modes,which can help achieve this.

To use the zone function,the optimal tuning parameters must be determined for each part of the temperature range to be applied.Then enter the parameter into the TC290 temperature controller where up to 10 zones can be defined with different P,I,D,heater ranges,manual outputs,ramp rates and control input settings.Specify the Upper Bound setting as the maximum temperature for the area.The minimum temperature of a region is the upper limit of the previous region,and 0 K is the starting point of the first region.When zone tuning is on,the appropriate control parameters are automatically selected each time the setpoint is changed.Zone tuning works best when used in conjunction with setpoint ramps (section 4.5.1.5.7).

You can determine the control parameters manually or use the auto-tuning function. Auto-tuning is a good way to determine a set of tuning parameters for a control system that can be used as area inputs (Section 2.9).

2.11 Thermoelectric devices

Thermoelectric devices,sometimes referred to as Peltier devices or solid-state heat pumps,are devices that utilize the Peltier effect.When a direct current is applied,heat is transferred from one side of the device to the other.By changing the polarity of the current,heat can be transferred in either direction.Thermoelectric devices have both heating and cooling capabilities,making them ideal for controlling temperatures close to room temperature.Since thermoelectric devices are solid state,they do not have the mechanical vibrations associated with mechanical coolers.Some thermoelectric coolers,when stacked together,are capable of cooling equipment to low temperatures (about 100K).These are typically used to cool and maintain the temperature of charge-coupled device (CCD) sensors.

Since thermoelectric devices can both heat and cool,they require a controller with a bipolar output to take advantage of this.

The TC290 temperature controller can be configured with output 3 for bipolar control.Closed-loop PID control works the same in bipolar mode as in unipolar mode,except that the output can go negative instead of stopping at zero.See Section 5.4 to set output 2 to bipolar mode.

The TC290 temperature controller cannot directly drive the thermoelectric device.Most thermoelectric devices require high current (about 3 A) and low voltage (usually less than 10 V).Output 3 is capable of ±100 mA.An external power amplifier is necessary to boost the power to a level that will effectively control the thermoelectric device.See Section 3.8.5 for more information on external power amplifiers using output 3.

Chapter 3 Installation

3.1 General

This chapter provides general installation instructions for the TC290 temperature controller.Read all of this chapter before installing and turning on the power content to ensure optimum performance and maintain operator safety.See Chapters 4 and 5 for instrument operating instructions.See Chapter 6 for installation and operation of the computer interface.

3.2 Inspection and Unpacking

Before opening the box,inspect the box for external damage.Before opening any container with

significant damage,take a photo.Check all items for visible and hidden damage during transit.If the contents of the box are visibly damaged,
please contact the shipping company and MAG immediately, preferably
within five days of receipt,for guidance on how to file a
proper insurance claim.MAG products are insured against damage during transportation,but claims must be made in a timely manner before MAG takes further action.Procedures vary by carrier.Keep all damaged shipping materials and contents until instructed to return or discard.
Open the shipping box and save the box and shipping materials until all contents have been counted.Check packing when unpacking every item on the list.The instrument itself can be shipped as multiple parts.The items included in the TC290 temperature controller are shown below.If there is a shortage of parts or accessories,please contact MAG immediately.If MAG is not notified within 30 days of shipment,MAG
will not be responsible for any lost items.
If an instrument must be returned for recalibration,replacement,or repair,a company sales representative must be notified by telephone prior to return.
TC290 temperature controller includes components:
1.1 set of TC290 temperature controller.
2.1 copy of TC290 temperature controller user manual or CD.
3.Sensor input connector,5-pin DIN (71430-250/0802) 2 pcs.
4.Heater output connector,double banana,for heater output 1 and 2 2 sets.
5.D-SUB connector 26P+ protective shell,2 sets for 8-way expansion board.(Optional accessories)
6.1 AC220V power cord

3.3 Definition of rear panel

This section describes the rear panel connections of the TC290 temperature controller.The rear panel consists of input A,B sensor input connectors (Figure 3-1 in 6),Output 3 analog voltage output and relay 1 and 2 terminal block connector (4),signal trigger interface connector (5),RJ-45 Ethernet connector (2),USB Type B connector (1),RS-485 interface connector (3),power input assembly (9),output 1 and 2 heater output connectors (8) and 8 expansion card inputs (7)..See

Section 3.5.1 for details on the rear panel header pins.

Warning:Always turn off the instrument before making any rear panel connections.This is especially important when connecting sensors to instruments.

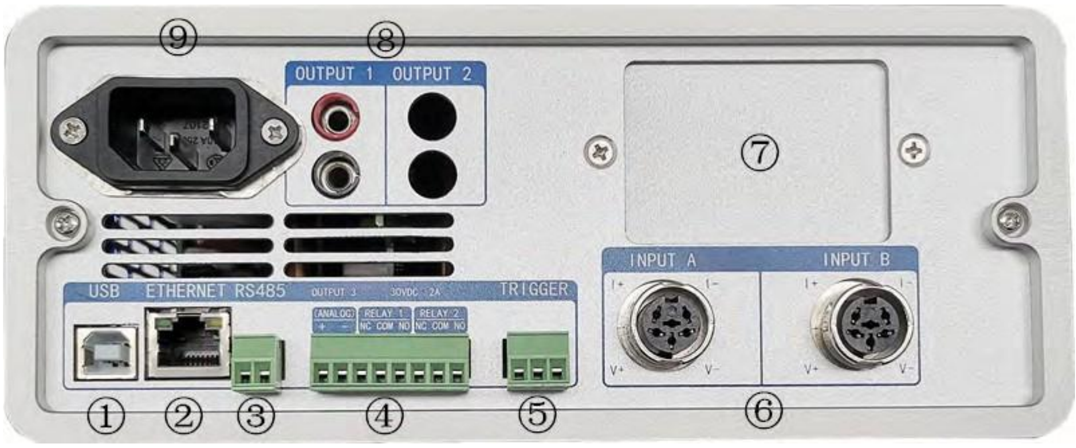


Figure 3 - 1 TC290 temperature controller rear panel

3.4 Power input

This section describes how to properly connect the TC290 temperature controller to line power.Please follow these instructions carefully to ensure that the instrument correct operation and operator safety.

The rated voltage of TC290 temperature controller is AC220V,the allowable range:AC90-264V,so it can adapt to many places in the world square voltage standard.

The TC290 temperature controller includes a 3-conductor power cord that mates with an IEC 320-C14 power cord receptacle.on both sides of the socket line voltage is present on the conductors and the center conductor is the safety ground.A safety ground is attached to the instrument enclosure to protect the user in the event of component failure.

WARNING:Always plug the power cord into a properly grounded outlet to ensure safe operation of the instrument.

TC290 temperature controller has no hardware switch.when the power cord is connected.the instrument will be in the live state.but the instrument will be in standby mode.consumption of small power.if the instrument is not used for a long time.should be unplugged.

3.5 Diode/Resistive Sensor Input

This section details how to connect diode and resistive sensors to the TC290 temperature controller Standard Input and the TC2901 Model 8-Way channel scan expansion card input channel.Refer to Section 4.4 to configure the inputs.See Section 3.6 for a description of the optional capacitive input and Section 3.7 for a description of the thermocouple input.

3.5.1 Sensor Input Connectors and Pinouts

The A and B channel input connectors are 5-hole DIN71251-250 sockets.Sensor socket pins are shown in Figure 3-2 and Table 3-2.two matched connectors (5-pin DIN plugs) are included in the connector kit included with the instrument.These are universal connectors,so additional matched connectors can be purchased from your local electronics supplier.It can also be ordered with MAG .

Figure 3 - 2 sensor input connectors

Pin	Dymbol	Description
1	I -	Current negative
2	V -	Voltage negative
3	none	shield
4	V +	Voltage positive
5	I+	current positive

Table 3 - 2 Diode/Resistor Input Connector Details

The 8-channel expansion card input connectors are two 25-hole DB25 sockets,and the pins of the sensor sockets are shown in Figure 3-3 and Table 3-3.two matched connectors (25-pin DB connector plugs) are included in the connector kit included with the instrument.

Figure 3 - 3 8 way expansion card sensor input connectors

DB25 sensor interface pin definition:

The first input:3 :I + 15:I- 4:V+ 16:V-

Second input:6 :I + 18:I- 7:V+ 19:V-

The third input:9 :I + 21:I- 10:V+ 22:V-

Fourth input:12 :I + 24:I- 13:V+ 25:V-

The rest of the pins are shield function pins.

Table 3-3 Details about the input connectors of the 8-way expansion card

3.5.2 Sensor Lead Cable

The sensor lead cables used outside the cooling system can be very different from the cables used inside.between the instrument and the vacuum enclosure,there is no heat leakage problem.In this case,the choice of cable should be based on minimizing error and noise pickup.For larger conductors,22 AWG to 28 AWG stranded copper wire is recommended because when stranded in a single cable it has lower resistance but still remains flexible.The arrangement of the wires in the cable is also important.For best results,voltage leads,V+ and V- should be twisted together and current leads I+ and I- should be twisted together.The twisted pairs of voltage and current leads should then be wrapped in braided or foil shields attached to the instrument shield pins.Cables of this type are available through local electronics suppliers.Assuming the instrument specification gives a sensor cable of 3 meters (10 feet),30 meters (100 feet) or longer cables can also be used,but environmental conditions may degrade accuracy and noise specifications.See Section 2.4.6 for information on wiring inside the cryostat.

3.5.3 Ground and Shield Sensor Leads

The sensor input needs to be isolated from ground to reduce the amount of ground-referenced noise present on the measurement leads.Connect the sensor to grounding in the instrument case or cooling system will destroy this isolation.Ground leads on multiple sensors prevent the sensor excitation current source from operating.

Shielded cable for sensor leads is important to prevent external noise from entering the measurement.When the shield is close to the measuring potential,shielding is most effective,so the TC290 temperature controller provides shielding at the measurement common.The shield of the sensor cable should be connected to the shield pin of the input connector.The shield should not be connected to the ground of the instrument case.If the cryostat is close to the ground wire,the ground terminal of one temperature controller should be connected to ground.Grounding multiple points will result in ground loops,which can add noise to the measurement.

3.5.4 Sensor Polarity

The MAG sensor comes with instructions explaining the specific definition of the sensor leads.For positive and negative leads (polarity) and voltage and current (if applicable),be sure to follow these instructions.A diode sensor cannot work with the wrong polarity because it is open circuit to the instrument.The two lead resistors will work with any lead arrangement,the sensor description may not be specified.The resistance of the four leads must be connected exactly according to the rules laid down by the lead arrangement,and messy wire connections can result in readings that look correct but not the most accurate.

3.5.5 Four-wire sensor measurement

All sensors,including two-wire and four-wire,can be measured with the four-wire technique.Four-lead measurement the purpose is to eliminate the effect of lead resistance on the measurement.Without leads,the lead resistance will introduce errors when measuring the sensor. In a four-lead measurement,the current and voltage leads lead to the sensor,respectively.For independent voltage leads,the leads there is very little current in them,so their resistance is not introduced into the measurement.Resistance in the current leads will not affect the measurement as long as the upper voltage output of the current source is not reached.When a two-pin sensor is used in a four-lead measurement,the resistance of the short wire on the sensor is insignificant and the effect is negligible.

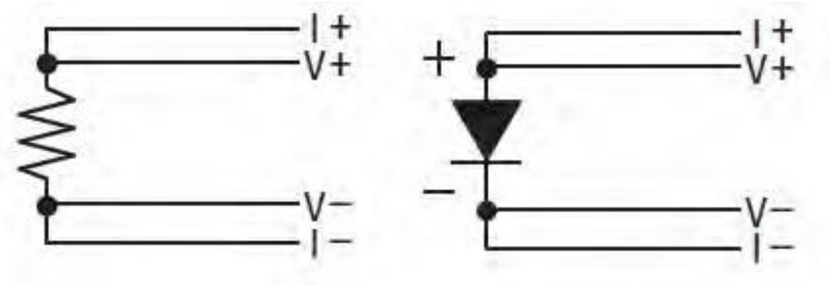


Figure 3 - 4 4 lead measurement

3.5.6 Two-wire sensor measurement

Occasionally,crowding in cryogenic systems forces users to adopt dual-lead sensors due to insufficient lead or lead space.If this is the case,the positive voltage-positive current and negative voltage-negative current leads should be connected at the cryogenic system vacuum leads.

Errors in resistance measurements are caused by the voltage drop that occurs when the resistance of the leads passes current.If the lead pair reads 10 kΩ affects 2Ω or 3Ω,the error can be ignored.When measuring the voltage of a diode sensor,the voltage error can be calculated as the lead resistance times the current,which is typically 10μA.

Example:10Ω lead resistance multiplied by 10μA results in a voltage error of 0.1 mV.Considering that the silicon diode is at 4.2 K sensitivity,the temperature error is only 3 mK.at 77 K,the sensitivity of the silicon diode is lower,so the error is close to 50mK.Again,this may not be a problem for users.Connectors are also a large source of error when making two-wire measurements.Splice contact resistance is unpredictable and varies with time and temperature.Minimize interconnections when making two-wire measurements.Refer to Figure 3-5 for a concept of two-wire sensor measurements.

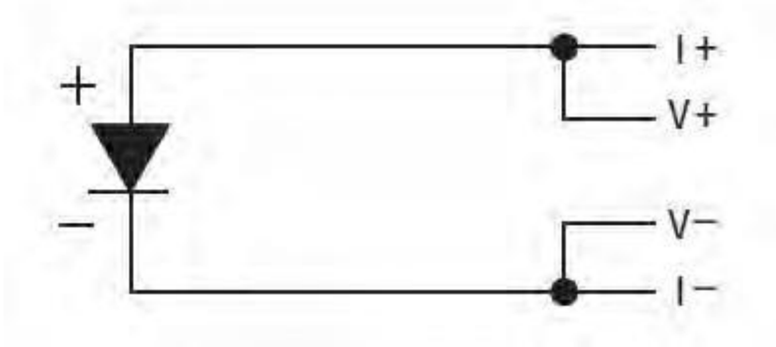


Figure 3 - 5 2-wire sensor measurement

3.5.7 Reducing Measurement Noise

Good instrument hardware setup techniques are one of the cheapest ways to reduce measurement noise.Recommendations are divided into two categories:(1) do not let the external noise enter the measurement range;(2) let the instrument isolate and make the most of other hardware functions.Here are some further suggestions:

1.Use the four-wire method to measure as much as possible.

2.Do not connect sensor leads to the outer shell or ground.

3.Use cross-shielded cables outside the cooling system.

4.Connect the shield pin on the sensor connector to the cable shield.

5.Do not connect multiple cable shields on the other end of the cable.

6.Run the different inputs and outputs in their respective shielded cables.

7.Use stranded wire in the cooling system.

8.Use a similar technique for the heater leads

9.Use a grounded socket for the power cord of the instrument.

10.Consider grounding the instrument case to other instruments or computers.

3.6 Capacitive sensor input (TC2903 expansion card)

This section provides information on configuring the capacitive sensor expansion card.Capacitive inputs are not installed on standard TC290 temperature controllers,but can be added by purchasing the TC2903 capacitor expansion card input option.For the installation of the TC2903 expansion card,please consult the MAG .

The TC2903 expansion card adds two capacitive inputs to the TC290 temperature controller,which are displayed as inputs C and D.The card provides the sensor,for independent voltage feedback and current excitation.The TC2903 expansion card is designed to control temperature in strong magnetic fields using the LakeShore Model CS-501 Capacitive Temperature Sensor.Standard input remains in the instrument,fully functional.

Note :After changing the control to capacitive sensor,the PID value needs to be optimized.

The TC290 temperature controller does not support the temperature conversion of capacitive input,and the temperature response of the capacitive sensor changes with the thermal cycle,making calibration is unpredictable.All Model 3061 optional measurement and control must be done in the sensor unit.With this option,two sensors should be installed at the control point.A resistive sensor is used on one of the standard inputs to establish control temperature and stabilize the system in low magnetic fields.Switch control to the capacitive sensor to maintain the current temperature before increasing the magnetic field strength.

3.6.1 Wiring,protection and shielding

Capacitive input uses the same 6-pin DIN connector as standard input,and the same pins for current excitation and voltage feedback.Cable capacitance in longer cables can cause erroneous sensor readings if proper protection and shielding are not used.To address this,a driven guard is provided on pin 6 and a shield pin is provided on pin 3.The guard pins should be connected to a foil shield that surrounds a twisted pair for I+ and V+.The shield for pin 3 should be connected to the foil shield that surrounds the twisted pair for I- and V-.See Figure 3-6.This wiring scheme is necessary to ensure correct sensor readings using the TC2903 Capacitive Expansion Card.

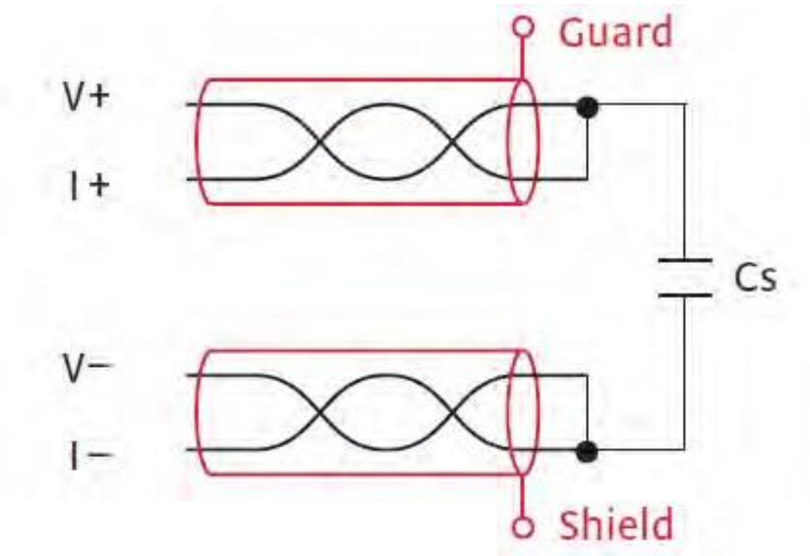


Figure 3 - 6 Capacitor Input Shield and Connection

NOTE:The 3.496 kHz excitation of the tab can interfere with sensitive DC measurements on the standard input.Twist the leads of each sensor and separate it from the leads of the other sensor.Test any system for sensor interference before sealing permanently.

3.7 Thermocouple sensor input (TC2902 expansion card)

The information in this section applies to the TC290 temperature controller configured with a thermocouple sensor input.The thermocouple input is not installed in the standard TC290 temperature controller,but can be added by purchasing the TC2902 dual thermocouple expansion card.For the installation of the TC2902 expansion card,please consult the MAG .

NOTE :Do not leave the thermocouple input disconnected.short circuit input when not in use.

3.7.1 Sensor input terminal

Connect the sensor wires to the screws on the off-white ceramic breakout board.When using thermocouples,the sensor connection is important,Because the measurement signal is very small.Correctly installed sensors can avoid many measurement errors.The module has two thermocouple inputs,each with two screw terminals;one positive and one negative.See Figure 3-7. Remove all insulation and tighten the screws on the thermocouple wires.Keep ceramic terminal blocks away from heat sources (including sunlight),and separate it from fans or room ventilation.

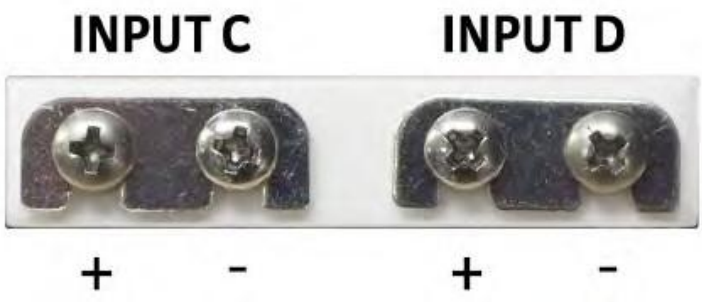


Figure 3 - 7 Thermocouple Input Definitions and Common Connector Polarity (showing input shorts)

3.7.2 Installation of thermocouples

Thermocouples are often used in high temperature applications.Using thermocouples at low temperatures presents some special challenges.Section 2.4 provides the generic installation guide.When using thermocouples at low temperatures,the following points should be considered:

1.Thermocouple wires generally conduct more heat than other sensor wires.To prevent the leads from heating the sample,smaller gauge wires and more thermal anchoring may be required.

2.In cryogenic systems,it is often necessary to connect wires and route them through vacuum-tight fittings.Remember,a thermocouple wire is a sensor;any time it connects or touches other metals,something can go wrong.

3.After the sensor is installed,it is difficult to perform temperature calibration and room temperature compensation calibration.Where possible,keep a spare wire from each unit for future use.

4.As long as the cryostat has a potential close to ground,a thermocouple can be spot welded to the cryostat for good thermal anchoring.

3.7.3 Grounding and shielding

When grounding thermocouple inputs,care must be taken to minimize noise generated by ground loops.For the lowest measurement noise,no ground the thermocouple sensor.If one of the thermocouples is grounded,the instrument will operate slightly louder.Make sure to minimize loop area when both thermocouples are grounded.The instrument does not provide a shield connection on the terminal block.Twisted thermocouple wire helps eliminate noise.If shielding is required,extend the shield from the oven or cryostat to cover the thermocouple wires,but do not connect the shield to the instrument.

3.8 Heater output settings

The following sections describe heater wiring from the vacuum enclosure to the meter between the two heater outputs.Specifications in Section 1.3.and See Section 2.5 for help in selecting and installing the appropriate resistance heater.

3.8.1 Description of heater output

Both power heater outputs (outputs 1 and 2) are conventional control outputs for cryostats.Both are variable DC Current source with software-settable ranges and limits.Both can be configured to use 25Ω or 50Ω heater resistors.At the 50Ω setting,both outputs are limited to a maximum output current of 1 A.Both outputs are limited to a maximum output current of 2 A at the 25Ω setting.The compliant voltage for each output is 50 V minimum,but can go up to 55 V if the heater resistance is higher than the rated setting.Heater power can be selected from one of three levels:high,medium or low.Each gear is ten times less powerful.See Table 4-14 for maximum current and power ratings for different heater resistors.

3.8.2 Heater output connector

Dual banana jacks on the rear panel of the instrument are used to connect wires to the heater outputs.Included in the connector kit included with the instrument two standard dual banana plug matched connectors.This is a regular jack,additional matched connectors can be purchased from your local electronics supplier,or from MAG .The heater is connected between the HI and LO terminals.

Figure 3 - 8 Rear panel showing heater output connectors

3.8.3 Heater output wiring

The heater output current determines the size of the wires required to connect the heater.The maximum current available from heater output 1 is 2A.When the cooling system needs less current to supply power,it can be limited by the gear setting.

When setting up a temperature control system,the heater wires must be able to carry a continuous current greater than the maximum current.wire manufacturing dealer recommends 26 AWG or larger wire to carry 2 A,but there is little advantage to using wire smaller than 20 AWG to 22 AWG outside the cryostat.Inside the cryostat,smaller gauge wires are usually required.

Twisted pair heater wires are recommended.Large changes in heater current can cause noise in the measurement leads,and twisted pairs can reduce impact.It is recommended to separate the heater leads from the measurement leads to further reduce interaction.

For best noise performance,do not connect resistive heaters or their leads to ground.Also do not connect the heater leads connect to sensor leads or any other instrument input or output.

3.8.4 Heater output noise

The output circuit of the TC290 temperature controller heater is capable of delivering 100 watts of power.This circuit generates some electrical noise.The TC290 temperature controller is designed to generate as little noise as possible,but even a small fraction of the output voltage or current can generate too much noise when making sensitive measurements nearby.

3.8.5 Use output 3 to control external power supply for power supply

When used in preheat control mode,output 3 cannot directly power the heater.This unpowered output must be used to program external power supply to power the heater.This section describes the selection and installation of an external power supply.Section 5.5 describes the operation of the preheat control mode.

3.8.5.1 Selecting the power supply

1.Voltage programmable:The power supply must be voltage programmable so that output 3 (control output) can control it.Ideally,the programming input of the power supply should have a range of 0 to 10 V,which corresponds to the 0 to 10 V range of the control output.This ensures that the 0 to 100% control output is within the 0 to 100% power supply output range.Power supplies with different programmed input ranges can be used as described in Section 3.8.5.4.

2.DC output capability:The power supply must be capable of continuous DC output.Most commercial audio amplifiers are not suitable because they are AC coupled and cannot provide a DC output.

3.Output type:Most voltage programmable power supplies are configured as voltage outputs.This is different from outputs 1 and 2 configured for current output on the TC290 temperature controller.The difference between the two is not significant when used in warm-up mode.

4.Output voltage:MAG recommends that the working output voltage be between 10 V and 50 V.Voltages above 50 V present a shock hazard and should only be used if the installer can ensure the safety of the operator.Voltages lower than 10 V become impractical because the voltage required to provide useful current is much higher than this for most low temperature wiring.

5.Output Power:There is no limit to the maximum power of the power supply.Typical preheat applications are usually between 25 W and 200 W.

3.8.5.2 Power Settings

During installation,follow all operating and safety instructions in the power supply manual.Consider the following recommendations for protecting power and heater loads.

1.In low temperature wire routing,short circuits are common.If the power supply is not specified for short-circuit protection,the power supply output should be wired with a series fuse to prevent damage.

2.Unipolar power supplies are designed to use a positive programming voltage,and some supplies may be damaged if the programming voltage is negative.Be careful when connecting the system to maintain the correct polarity.Also do not set the control output of the TC290 to bipolar mode.

3.Some power supplies may be damaged if programming voltages are present on the inputs when the power is turned off.This can happen if the TC290 temperature controller and power supply are turned on and off separately when using different line power sources.This can be avoided if both meters share a switching power strip.

4.The heaters and wiring in the system must be rated for the maximum current and maximum voltage the power supply can provide.If the load cannot handle the full power of the power supply,the TC290 temperature controller can be set to use less than full power to preheat.

3.8.5.3 Connecting to TC290 temperature controller

The voltage programming cable is connected to the removable terminal block on the rear panel of the TC290 temperature controller (Figure 3-9).The polarity of the output leads is shown on the silkscreen.The negative (–) terminal is internally connected to the instrument common to provide a ground reference.

Figure 3 - 9 output terminals

In the most basic configuration,a two-conductor cable is connected directly from the output terminal to the power programming input.Recommended copper wire size is 20 AWG to 26 AWG.

3.8.5.4 Programming voltage below 10V

If the programming input voltage range of the power supply is less than 0 V to 10 V,the voltage divider of Figure 3-10 can be used to reduce the control output voltage to ensure full output resolution and prevent overloading of the programming input of the external power supply.The output voltage is proportional to the ratio of resistors R1 and R2:Vout=10V x R1/(R1+R2).It is also important to keep the sum of R1+R2>1000Ω,otherwise the TC290 temperature controller output may not reach the output voltage setting due to the internal overload protection.For a programmed input range of 0 V to 5 V,the recommended values are:R1=R2=2000Ω.For a programmed input range of 0 V to 1 V,the recommended values are:R1=500Ω,R2=4500Ω.The exact resistance value,type and tolerance are usually not important for this application.

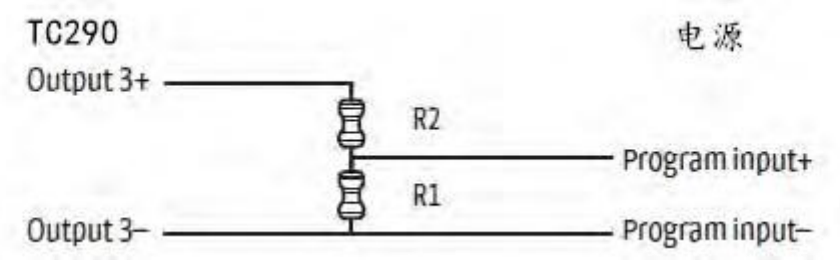


Figure 3 - 10 output 3 voltage divider circuit

Chapter 4 Operation

4.1 General

This chapter describes the general operating characteristics of the TC290 temperature controller.See Chapter 5 for advanced operations.See Chapter 6 for a description of the computer interface.

4.2 Front panel description

4.2.1 Description of the main interface of the touch screen

Status line: It can display the operating status of remote mode,temperature alarm,temperature overrun,PID tuning PID error,etc.

Input display: Display the name,temperature value,maximum value,minimum value,etc.of the input channel.

Loop display: Display the input channel,loop mode,temperature control point,heater status,pid status,etc.associated with the current loop.

Switch page:switch to other input channel display page.

Graph: Set to display the temperature sampling curve graph of each input channel.

Control: Quickly set the common parameters of the control loop.

Setting: Enter the setting menu to set all parameters.

Heater: Quickly set common parameters of heater.

4.2.2 Description of touch screen setting interface

Input settings: Set the sensor type,auto range,temperature control output,input name,preferred unit,filter,curve,expansion card,etc.of the 10 input channels.

Output setting: Set the control mode,temperature control point,temperature measurement channel,PID,heating rate,manual output of the two output loops,and the display mode,load resistance,heating power,maximum output current,etc.of the 3-way heater.

Display settings: Set the display mode of the main display interface,which is divided into monitoring display and temperature control display.The monitoring display can display the input data of two,four or ten sensors on one page;the temperature control display has more control loops than the monitoring display.The display can display loop 1,loop 2,and both loops at the same time.

Reading reset: It can display the maximum and minimum temperature of ten input channels,and can reset the maximum and minimum values to zero.

Curve entry: The sensor curve can be viewed,edited,copied,and deleted.For a single curve,the name,serial number,number of points,data format,and upper temperature limit can be edited,and the curve points can be manually entered and modified.

Zone setting:10 zones can be set for each of the two control loops for precise temperature control in sections,including loop selection,zone number,temperature measurement channel,manual output,pid,heating power,upper boundary,heating rate and other parameter settings.

PID tuning: Set the loop and PID tuning mode of PID tuning.

Remote mode:switch between remote and local mode,and automatically switch to remote mode when communicating with the instrument.After communication,you need to manually switch to local mode to operate the touch screen.

Interface setting: Set 458 communication baud rate,communication address,communication instruction set.

Relay setting: Set the control parameters of two relay outputs,including working mode,alarm input,and alarm mode.

Alarm settings: Set the alarm parameters of 10 input channels,including high temperature alarm point,low temperature alarm point,temperature dead zone,temperature protection,state latch,sound alarm,display alarm,and alarm state reset.

System settings:including clock settings,factory reset,screen brightness adjustment,system language,touch tone,etc.

4.3 Display Settings

The front panel uses a 5-inch color capacitive touch screen,the display is very clear,and can display up to 10 readings at the same time.

4.3.1 Display Mode

The TC290 temperature controller offers two display modes designed to accommodate different instrument configurations and user preferences.Monitor display mode provides large-format sensor readings for 1 to 10 sensor inputs on one screen,along with input-related information.The temperature control display mode provides information on the sensor input as well as the set point and heater output of the loop output.

Menu navigation:Settings - Display Settings - (monitoring display,temperature control display).As shown below:

4.3.2 Monitoring Display Mode

There are four types of monitoring display modes:two inputs,four inputs,ten inputs,and valid inputs.

Two input channels display the data and related information of two input channels on each page of the main interface.Four and ten inputs is to display four and ten input information respectively.The valid input is to display the input data of the four sensors.In addition to displaying the A and B channels,when the 8-channel expansion card scanning is closed,the C and D channels are automatically displayed as the currently selected fixed channels,and the other invalid channels of C and D are not.display mode.

Menu Navigation:Settings - Display Settings - Display Mode - (Two Inputs,Four Inputs,Ten Inputs).Enter as shown in Figure 10:

4.3.3 Temperature control display mode

The temperature control display mode adds the display of the output loop on the basis of the monitoring display mode.

The output loop can choose loop 1,loop 2 and two loop display.loop 1 indicates that the parameters of loop 1 are displayed on the home screen,loop 2 is to display the relevant parameter information of loop 2 on the main interface,and two loops is to display the relevant parameter information of loop 1 and loop 2 on the main interface.

Note: In the temperature control display mode,the output loop parameters displayed on the main interface can be directly modified by touching this parameter.

Menu Navigation:Settings - Display Settings - Output Loops - (Loop 1,Loop 2,Two Loops).Loop 1 as shown below:

4.4 Input settings

The TC290 temperature controller supports a wide range of temperature sensors from DEXINM AG and other manufacturers.The appropriate choice must be made for each input the appropriate sensor type.If an accurate sensor model is not shown,use the sensor input performance table in Table 4-1 to select an input type with similar range and excitation.For more details on the sensor,please refer to the instruction manual attached by MAG . **NOTE:**Any unused inputs should be set to disabled.

Sensor Type	Display	Input	Excitation	Coefficient	Curve	Sensor Model

	Message	Range	Current		Format	
silicon diode	diode	0V–2.5V	10 µA,1 mA	negative	V/K	DT-400 series,DT-500 DT-670 series
GaAlAs diode	diode	0V–10V	10 µA,1 mA	negative	V/K	TG-120 series
Platinum resistance Rhodium Iron Resistors	PTC RTD	0Ω to 10K –	1 mA	positive	Ω /K	PT-100 Platinum Series RF-800 RF-100 Rhodium Iron
negative temperature Coefficient RTD	NTC RTD	0 Ω to 10 0 K	100nA to 1mA	negative	Log Ω /K	Cernox™,Carbon Glass Germanium,Rox™ and Thermox™
Thermocouple	Thermocouple	± 50mV	NA	positive	mV/K	Chromel- AuFe (0.07%) TypeE (Chromel-Constantan) TypeK(Chromel-Alumel) TypeT(Copper-Constantan)

Table 4 - 1 Sensor Input Type

Menu Navigation:

Settings-Input Settings - Select Input (A,B,C,D) - Sensor Type (Off,Diode,PTC,NTC,Thermocouple).

4.4.1 Diode Sensor Input Settings

Diode sensors include silicon and gallium aluminum arsenide sensors,see Table 4-1 for details.Input range selectable from 0–2.5 V or 0–10 V,the standard excitation current is 10 µA. As an alternative to the standard diode excitation current of 10µA,you can choose a 1 mA excitation.1 mA excitation current without calibration,it will not work properly with standard MAG diode sensors.To prevent accidental setting of the 1 mA excitation current,the diode current setting is automatically set to 10 μA each time the sensor type is set to diode.

4.4.2 PTC sensor input settings

PTC resistive sensors include platinum and rhodium iron sensors detailed in Table 4-1.Table 1-2 provides more detailed specifications.TC290 temperature controller provides 1 mA excitation current for the PTC resistive sensor type.For better reading resolution,select the resistance range.Autoranging is enabled by default to provide the best reading resolution without affecting sensor current excitation.See Section 4.4.4 for details on manually selecting ranges.To compensate for the thermo-EMF voltage,current reversal is also enabled by default.See Section 4.4.5 for details on the Thermal EMF Compensation (Current Reversal) feature.

4.4.3 NTC sensor input settings

NTC resistive sensors include cernox™,rox,thermox,and other sensors detailed in Table 4-1.More specifications detail are shown in Table 1-2.Depending on the resistance range,the excitation current of the NTC RTD sensor type can vary between 100 na and 1 ma.When autoranging is enabled,the range is automatically selected so that the excitation voltage is below 10 mV.This will keep the power consumption of the sensor to a minimum,but still be sufficient to provide accurate measurements.To compensate for the thermo-EMF voltage,current reversal is also enabled by default.See Section 4.4.5 for details on the Thermal EMF Compensation (Current Reversal) feature.

4.4.4 Range selection

The TC290 temperature controller is equipped with an automatic range change function,which can automatically select the appropriate resistance range for the connected resistance temperature device.In some cases,manual resistance range selection may be required.To manually select the resistance range,set the Autoranging parameter to Off,then use the Range Setting parameter to select the desired range.Autorange is turned on by default when the Sensor Type parameter is set to PTC RTD or NTC RTD.Autoranging is not available for diode sensor types.

Sensor Type	Available Range Settings	Maximum Sensor Power	Sensor Excitation
diode	2.5 volts (silicon)	25μW (at 10μA)	10 μA,1 mA
	10V (GaAlAs)	100μW (at 10μA)	10 μA,1 mA
PTC RTD	10Ω	10μW _	1 mA

	30Ω	30μW _	
	100Ω	100μW _	
	300Ω	300μW _	
	1K	1 mW	
	3K	3 mW	
	10K	10 mW	
	10Ω	10μW _	1 mA
	30Ω	2.7μW _	300 μA
	100Ω	1μW _	100 μA
	300Ω	270μW _	30 μA
NTC RTD	1K	100 nW	10 μA
	3K	27nW _	3 μA
	10K	10nW _	1 μA
	30K	2.7nW _	300nA
	100K	1 nW	100nA _

Table 4 - 2 ranges and sensor power

4.4.5 Thermal EMF Compensation

To keep power low and to avoid sensor self-heating,the excitation of the sensor is kept low.Two major problems arise when measuring the small DC voltages generated..The first is that external noise enters the measurement through the sensor leads,which is discussed in Sensor Installation.The second is the presence of thermoelectromotive voltage or thermocouple voltage in the leads.Thermoelectromotive voltage occurs when there is a temperature gradient across one voltage lead.The thermoelectromotive voltage must be present because the temperature of the sensor is almost different from the temperature of the instrument.To minimize this,route carefully,making sure that the voltage leads are symmetrical with the type of metal used and connection,and keep unnecessary heat sources away from the leads.Even in well-designed systems,thermo-EMF voltages can be an important part of low-voltage sensor measurements. TC290 temperature controller can use thermal compensation algorithm.The instrument automatically reverses the polarity of the current source every other reading.Regardless of the current direction of flow,the average of the positive and negative sensor readings will cancel out the thermo-EMF voltage present in the same polarity.This correction algorithm is enabled by default for RTD sensor types.

4.4.6 Thermocouple Sensor Input Settings

When the TC2902 temperature controller expansion card is installed in the TC290 temperature controller.thermocouple Settings are available under the sensor type parameter in the Input Settings menu. Standard diode /RTD sensor inputs can still be used when installing thermocouple options.

Thermocouples include various commercial (e.g..E.K.T) and special types such as Cryogenic (Chromel-AUFE). For the types listed in Table 4-1.the standard curves are included in the TC290 temperature controlle. Other types can be used as long as the appropriate temperature response curve is loaded as a user curve.Typical thermocouple specifications are shown in Table 1-2. The TC290 temperature controller provides a thermocouple range without excitation.as thermocouples do not require it.

4.4.7 Capacitive Sensor Input Settings

When the TC2903 capacitor expansion card is installed in the TC290 temperature controller,under the sensor type parameter in the input setting menu,capacitor settings are available.Standard sensor inputs can still be used when the capacitive option is installed.

The TC290 temperature controller capacitive sensor does not support temperature conversion,so the temperature response curve cannot be selected.Expansion card not supported Any function of the TC290 temperature controller that requires temperature operation.

4.4.8 Eight-channel scan expansion card input settings

When the TC2901 8-channel scanning expansion card is installed in the TC290 temperature controller,8 additional channels C1,C2,C3,C4 and D1,D2,D3 and D4 are available.The TC290 temperature controller scans the channel at a lower update rate.Scanner option channels can be configured as diode,NTC resistor,or PTC resistor sensors.

TC2901 8-channel scanning expansion card can also turn off the scanning function and become a two-channel expansion card.the physical input sensor location for each channel.This results in a four-fold increase in read speed.

4.4.9 Curve selection

The TC290 temperature controller supports a wide range of temperature sensors from Dexin

Electronics and other manufacturers.After selecting the appropriate sensor type.you can select the appropriate curve.The TC290 temperature controller can use curves from multiple sources.Standard curves are preloaded with each instrument and are numbered 1 to 20.User curves numbered 21 to 64 can be used when the sensor does not match the standard curve.You can enter your own curves from the front panel or computer software.Table 4-11 provides a complete list of standard sensor curves for the TC290 temperature controller.

During normal operation,only curves matching the selected input type are displayed.If the curve to be selected does not appear in the selection sequence,make sure the curve format matches the recommended format for the selected input type.See Table 4-1.

NOTE: The instrument's sensor readings can always be displayed in sensor units.If a temperature response curve is selected for the input,its readings can also be displayed in temperature.

Curve Number	Curve Name	Sensor Type	Model	Temperature Range	Data Point
1	DT-470	diode	DT-470	1.4 - 475K	255
2	DT - 670	diode	DT-670	1.4 - 500K	255
3	DT-500-D*	diode	DT-500-D	1.4 - 365K	255
4	DT-500-E1*	diode	DT-500-E1	1.1 - 330K	255
5	reserved	--	--	--	--
6	PT-100	PTC RTD	PT-100	30 - 800K	255
7	PT-1000*	PTC RTD	PT-1000	30 - 800K	255
8	RX-102A-AA	NTC RTD	Rox RX-102A	0.05 - 40K	255
9	RX-202A-AA	NTC RTD	Rox RX-202A	0.05 - 40K	255
10	reserved	--	--	--	--
11	reserved	--	--	--	--
12	Type K	Thermocouple	Type K	3 - 1645K	255
13	Type E	Thermocouple	Type E	3 - 1274K	255
14	Type T	Thermocouple	Type T	3 - 670K	255
15	AuFe 0.03%*	Thermocouple	AuFe 0.03%*	3.5 - 500K	255
16	AuFe 0.07%	Thermocouple	AuFe 0.07%	3.15 - 610K	255
17	reserved	--	--	--	--
18	reserved	--	--	--	--
19	reserved	--	--	--	--
20	reserved	--	--	--	--
21-64	User curve	--	--	--	255

Table 4 - 3 sensor curves

After configuring the input,the temperature profile can be selected.Any standard that matches the sensor type format of the input configuration or the user's curve will be available under the Curve parameter in the Select Curve menu for this input.You can also select"None".When set to"None",front panel readouts configured for Kelvin or Celsius will display a"No Curve"message.

4.4.10 Filters

The reading filter exponentially smooths the sensor input readings.If a filter is turned on for a sensor input,this input is filtered all read values entered.This filter is a running average,so it doesn't change the update rate of the input.Filtered readings are also not used for control functions,but are used for all input functions,including max/min.

The number of filter points determines the filter bandwidth.A filter point corresponds to a new reading on that input.more points can smoother,but also slows down the instrument's response to actual temperature changes.The default number of filter points is 8,which has a 6 time constant of 4.5 s for a step change value of 45 readings.

time required to settle within 36.8% of the step value after a step change) for a given number of filter points can be obtained using the following formula:TC = 0.1 / (l n (N / (N - 1)),where TC is a time constant and N is the number of filter points.A reading is generally considered to be determined after six time constants Table 4-4 shows the sampling of filter settings and the resulting time constant,settling time,and equivalent noise bandwidth.

Filter Point	Time Constant	Settling Time (6 Time Constants)	Equivalent Noise Bandwidth
2	0.14s	0.9s	1.733 Hz
4	0.35s	2.1s	0.719 Hz
8	0.75s	4.5s	0.334 Hz
16	1.55s	9.3s	0.161 Hz
32	3.15s	18.9s	0.079Hz
64	6.35s	38.1s	0.039 Hz

Table 4 - 4 Filter Settling Time and Bandwidth

The filter window is the limit value for restarting the filter.If a single reading deviates from the filter value by more than the limit,the instrument will assume the change was intentional,restart the filter.The filter window is set as a percentage of the full scale range.

4.4.11 Enter name

To improve usability and reduce confusion,the TC290 temperature controller provides a way to assign each sensor input a name.whenever possible,the assigned input name will be used on the front panel display to indicate which sensor reading is displayed.

Menu Navigation:

Settings - Input Settings - Select Input (A,B,C,D) - Input Name.

4.4.12 Temperature Limits

The temperature limit parameter provides a way to protect your equipment from damage when any sensor input exceeds the specified temperature.When the speed limit is reached,all control outputs are turned off.This parameter is available for each of the sensor inputs.A temperature limit of 0 K will turn this feature off.

Menu Navigation:

Settings - Alarm Settings - Select Inputs (A,B,C,D) - Temperature Protection.

4.4.13 Preferred Units

The Preferred Units parameter setting determines which units are used to display setpoint and max/min parameter.Sensor readings in all display modes are also displayed in preferred units,where each sensor can be assigned a specific display unit.

Menu Navigation:

Settings - Input Settings - Select Input (A,B,C,D) - Preferred Units.

4.4.14 Max/Min

The"Max/Min"function captures and stores the highest (max) and lowest (min) readings taken since the last reset.Enter the preferred units parameter under the Settings menu to determine the units used to capture the maximum and minimum values .

The maximum and minimum values are always captured,so there is no need to turn this feature on or off.the reading is reset when the instrument is turned off.the sensor input parameters are changed.or the Max/MIN reset key is pressed.

Menu Navigation:Setup — Reading Reset

4.5 Output and Control Settings

After configuring the sensor inputs (section 4.4),the outputs can be configured.The output settings menu is used to create controls that control temperature loop,whether using feedback (closed loop) or manually setting the output (open loop).This section describes how to operate the output and control characteristics,and how to set the control parameters.Each control parameter should be considered before turning on the control loop output,otherwise the instrument may not be able to perform the simplest control functions.A good starting point is to decide which control loop to use,whether to operate in open-loop or closed-loop control mode,and which regulation mode is best for the application.Once these parameters are selected,the other parameters will also be in place.Section 2.7 of this manual describes the principles of closed loop proportional,integral and derivative (PID) control.

4.5.1 Heater output

Heater outputs 1 and 2 are the heater outputs of the conventional control loop of the cryogenic temperature controller.Both outputs are the same.Lose outputs 1 and 2 can deliver up to 100W of power,and they each contain a full set of hardware and software features,making them extremely flexible and easy to use..The heater output is a well regulated DC output.This provides quiet,stable control and a wide range of temperature control systems in one integrated module.The power range of each output offers three gears of high,medium and low.

Heater outputs 1 and 2 can also be configured to be controlled by Loop 1 simultaneously,allowing Loop 1 to deliver up to 200W output.It is very suitable for some occasions that require high power.

4.5.1.1 Maximum Current and Heater Resistance

The output of the TC290 temperature controller heater is designed to work best with 25Ω or 50Ω heaters.Heater Resistance and Maximum Current parameters can limit the maximum available power into the heater.This helps prevent heater damage or limit the maximum heater power entering the system.When using a 25Ω or 50Ω heater,the maximum current setting will provide multiple current limits corresponding to the heater power rating when the heater resistance parameters are set accordingly.These parameters work in conjunction with the heater gear parameters (section 4.5.1.5.8) to provide safety and flexibility.

If not using a standard heater resistance,set the heater load resistance to 25Ω for resistances less than 50Ω.For resistances higher than 50Ω,the heater load resistance is set to 50Ω.The user maximum current setting is useful when using non-standard heater resistance values.See Section 4.5.1.1.1 for more information on user maximum current.Tables 4-5 provide examples of different heater resistance and maximum current settings and the resulting maximum heater power.

Menu Navigation:

Settings - Output Settings - Heater 1 or 2 Settings - (Load Resistance,Maximum Output Current)

4.5.1.1.1 Self-set maximum current

When using heaters other than 25Ω,100 W or 50Ω,50 W,there are several fixed value may not be appropriate.The self-set maximum current setting suffices for this situation.The optimum maximum current value should be calculated based on the rated power of the heater or the desired maximum heater output power,whichever is lower.To maximize heater setting resolution,the heater output consistency voltage (50 V for both heater outputs) should also be considered.The current limit for this calculation can then be entered using the"Customize Max Current"setting.

To calculate the maximum current setting based on the heater or load power limit,use the following two formulas to calculate the current I =Sqrt(P/R) and I = 50 V/R,where P is the maximum allowable power and R is the heater resistance.With both the load power limit and the voltage compliance limit in place for the heater output (50 V),the lower current calculated is the correct maximum current setting.

Example 1:A 50Ω,30 W heater connected to output 1.

Power Limit Voltage Compliance Limits

I = Squrt(P/R)	I = 50 V/R
I = Squrt(30W/ 50Ω)	I = 50V /50Ω
I = 0.77A	I = 1A

The self-set maximum current should be set to the lesser of the two or 0.77 A.In this example,the heater gets the required 30 W power.

Example 2:A 75Ω,50 W heater connected to output 1.

Power Limit Voltage Compliance Limits

I = Squrt(P/R)　　　　　　I = 50 V/R

Squrt (50W/75Ω)　　　I = 50V /75Ω

I = 0.81A　　　　　　　　I = 0.66A

The self-set maximum current should be set to the lesser of the two or 0.66 A.In this example, The heater can only get 33 W of the required 50 W of power.

To enter a self-set maximum current,first set the heater load resistance to 25Ω for any resistance less than 50Ω,or set the heater load resistance to 50Ω for any resistance above 50Ω.Set the"Maximum output current"to"Self-set current".Enter the calculated current limit value in the"Maximum current set by yourself"parameter.

	Heater load resistance					
Maximum current	10Ω	25Ω	30Ω	40Ω	50Ω	100Ω
2A	40W	100W	--	--	--	--
1.667A	28W	69.5W	83W	--	--	--
1.414A	20W	50W	60W	--	--	--
1.25A	15W	39W	46W	62.5W	--	--
1A	10W	25W	30W	40W	50W	--
0.707A	5W	12.5W	15W	20W	25W	--
0.5A	2.5W	6W	7.5W	10W	12.5W	25W

Table 4 - 5 self-set maximum current

4.5.1.2 Power-on Enable

All configuration parameters of TC290 temperature controller can be stored in memory.Some systems require the heater range to be turned off when power is restored.The Power-Up Enable feature allows you to choose whether to turn off the heater each time the instrument is powered up.Set the power-up enable parameter to off to ensure that the heater is turned off when powered up.

Menu Navigation:

Settings - Output Settings - Output Loop 1 or 2 Settings - Power On Enable

4.5.1.3 Heater output display

Heater output can be displayed in percent of full-scale current or percent of full-scale power.on the main screen of the display,the heater output display is shown in these units,and the manual output parameters are set in these units.Available full-scale current and power are determined by heater resistance,maximum current setting,and heater range.

NOTE: The heater output display is a calculated value to aid in system setup and adjustment.It is not a measurement and may not be an accurate representation of the actual power in the heater.

Menu Navigation:

Settings - Output Settings - Heater 1 or 2 Settings - Display Mode

4.5.1.4 Control Mode

The heater output can be configured to one of four output modes:Off,Closed Loop PID,Zone or Open Loop.Shutdown mode prevents current source is given to the output.Closed-loop PID is the most commonly used temperature control mode,and zone mode builds on the closed-loop mode by providing automatic changes in control parameters in up to ten different temperature zones.Open loop mode provides a method of applying a constant current to the output.

Menu Navigation:

Settings - Output Settings - Output Loop 1 or 2 Settings - Control Mode

4.5.1.4.1 Closed-loop PID mode

The closed-loop PID mode is the most commonly used closed-loop control mode,which uses the output of the TC290 temperature controller heater to strictly control the temperature.In this mode,the controller attempts to maintain the load at the set point temperature entered by the user.To do this,it uses feedback from input sensors to calculate and actively adjust control output settings.The TC290 temperature controller uses a control algorithm called PID,which involves three terms used for regulatory control.See Section 4.5.1.5 for details on assigning control inputs to closed-loop feedback.See Sections 2.7 and 2.8 for a detailed discussion of PID control and manual tuning.

In closed loop PID mode,the controller will accept user input proportional,integral and derivative parameters to provide a 3-term PID control.During closed loop control,a manual output can be used to increase the calculated PID control output.

4.5.1.4.2 Area Mode

The optimal control parameter values at different temperatures in the system are often different.Once the control has been selected for each temperature range (or zone) control parameter values,the instrument will update the control settings each time the setpoint enters a new zone.

Note: Control parameters can be changed manually if desired,just like in closed loop PID mode,but they will be updated automatically once the setpoint crosses the zone boundary.

The control algorithm for each zone is the same as the closed-loop PID mode.The area function is useful on its own,but used in conjunction with other functions,it is more powerful.We recommend using zone mode with setpoint ramp (section 4.5.1.5.7).See Section 5.3 for details on setting up regions.See Section 2.7 for a detailed discussion of PID control.

4.5.1.4.3 Open Loop Mode

Open loop output mode allows you to directly set the output using only the manual output and gear parameters.This guarantees a constant current to the load,but it cannot actively control the temperature.Any change in load characteristics will result in a temperature change.

You can configure any output to open loop mode.When configuring an output in this mode,the output settings menu can use manual output and heater gear parameters to set the output.For convenience,a control input parameter can be used to assign a sensor input and then allow the output to be displayed on the front panel when using the display mode for that sensor input.When displayed on the front panel,the manual output and heater position are directly accessible from the control page for quick access to these settings.See Section 4.3.1 for details on configuring display modes.

Warning: Since there is no sensor feedback in open loop mode,there is nothing to prevent the system from overheating.We recommend using the temperature limit feature to help protect the system from overheating.See Section 4.4.12 for temperature limits.

4.5.1.5 Control parameters

Once the output mode is selected,the control parameters can be used to start controlling the temperature.Control inputs are used to create control loops.The P,I and D parameters provide fine-tuning of the control algorithm.Manual output provides a reference output power to control.The set point is used to set the desired target temperature,the heater range is used to turn on the control output,and the power range of the output is set.These parameters are described in detail in Sections 4.5.1.5.1 to 4.5.1.5.8.

4.5.1.5.1 Control Inputs

For closed loop control (closed loop PID,zone,preheat power),a control loop must be created.The control loop controls the temperature by consists of the control output and the input fed back to the control algorithm.Use the control input parameter to assign the control input sensor to the desired output.

In monitored output mode.control input parameters are used to determine the source of the output voltage. In open-loop mode.the control input parameters can be simply set to facilitate easy access to the manual output and heater gear parameters of the relevant output using the control operation page.

4.5.1.5.2 Proportion (P)

The proportional parameter (also called gain) is the P part of the PID control equation and has a range of 0 to 1000 with a resolution of 0.1.The default value is 50.When using closed-loop control,enter a value greater than 0 for p.

To set P,you can quickly input parameters on the control page of the main interface of the display,or you can go to Settings - Output Settings - Loop 1 or 2 Input parameters under the setting page.The quick input interface is as follows:

4.5.1.5.3 Credits (I)

The integral parameter (also called reset) is part of the PID control equation.Its range is 0 to 1000 with a resolution of 0.1.The default value is 20.Setting i to 0 will turn off the reset function.The i setting is related to seconds in the following ways:

Isetting =1000/Iseconds

For example,setting the reset number to 20 corresponds to a time constant of 50 s.The system usually takes several time constants to enter set point.If the 50 s time constant is correct for the system being controlled,it will cause the system to stabilize at the new set point between 5 minutes and 10 minutes.

The setting method of I is the same as the setting method of P.

4.5.1.5.4 Differentiation (D)

The derivative parameter (sometimes called the rate) is the D part of the PID control equation.The derivative time constant should normally be at the integral time between 1/4 and 1/8 of the second,if used.For the convenience of the operator,the differential time constant of the TC290 temperature controller is expressed as 1/4 of the integral time.The range is between 0% and 200%.Start with a setting of 0%,50% or 100% and decide which setting gives you the type of control you need.Don't be surprised if the setting you want is 0%.Note that by using a percentage of the integration time,the derivative is automatically scaled as the integration value changes and does not need to be revisited as often.

The setting method of D is the same as that of P.

4.5.1.5.5 Manual output

Manual output is the manual setting of the control output.It can work in two different ways depending on the control mode.In open loop control mode,the manual output is the only output for the load.You can set the control output directly from the display or through the computer interface.In closed loop control mode,the manual output is added directly to the output of the PID control equation.In practice,the manipulation of the governing equations is relative to the manual output settings.

Manual output is set as a percentage of full scale.Percent of full scale is defined as full scale current or power within the selected heater range percentage of the rate.See Section 4.5.1.3 to set the heater output display.Available full-scale current and power are determined by heater resistance,maximum current setting,and heater range.The manual output setting range is 0% to 100% with a resolution of 0.01%.

The setting method of manual output is the same as that of P.

4.5.1.5.6 Temperature control point

Use the Control Point parameter to set the desired load temperature for the control loop.Before entering a setpoint,it must be entered through the configuration sensors and use control input parameters to assign them to control outputs to create a control loop.Setpoints can be entered in either temperature units or sensor units,depending on the preferred unit setting for sensor input.When controlling temperature units,the temperature control point ramp function is available to provide smooth,continuous control from one temperature to the next.See Section 4.4 for details on input settings.See Section 4.5.1.5.1 for details on assigning control inputs.See Section 4.5.1.5.7 for details on the temperature control point ramp function.

Most applications require control in units of temperature. To control in units of temperature.set the preferred unit parameter for the control input sensor to Kelvin or Celsius. When controlling the temperature.the range of Settings available for the temperature control point is limited by the temperature control point limit parameter of the specified temperature curve. For more information on setting the preferred unit parameters.see Section 4.4.13. Refer to Section 5.8.1 for details on setting curviline temperature control point limits.

Note:The temperature control point limit function only limits the temperature control point input.For greater protection,if the sensor reading is observed to be higher than the indicated temperature,you can use the temperature limit function to turn off all heater outputs.See Section 4.4.12 for details on the temperature limit function.

Temperature control in the sensor unit may be required in some cases,for example when temperature profiles are not available.For these applications,The TC290 temperature controller can control the temperature in the sensor unit.To control the sensor unit,set the preferred unit parameter to sensor.When controlling the sensor unit,the temperature control point resolution matches the display resolution of the sensor input type given in the specification (section 1.3).

NOTE:Temperature control in the sensor unit is unpredictable as most sensors do not have a linear response to temperature,due to it has different sensitivities in different temperature ranges.

If you change the preferred unit from sensor to temperature (Kelvin or Celsius),or from temperature to sensor,the TC290 temperature controller uses the specified temperature curve to convert the temperature control point to the new control unit.If the preferred unit parameter is changed while the control loop is active,this will have a small disruption in the control output.

Note:When controlling the temperature,the temperature control point is limited by the set value of the control input temperature curve.When controlling in the sensor unit,the temperature control point is limited by the configured control sensor.

The setting method of temperature control point is the same as that of P.

4.5.1.5.7 Temperature control point rate

When the temperature control point unit is expressed as temperature.the TC290 temperature controller can generate a smooth temperature control point ramp. You can set the ramp rate to degrees per minute.ranging from 0 to 100.with a resolution of 0.1. Once the ramp function is enabled.its action is initiated by the temperature control point change. When you enter a new temperature control point.the instrument changes the temperature control point temperature from the old value to the new value at the ramp rate.Always input a positive ramp rate; Instruments use it to raise or lower the temperature.

Always use the ramp function to minimize temperature overshoot and undershoot.When the ramp is not used,the change of temperature control point will cause the error of PID equation to become very large,which causes the effect of i to control the output equation to become larger,and the longer the error exists.Once the set point temperature is reached,a large overshoot or undershoot will result because the I effect is reduced only when the error polarity is reversed.Use a ramp rate to prevent the control output from reaching the 100% or 0% limit while ramping for best results.

The ramp function is useful on its own,but it's even more powerful when used in conjunction with other functions.Temperature control point ramps are typically used in districts control mode.As the temperature is gradually increased in different temperature zones,the control parameters are automatically selected for optimal control.The ramp can be started and the status read using the computer interface.In a computer-controlled experiment,the instrument generates temperature-controlled point ramps while the computer is busy acquiring the necessary data.

Note:When an incomplete ramp is turned off,the temperature control point will remain at the maximum current setting (the reading will not jump to the ramp end).

If the input type or input profile changes during the ramp,both the ramp and the heater will turn off.

If the ramp is on and the temperature control point is set to the sensor unit,the ramp function will remain on,but when another temperature control point is entered when the temperature control point directly enters the new set value.

Menu Navigation:

Settings - Output Settings - Output Loop 1 or 2 Settings - Control Point Rate

To stop the temp ramp,set the temp rate to 0,

4.5.1.5.8 Heater gear

The heater gear setting is used to turn on the control output and set the output power range of the heater output.Gear can be selected to turn off the output settings.Heater outputs 1 and 2 provide low,medium (med) and high settings,with ten levels of power based on the maximum output power of the connected heater.High range provides maximum power,mid range provides (max power)/10,and low range provides (max power)/100.See Section 2.5.1 for details on how to calculate the maximum output power.The unpowered analog output 3 does not have multiple output ranges and only provides an on setting that enables the output.

NOTE:While controlling the temperature,the following will cause the heater gear to automatically shut down:

1.Exceed the temperature limit set value

2.Setting change control input

3.When the power-on enable is set to off,when restarting.

4.Input errors,such as too high temperature,too low temperature,too high sensor value,too low sensor value,etc.

See Section 1.3 for specifications on heater output.See Section 2.5 for the principle of heater operation.Section 3.8 provides various heaters

Installation Precautions.

The setting method of the heater gear is the same as the setting method of P.

4.5.1.5.8 Turn off all heaters

Turning off all heater buttons is one way to turn off all control outputs. It is equivalent to setting all output heater gear parameters to off.

Menu Navigation:

Main interface — heater button —close all heater buttons

4.5.2 Unpowered analog output

The unpowered analog output 3 is a variable DC voltage source with a voltage range of -10 V to +10 V. The voltage is generated by A 16-bit D/A converter with A resolution of 0.3mV or 0.003% full scale. This output can be configured in open loop.preheat power.or monitor output mode. Open-loop mode can be used to set the output to a specific constant value. For more information about open-loop mode.see Section 4.5.1.4.3. The preheat power mode uses a programmed input that outputs an external power supply to preheat the system quickly to a user-specified temperature. The monitor output mode uses the output to provide a voltage proportional to the input sensor readings used by an external device such as a data logger.

NOTE:The unpowered analog outputs are not used to provide heater power,and although they are short circuit protected,they should not be used to drive resistors below 1 K.

4.5.2.1 Preheating the power supply

The preheat power mode is designed to control an external power supply that is used to rapidly increase the temperature in the control system,for example,bring the system to room temperature for sample change.See Section 5.5 for more information on warm-up supply operations.See Section 3.8.5 for steps to install an external power supply in warm-up power mode.

4.5.2.2 Monitor output

See Section 5.6 for more information on monitor output modes.

4.6 Interface Settings

The TC290 temperature controller has three computer interfaces:RS-485,USB and Ethernet.The three interfaces are internally connected to one RS-485, Each interface can be used separately,but the three interfaces cannot be operated at the same time. Use the display screen Settings -

Interface Settings to change the baud rate and address of the RS-485.

4.6.1 USB

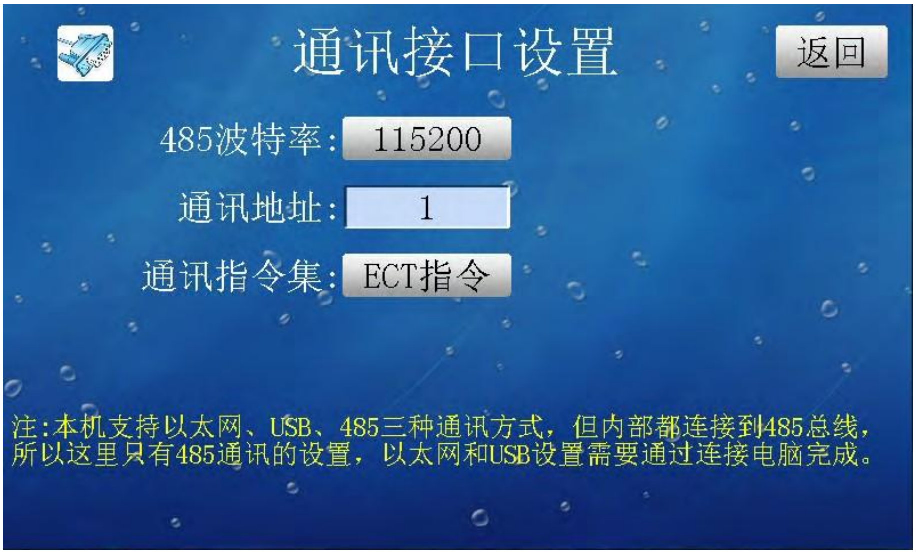
The USB interface is a convenient way to connect to most modern computers,since at the time of writing this manual,nearly all new USB ports are provided on PCs.The TC290 temperature controller USB driver,which must be installed before using the interface (section 6.3.3),creates a virtual serial COM port that can be used in the same way as a traditional serial COM port.See Chapter 6 for details on computer interface operation.

4.6.2 Ethernet

The Ethernet interface allows the TC290 to connect to a computer network.It is also possible to use a crossover Ethernet cable to connect directly to PC.The advantages of using an Ethernet interface include the ability to communicate directly with the TC290 from any PC on the same local network,and even communicate with PCs around the world over the Internet.See Section 6.4.1 for details on Ethernet configuration.

4.6.3 RS-485

RS-485 interface is an instrument with hardware and programming standards that simplify instrument interface.The instrument can be connected to the RS-485 network through a 2-core signal line with a shielded layer



Chapter 5 Advanced Operations

5.1 General

This chapter introduces the advanced operation of the TC290 temperature controller.

5.2 PID auto-tuning

The TC290 temperature controller has an auto-tuning function that automatically adjusts the tuning process of a typical cryogenic system.More information about algorithms,see Section 2.9. Before starting the automatic tuning process.the control input sensors and heater outputs of the cooling system should be correctly configured to enable closed-loop control.Assign a valid temperature response curve to the control sensor.The appropriate heater setting as described in Section 2.8.1 should also be determined.The system must roughly maintain the temperature within 5 K of the control point,where the parameters need to be re-tuned in order to initiate the auto-tuning process.Autotune works with only one control loop at a time and does not set a manual output or heater gear.

To start the auto-tuning process,press on the Settings - PID Tuning page and select Tuning Mode.There are three auto-tuning modes available.They result in slightly different system characteristics.Autotune PI is recommended for most applications.

1.Auto-tune P:Only set the P parameter value.I and D are set to 0 regardless of the initial value.This mode is recommended for systems with long lag times or nonlinear systems to pre-stabilize PI control.Overshoot or undershoot is expected at the temperature control point,and the temperature control stabilizes below the set value.

2.Autotune PI:Set the values of the P and I parameters.D is set to 0.This mode is recommended for stable control at constant temperature.After the temperature control point is changed,the stabilization time may be slightly longer than the automatic PID.Expect overshoot or undershoot at the temperature control point and stable temperature control at the setpoint.

3.Auto-tune PID:Set the values of P,I and D parameters.D is always set to 100%.This mode is recommended when the temperature control point changes frequently,but allows the temperature to stabilize between changes.In noisy systems,the stability of the temperature control point may be worse than that of the autotune PI.Expect slightly less overshoot or undershoot than other control modes at setpoint.

When the auto-tuning process is initiated,the message"PID Tuning"will appear in the status bar above the display.If an error occurs,it will show"PID Error".When the process completes successfully,the previous p,i,and d parameters are replaced with the newly obtained values.To cancel the auto-tuning process,go to"Settings - PID Tuning - Select Tuning Loop"and select None under the menu.

5.3 Regional Settings

The TC290 temperature controller allows you to build up to ten custom continuous temperature zones,and the controller will automatically use a pre-programmed PID value,heater range,manual output,ramp rate and control input.Zone control can function in both control loops at the same time.Use area 1 as the lowest configuration area and use area 10 as the highest configuration area.Region boundaries are always expressed in Kelvin (K).The bottom of the first region is always 0 K;therefore,only the upper limit is required for all subsequent regions.

To use zone programming,the output mode must be set to zone mode (see Section 4.5.1.4.2 Setting Zone Mode).In zone mode,the instrument will update the control settings each time the setpoint enters a new zone.If a setting is changed manually,the controller will use the new setting in the same zone and update to the programmed zone table setting when the setpoint crosses the new zone.

Zone settings include control input parameters for each temperature zone.This allows each temperature zone to use a different feedback transmission sensor.For example,a diode sensor can be used when cooling from room temperature to 10 K,at which point the control input can be switched to a CERNOX™ sensor for temperatures below 10 K.

To illustrate how to update control parameters in zone mode,consider the zone settings in the table below.Start at room temperature (about 300 K),The temperature control point is set to 2 K (Temperature control point ramp open),the temperature control point will start ramping at the current temperature control point ramp rate,then once the temperature control point exceeds 100 K,the control parameters for zone 8 will be used.Then,when the control parameters of zone 7 are loaded,the temperature control point ramp will continue to slope towards 2 k at a rate of 20 k/min until it crosses 50 k.This mode will continue until the final setpoint of 2 K is reached,or another setpoint is entered.Note that input B will be used for all regions above 10K (regions 4 to 8) and input A will be used for all regions below 10K (regions 1-3).

Area	Lower Boundary	Upper Boundary	P	I	D	Manual Output	Gear	Rate	Control Input
10	n/a	0K	50	20	0	0.0%	closure	0.1 K/Min	default
9	n/a	0K	50	20	0	0.0%	closure	0.1 K/Min	default
8	100.001 K	500K	200	20	0	0.0%	high	30K /Min	enter BA
7	50.001 K	100K _	185	25	0	0.0%	middle	20K /Min	Enter B
6	25.001 K	50K	150	30	0	0.0%	middle	10K /Min	Enter B
5	15.001K	25K _	100	30	0	0.0%	middle	5K /Min	Enter B
4	10.001K	15K	85	35	0	0.0%	middle	2 K/Min	Enter B
3	7.001K	10K _ _	85	35	0	0.0%	middle	0.9 K/Min	Enter A
2	4.001 K	7K _	70.0	40.0	0	0.0%	Low	0.7 K/Min	Enter A
1	0K	4K _	50.0	50.0	0	0.0%	Low	0.5K /Min	Enter A

Table 5 - 1 Example Locale Settings

NOTE :The accuracy and location of the sensors will affect how smoothly the transition from one feedback sensor to another.When converting,large differences between the temperature readings of each sensor can cause temporary instability in temperature control due to sudden large errors introduced into the control equations.

Note :It is strongly recommended to use the temperature control point ramp function when changing the sensor input using the control input area parameter.Otherwise,a change in the temperature control point could cause the control input sensor to be used outside its usable range,which would create an overload condition closing the control loop.

5.4 Bipolar Control

The most common temperature-controlled output device is the resistance heater,which requires only a unipolar output because no matter the polarity of the excitation voltage,they both add heat.However,the temperature control device is bipolar.These devices,like thermoelectrics,can work in both polarities,and when current is applied,heat moves from one side of the device to the other.Therefore,a bipolar temperature control device can be used to heat or cool the surface.For these types of bipolar devices,the TC290 temperature controller has a bipolar control mode.In this mode,the TC290 temperature controller is configured to use output 3 to drive these devices to control the temperature.See Section 2.11 for more information on thermoelectric devices.

To use output 3 for bipolar control,first set the heater output type parameter to voltage,then set the polarity to bipolar.The thermoelectric device can then be controlled using a closed-loop PID control mode,providing a control output of -10 V to +10 V.See Section 2.11 for information on thermoelectric devices.Refer to Section 3.8.5.4 for information on scaling the output below 10 V.

Menu Navigation:

Settings - Output Settings - Heater 3 Settings - Output Polarity

5.5 Preheating the power supply

The preheat power mode is used to control an external power supply to rapidly increase the temperature in the control system,for example,by placing the system in room temperature to change samples.See Section 3.8.5 for information on preheating power mode using an external power supply.

The control input parameter determines which sensor is used for feedback in preheat power mode.Details information about control input parameters,see Section 4.5.1.5.

Once the preheat power mode is configured.set the desired temperature with the temperature control point parameter.then set the heater to on with the heater gear parameter to activate the output. The display is set to display the current preheating control loop.

Menu Navigation:

Settings - output settings - output loop 1 or 2 settings - control mode - (select preheat power)

5.5.1 Preheat percentage

When using the preheat mode to control an external power supply,the preheat percentage parameter is used to determine the amount of voltage applied to the unpowered output 3.The applied voltage will be the full scale output (+10 V) multiplied by the preheat percentage.For example,if the preheat percentage is set to 50%,when the output is on,the control output voltage for a given unpowered output will be 50% of 10 V,or 5 V.

Menu Navigation:

Settings - Output Settings - Heater 3 Settings - Preheat Voltage Ratio

5.5.2 Preheating control

The preheat control parameters determine what happens when the control set point is reached.Options include:

1.Auto off:Once the heater gear is set to on,the preheat percentage voltage will be applied to the output (section 5.5.1) and the output will remain on until the control input temperature reaches the control setpoint.The output will then be off (0 V) and the heater gear setting will automatically be set to off,effectively shutting down all temperature control of the control loop.If the heater range is manually set to on again,the cycle will start again and the output will turn on and remain on until the control input temperature reaches the set point again.

2.Continuous:This mode implements what is commonly referred to as on/off control.Once the heater gear is set to ON,the preheat percentage voltage will be applied to the output until the control input temperature reaches the setpoint.The output will then be off (0 V) until the temperature drops 1 K below the set point,at which point the preheat percentage voltage is again applied to the output.In this mode,the heater position is never automatically set to off.

Menu Navigation:

Settings - Output Settings - Heater 3 Settings - Preheat Control

5.6 Monitor output

In monitor output mode,the unpowered analog output 3 will track the assigned control input based on the input's scaling parameter.a common use of this feature is to send a voltage proportional to temperature to a data acquisition system

The control input parameter setting determines which sensor input the output tracks.The remaining parameters detailed in this section indicate how to set output value.

An output configured in monitor output mode is not affected by the"Turn off all heaters"button as it does not have a heater position setting,and it is always enabled by design.

Menu Navigation:

Settings - Output Settings - Output Loop 1 or 2 Settings - Control Mode - (select monitor output)

Settings - Output Settings - Heater 3 Settings - Monitor Inputs

5.6.1 Monitoring unit

Monitor the output scaling parameter settings with the unit input selected for this parameter.

5.6.1.1 Polarity and monitor output scaling parameters

In monitor output and open loop mode,the unpowered analog output can be configured as unipolar (0 V to +10 V) or bipolar (-10V to +10 V) output.In bipolar mode,monitor the output -10 V setting to determine the temperature or sensor value that the output should be -10 V.In unipolar mode,monitor the output 0 V setting to determine the temperature or sensor value at which the output should be 0 V.The Monitor Output +10 V setting determines the temperature or sensor value at which the output should be +10 V in unipolar or bipolar mode.

For example,if the polarity is set to bipolar,then set the monitor output -10 V parameter to 0 K and monitor the output +10 V,Setting the parameter to 100 K will cause the analog output to correspond to the input temperature,in this case,if the actual reading is 50K,the output will be 0 V.If we set the polarity parameter to unipolar,in this case,if the actual reading is 50K,the analog output will be +5 V.

Menu Navigation:

Settings - Output Settings - Heater 3 Settings - Output Polarity

Settings - output settings - heater 3 settings - full output corresponding value or zero output corresponding value

5.7 Alarms and Relays

5.7.1 Alarm

Each input to the TC290 temperature controller has high and low alarm functions input reads from any source can be compared to the alarm set value readings above the high alarm.set point trigger a high alarm for that input and readings,below the low alarm set point trigger a low alarm for that input

Menu Navigation:

Settings - Alarm Settings - Select Input

NOTE :The low and high setpoint limits are determined by the preferred units of the associated sensor input.

5.7.1.1 Alarm annunciator

When any alarm that is enabled also has the visible parameter enabled,the alarm symbol will flash in the status bar if the alarm is active.at the same time Input channel readouts also show alarm status.If the Enable Alarm Sounds parameter is set to On,the buzzer inside the instrument will sound when the alarm is activated.The two relays on the TC290 temperature controller can also be connected to the alarm functions described in Section 5.7.2.

It may be necessary if the alarm status does not need to be shown on the display,e.g.if the relay is triggered using the alarm function,set the visible parameter to off.When an alarm is triggered,the audible parameter can be set to off to keep the buzzer silent.

Menu Navigation:

Settings - Alarm Settings - Sound Alarm or Display Alarm

5.7.1.2 Status Latch

State Latch Open:Typically used to latch faults in systems or experiments that require operator intervention.Even if the alarm state is resolved.The operator can still see the alarm status for diagnostic purposes.Relays are often used to signal remote monitors,or for added safety,to disconnect critical equipment in a timely manner.Lock alarms can be cleared by setting - Alarm Setting - Alarm reset

State Latch Off:Often associated with relay operation to control part of a system or experiment.Alarm status follows reading.The deadband parameter prevents the relay from turning on and off repeatedly when the sensor input reading is near the alarm set point.

Figure 5-1 illustrates the interaction between the alarm setpoint and deadband when state latching is off.The high alarm point setting value is 100K,When the dead zone is 5 K,when the sensor input temperature rises to 100 K,the high alarm is triggered,and the high alarm will not be released until the temperature drops to 95 K.In addition,the same 5 K deadband is applied to the low alarm set point.

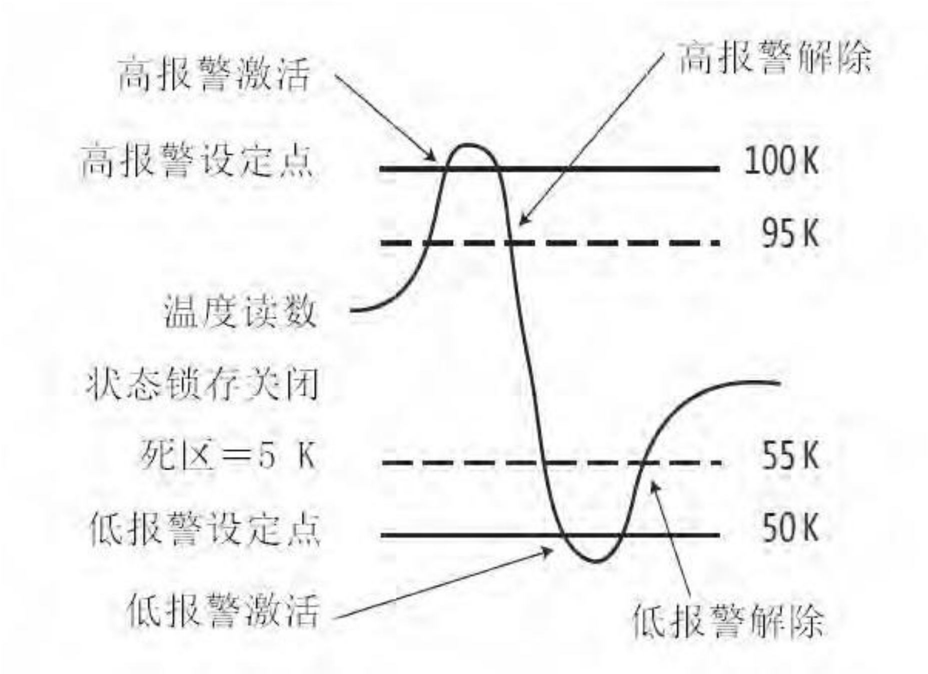


Figure 5 - 1 Deadband Example

Menu Navigation:

Settings - Alarm Settings - Status Latch

Settings - Alarm Settings - Temperature Deadband

NOTE:The low and high alarm point limits are determined by the preferred units of the associated sensor input.

5.7.2 Relays

The TC290 temperature controller has two relays,1 and 2.They are usually considered alarm relays,but they can also be controlled manually.Two relays can be used with a sensor input for independent high and low operation,or each relay can be assigned to a different input.

When using a relay for alarm operation,first set the alarm function.The relays are rated for 30 Vdc and 3 A.Its terminals are located on the detachable wiring socket on the rear panel of the TC290 temperature controller.

Menu Navigation:

Settings - Relay - Operating Mode (Off,On,Alarm)

Settings - Relay - Alarm Inputs (Input A...Input D4)

Settings - relay - alarm mode (low temperature,high temperature,high and low)

5.8 Curve numbering and storage

The TC290 temperature controller has 20 standard curve positions,numbered 1 to 20.Currently,not all locations are curvilinear occupied,other positions are reserved for future updates.If you are using a standard curve position,you can use the View operation to view the curve.The standard curve cannot be changed by the user,and reserved positions cannot be used for the user curve.

The TC290 temperature controller has 44 user curve positions,numbered 21 to 64.Each location can hold 250 data pairs (break points),including the value in sensor units and the corresponding value in Kelvin.Using less than 250 breakpoints also does not increase the number of available curve positions.Curves generated using the software are stored in the user curve position.

5.8.1 Curve parameters

Each curve has parameters that identify and allow the instrument to use the curve effectively.The curve can be used for temperature conversion or temperature control,Before the control,the parameters must be set correctly.

Curve number:1 to 64.

Name:Defaults to the name of the front panel user curve entry.Curve names of up to 16 characters can be entered from the display or computer interface.

Serial Number:The sensor serial number of up to 16 characters (Letters or numbers) can be entered from the front panel or computer interface.

format:The format parameter tells the instrument what the breakpoint data format is.Different sensor types require different formats.The format of the MAG sensor is shown in Table 5-2.

Format	Describe	Sensor Unit Full Scale Range	Sensor Unit Maximum Resolution
V/K	Voltage to Kelvin	10V	0.00001 V
Ω /K	platinum resistance sensors to Kelvin	10KΩ _	0.001Ω _
Log Ω /K	Log resistance of NTC sensor to Kelvin	4 log Ω	0.00001 log Ω
mV/K	Thermocouple Sensor Millivolts vs Kelvin	± 100mV	0.0001 mV

Table 5 - 2 Curve Parameters

Temperature upper limit:Limit the curve temperature to a range less than or equal to the set value.An upper temperature limit can be included in each curve.The default value is 375K.If no limit is required,enter a setting of 9999 K.

Temperature Coefficient:The temperature coefficient is derived from the first two breakpoints by the TC290 temperature controller.The user does not have to enter this setting.If it is not correct,check that the first two breakpoints are entered correctly.A positive coefficient means that the sensor signal increases with increasing temperature.A negative coefficient means that the sensor signal decreases with increasing temperature.

5.8.2 Curve Points

The temperature response data for the calibrated sensor must be reduced to a table of breakpoints before being entered into the instrument.The curve consists of 2 to 250 breakpoints.each consisting of a sensor unit value and a Kelvin temperature value..The TC290 temperature controller uses linear interpolation to calculate the temperature between breakpoints.If the sensor reading is outside the breakpoint range,the instrument will show either over temperature or under temperature on the display.Sensor units are defined by the format settings in Table 5-2. Breakpoint setting resolution is 6-bit temperature.Most temperature values are entered with 0.001 resolution.1000 K and above can be entered temperature value with a resolution of 0.01.Temperature values below 10 K can be entered with a resolution of 0.0001.The temperature range for the curve input is 0 K to 9999.99 K.

Sensor Type	Model	Format	Limit (K)	Temperature Coefficient	Resolution
Silicon Diode	DT-670	V/K	475	minus	0.00001 V
GaAlAs Diode	TG-120	V/K	325	minus	0.00001 V
Platinum 100	PT-100	Ω /K	800	positive	0.001Ω _
Platinum 1000	-	Ω /K	800	positive	0.01Ω _
Rhodium-Iron	RF-800	Ω /K	325	positive	0.001Ω _
Carbon-Glass	CGR-1-1000	log Ω /K	325	minus	0.00001 log Ω
Cernox™	CX-1050	log Ω /K	325	minus	0.00001 log Ω
Germanium	GR-200A-100	log Ω /K	325	minus	0.00001 log Ω
Rox™	RX-102A	log Ω /K	40	minus	0.00001 log Ω
Type K	9006-005	mV/K	1500	positive	0.0001 mV
Type E	9006-003	mV/K	930	positive	0.0001 mV
Type T	9006-007	mV/K	673	positive	0.0001 mV
Au-Fe 0.03%	-	mV/K	500	positive	0.0001 mV
Au-Fe 0.07%	9006-001	mV/K	610	positive	0.0001 mV

Table 5 - 3 Typical Curve Parameters

Setting the resolution is also a six-digit number in the sensor unit.Curve format parameters and sensor units define range and resolution,the rates are shown in Table 5-2.The sensor type determines the actual setting resolution.Table 5-3 lists the recommended sensor cell resolutions. When entering a breakpoint,the sensor unit value increases as the point number increases.There should not be any empty breakpoint locations in the middle of the curve.

The program in the TC290 temperature controller will consider the blank breakpoint to be the end point of the curve.

5.9 Touch screen curve input operation

There are four related operations for touch screen curve input:edit curve,view curve,erase curve and copy curve;details are as follows.

Operate	Describe	Reference Chapter
Edit curve	Edit Curve allows you to edit the curve at any user curve position.The standard curve cannot be changed.	5.9.1
View curve	View Curve allows you to view any curve at any curve position.No curves can be changed.	5.9.2
Delete curve	Delete Curve allows you to delete a curve from any user curve position.Standard curves cannot be deleted.	5.9.3
Copy curve	Copy Curve allows you to copy a curve from any location to any user curve location.Unable to copy curve to standard curve location.	5.9.4

Menu Navigation:

Settings - Curve Entry - (Edit Curve,View Curve,Delete Curve and Copy Curve)

5.9.1 Editing Curves

Use the Edit Curve operation to import new curves or edit existing user curves.Only user curves (21 to 64) can be edited.Entering the identification parameters associated with the curve is just as important as entering the breakpoints.The curve parameters are shown in Table 5-2.The typical curve parameters of commonly used sensors are shown in Table 5-3.Please read this section in its entirety and collect all necessary data before starting this process.

Note:If you are importing a curve with similar parameters to an existing curve,first copy the similar curve to a new location,then edit the curve to the desired parameters.

To perform an Edit Curve operation,follow these steps.

1.On the touch screen curve input interface,press the Edit button.

2.Scroll the curve number to the position to be edited,and then press the Enter Edit button.

3.Edit the parameters corresponding to the curve.

4.Press the submenu button to enter the Edit Curve Point page.

The Edit Curve Points submenu contains all curve breakpoints of the selected curve,each page displays 1 pair of curve point data,Toggle pages with the + and - buttons.Each curve point contains:breakpoint number,breakpoint sensor value,breakpoint temperature value.Directly touch the corresponding value to pop up the input keyboard,after the input is completed,click the confirm key to save.

After the curve import is complete,a new curve must be assigned to the import.The TC290 temperature controller will not automatically assign the new curve to any input.See Section 4.4.9 for details on assigning curves to sensor inputs.

Things to consider when generating thermocouple curves:

1.You can enter temperature response curves for all types of thermocouples.Enter curve data in mv/k format with thermocouple voltage in millivolts and temperature in Kelvin.

2.The curve must correspond to 0 mV at 273.15 K (0°C).When the temperature is above 273.15 K,the thermocouple voltage (unit:millivolts) is positive;when the temperature is below this point,the thermocouple voltage (unit:millivolts) is negative.

3.To convert a curve published in Celsius to Kelvin,add 273.15 to Celsius.

4.The input voltage of the TC290 temperature controller is limited to ±50 mV,so the instrument cannot use any part of the curve with a voltage range exceeding ±50 mV.

5.A sensor too high or sensor too low message appears on the display,indicating that the measured thermocouple input is over or under the ±50 mV range.

5.9.2 Viewing curves

The View Curves operation provides read-only access to all standard and user curves.

To perform the View Curve operation,follow the steps below.

1.On the touch screen curve input interface,press the View button.

2.Scroll the curve number to the position you want to edit,then press the Enter View button.

3.View the corresponding parameters of the curve

4.Press the submenu button to enter the"View Curve Points"page,select the breakpoint number to view the breakpoint value

5.Press the back button continuously to exit the curve menu and return to normal operation.

5.9.3 Delete Curves

You can delete user curves that you no longer need.Deleting a curve sets all identification parameters to default values and clears all point value.

To perform a delete curve operation,follow the steps below.

1.On the touch screen curve input interface,press the delete button.

2.Scroll the curve number to the position to be edited,and then press the delete button to complete the operation.

3.Press the back button continuously to exit the curve menu and return to normal operation.

5.9.4 Copy the curve

copied from one location inside the TC290 temperature controller to another.This is a good way to make subtle changes to the existing curve.If you need the same curve with two different temperature limits,or if you need to extend the range of the standard curve,you may need to duplicate the curve.The copied curve is the same as the original curve.

Note:The duplicator allows you to overwrite existing user curves.Before proceeding with the copy curve operation,please make sure that the curve number to be written is correct.

1.To execute the"Copy Curve"operation,please press the Copy button in the curve input interface of the touch screen.

2.Scroll the trace number from position and trace number to position respectively and press the copy button to complete the operation.

3.Press the back button continuously to exit the curve menu and return to normal operation

5.10 LabVIEW software curve entry operation

TC290 temperature controller can import the curve data sheet into the instrument memory from the supporting LabVIEW software.For the specific method of using LabVIEW software.please refer to the operation instructions of LabVIEW software in the TC290 temperature controller CD.

Chapter 6 Computer Interface Operation

6.1 General

This chapter provides operating instructions for the computer interface of the MAG TC290 temperature controller.Three Calculations Equipped with TC290 temperature controller

Each of the machine interfaces allows remote operation.The first is the RS-485 interface described in Section 6.2.The second is the USB interface described in Section 6.3.The third is the Ethernet interface described in Section 6.4.The three interfaces share a common set of commands detailed in Section 6.6.Only one of the interfaces can be used at a time.

Normal operation on the touch screen is called local operation.After connecting any interface of the TC290 temperature controller to the computer and sending instructions,the TC290 temperature controller automatically switches to the remote mode.The remote mode in the touchscreen settings can be switched between remote and local mode.During remote mode operation,when the remote icon flashes on the touch screen status bar,operations on the touch screen will be disabled.

6.2 RS-485 interface

RS-485 interface is an instrument bus with hardware and programming standards that simplify instrument interface.RS485 adopts differential signal Logic,+2V～+6V means"1",-6V～-2V means"0".RS485 adopts two-wire half-duplex communication mode.In the RS485 communication network,the master-slave communication method is generally used,that is,a master with multiple slaves.

connected to the RS-485 network through a 2-core signal line with a shielding layer,and the longest distance of the RS-485 network is less than 1200 meters.The RS-485 network can connect up to 247 temperature controllers.If the distance is long or the communication is unstable,485 repeaters can be added to improve the communication.

Rs-485 communication network needs to consider two problems:(1) common mode interference problem:RS-485 interface adopts differential transmission signal mode.does not need to detect the signal relative to a reference point.the system only needs to detect the potential difference between the two lines. But people often ignore that the transceiver has a certain common mode voltage range.RS-485 transceiver common mode voltage range is -7 ~ +12V.only meet the above conditions.the whole network can work normally. When the common-mode voltage of the network line exceeds this range.it will affect the stability and reliability of the communication and even damage the interface. (2)EMI problem:the common-mode part of the output signal of the transmitter driver needs a return path.If there is no return channel with low resistance (signal ground).it will return to the source in the form of radiation.and the whole bus will radiate electromagnetic waves outwardly like a huge antenna.

The 485 communication baud rate and communication address can be changed under the touch screen setting-interface setting.

6.3 USB interface

The TC290 temperature controller USB interface provides a convenient way to connect to most modern computers,since this manual was written,almost all new PCs offer a USB interface.The USB interface is implemented as a virtual serial COM port connection,providing an easy migration path for existing RS-232-based remote interface software.It also provides a simpler means of communication than standard USB implementations.

6.3.1 Physical connection

The TC290 temperature controller has a Type B USB interface on the rear panel.This is the standard connector used on USB peripherals,and it allows the TC290 to be connected to a host computer using a generic USB A-TYPE to B-TYPE cable.According to the definition of the USB2.0 standard,the maximum length of a USB cable is 5 meters.Can be extended up to 5 times using 1 USB hub every 5 meters for a maximum total length of 30 meters.

6.3.2 Hardware Support

The USB interface emulates an RS-232 serial port with a variable baud rate,but uses the physical connection of USB.This programming interface requires a certain configuration to communicate with the TC290 temperature controller normally.The instrument default configuration is 115200 N 8 1.

The USB hardware connection uses the USB 2.0 standard's full-speed (12,000,000 bits/sec) profile;however,due to the virtual serial COM port emulated by the interface,the maximum data throughput is still limited to a baud rate of 115,200 bits/sec.

6.3.3 Install USB driver

USB Drivers Drivers can be installed from the web or from the CD that came with the TC290 temperature controller.Search the CP2102 driver from the Internet can be downloaded and installed.

6.4 Ethernet

The Ethernet interface provides a method for connecting the TC290 temperature controller to an Ethernet-based computer network.ethernet network provides the ability to communicate over long distances,typically using existing equipment (Internet,pre-existing local network).The TC290 temperature controller Ethernet interface enables the use of TCP socket connections and the use of a common command set to send commands and queries to the instrument.The TC290 temperature controller features an embedded web interface that provides status information and other utilities.

For detailed configuration instructions of Ethernet,see"Zhiyuan Electronics IPort-3 User Manual"on the CD-ROM of the TC290 temperature controller.

6.5 Command overview

This section provides all commands for interface communication.

After the communication connection is completed,send ? directly.All commands currently supported by the instrument are returned.

Communication interface:Both USB and LAN are converted to RS485,and RS485 is used internally.RS485 can also realize multi-device connection externally.The serial port configuration is"115200,8n1".

Communication format:ASCII string command,the command terminator is carriage return and line feed (0x0D 0x0A),and the serial port transmission timeout is also regarded as the end of the command.The timeout is 3 bytes of time.

Multi-machine communication:use"@addr inst"style with address instructions,such as"@1 *IDN?"to query the IDN of 1#machine.

Stand-alone communication:You can use ordinary commands without addresses,or you can use commands with addresses.

Instruction set description

*IDN?

Function:Query device identification

Return:ECTI,MODEL2880,SN1234,Ver1.00

ALARM <temperature measurement channel number A-D>,<enable switch 0|1>,<high threshold>,<low threshold>,< difference >,<output lock 0|1>,<sound switch 0|1>,< Display switch 0|1>

Function:Set the temperature measurement over-limit alarm parameters,and the threshold value is set according to the selected unit of the temperature measurement channel.

ALARM.<Temperature measurement channel number AD>

Function:Query temperature measurement alarm parameters

Return:<enable switch 0|1>,<high threshold>,<low threshold>,< difference >,<output lock

0|1>,<sound switch 0|1>,<display switch 0|1>

ALARMST.<Temperature measurement channel number A-D>

Function:Query temperature measurement alarm status

Return:<high alarm>,<low alarm>

ALMRST

Function:fault alarm relay reset

ANALOG <output channel 2>,<temperature measurement channel A-D>,<temperature unit 1-3 corresponds to K|C|S>,<+100% corresponds to temperature value>,<0%/-100% corresponds to temperature value>,< Output signal polarity 0-1 corresponds to single and bipolar >

Function:temperature monitoring analog output (10V/±10V) parameter setting.The monitoring function is enabled with the OUTMODE instruction.

ANALOG.<output channel 2>

Function:Query temperature monitoring analog output (10V/±10V) parameter settings

Return:<temperature measurement channel A-D>,<temperature unit 1-3 corresponds to K|C|S>,<+100% corresponds to temperature value>,<0%/-100% corresponds to temperature value>,<output signal polarity 0 -1 corresponds to single bipolar >

ATUNE <temperature control channel 1|2>,<setting mode 0-2 corresponds to P|PI|PID>

Function:Self-tuning of temperature control parameters

COMM <device address 1-255>

Function:Configure the device communication address

COMM?

Function:Query device communication address

Return:<device address 1-255>

CRDG.<Temperature measurement channel A-D>

Function:Query the temperature value in degrees Celsius

Return:<temperature measurement channel temperature value C>

CRVDEL <Temperature curve number 21-59>

Function:delete the selected temperature curve

CRVHDR <Temperature curve number 21-59>,<Name up to 15 characters>,<SN up to 15 characters>,<Data format 1-4 corresponds to mV/K|V/K|Ω/K|logΩ/K>,<temperature upper limit

value K>,<temperature coefficient 1-2 corresponds to negative | positive temperature coefficient>

Function:configure temperature curve header information

CRVHDR.<Temperature Curve No.21-59>

Function:Query temperature curve header information

Return:<name up to 15 characters>,<SN up to 15 characters>,<data format 1-4 corresponds to mV/K|V/K|Ω/K|logΩ/K>,<temperature upper limit value K>,<Temperature coefficient 1-2 corresponds to negative|positive temperature coefficient>

CRVPT <Temperature curve number 21-59>,<Temperature point number 1-250>,<sensor measurement value>,<corresponding temperature value K>

Function:configure the temperature curve point parameters

CRVPT.<Temperature curve number 21-59>,<Temperature point number 1-250>

Function:Query temperature curve punctuation parameters

Return:<sensor measurement value>,<corresponding temperature value K>

DFLT 99

Function:configure instrument parameters to factory defaults

DIOCUR <temperature measurement channel number A-D>,<excitation current selection 0-1 corresponds to 10uA|1mA>

Function:Select diode sensor excitation current,default is 10uA

DIOCUR.<Temperature measurement channel number A-D>r\n"

Function:Query diode sensor excitation current

Return:<Excitation current selection 0-1 corresponds to 10uA|1mA>

FILTER <temperature measurement channel number A-D>,<filter switch 0-1 corresponds to ON|OFF>,<filter points 2-64>,<filter window 1-10%>

Function:Configure temperature measurement filter parameters

FILTER.<Temperature measurement channel number A-D>r\n"

Function:Query temperature measurement filter parameters

Return:<filter switch 0-1 corresponds to ON|OFF>,<filter points 2-64>,<filter window 1-10%>

HTR.<Temperature control channel 1|2>r\n"

Function:query heating output

Returns:<current or voltage percentage>

HTRSET <temperature control channel 1|2>,<heating resistance value 1-2 corresponds to 25|50Ω>,<maximum current 0-4 corresponds to custom|0.707|1|1.414|2>,<maximum custom setting current>,<Display mode 1-2 corresponds to Current|Power>,<CH2 output mode 0-1 corresponds to Current|Voltage>

Function:Configure heating output parameters.<Maximum current> is also the maximum allowable current value of each channel when CH1 and CH2 are connected in parallel,so it should be set to half of the actual current.

HTRSET.<Temperature control channel 1|2>

Function:Query heating output parameters

Return:<Heating resistance value 1-2 corresponds to 25|50Ω>,<Maximum current 0-4 corresponds to custom |0.707|1|1.414|2>,<Maximum custom setting current>,<Display mode 1-2 corresponds to current |Power>,<CH2 output mode 0-1 corresponds to Current|Voltage>

HTRST.<Temperature control channel 1|2>

Function:Query heating output status

Return:<Fault code 0-2 corresponds to OK|OPEN|SHORT>

INCRV <Temperature measurement channel number A-D>,<Select temperature curve number 0-59,0 no curve>

Function:configure temperature measurement sensor curve

INCRV.<Temperature measurement channel number A-D>

Function:Query temperature sensor curve

Return:<Select temperature curve serial number 0-59,0 no curve>

INNAME <temperature measurement channel number A-D>,<channel name 15 characters>

Function:Set the name of the temperature measurement channel

INNAME.<Temperature measurement channel number A-D>

Function:Query the name of the temperature measurement channel

Return:<channel name 15 characters>

INTYPE <temperature measurement channel number A-D>,<sensor type 0-4 corresponds to Disable|Diode|PTC|NTC|Thermocouple>,<auto range 0|1>,<range>,<RTD thermoelectric compensation 0|1>,< Units 1-3 correspond to K|C|Sensor>

Function:Configure temperature measurement channel parameters

Range:diode 0-1 corresponds to 2.5|10V

Range:PTC RTD 0-6 corresponds to 10|30|100|1k|3k|10k

Range:NTC RTD 0-8 corresponds to 10|30|100|1k|3k|10k|30k|100k

Range:Thermocouple 0 corresponds to 50mV

INTYPE.<Temperature measurement channel number A-D>

Function:Query temperature measurement channel parameters

Return:<sensor type 0-4 corresponds to Disable|Diode|PTC|NTC|Thermocouple>,<auto range 0|1>,<range>,<RTD thermoelectric compensation 0|1>,<unit 1-3 corresponds to K| C|Sensor>

KRDG.<Temperature measurement channel A-D>

Function:Query Kelvin temperature value

Return:<temperature value K of temperature measurement channel>

MDAT.<Temperature measurement channel A-D>

Function:query extreme value

Return:<minimum value>,<maximum value>

MNMXRST

Function:reset extreme value record

MOUT <output channel 1|2>,<output percentage 0-100%>

Function:Manually set the output percentage

MOUT.<output channel 1|2>

Function:Program manual output percentage

Return:<output percentage 0-100%>

OUTMODE <output channel 1|2>,<output mode 0-5 corresponds to OFF|PID|ZONE|MANU|MONITOR|WARMUP>,<start 0|1>

Function:configure output parameters

OUTMODE.<output channel 1|2>

Function:query output parameters

Return:<output mode 0-5 corresponds to OFF|PID|ZONE|MANU|MONITOR|WARMUP>,<start at boot 0|1>

PID <output channel 1|2>,<P 0.1-1000>,<I 0.1-1000>,<D 0-200>

Function:configure temperature control PID parameters

PID.<output channel 1|2>

Function:Query temperature control PID parameters

Return:<P 0.1-1000>,< I 0.1-1000>,<D 0-200>

POLARITY <output channel 2>,<output polarity 0-1 corresponds to single and bipolar>

Function:Configure output polarity

POLARITY.<output channel 2>

Function:Query output polarity

Return:<output polarity 0-1 corresponds to single and bipolar>

RAMP <output channel 1|2>,<RAMPING enable 0|1>,<rate value 0.1-100K/min>

Function:Configure output SP ramp parameters

RAMP.<output channel 1|2>

Function:Query output SP ramp parameters

Return:<RAMPING enable 0|1>,<rate value 0.1-100K/min>

RAMPST.<output channel 1|2>

Function:Query output RAMPING status

Return:<RAMPING 0|1>

RANGE <output channel 1|2>,<range 0-3 corresponds to OFF|LOW|MED|HIGH>

Function:configure the output range

RANGE.<output channel 1|2>

Function:Query the output range

Return:<range 0-3 corresponds to OFF|LOW|MED|HIGH>

RDGST.<Temperature measurement channel number A-D>

Function:Query temperature measurement status

Returns:<status word>

Status word B0 is invalid

Status word B1

Status word B2

Status word B3

Status word B4T.UNDER

Status word B5T.OVER

Status word B6S.UNDER

Status word B7S.OVER

RELAY <relay channel 1|2>,<mode 0-2 corresponds to OFF|ON|ALARM>,<alarm temperature measurement channel A-D>,<alarm form 0-2 corresponds to LOW|HIGH|BOTH>

Function:Configure relay output parameters

RELAY.<relay channel 1|2>

Function:Query relay output parameters

Return:<mode 0-2 corresponds to OFF|ON|ALARM>,<alarm temperature measurement channel A-D>,<alarm form 0-2 corresponds to LOW|HIGH|BOTH>

RELAYST.<relay channel 1|2>

Function:Query relay output status

Return:<output 0-1 corresponds to OFF|ON>

SCAL <standard curve 1|6|7>,<target curve 21-59>,<SN 15 characters>,<T1 first point temperature value K>,<U1 first point measurement value>,<T2 second point temperature Value K>,<U2 second point measurement value>,<T3 third point temperature value K>,<U3 third point measurement value>

Function:Sensor temperature curve software three-point calibration

SETP <output channel 1|2>,<set value unit is the same as the corresponding temperature measurement channel>

Function:Set temperature control loop SP

SETP.<output channel 1|2>

Function:Query control loop SP

Return:<set value>

SLEEP

Function:Instrument sleep

SRDG.<Temperature measurement channel A-D>

Function:Query the output value of the temperature sensor

Return:<temperature sensor output value>

STATE?

Function:Query instrument status

Returns:<status word>

Status word B0SLEEP Sleeping

Status word B1WAKEUP is waking up

Status word B2ACTIVE running

Status word B3SHUTDOWN is shutting down

Status word B4

Status word B5

Status word B6

Status word B7

TEMP?

Function:Query the temperature value of thermocouple compensation

Return:<Thermocouple compensation temperature value K>

TLIM <temperature measurement channel A-D>,<temperature upper limit value K>

Function:Set the upper limit of temperature measurement,unit:K

TLIM.<Temperature channel A-D>

Function:Query the upper limit of temperature measurement,unit:K

Return:<temperature upper limit value K>

TUNEST?

Function:Query the setting status of temperature control parameters

Return:<activity status 0|1>,<temperature control channel 1|2>,<error 0|1>,<progress stage>

WAKEUP

Function:Instrument wake up

WARMUP <output channel 2>,<control type 0-1 corresponds to automatic shutdown after reaching the set temperature | continue output>,<control output percentage>

Function:Set heating control parameters

WARMUP.<output channel 2>

Function:Query heating control parameters

Return:<control type 0-1 corresponds to automatic shutdown after reaching the set temperature | continue output>,<control output percentage>

ZONE <output channel 1|2>,<segment number 1-10>,<segment temperature upper point K>,<P 0.1-1000>,<I 0.1-1000>,<D 0-200>,< MOUT 0-100%>,<range 0-3 corresponds to OFF|LOW|MED|HIGH>,<temperature measurement channel 0-4 corresponds to previous A-D>,<rate 0.1-100K/min>

Function:Set segmented temperature control parameters

ZONE.<output channel 1|2>,<segment number 1-10>

Function:Query segmented temperature control parameters

Return:<Sectional point K>,<P 0.1-1000>,<I 0.1-1000>,<D 0-200>,<MOUT 0-100%>,<Range 0-3 corresponds to OFF|LOW |MED|HIGH>,<temperature measurement channel 0-4 corresponds to previous A-D>,<rate 0.1-100K/min>

Chapter 7 Options and Accessories

7.1 General

This chapter introduces the models,options and accessories of the TC290 temperature controller.

7.2 Model

Model	Model Description
TC290	Standard temperature controller,2 diode/RTD inputs and 2 control outputs.

7.3 Options

Model	Model Description
TC2901	Diode/RTD expansion card.Add 8 scan diode/RTD inputs to the TC290 temperature controller.
TC2902	Dual thermocouple input expansion card.Add 2 thermocouple inputs to the TC290 temperature controller.
TC2903	Capacitive input expansion card.Add a capacitive sensor input to the TC290 temperature controller.
TC2905	100W heating card,increase to 2-way 100W,or 1-way 200W function.

7.4 Accessories

Model	Model Description
290-1	4 heater output plugs.Dual banana jacks for heater output.
290-2	2 sensor input connectors.6-pin DIN plug for diode/resistor input.
290-3	3 terminal block connectors.For RS485,relay and output 3,TIGGER wiring.
290-4	Standard 220V AC power cord.
290-5	TC290 temperature controller User Manual and CD-ROM.

Chapter 8 Services

8.1 General

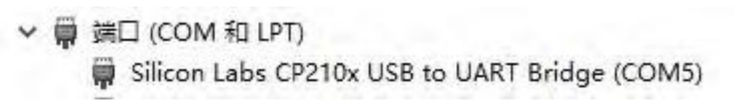
This chapter provides basic service information for the TC290 temperature controller.Customer service for the product is limited to the information described in this chapter.If the instrument requires service,a factory-trained service person should be consulted.

8.2 USB Troubleshooting

This section provides USB interface troubleshooting for new installations,existing installations,and intermittent failures.

8.2.1 New installation

1.Check the USB drivers are installed correctly and that the device is working properly.You can use the device manager to check the device status to see if there is a question mark or exclamation mark before the device driver,if not,it means it is normal.As shown below:



2.Check that the correct COM port is used.The COM port number can be checked and changed using the Device Manager COM port right-click properties.

3.Check the communication settings are correct.Including the baud rate communication address data bit start bit stop bit check bit.

4.Check the cable connection and length are less than 5 meters.

5.Send message terminator.

6.Send the entire message string at once,including the terminator.(Many terminal emulators not available.)

7.Only send one simple command at a time until communication is established.

8.Make sure to spell the command correctly and use the correct grammar.

8.2.2 The existing installation is no longer working

1.Disconnect power to the instrument,then turn it on again to see if it is a soft fault.

2.Power off the computer and then power on again to see if the communication port is locked.

3.Check all cable connections.

4.Check if the COM port assignment has changed.The COM port number can be checked using Device Manager.

5.Check that the USB driver is installed correctly and the device is working properly.You can use the device manager to check the device status to see if there is a question mark or exclamation mark in front of the device driver.

8.2.3 Intermittent Locking

1.Check that the cable connection and length are less than 5 meters.

2.Increase the delay between all commands to 100 ms to ensure the instrument does not time out.

3.Make sure the USB cable is not unplugged and the TC290 is not powered off when the COM port is open.The USB driver creates a COM port when it detects a USB connection,and deletes the COM port when no USB connection is detected.If the COM port is removed while the software is in use,it may cause the software to lock up or crash.

8.3 Factory reset menu

Sometimes it is necessary to reset the instrument parameter values or clear the contents of the curve memory.They are all stored in non-volatile memory called novram,and this part of the data can be erased.However,the meter calibration data is not affected,and there is no need to worry about it being cleared.

8.4 Calibration procedure

Instrument calibration can be obtained through the MAG after-sales service.For technical consultation,please contact MAG by telephone.

8.5 Electrostatic discharge

Electrostatic discharge (ESD) can damage electronic parts,assemblies and equipment.ESD is electrostatic charge transfer between objects under different electrostatic potentials generated by direct contact or electrostatic field induction..The human body is the most common low-energy source of damage to ESD-sensitive devices,generating and maintaining static electricity.running through a carpet at low humidity can generate up to 35,000 volts of static electricity.

Electrostatic discharge levels of as little as a few hundred volts can damage electronic components during testing,handling,repair,or assembly,Such as semiconductors,thick and thin film resistors and piezoelectric crystals.Discharge voltages below 4000 V cannot be seen,felt or heard.

Before attempting installation,observe all necessary precautions to prevent damage to ESDS components.By providing a conductive surface and discharge paths that bring the device and all its contacts to ground potential.At a minimum,the following precautions should be observed:

1.Disconnect or disconnect all power,signal sources and loads used with the unit.

2.Place the unit on a grounded conductive work surface.

3.Technicians should be grounded via a conductive wrist strap (or other device),with a 1 M series resistor to protect the operator.