GAMRY INSTRUMENTS

TDC5™ Temperature Controller

Operator's Manual

Revision 1
January 21, 2019
Part # 988-00072

Limited Warranty

Gamry Instruments, Inc. warrants to the original user of this product that it shall be free of defects resulting from faulty manufacture of the product or its components for a period of two years from the date of shipment.

Gamry Instruments, Inc. makes no warranties regarding either the satisfactory performance of the TDC5 Temperature Controller including the software used with this product or the fitness of TDC5-based systems for any particular purpose. The remedy for breach of this Limited Warranty shall be limited solely to repair or by replacement, as determined by Gamry Instruments, Inc., and shall not include other damages.

Gamry Instruments, Inc. reserves the right to make revisions to the TDC5 at any time without incurring any obligation to install same on TDC5s previously purchased. All system specifications are subject to change without notice.

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If You Have Problems

Contact us at your earliest convenience. We can be contacted via:

Telephone	(215) 682-9330	9:00 AM–5:00 PM US Eastern Standard Time
	(877) 367-4267	Toll-free US & Canada Only
Fax	(215) 682-9331	
E-mail	techsupport@gamry.com	
Mail	Gamry Instruments, Inc. 734 Louis Drive Warminster, PA 18974 USA	

If you write to us about a problem, provide as much information as possible.

If you are having problems in installation or use of this TDC5 Temperature Controller, please call from a telephone next to the instrument, where you can change instrument settings while talking to us.

We are happy to provide a reasonable level of free support for TDC5 purchasers. Reasonable support includes telephone assistance covering the normal installation, use, and simple tuning of the TDC5.

Disclaimers

Gamry Instruments, Inc. cannot guarantee that the TDC5 will work with all computer systems, heaters, cooling devices, or cells.

The information in this manual has been carefully checked and is believed to be accurate as of the time of printing. However, Gamry Instruments, Inc. assumes no responsibility for errors that might appear.

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Chapter 1: Safety Considerations

Introduction

The Gamry Instruments TDC5 is based on a standard temperature controller, the Omega Engineering Inc. Model CS8DPT. Gamry Instruments has performed slight modifications of this unit to allow easier incorporation of it into an electrochemical test system.

Omega provides a User's Guide that covers safety issues in detail. In most cases, the Omega information is not duplicated here. If you do not have a copy of this document, contact Omega at http://www.omega.com.

Your TDC5 Temperature Controller has been supplied in a safe condition. Consult the Omega User's Guide to ensure continued safe operation of this device.

Inspection

When you receive your TDC5 Temperature Controller, inspect it for evidence of shipping damage. If you note any damage, please notify Gamry Instruments Inc. and the shipping carrier immediately. Save the shipping container for possible inspection by the carrier.

Warning: A TDC5 Temperature Controller damaged in shipment can be a safety hazard. The protective grounding can be rendered ineffective if the TDC5 is damaged in shipment. Do not operate damaged apparatus until a qualified service technician has verified its safety. Tag a damaged TDC5 to indicate that it could be a safety hazard.

As defined in IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus, the TDC5 is a Class I apparatus. Class I apparatus is only safe from electrical shock hazards if the case of the apparatus is connected to a protective earth ground.

In the TDC5 this protective ground connection is made via the ground prong in the AC line cord. When you use the TDC5 with an approved line cord, the connection to the protective earth ground is automatically made prior to making any power connections.

Warning: If the protective ground is not properly connected, it creates a safety hazard, which could result in personnel injury or death. Do not negate the protection of this earth ground by any means. Do not use the TDC5 with a 2 wire extension cord, with an adapter that does not provide for protective grounding, or with an electrical outlet that is not properly wired with a protective earth ground.

The TDC5 is supplied with a line cord suitable for use in the United States. In other countries, you may have to replace the line cord with one suitable for your electrical outlet type. You must always use a line cord with a

CEE 22 Standard V female connector on the instrument end of the cable. This is the same connector used on the US standard line cord supplied with your TDC5. Omega Engineering (http://www.omega.com) is one source for international line cords, as described in their User's Guide.

Warning: If you replace the line cord, you must use a line cord rated to carry at least 15 A of AC current. If you replace the line cord you must use a line cord with the same polarity as that supplied with the TDC5. An improper line cord can create a safety hazard, which could result in injury or death.

The wiring polarity of a properly wired connector is shown in the Table 1-1 for both US line cords and European line cords that follow the "harmonized" wiring convention.

Table 1-1
Line Cord Polarities and Colors

	Line	**Neutral**	**Earth Ground**
US	Black	White	Green
European	Brown	Light Blue	Green/Yellow

If you have any doubts about the line cord for use with your TDC5, please contact a qualified electrician or instrument service technician for assistance. The qualified person can perform a simple continuity check that can verify the connection of the TDC5 chassis to earth and thereby check the safety of your TDC5 installation.

Line Voltages

The TDC5 is designed to operate at AC line voltages between 90 and 240 VAC, 50 or 60 Hz. No modification of the TDC5 is required when switching between US and international AC line voltages.

Switched AC Outlet Fuses

Both of the switched outlets on the back of the TDC5 have fuses above and to the left of the outputs. In accordance with international safety standards, both the line and neutral connections are fused. For Output 1, the maximum allowed fuse rating is 3 A; for Output 2, the maximum allowed fuse is 5A.

The TDC5 is provided with 3 A and 5 A, fast-blow, 5 × 20 mm fuses in the switched outlets.

You may wish to tailor the fuses in each outlet for the expected load. For example, if you are using a 200 W cartridge heater with a 120 VAC power line, the nominal current is a bit less than 2 A. You may want to use a 2.5 A or 3 A fuse in the switched outlet to the heater. Keeping the fuse rating just above the rated power can prevent or minimize damage to an improperly operated heater.

TDC5 Electrical Outlet Safety

The TDC5 has two switched electrical outlets on the rear panel of its enclosure. These outlets are under the control of the TDC5's controller module or a remote computer. For safety considerations, whenever the TDC5 is powered, you must treat these outlets as being on.

In most cases, the TDC5 will power one or both of these outlets when it is first powered up.

Warning: The switched electrical outlets on the TDC5 rear panel must always be treated as on whenever the TDC5 is powered. Remove the TDC5 line cord if you must work with a wire in contact with these outlets. Do not trust that the control signals for these outlets, when off, remains off. Do not touch any wire connected to these outlets unless the TDC5 line cord has been disconnected.

Heater Safety

The TDC5 Temperature Controller is often used to control an electrical heating apparatus that is located on or very near to an electrochemical cell filled with electrolyte. This can represent a significant safety hazard unless care is taken to insure that the heater has no exposed wires or contacts.

Warning: An AC-powered heater connected to a cell containing electrolyte can represent a significant electrical-shock hazard. Make sure that there are no exposed wires or connections in your heater circuit. Even cracked insulation can be a real hazard when salt water is spilled on a wire.

RFI Warning

Your TDC5 Temperature Controller generates, uses, and can radiate radio-frequency energy. The radiated levels are low enough that the TDC5 should present no interference problem in most industrial laboratory environments. The TDC5 may cause radio-frequency interference if operated in a residential environment.

Electrical Transient Sensitivity

Your TDC5 Temperature Controller was designed to offer reasonable immunity from electrical transients. However, in severe cases, the TDC5 could malfunction or even suffer damage from electrical transients. If you are having problems in this regard, the following steps may help:

If the problem is static electricity (sparks are apparent when you touch the TDC5:

Placing your TDC5 on a static control work surface may help. Static-control work surfaces are now generally available from computer supply houses and electronics tool suppliers. An antistatic floor mat may also help, particularly if a carpet is involved in generating the static electricity.

Air ionizers or even simple air humidifiers can reduce the voltage available in static discharges.

If the problem is AC power-line transients (often from large electrical motors near the TDC5):

Try plugging your TDC5 into a different AC-power branch circuit.

Plug your TDC5 into a power-line surge suppressor. Inexpensive surge suppressors are now generally available because of their use with computer equipment.

Contact Gamry Instruments, Inc. if these measures do not solve the problem.

Chapter 2: Installation

This chapter covers normal installation of the TDC5 Temperature Controller. The TDC5 was designed to run the experiments in the Gamry Instruments CPT Critical Pitting Test System, but it is also useful for other purposes.

The TDC5 is an Omega Engineering Inc., Model CS8DPT Temperature Controller. Please review the Omega User's Guide to familiarize yourself with the operation of the temperature controller.

Initial Visual Inspection

After you remove your TDC5 from its shipping carton, check it for any signs of shipping damage. If any damage is noted, please notify Gamry Instruments, Inc. and the shipping carrier immediately. Save the shipping container for possible inspection by the carrier.

Warning: The protective grounding can be rendered ineffective if the TDC5 is damaged in shipment. Do not operate damaged apparatus until its safety has been verified by a qualified service technician. Tag a damaged TDC5 to indicate that it could be a safety hazard.

Unpacking Your TDC5

The following list of items should be supplied with your TDC5:

Qty	Gamry P/N	Omega P/N	Description
1	990-00491		Gamry TDC5 (modified Omega CS8DPT)
1	988-00072		Gamry TDC5 Operator's Manual (this document)
1	720-00078		Main Power Cord, USA version
1	985-00192		USB 3.0 type A male/male cable, 6 ft.
1		M4640	Omega User's Guide
1	990-00055		RTD Probe
1	720-00016		TDC5 Adapter for RTD cable

Contact your local Gamry Instruments representative if you cannot find any of these items in your shipping containers.

Physical Location

You can place your TDC5 on a normal workbench surface. You will need access to the rear of the instrument because power connections are made from the rear. The TDC5 is not restricted to operation in a flat position. You can operate it on its side, or even upside-down.

Differences Between an Omega CS8DPT and a TDC5

Hardware Differences

A Gamry Instruments TDC5 has one addition compared to an unmodified Omega CS8DPT: A new connector is added to the front panel. It is a three-pin connector used for a three-wire 100 Ω platinum RTD. The RTD connector is wired in parallel with the input terminal strip on the Omega CS8DPT. You can still make use of the full range of input connections.

If you make other input connections:

- Be careful to avoid connecting two input devices, one to the 3-pin Gamry connector and one to the terminal strip. Unplug the RTD from its connector if you connect any sensor to the input terminal strip.
- You must reconfigure the controller for the alternate input. Consult the Omega manual for additional details.

Firmware Differences

The firmware configuration settings for the PID (proportional, integrating and derivative) controller in the TDC5 are changed from the Omega defaults. See Appendix A for details. Basically, Gamry Instruments' controller setup includes:

Configuration for operation with a three-wire 100 Ω platinum RTD as the temperature sensor,

PID tuning values appropriate for a Gamry Instruments Flexcell™ with a 300 W heating jacket and active cooling through the Flexcell's heating coil.

AC Line Connection

The TDC5 is designed to operate at AC line voltages between 90 and 240 VAC, 50 or 60 Hz. You must use a suitable AC power cord to connect the TDC5 to your AC power source (mains).

Your TDC5 was shipped with a USA-type AC power input cord. If you need a different power cord, you may obtain one locally or contact Omega Engineering Inc. (http://www.omega.com).

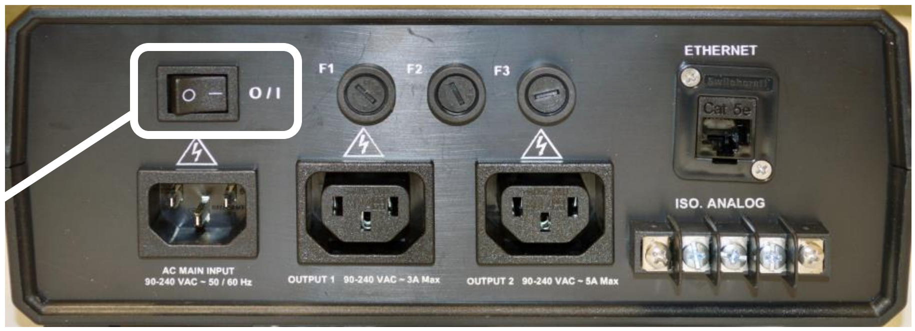
The power cord using with the TDC5 must terminate with a CEE 22 Standard V female connector on the instrument end of the cable and must be rated for 10 A service.

Warning: If you replace the line cord you must use a line cord rated to carry at least 10 A of AC current. An improper line cord can create a safety hazard, which could result in injury or death.

Power-up Check

After the TDC5 is connected to an appropriate AC voltage source, you can turn it on to verify its basic operation.

The power switch is a large rocker switch on the left side of the rear panel.



Make sure that a newly installed TDC5 has no connection to its switched **OUTPUT** outlets when it is first powered. You want to verify that the TDC5 powers up correctly before you add the complexity of external devices.

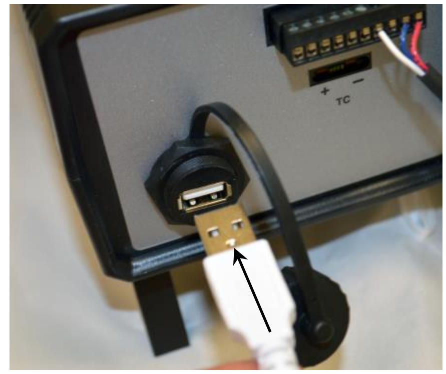
When the TDC5 is powered up, the temperature controller should light up and display a couple of status messages. Each message will be displayed for a few seconds.

If you connected an RTD to the unit, the upper display should show the current temperature at the probe (the units are degrees Celsius). If you do not have a probe installed, the upper display should show a line containing the characters **oPER**, as shown below:

Once the unit has powered up correctly, turn it off before making the remaining system connections.

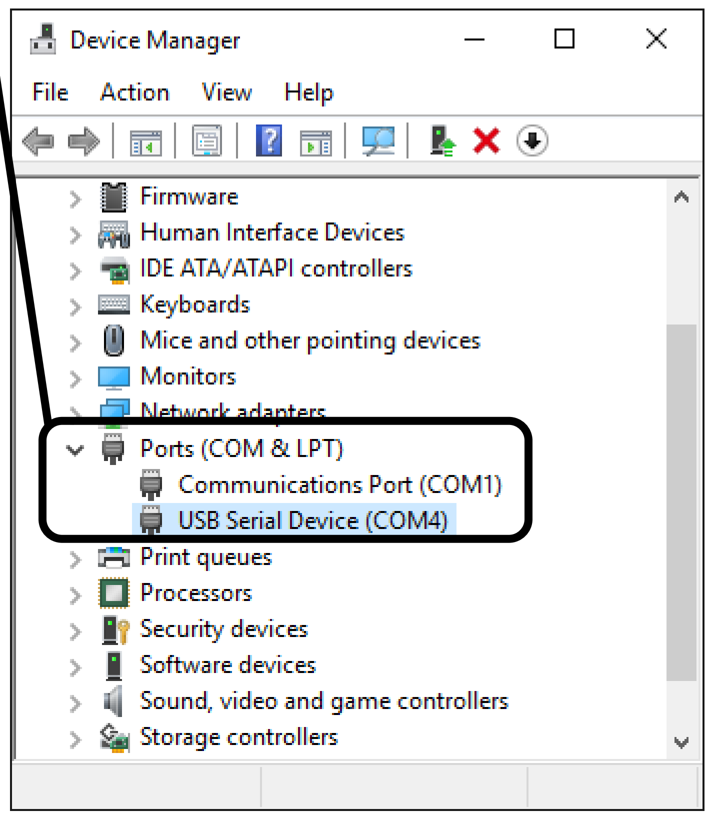
USB Cable

Connect the USB cable between the USB Type-A port on the front panel of the TDC5 and a USB Type-A port on your host computer. The supplied cable for this connection is a dual-ended USB Type-A cable. Type A is a rectangular connector. (Type B is an almost square USB connector.)

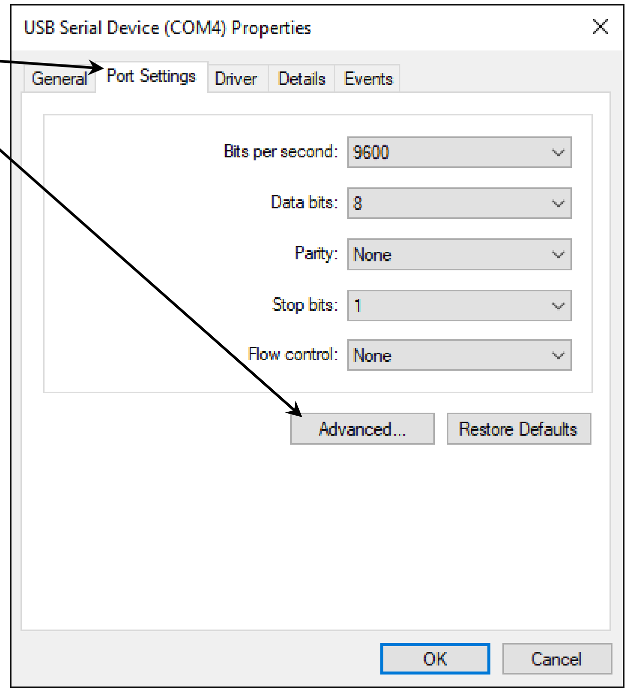


Using Device Manager to Install TDC5

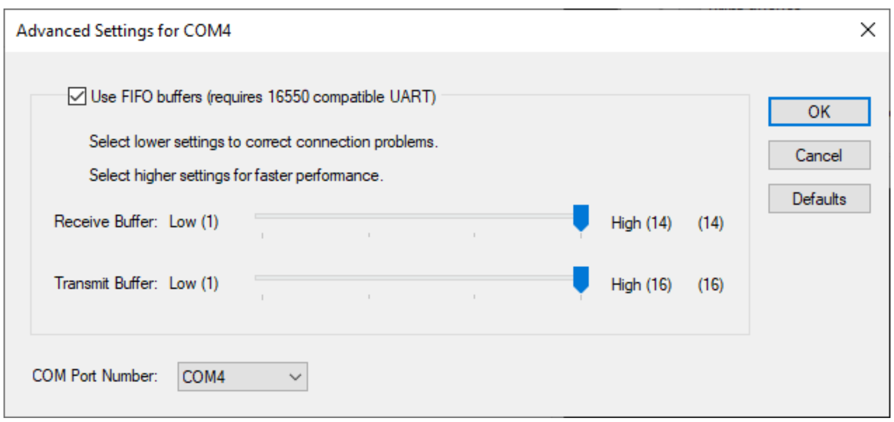
1. After the TDC5 is plugged into an available USB port on the host computer, turn on the host computer.
2. Log into your user account.
3. Run **Device Manager** on the host computer.
   In Windows® 7, you can find **Device Manager** in the **Control Panel**. In Windows® 10, you can find it by searching in the Windows® search box.
4. Expand the **Ports** section in **Device Manager** as shown.
5. Turn on the TDC5 and look for a new entry that suddenly appears under **Ports**. This entry will tell you the COM number associated with the TDC5. Take note of this for use during installation of the Gamry Instruments software.
6. If the COM port is higher than number 8, decide on a port number less than 8.
7. Right-click on the new **USB Serial Device** that suddenly appeared, and select **Properties**.
   A **USB Serial Device Properties** window like the one shown on the next page appears.



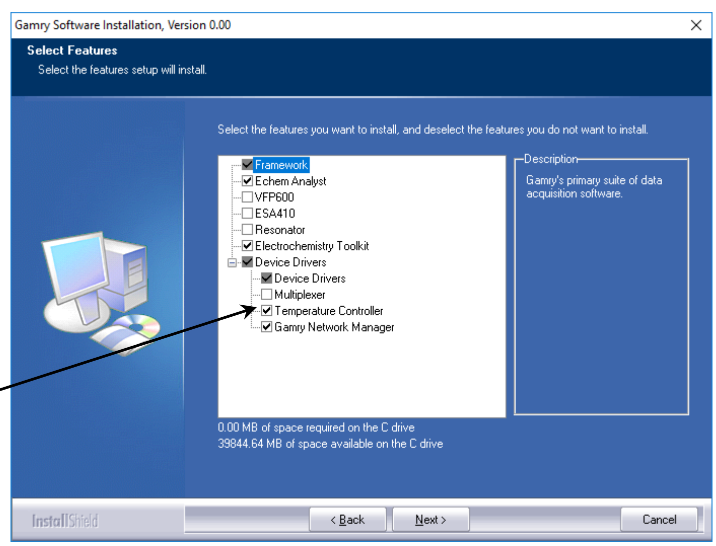
8. Select the **Port Settings** tab.
9. Click the **Advanced…** button.



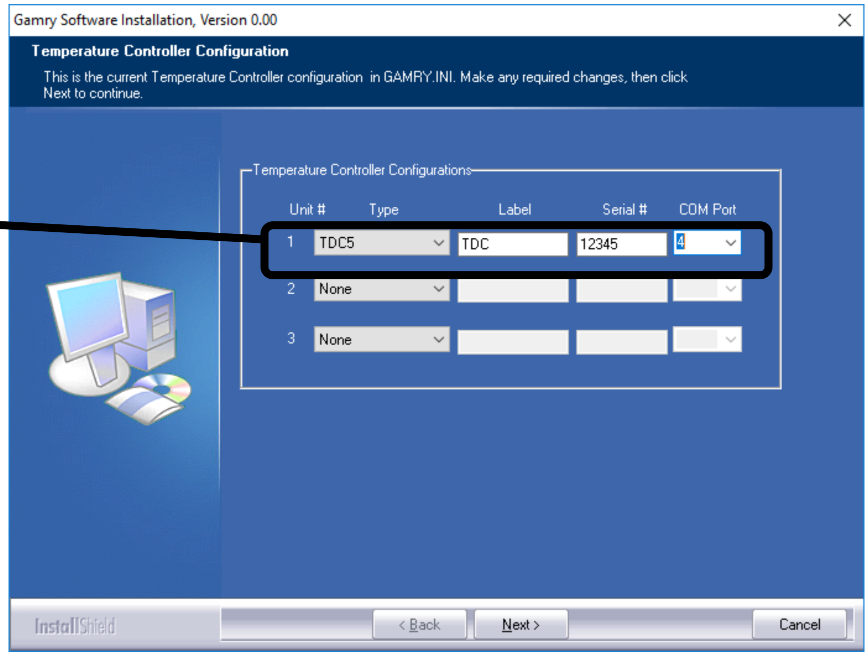
The **Advanced Settings for COM*x*** dialog box appears as shown below. (Here ***x*** stands for the particular port number you have chosen.)



10. Select a new **COM Port Number** from the drop-down menu. Select a number of 8 or less. You do not need to change any other settings. After you have made a selection, remember this number to use during the Gamry Software Installation.
11. Click the **OK** buttons on the two open dialog boxes to close them.
12. Close the **Device Manager** by clicking on the **X** in the upper right-hand corner.
13. Proceed with the Gamry Software Installation.
14. Make sure to select **Temperature Controllers** in the **Select Features** dialog box during installation:



15. During installation, be sure to choose the TDC5 in the **Temperature Controller Configurations Type** drop-down menu. Choose the correct **COM port** that you noted down earlier.



Connecting the TDC5 to a Heater or Cooler

There are many ways to heat an electrochemical cell. These include an immersible heater in the electrolyte, heating tape surrounding the cell, or a heating mantle. The TDC5 can be used with all these types of heaters, as long as they are AC-powered.

Warning: An AC-powered heater connected to a cell containing electrolyte can represent a significant electrical-shock hazard. Make sure that there are no exposed wires or connections in your heater circuit. Even cracked insulation can be a hazard when salt water is spilled on a wire.

The AC power for the heater is drawn from **Output 1** on the rear panel of the TDC5. This output is a IEC Type B female connector (common in the USA and Canada). Electrical cords with the corresponding male connector are available worldwide.

Please check that the fuse on **Output 1** is appropriate for use with your heater. The TDC5 is shipped with a 3 A **Output 1** fuse already installed.

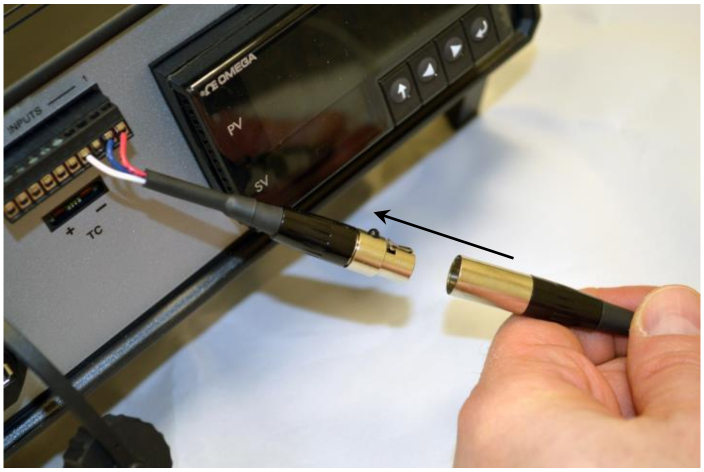
In addition to controlling a heater, the TDC5 can control a cooling device. The AC power for the cooler is drawn from the outlet labeled **Output 2** on the rear of the TDC5.

The cooling device can be as simple as a solenoid valve in a cold-water line leading to a water jacket surrounding the cell. Another common cooling device is the compressor in a refrigeration unit.

Before connecting a cooling device to the TDC5, verify that the **Output 2** fuse is the correct value for your cooling device. The TDC5 is shipped with a 5 A **Output 2** fuse already installed.

Connecting the TDC5 to an RTD Probe

The TDC5 must be able to measure the temperature before it can control it. The TDC5 uses a platinum RTD to measure the cell temperature. A suitable RTD is supplied with the TDC5. This sensor plugs into adapter cable supplied with your TDC5:



Contact Gamry Instruments, Inc. at our US facility if you need to substitute a third-party RTD into a CPT system.

Place the active end of the RTD as close as possible to the working electrode in your cell. This minimizes the effect of thermal gradients on the control accuracy.

Cell Cables from the Potentiostat

A TDC5 in your system does not affect the cell cable connections. These connections are made directly from the potentiostat to the cell. Please read the your potentiostat's Operator's Manual for cell cable instructions.

Setting up the TDC5 Operating Modes

The PID controller built into the TDC5 has a number of different operating modes, each of which is configured by means of user-entered parameters.

Please refer to the Omega documentation supplied with your TDC5 for information about the various controller parameters. Do not change a parameter without some knowledge of that parameter's effect on the controller.

The TDC5 is shipped with default settings appropriate for heating and cooling a Gamry Instruments FlexCell using a 300 W heating jacket and a solenoid-controlled cold-water flow for cooling.

Appendix A lists the factory TDC5 settings.

Checking TDC5 Operation

To test the operation of the TDC5, run a simple check-out script provided with the CPT Critical Pitting Test System. The name of this script is `CHECK110.EXP`. Use the procedure in the CPT Installation Manual to perform this checkout.

Chapter 3 : Use

This chapter covers normal use of the TDC5 Temperature Controller. The TDC5 is intended primarily for use in the Gamry Instruments CPT Critical Pitting Test System. It should also prove useful in other applications.

The TDC5 is based on the Omega CS8DPT temperature controller. Please read the Omega documentation to familiarize yourself with the operation of this apparatus.

Using Framework Scripts to Set Up and Control Your TDC5

For your convenience, the Gamry Instruments Framework™ software includes a number of Explain™ scripts that simplify setup and tuning of the TDC5. These scripts include:

`TDC5 Start Auto Tune.exp`	Used to start the controller auto-tune process
`TDC5 Initialize Settings.exp`	Restores the TDC5 to the factory default settings

Tuning the TDC5 so that it works optimally on your experimental setup is very difficult using the front-panel controls of the TDC5. We *strongly recommend* that you use the scripts listed above to tune your TDC5.

There is one downside to using these scripts. They only run on a computer that has a Gamry Instruments potentiostat installed in the system and currently connected. If you do not have a potentiostat in the system, the script will show an error message and terminate before it outputs anything to the TDC5.

You cannot run any TDC5 script on a computer that does not include a Gamry Instruments potentiostat.

Thermal Design of Your Experiment

The TDC5 is used to control the temperature of a electrochemical cell. It does so by turning on and off a heat source that transfers heat to the cell. Optionally, a cooler can be used to remove heat from the cell. In either case, the TDC5 switches AC power to the heater or cooler to control the direction of any transfer of heat.

The TDC5 is a closed-loop system. It measures the temperature of the cell and uses feedback to control the heater and cooler.

Two major thermal problems are present to some degree in all system designs:

The first problem is temperature gradients in the cell. They are invariably present. However, they can be minimized by proper cell design.

Stirring the electrolyte helps a great deal.

The heater should have a large area of contact with the cell. Water jackets are good in this regard. Cartridge type heaters are poor.

Insulation surrounding the cell may minimize inhomogeneities by slowing the loss of heat through the walls of the cell. This is especially true near the working electrode, which may represent the major pathway of escaping heat. It is not unusual to find the electrolyte temperature near the working electrode 5–20°C lower than that of the bulk of the electrolyte.

If you cannot prevent thermal inhomogenieties, you can at least minimize their effects. One important design consideration is the placement of the RTD used to sense the cell temperature. Place the RTD as close as possible to the working electrode. This minimizes the error between the actual temperature at the working electrode and the temperature setting.

A second problem concerns the rate of temperature change. You would like to have the rate of heat transfer to the cell's contents high, so that changes in the cell's temperature can be made quickly. A more subtle point is that the rate of heat loss from the cell should also be high. If it is not, the controller risks gross overshoots of the set point temperature when it raises the cell temperature. Ideally, the system actively cools the cell as well as heats it. Active cooling can consist of a system as simple as tap water flowing through a cooling coil and a solenoid valve. Temperature control via an external heater such as a heating mantle is moderately slow. An internal heater, such as a cartridge heater is often quicker.

Tuning the TDC5 Temperature Controller: Overview

Closed-loop control systems such as the TDC5 *must* be tuned for optimal performance. A poorly tuned system suffers from slow response, overshoot, and poor accuracy. The tuning parameters depend greatly on the characteristics of the system being controlled.

The temperature controller in the TDC5 can be used in an ON/OFF mode or a PID (Proportional, Integral, Derivative) mode. The ON/OFF mode uses hysteresis parameters to control its switching. The PID mode uses tuning parameters. The controller in PID mode reaches the set-point temperature quickly without much overshoot and maintains that temperature within a closer tolerance than the ON/OFF mode.

When to Tune

The TDC5 is normally operated in PID (proportional, integrating, derivative) mode. This is a standard method for process-control equipment that allows for rapid changes in the set parameter. In this mode the TDC5 must be tuned to match it to the thermal characteristics of the system that it is controlling.

The TDC5 is shipped in a default for PID-control mode configuration. You must explicitly change it to operate in any other control mode.

The TDC5 is initially configured with parameters appropriate for a Gamry Instruments FlexCell™ heated with a 300 W jacket and cooled using solenoid-valve controlling water-flow through a cooling coil. The tuning settings are described below:

FACTORY-SET TUNING PARAMETERS

Parameter (Symbol)	Setting
Proportional Band 1	9°C
Reset 1	685 s
Rate 1	109 s
Cycle Time 1	1 s
Dead Band	14 db

Retune your TDC5 with your cell system before you use it to run any real tests. Retune whenever you make major changes in the thermal behavior of your system. Typical changes that may require retuning include:

Changing to a different cell,

Addition of thermal insulation to the cell,

Addition of a cooling coil,

Changing the position or power of the heater, or

Changing from an aqueous electrolyte to an organic electrolyte.

In general you do not have to retune when switching from one aqueous electrolyte to another. Tuning is therefore only an issue when you first set up your system. After the controller has been tuned for your system, you may ignore tuning as long as your experimental setup remains relatively constant.

Restoring Factory Settings

The TDC5 is configured using many settings (fully listed in Appendix A) which can be entered by a complicated user interface using the four buttons on the front of the TDC5. We anticipate that anyone using this interface is likely to scramble the TDC5 settings at least once. Various “automatic” TDC5 operations could also result in incorrect settings, especially if they are interrupted in mid-operation.

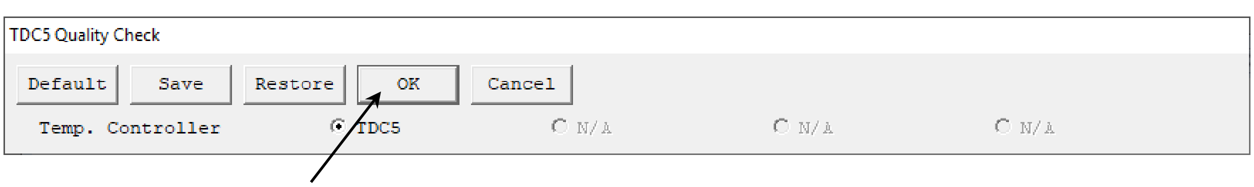
Re-entering all the default settings manually would be time-consuming and error-prone. For this reason, Gamry Instruments has provided an Explain script that resets all TDC5 settings to the default settings:

Start the Gamry Instruments Framework™ software.

Select **Experiment > Named Script… > TDC5 Initialize Settings.exp** from the Framework menu. (The Framework script that resets the TDC5 is `TDC5 Initialize Settings.exp`).

When this script runs, it displays a **TDC5 Quality Check** window similar to that in Figure 3-1.

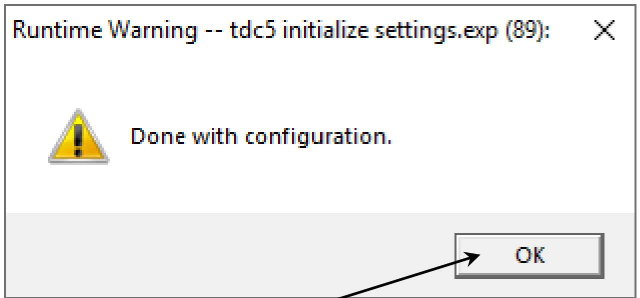
Figure 3-1. Initial Dialog Box Displayed by a TDC5 Script



When you click the **OK** button, the script sends configuration data to the TDC5.

This process should take less than one minute. At the end of the transfer process, a second dialog box, similar to Figure 3-2, appears.

Figure 3-2. Final Dialog Box Displayed by a TDC5 Script



Click the **OK** button to end the reset process.

Automatic versus Manual Tuning

Tune your TDC5 automatically whenever possible.

Unfortunately, the system response with many electrochemical cells is too slow for auto tuning. You cannot auto tune if a 5°C increase or decrease in the system temperature takes more than ten minutes. In most cases, auto tune on an electrochemical cell will fail unless the system is actively cooled.

A full description of the manual tuning of PID controllers is beyond the scope of this manual. However, a later section of this chapter does give a relatively simple step-by-step procedure for manually tuning the TDC5.

The following table contains the tuning parameters for a Gamry Instruments Flex Cell used with a 300 W heating mantle and switched cooling using water flow though the standard cooling coil. The solution was stirred.

Parameter (Symbol)	Setting
Proportional Band 1	9°C
Reset 1	685 s
Rate 1	109 s
Cycle Time 1	1 s
Dead Band (db)	14

Auto Tuning the TDC5

We strongly recommend that you auto-tune the TDC5 as explained in the *Omega® User's Guide*, section 4.6.2.

Appendix A: Default Controller Configuration

Initialization Mode Menu

Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Notes
INPt	t.C.	k					Type K thermocouple
		J					Type J thermocouple
		t					Type T thermocouple
		E					Type E thermocouple
		N					Type N thermocouple
		R					Type R thermocouple
		S					Type S thermocouple
		b					Type B thermocouple
		C					Type C thermocouple
	Rtd	N.wIR	3 wI				3-wire RTD
			4 wI				4-wire RTD
			2 wI				2-wire RTD
		A.CRV	385.1				385 calibration curve, 100 Ω
			385.5				385 calibration curve, 500 Ω
			385.t				385 calibration curve, 1000 Ω
			392				392 calibration curve, 100 Ω
			391.6				391.6 calibration curve, 100 Ω
	tHRM	2.25k					2250 Ω thermistor
		5k					5000 Ω thermistor
		10k					10,000 Ω thermistor
	PRoC	4–20					Process input range: 4 to 20 mA
			Note: This Manual and Live Scaling submenu is the same for all **PRoC** ranges.				
			MANL	Rd.1			Low display reading
				IN.1			Manual input for Rd.1
				Rd.2			High display reading
				IN.2			Manual input for Rd.2
			LIVE	Rd.1			Low display reading
				IN.1			Live Rd.1 input, ENTER for current
				Rd.2			High display reading
				IN.2			Live Rd.2 input, ENTER for current
		0–24					Process input range: 0 to 24 mA
		+-10					Process input range: -10 to +10 V
			Note: +- 1.0 and +-0.1 support SNGL, dIFF and RtIO **tYPE**				
		+-1	tYPE	SNGL			Process input range: -1 to +1 V

Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Notes
				dIFF			Differential between AIN+ and AIN-
				RtLO			Ratiometric between AIN+ and AIN-
		+-0.1					Process input range: -0.1 to +0.1 V
			Note: The +- 0.05 input supports dIFF and RtIO **tYPE**				
		+-.05	tYPE	dIFF			Differential between AIN+ and AIN-
				RtLO			Ratiometric between AIN+ and AIN-
							Process input range: -0.05 to +0.05 V
tARE	dSbL						Disable tARE feature
	ENbL						Enable tARE on oPER menu
	RMt						Enable tARE on oPER and Digital Input
LINR	N.PNt						Specifies the number of points to use
			Note: The Manual / Live inputs repeat from 1..10, represented by ***n***				
	MANL	Rd.***n***					Low display reading
		IN.***n***					Manual input for Rd.***n***
	LIVE	Rd.***n***					Low display reading
		IN.***n***					Live Rd.***n*** input, ENTER for current
RdG	dEC.P	FFF.F					Reading format -999.9 to +999.9
		FFFF					Reading format -9999 to +9999
		FF.FF					Reading format -99.99 to +99.99
		F.FFF					Reading format -9.999 to +9.999
	°F°C	°C					Degrees Celsius annunciator
		°F					Degrees Fahrenheit annunciator
		NoNE					Turns off for non-temperature units
	d.RNd						Display Rounding
	FLtR	8					Readings per displayed value: 8
		16					16
		32					32
		64					64
		128					128
		1					2
		2					3
		4					4
			Note: Four digit displays offer 2 annunciators, Six digit displays offer 6				
	ANN.*n*	ALM.1					Alarm 1 status mapped to "1"
		ALM.2					Alarm 2 status mapped to "1"
		oUt#					Output state selections by name
	NCLR	GRN					Default display color: Green
		REd					Red

Appendix A: Default Controller Configuration

Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Notes
		AMbR					Amber
	bRGt	HIGH					High display brightness
		MEd					Medium display brightness
		Low					Low display brightness
ECtN	5 V						Excitation voltage: 5 V
	10 V						10 V
	12 V						12 V
	24 V						24 V
	0 V						Excitation off
CoMM	USb						Configure the USB port
		Note: This **PRot** submenu is the same for USB, Ethernet, and Serial ports.					
		PRot	oMEG	ModE	CMd		Waits for commands from other end
					CoNt		Transmit continuously every ###.# sec
				dAt.F	StAt	No	
						yES	Includes Alarm status bytes
					RdNG	yES	Includes process reading
						No	
					PEAk	No	
						yES	Includes highest process reading
					VALy	No	
						yES	Includes lowest process reading
					UNIt	No	
						yES	Send unit with value (F, C, V, mV, mA)
				_LF_	No		
					yES		Appends line feed after each send
				ECHo	yES		Retransmits received commands
					No		
				SEPR	_CR_		Carriage Return separator in **CoNt**
					SPCE		Space separator in **CoNt** Mode
			M.bUS	RtU			Standard Modbus protocol
				ASCI			Omega ASCII protocol
		AddR					USB requires Address
	EtHN	PRot					Ethernet port configuration
		AddR					Ethernet "Telnet" requires Address
	SER	PRot					Serial port configuration
		C.PAR	bUS.F	232C			Single device Serial Comm Mode
				485			Multiple devices Serial Comm Mode
			bAUd	19.2			Baud rate: 19,200 Bd

Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Notes
				9600			9,600 Bd
				4800			4,800 Bd
				2400			2,400 Bd
				1200			1,200 Bd
				57.6			57,600 Bd
				115.2			115,200 Bd
			PRty	odd			Odd parity check used
				EVEN			Even parity check used
				NoNE			No parity bit is used
				oFF			Parity bit is fixed as a zero
			dAtA	8bIt			8 bit data format
				7bIt			7 bit data format
			StoP	1bIt			1 stop bit
				2bIt			2 stop bits gives a “force 1” parity bit
		AddR					Address for 485, placeholder for 232
SFty	PwoN	RSM					RUN on power up if not previously faulted
		wAIt					Power on: **oPER** Mode, ENTER to run
		RUN					RUN’s automatically on power up
	RUN.M	dSbL					ENTER in **Stby, PAUS, StoP** runs
		ENbL					ENTER in modes above displays RUN
	SP.LM	SP.Lo					Low Setpoint limit
		SP.HI					High Setpoint limit
	SEN.M						Sensor Monitor
		LPbk	dSbL				Loop break timeout disabled
			ENbL				Loop break timeout value (MM.SS)
		o.CRk	ENbl				Open Input circuit detection enabled
			dSbL				Open Input circuit detection disabled
		E.LAt	ENbl				Latch sensor error enabled
			dSbL				Latch sensor error disabled
	OUT.M						Output Monitor
		oUt1					**oUt1** is replaced by output type
			o.bRk				Output break detection
				dSbL			Output break detection disabled
				ENbl	P.dEV		Output break process deviation
					P.tME		Output break time deviation
		oUt2					**oUt2** is replaced by output type
		oUt3					**oUt3** is replaced by output type
		E.LAt	ENbl				Latch output error enabled

Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Notes
			dSbL				Latch output error disabled
t.CAL	NoNE						Manual temperature calibration
	1.PNt						Set offset, default = 0
	2.PNt	R.Lo					Set range low point, default = 0
		R.HI					Set range high point, default = 999.9
	ICE.P	ok?					Reset 32°F/0°C reference value
		dSbL					Clears the ICE.P offset value
SAVE	_____						Download current settings to USB
LoAd	_____						Upload settings from USB stick
VER.N	1.00.0						Displays firmware revision number
VER.U	ok?						ENTER downloads firmware update
F.dFt	ok?						ENTER resets to factory defaults
I.Pwd	No						No required password for INIt Mode
	yES	_____					Set password for INIt Mode
P.Pwd	No						No password for PRoG Mode
	yES	_____					Set password for PRoG Mode

Programming Mode Menu

Level 2	Level 3	Level 4	Level 5	Level 6	Notes
SP1					Process goal for PID, default goal for **oN.oF**
SP2	ASbo				Setpoint 2 value can track **SP1**, **SP2** is an absolute value
	dEVI				**SP2** is a deviation value
ALM.1	***Note:*** This submenu is the same for all other Alarm configurations.				
	tyPE	oFF			ALM.1 is not used for display or outputs
		AboV			Alarm: process value above Alarm trigger
		bELo			Alarm: process value below Alarm trigger
		HI.Lo.			Alarm: process value outside Alarm triggers
		bANd			Alarm: process value between Alarm triggers
	Ab.dV	AbSo			Absolute Mode; use **ALR.H** and **ALR.L** as triggers
		d.SP1			Deviation Mode; triggers are deviations from **SP1**
		d.SP2			Deviation Mode; triggers are deviations from **SP2**
		CN.SP			Tracks the Ramp & Soak instantaneous setpoint
	ALR.H				Alarm high parameter for trigger calculations
	ALR.L				Alarm low parameter for trigger calculations
	A.CLR	REd			Red display when Alarm is active
		AMbR			Amber display when Alarm is active
		dEFt			Color does not change for Alarm
	HI.HI	oFF			High High / Low Low Alarm Mode turned off

Appendix A: Default Controller Configuration

Level 2	Level 3	Level 4	Level 5	Level 6	Notes
		GRN			Green display when Alarm is active
		oN			Offset value for active High High / Low Low Mode
	LtCH	No			Alarm does not latch
		yES			Alarm latches until cleared via front panel
		botH			Alarm latches, cleared via front panel or digital input
		RMt			Alarm latches until cleared via digital input
	CtCL	N.o.			Output activated with Alarm
		N.C.			Output deactivated with Alarm
	A.P.oN	yES			Alarm active at power on
		No			Alarm inactive at power on
	dE.oN				Delay turning off Alarm (sec), default = 1.0
	dE.oF				Delay turning off Alarm (sec), default = 0.0
ALM.2					Alarm 2
oUt1					**oUt1** is replaced by output type
	Note: This submenu is the same for all other outputs.				
	ModE	oFF			Output does nothing
		PId			PID Control Mode
			ACtN	RVRS	Reverse acting control (heating)
				dRCt	Direct acting control (cooling)
				RV.DR	Reverse/Direct acting control (heating/cooling)
		PId.2			PID 2 Control Mode
			ACtN	RVRS	Reverse acting control (heating)
				dRCt	Direct acting control (cooling)
				RV.DR	Reverse/Direct acting control (heating/cooling)
		oN.oF	ACtN	RVRS	Off when > SP1, on when < SP1
				dRCt	Off when < SP1, on when > SP1
			dEAd		Deadband value, default = 5
			S.PNt	SP1	Either Setpoint can be used of on/off, default is SP1
				SP2	Specifying SP2 allows two outputs to be set for heat/cool
		ALM.1			Output is an Alarm using ALM.1 configuration
		ALM.2			Output is an Alarm using ALM.2 configuration
		RtRN	Rd1		Process value for oUt1
			oUt1		Output value for Rd1
			Rd2		Process value for oUt2
		RE.oN			Activate during Ramp events
		SE.oN			Activate during Soak events
		SEN.E			Activate if any sensor error is detected
		OPL.E			Activate if any output is open loop
	CyCL				PWM pulse width in seconds
	RNGE	0-10			Analog Output Range: 0–10 Volts
			oUt2		Output value for Rd2

Level 2	Level 3	Level 4	Level 5	Level 6	Notes
		0-5			0–5 Volts
		0-20			0–20 mA
		4-20			4–20 mA
		0-24			0–24 mA
oUt2					**oUt2** is replaced by output type
oUt3					**oUt3** is replaced by output type (1/8 DIN can have up to 6)
PId	ACtN	RVRS			Increase to **SP1** (i.e., heating)
		dRCt			Decrease to **SP1** (i.e., cooling)
		RV.DR			Increase or Decrease to **SP1** (i.e., heating/cooling)
	A.to				Set timeout time for autotune
	tUNE	StRt			Initiates autotune after StRt confirmation
	GAIN	_P_			Manual Proportional Band setting
		_I_			Manual Integral Factor setting
		_d_			Manual Derivative Factor setting
	rCg				Relative Cool Gain (heating/cooling mode)
	oFst				Control Offset
	dEAd				Control Dead band/Overlap band (in process unit)
	%Lo				Low clamping limit for Pulse, Analog Outputs
	%HI				High clamping limit for Pulse, Analog Outputs
	AdPt	ENbL			Enable fuzzy logic adaptive tuning
		dSbL			Disable fuzzy logic adaptive tuning
PId.2	***Note:*** This menu is the same for PID menu.				
RM.SP	oFF				Use **SP1**, not remote Setpoint
	oN	4–20			Remote analog Input sets **SP1**; range: 4–20 mA
			Note: This submenu is the same for all **RM.SP** ranges.		
			RS.Lo		Min Setpoint for scaled range
			IN.Lo		Input value for **RS.Lo**
			RS.HI		Max Setpoint for scaled range
			IN.HI		Input value for **RS.HI**
		0–24			0–24 mA
		0–10			0–10 V
M.RMP	R.CtL	No			Multi-Ramp/Soak Mode off
		yES			Multi-Ramp/Soak Mode on
		RMt			**M.RMP** on, start with digital input
	S.PRG				Select program (number for **M.RMP** program), options 1–99
	M.tRk	RAMP			Guaranteed Ramp: soak SP must be reached in ramp time
		0–1			0–1 V

Level 2	Level 3	Level 4	Level 5	Level 6	Notes
		SoAk			Guaranteed Soak: soak time always preserved
		CYCL			Guaranteed Cycle: ramp can extend but cycle time can't
			Note: tIM.F does not appear for 6 digit display that use a HH:MM:SS format		
	tIM.F	MM:SS			"Minutes : Seconds" default time format for R/S programs
		HH:MM			"Hours : Minutes" default time format for R/S programs
	E.ACt	StOP			Stop running at the end of the program
		HOLd			Continue to hold at the last soak setpoint at program end
		LINk			Start the specified ramp & soak program at program end
	N.SEG				1 to 8 Ramp/Soak segments (8 each, 16 total)
	S.SEG				Select segment number to edit, entry replaces # below
			MRt.#		Time for Ramp number, default = 10
			MRE.#	oFF	Ramp events on for this segment
				oN	Ramp events off for this segment
			MSP.#		Setpoint value for Soak number
			MSt.#		Time for Soak number, default = 10
			MSE.#	oFF	Soak events off for this segment
				oN	Soak events on for this segment

Changes that Gamry Instruments Has Made to Default Settings

Set Omega Protocol, Command Mode, No Line Feed, No Echo, Use <CR>

Set Input Configuration, RTD 3 Wire, 100 ohms, 385 Curve

Set Output 1 to PID Mode

Set Output 2 to On/Off Mode

Set Output 1 On/Off Configuration to Reverse, Dead Band 14

Set Output 2 On/Off Configuration to Direct, Dead Band 14

Set Display to FFF.F degrees C, Green Color

Set Point 1 = 35 degrees C

Set Point 2 = 35 degrees C

Set Proportional Band to 9C

Set Integral factor to 685 s

Set Derivative factor Rate to 109 s

Set Cycle time to 1 s

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