

Physiological - Biological Temperature Controller

TMP-5x series

User Manual

SUPERTECH Instruments

It is optimized for seriously shielded environments in microelectrode laboratories. Its output current is as smooth as the current of a lead battery (with the 12 V FINE DC power driver stage). This design fulfills all requirements of any sophisticated electrophysiology application, even in close proximity to any, high impedance recording electrode. The best references of the noise free performance are the patch clamp setups with G Ω impedance electrodes next to the heating elements.

General Description

The Physiological - Biological Temperature Controller is an intelligent PID controller, based on an internal microcontroller. Typical PID controllers modulate the effective value of the output voltage by PWM. In our equipment the PID characteristics were realized by slow PWM modulation through exponential output voltage changes. We implemented a learning algorithm into the firmware to introduce adaptive PID parameters. The reason, why we made such huge efforts instead of the simple way was to provide fully noise free heating. Furthermore we have built sophisticated fault diagnostic features into the firmware. These unique fault diagnostic algorithms have been developed specifically for biological heating applications.

We have developed a universal Physiological - Biological Temperature Controller construction that can be manufactured with three different power driver stages, depending on the power requirement of the thermal process under control. Certainly, only one power driver stage can be installed in a Physiological - Biological Temperature Controller. The price of the Temperature Controller does not depend on the kind of the power driver stage installed in it. The appropriate power driver stage for the actual heating application should be chosen before placing an order (our design engineers are open for discussion).

Choice of the Power Driver Stages

- **12 V FINE DC:** max. 36W. It is optimized for microelectrode laboratories, for seriously shielded environments. Its output current is as smooth as the current of a lead battery. This power driver stage fulfills all special requirements of any sophisticated electrophysiology application, even in close proximity to any, high impedance recording electrode, like in a patch clamp setup.
- **24 V pulsing DC:** max. 75 W. Extra Low Voltage, electrically secure heating for general purpose.
- **115/230 VAC Huge-power:** up to 3.5 kW. It is optimal to control the temperature of large heated objects.

Parts of the System

- Physiological - Biological Temperature Controller
- Small Animal Heating Pad
- Optional External Temperature Sensor

In our terminology, the expression "internal sensor" means that the temperature sensor is built into the heated object. In every heated object manufactured by Supertech Instruments there is a built-in internal temperature sensor.

Special Considerations about the External Temperature Sensors

An external temperature sensor (DS18S20 from successor of Dallas Semiconductor) can be connected to the Physiological - Biological Temperature Controller. A tailored sensor with 1.5 meter BNC cable is available in our product choice. The actually used sensor can be selected with a toggle switch on the back side of the Temperature Controller. However, we **DO NOT RECOMMEND** using an external temperature sensor. Eliminating an external temperature sensor is possible because there is a built-in internal temperature sensor in every heated object manufactured by Supertech Instruments. Please **DO NOT** use an external sensor, except under particular circumstances. The reasons are below, why we suggest this.

1) Using an external temperature sensor, the average temperature of the heated object will be accurately the same as it has been set on the Physiological - Biological Temperature Controller, but a hysteresis (fluctuation in temperature) will appear. The reason of the appearance of the hysteresis is explained in the next paragraph. Using an internal temperature sensor built into the heating pad, the average temperature of the heated object will surely be a little bit less than the setup temperature of the Physiological - Biological Temperature Controller, but the hysteresis will be negligible. Occasional calibration of the temperature of the heated object (animal) may be necessary. The calibration process is uncomfortable, but eliminating the hysteresis is essential, because the target is a living animal or biological tissue. The change of temperature has a stimulating effect on the biological object, which may disturb or modulate the experiment.

2) Heating tasks in biology bring up special difficulties. The heat capacity and the thermal time constant of the heated object are huge because the object is usually an animal or living tissue. The thermal resistance between the external temperature sensor and the heated object is significant (in simple words, there is a bad thermal connection). This is true either for a technically realized heated object or for a heating pad - animal combination. This can result a significant hysteresis (5-6 Centigrade in exceptionally bad cases) when using an external sensor. This big hysteresis appears in our competitor's products, too. It has been measured in different labs under different circumstances, but neither hardware nor software based solution could be found to eliminate this effect. As a good solution, we developed a predictive, learning

algorithm for the Physiological - Biological Temperature Controller with a software module running in the built-in microcontroller. This algorithm uses the device's internal temperature sensor. This way a stable, fine regulation of the temperature can be achieved.

3) Most cases the heated object is an animal. The animal is not an "iron cube". It has its internal temperature regulation that may interfere with the predictive algorithm running in the microcontroller of the Physiological - Biological Temperature Controller. The natural temperature regulation process in the animal is not synchronized to the software-based control process. That is, why the animal itself can not be included in the intelligent predictive algorithm.

4) DS18S20 is one of the most sophisticated temperature sensors available. It communicates with the host microcontroller in a fully digital way on a 1-wire bus, on standard TTL voltage level. Although it is a professional sensor, the TTL voltage level is much higher than the amplitude of the usual electrophysiological signals. As a result it generates digital noise, so it should not be placed in a highly sensitive shielded environment or in a tissue bath close to the working biological target.

5) Using the internal temperature sensor (built in the heating pad) makes it easier to prepare the tissue or the animal. It is not necessary to keep the rectal or tissue bath sensor always clean and sterile.

6) It is not necessary to buy an external temperature sensor.

If you decide to use the internal (built into the Heating Pad) temperature sensor, you can monitor the core temperature of the target animal exactly by using a Biological Temperature Meter manufactured by Supertech Instruments. You can see the description of this equipment at our website.

Security Rules

The Temperature Controller equipment is supplied from the 115/230 VAC / 50 (or 60) Hz mains system. This is a dangerous voltage! All general electrical security precautions should be kept in mind during the usage of the equipment!

That pieces of Physiological - Biological Temperature Controllers, what are equipped with the 115/230 VAC Huge-power driver stage, are especially dangerous equipments. The output wires of such Temperature Controllers are driven by 115/230 VAC voltage! The output wiring is usually made by the user or by a technician involved by the user. Because of this reason the professional quality and the electric security are not the responsibility of Supertech Instruments, except that case if our specialist installs the whole heating system. The electrical security aspects of the 115/230 VAC Temperature Controllers are completely under the sole responsibility of the user!

Specifications / Technical Data

The controlled temperature range: 0 Centigrade to 70 Centigrade, in 1 Centigrade steps

The available temperature range in a given application does not depend on the Physiological - Biological Temperature Controller, but on the heater device itself. Either the temperature sensor or the Physiological - Biological Temperature Controller have a full scale value of 120 Centigrade. In most cases the real allowed temperature limit is much less than 120 Centigrade. Higher temperatures can be reached with specially designed, larger power heating devices. If you require higher temperature than 50 Centigrade, please consult our development engineers in advance.

Resolution of the temperature measurement: 0.1 Centigrade

Hysteresis (approximately): 0.3 - 0.5 Centigrade. The actual hysteresis depends on the thermal capacity and the heat drain appearing on the heated object.

Both internal and external temperature sensors can be connected to the Physiological - Biological Temperature Controller. The internal/external sensor selector switch is located at the back side of the Temperature Controller.

Display: 4 x 16 characters alphanumeric LCD with bright blue backlight

Programming: three pushbuttons on the front, in menu system

Automatic internal diagnostic and fault protection algorithms in the software

Flash program memory

Non-volatile EEPROM memory to store parameters used the previous time

Temperature sensor (either in internal or external arrangement): DS18S20 from the successor of Dallas Semiconductor

Dimensions of the instrument: 290 x 250 x 90 mm

Mains voltage: 100-120V or 220-230V (chosen by an internal selector switch, fixed in the factory)

Power consumption of the Physiological - Biological Temperature Controller itself: 80 VA. The output power consumed by the heated object is additional.

Weight: 2.8 kg

First Time Installation and Setup

In switched off state of the Physiological - Biological Temperature Controller please connect all the cables: the mains cable, the 3-pin connector of the Heating Pad (or other heated device) and the BNC cable of the external temperature sensor (optional). If you use the external temperature sensor at all, please establish a correct and sure thermal connection between the sensor and the controlled object. Switch on the Physiological - Biological Temperature Controller and the system is ready to use.

Front Panel Controls

The equipment is assembled with a 4 x 16 character blue LCD display and a user-friendly 3-button keypad on its front plate. The development strategy of the Physiological - Biological Temperature Controller was to design an easy-to-use user interface, while highly professional capabilities are activated behind the simple menu system.

On the front panel of the Physiological - Biological Temperature Controller there are only three buttons, but with them you can do (nearly all) what you would like to do.

Up and Down buttons: Use them to choose from the menu items and configure the values. Where you see the cursor you can adjust the appropriate menu point or you can modify that numeric value what is under the cursor.

F (Function) button: Use it in the menu as enter, during the programming and parameter setup actions. When you are in a programming phase and the Function button works as enter, the microcontroller automatically saves the newly selected value after the key pressed. When the equipment is actually working in a selected function, the Function button can be used as escape to inactivate and leave the actual task and to jump to the main menu.

There is a yellow LED on the front plate of the Physiological - Biological Temperature Controller to show the heating periods. It shows qualitatively the fact of the heating, not the amount of the heating power.

The mains switch is located at the right side of the front. If the Physiological - Biological Temperature Controller is switched off, it is necessary to wait until the power supply loses all its energy. It is prohibited to switch the Temperature Controller on again, without waiting enough; otherwise a faulty reset condition would happen, even, the internal software (firmware) can be destroyed! The enough time before the Controller can be switched on again after switching off, if the last screen content (not the backlight, but the letters) disappears completely and 10 seconds more is spent.

Connectors and Controls on the Back Side

There is the AC input plug at the left side. Connect it to the 115/230 VAC mains electric system with the appropriate cable.

The connector at the middle of the back plate is the output connector. There are three different connectors used for the different types of power driver stages, respectively. Use the appropriate plug to connect the output load or the complete heated object.

This is a principal question, that a control process can be based on one sensor only. That is the reason, why a selector switch is located at the back side of the Physiological - Biological Temperature Controller to select the actual sensor.

Most of the heated objects (e.g. Stage Incubator, Heating Pads, Mouse Stereotaxic Frame Adaptor, etc.) in our product choice have got internal temperature sensors. If you use such a heated object, you should choose the "Internal" sensor with the switch located at the right side of the back plate. In the other position of this switch, the Physiological - Biological Temperature Controller uses an "External" temperature sensor.

If an "External" sensor is used, it should be connected to the BNC connector below the switch. The DS18S20 sensor chip (manufactured by the successor of Dallas Semiconductor) is accepted by the Physiological - Biological Temperature Controller as an "External" sensor. In our choice there are tailored DS18S20 sensors with cable and BNC plug.

If the Physiological - Biological Temperature Controller is switched on and operates, it is prohibited to change the position of the Internal / External sensor selector switch, because this action will generate an error message. The reason is described in the Error Messages section. It is advisable to decide, which sensor will be used and it should be selected before switching on the Physiological - Biological Temperature Controller.

The external temperature sensor (if it is selected as the working sensor) must be in very good thermal connection with the heated object to provide a low level of hysteresis and not to generate an error message.

Functions in the Firmware

The firmware in the internal microcontroller of the Physiological - Biological Temperature Controller realizes intelligent PID characteristics by slow PWM modulation through exponential output voltage changes. After switching the Temperature Controller on, in the first few heating cycles, the firmware measures the heat capacity and the thermal time constant of the object heated actually. After measuring these values, the firmware optimizes the parameters of the internal temperature control algorithm. This way the firmware tries to minimize the hysteresis.

After switching the Physiological - Biological Temperature Controller on, the microcontroller loads the default temperature setup value saved last time. Then it starts to heat up and control the temperature.

Any time during the control process the actual temperature setup value can be modified with the Up and Down button, respectively. The modified value will be the valid setup value, but temporarily, until the Physiological - Biological Temperature Controller remains switched on. If the modified setup value should be saved as the new default value, it can be saved with pressing the F button. After switching the Controller off and on again, the last saved setup value will appear as the default.

There is a "hidden" function in the firmware. It is useful, if an inexperienced user works with the Physiological - Biological Temperature Controller or if the heated object is very sensitive to overheating. The highest selectable temperature setup value will be asked by the firmware, if you switch the Controller on with F button is pressed. After selecting the temperature limit, the firmware saves it (if F button is pressed) and the normal temperature control task is started. This saved limit works every time as the highest possible temperature in the normal control process.

Error Messages

There are sophisticated protection features built into the firmware. One of them is a protection against the electronic fault in the circuit of the sensor. The other protection features are implemented to deal with the faults around the "thermal connection". They realize the fact, if the sensor can not detect the real temperature of the heated object. They are specialized protections for the biological heating tasks, because they will protect the sensitive living heated objects (animals, cells, etc.) against overheating, if the control procedure fails.

If any of the protection aspects became active (in other words any fault condition appears), the Physiological - Biological Temperature Controller stops heating, a rude beep noise is started and the fault is described on the LCD screen to inform the user about the details. If any fault appears there is no other exit or solution than switching the Temperature Controller off, repairing the fault and switching the Controller on again. If there is more than one fault conditions appear in the same time, the more serious one will be described on the screen.

Error Message (1):

" FAULT! I can not find the sensor! The electronic circuit is bad. "

This error message means that the protection algorithm detects, that there is a short circuit or a broken wire in the circuit of the sensor. In such case the measured value can not be accepted and the control procedure should be stopped. If you see this error message, please try to find and repair the faulty wire or connector. If the repairing attempt is not successful, send the heating equipment or the external sensor to the repair service location of Supertech Instruments.

The position of the Internal / External sensor selector switch should be selected in switched off state of the Temperature Controller. If the position of the Internal / External sensor selector switch is changed while the Physiological - Biological Temperature Controller is switched on and operates, this action also generates Error Message (1). In this case there is no real failure. The internal microcontroller checks the presence of the sensor in every 0.7 second. If the switch is in a transient state at the time of checking, it will report a sensor fault and the program hangs up and you can clear the error message only by a power on reset.

Error Message (2):

“ FAULT! Thermal connection lost! Sensor is improperly positioned. ”

There are two possible reasons, which can generate this error message. They are the following.

In every heating phase, immediately after the heating is switched on, a local time counter is cleared to zero and restarted in the firmware and the actually measured temperature is recorded for later comparison. During the counting, the normal temperature control procedure is running. If this time counter reaches 3 minutes, the actual temperature is checked again and compared to the initial value (recorded at the beginning of the heating phase). If the temperature difference is less than 0.5 Centigrade, it means a fault condition. On the one hand this protection is useful, if the thermal time constant or the heat capacity of the heated object is too big in comparison to the heating power. On the other hand this protection is useful, if the Physiological - Biological Temperature Controller is started with lost thermal connection (e.g. the rectal sensor has not been put into the rectum of the animal).

In the firmware there is a continuous comparison of the temperature setup value and the actually measured temperature. If the difference is more than 5 Centigrade, it is interpreted as a fault condition. This comparison is a second protection. It also detects that case if the sensor has bad thermal connection. The first heating cycle is an exception from this failure check, because in the first heating up any difference is allowed. There is an uncomfortable side-effect of this protection feature. The setup temperature value should not be increased too quickly, because it would be realized as an artificial thermal connection fault. If you change the setup temperature value, you should wait for the speed of heating up not to exceed the allowed 5 Centigrade temperature difference.

Warranty

Supertech Instruments gives you 5 years of full warranty for electronic products and 3 years of full warranty for mechanical products by default. Longer warranty periods can also be defined and agreed (the actual conditions should be discussed before placing the order).

Supertech Instruments gives you full warranty for its products against defects in materials or workmanship as long as the equipment has been subjected to normal and proper use. During the warranty period, faulty products will be repaired or replaced free of charge provided they are returned to our workshop. Postage of the warranty repair actions is paid by the Customer. The exceptions are the Vibration Isolation Tables. There are special conditions introduced for repairing of Vibration Isolation Tables (see the appropriate User Manual).

Supertech Instruments will undertake the servicing and calibration after the expiration of the warranty period for a nominal fee.

The warranty does not cover the faults made by the user.

The measuring equipments manufactured by Supertech Instruments are for experimental and/or lab animal purposes only and are not intended for human use.

Electrical safety measurements of proper operation of the 115 / 230 V AC mains electric system (from the equipments have been supplied) is the sole responsibility of the user.

You can find the general commercial and warranty conditions in the beginning of the Price List page of our website.

Further Information Sources

As the first step for further technical information please visit our website (www.superte.ch). On the website of Supertech Instruments you can find related products and further information.

On the Download page of our website you can find many more useful documents, technical descriptions and application leaflets to support our products. Please check the list of the available documents.

Technical hotline via email (all of them work):

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office@super-tech.eu (European Branch Office)

International technical hotline on the phone: +36 20 9234 386

In the past Supertech Instruments used several websites with similar contents for the different affiliates. For the sake of stability and continuity we keep working all the previously used domain names forever, but now they are automatically redirected to this one website presenting our measuring equipments:

www.superte.ch

Specifically for our featured products we introduced several dedicated websites. These dedicated websites can be accessed directly if you prefer this way. Certainly they are linked on the Product page of the general website of Supertech Instruments, too. The specific websites are opened automatically if you click on the respective product group on the Products page of our website.

www.opticaltable.eu (Vibration Isolation Table and Support Systems)

www.ivftable.com (IVF Vibration Isolation Solutions)

www.optogenetics.uk (Optogenetics - LED Driver Units)

www.electroporation.uk (Electroporation / Electroporators)