

OPERATING INSTRUCTIONS AND SYSTEM DESCRIPTION FOR THE

PTC-10

PELTIER TEMPERATURE CONTROL SYSTEM



VERSION 2.51
npi 2002

npi electronic GmbH, Hauptstrasse 96, D-71732 Tamm, Germany
Phone +49 (0)7141-601534; Fax: +49 (0)7141-601266
support@npielectronic.com; <http://www.npielectronic.com>

Table of Contents

1. Safety Regulations.....	3
2. PTC-10 Components	4
3. PTC-10 System.....	4
3.1. System Description.....	4
3.2. Description of the Front Panel.....	5
3.3. Rear Panel Elements.....	10
3.4. Electronic Control and Protection Circuits	10
3.5. Connection of Peltier Elements	10
3.6. Modes of Operation.....	11
3.7. Setting the DESIRED TEMPERATURE.....	12
4. Grounding.....	12
5. Operating guide – Tuning procedure.....	14
5.1. PTC-10 and the HCMIS micro incubator.....	16
Connection.....	16
Operation	16
6. Literature	17
7. Technical Data.....	17

1. Safety Regulations

VERY IMPORTANT: Instruments and components supplied by npi electronic are NOT intended for clinical use or medical purposes (e.g. for diagnosis or treatment of humans), or for any other life-supporting system. npi electronic disclaims any warranties for such purpose. Equipment supplied by npi electronic must be operated only by selected, trained and adequately instructed personnel. For details please consult the GENERAL TERMS OF DELIVERY AND CONDITIONS OF BUSINESS of npi electronic, D-71732 Tamm, Germany.

- 1) GENERAL: This system is designed for use in scientific laboratories and must be operated by trained staff only. General safety regulations for operating electrical devices should be followed.
- 2) AC MAINS CONNECTION: While working with the npi systems, always adhere to the appropriate safety measures for handling electronic devices. Before using any device please read manuals and instructions carefully.
The device is to be operated only at 115/230 Volt 60/50 Hz AC. Please check for appropriate line voltage before connecting any system to mains.
Always use a three-wire line cord and a mains power-plug with a protection contact connected to ground (protective earth).
Before opening the cabinet, unplug the instrument.
Unplug the instrument when replacing the fuse or changing line voltage. Replace fuse only with an appropriate specified type.
- 3) STATIC ELECTRICITY: Electronic equipment is sensitive to static discharges. Some devices such as sensor inputs are equipped with very sensitive FET amplifiers, which can be damaged by electrostatic charge and must therefore be handled with care. Electrostatic discharge can be avoided by touching a grounded metal surface when changing or adjusting sensors. **Always turn power off when adding or removing modules, connecting or disconnecting sensors, headstages or other components from the instrument or 19" cabinet.**
- 4) TEMPERATURE DRIFT / WARM-UP TIME: All analog electronic systems are sensitive to temperature changes. Therefore, all electronic instruments containing analog circuits should be used only in a warmed-up condition (i.e. after internal temperature has reached steady-state values). In most cases a warm-up period of 20-30 minutes is sufficient.
- 5) HANDLING: Please protect the device from moisture, heat, radiation and corrosive chemicals.
- 6) INSTRUMENT COOLING: To prevent damage from overheated components, adequate airflow around the heat sink in the rear of the instrument must be ensured.

PELTIER ELEMENTS MUST BE MOUNTED ALWAYS ON APPROPRIATE HEAT SINKS TO AVOID DAMAGE THROUGH OVERHEATING.

2. PTC-10 Components

The following items are shipped with the PTC-10 system:

- ✓ PTC-10 19" cabinet
- ✓ Power cord
- ✓ User manual

Optional accessories:

- ⇨ Miniature temperature sensor
- ⇨ Subminiature temperature sensor
- ⇨ PT 100 temperature sensor
- ⇨ HCMIS micro incubator
- ⇨ Recording chamber
- ⇨ Heated perfusion tube
- ⇨ Thermal foil

3. PTC-10 System

3.1. System Description

The PTC-10 temperature control system is designed for heating and cooling purposes in electrophysiological experiments. The PTC-10 system provides a temperature controller channel and is housed in a 19 inch standard rackmount cabinet with built-in power supply and cooling elements for the power devices. The PTC-10 system guarantees low noise operation and has special protection features to prevent the preparation from damage.

The PTC-10 system incorporates two electronic thermometers for small semiconductor sensor (standard is R2252, i.e. the sensor has a resistance of 2252 Ω at 25 °C or optionally PT 100, i.e. 100 Ω at 0 °C), two digital temperature displays (XX.X °C), a set value control with direct readout (XX.X °C), a PI (proportional-integral) controller with adjustable parameters, an output power control unit and a high-power bipolar output stage (\pm 15 V DC, continuous operation) for Peltier elements (i.e. heat / cool operation) or resistive (i.e. heat only) loads with electronic protection circuits. For heat-only applications the bipolar output can be switched to unipolar operation (+15V). The power output is short circuit protected, the output power is limited electronically. Maximum output voltage is approximately 15 Volt, the current is limited to 3 A.

A large variety of sensors and thermal elements are available (see also **Optional accessories** in chapter 2). Please contact npi for details.

Important: Peltier elements must be mounted always on appropriate heat sinks to avoid damage because of overheating.

3.2. Description of the Front Panel

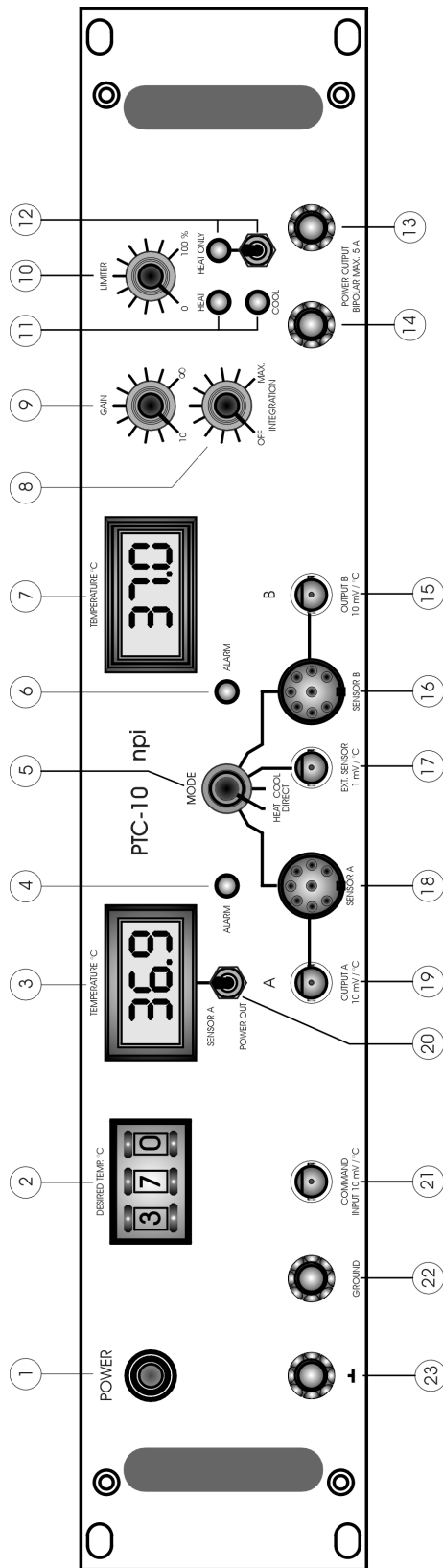


Figure 1: PTC-10 front panel view

In the following description of the front panel elements each element has a number that is related to that in Figure 1. The number is followed by the name (in uppercase letters) written on the front panel and the type of the element (in lowercase letters). Then, a short description of the element is given.

(1) POWER pressure switch



Switch to turn POWER on (switch pushed) or off (switch released).

(2) DESIRED TEMP./°C potentiometer



Digital potentiometer to set the working temperature of the controller system, range: 02.0 °C to 45.0 °C, XX.X °C or 0-100% of output voltage (DIRECT mode).

Display A unit



The **Display A unit** consists of **(3) TEMPERATURE °C A** display and **(20) SENSOR A / POWER OUT** switch

(3) TEMPERATURE °C A display

Digital display to indicate the temperature determined by SENSOR A **(18)** or the voltage at the POWER OUTPUT connectors **(13 / 14)**. Switch **(20)** is used to select one of these functions of display A.

(20) SENSOR A / POWER OUT switch (display mode switch)

Switch to select the mode of display A **(3)**:

SENSOR A (upper position): the temperature determined by SENSOR A **(18)** is displayed (XX.X °C)

PWR OUT (lower position): the voltage at the POWER OUTPUT **(13 / 14)** is displayed.

(4) ALARM LED



LED to indicate that temperature SENSOR A **(18)** is not connected, broken or short-circuited. The POWER OUTPUT **(13 / 14)** shuts down if this LED is on and the MODE switch **(5)** is set to SENSOR A.

MODE of operation unit channel A

The MODE of operation unit of channel A consists of **(5)** MODE switch, **(17)** EXT.SENSOR 1mV / °C connector, **(18)** SENSOR A connector, **(16)** SENSOR B connector

(5) MODE switch

Switch to select the operation modes of the PTC-10. Five modes are available:

SENSOR A: the temperature determined by **SENSOR A (18)** is used for the control system

DIRECT HEAT: the voltage at the **POWER OUTPUT (13 / 14)** can be set directly from the **DESIRED TEMP.** potentiometer **(2)** (0 - ±15 V, no control). Works only if the Peltier element is connected with right polarity (see chapter 3.5).

DIRECT COOL: the voltage at the **POWER OUTPUT (13 / 14)** can be set directly from the **DESIRED TEMP.** potentiometer **(2)** (0 - ±15 V, no control). Works only if the Peltier element is connected with right polarity (see chapter 3.5).

EXT. SENSOR (EXTERN SENSOR): an external thermometer connected to **BNC (17)** (sensitivity: 1mV / °C) is used for the controller loop

SENSOR B: temperature determined by **SENSOR B (16)** is used as feedback temperature in the controller loop.

(17) EXT. SENSOR 1mV/°C connector

BNC connector to connect external thermometer with a voltage output of 1mV/°C (see also **(5)**).

(18) SENSOR A connector

8-pole connector for temperature **SENSOR A**.

(16) SENSOR B connector

8-pole connector for temperature **SENSOR B**.

(6) ALARM LED

LED to indicate that temperature **SENSOR B (16)** is not connected, broken or short-circuited. The **POWER OUTPUT (13 / 14)** shuts down if this LED is on and the **MODE switch (5)** is set to **SENSOR B**.

(7) TEMPERATURE °C B display



Digital display to indicate the temperature determined by SENSOR B (16).

(8) INTEGRATION potentiometer



Potentiometer to set the INTEGRATION parameter (time constant) of the temperature controller (PI controller), time range: 50 ms - 20 s.

(9) GAIN potentiometer



Potentiometer (logarithmic scale) to change the GAIN parameter (amplification of the error signal, see chapter 3.4) of the temperature controller (PI controller), range: 10 to ∞.

(10) LIMITER potentiometer



Potentiometer to set the voltage range of the POWER OUTPUT (13 / 14), 100% = ±15 Volt.

(11) HEAT / COOL LEDs



LEDs that indicate the state of the POWER OUTPUT (13 / 14).

HEAT (yellow LED): output polarity positive (“active” side will be heated, see also chapter 3.5)

COOL (green LED): output polarity negative (“active” side will be cooled, see also chapter 3.5)

(12) HEAT ONLY LED, HEAT ONLY switch



The HEAT ONLY toggle switch sets the controller into HEAT ONLY mode. The red LED indicates the state of the controller (LED on = HEAT ONLY).

(13) / (14) POWER OUTPUT Max. 5A connectors

Banana jack connectors for the Peltier element. Red jack **(13)** supplies positive voltage for heating and negative voltage for cooling. The “active” side of the Peltier element is connected here (see also chapter 3.5). This output supplies a maximum voltage of $\pm 15\text{V DC}$ and a maximum current of 5A. Blue jack **(14)** is connected to internal ground (see also **(22)**). The “opposite” side of the Peltier element is connected here (see also chapter 3.5).

Note: It is not recommended to use jack **(14)** for grounding purposes. Use instead GROUND / PROTECTIVE EARTH connectors **(22)** or **(23)** to ground your system.

(15) OUTPUT B 10mV/°C connector

BNC connector monitoring the temperature determined by SENSOR B **(16)**, sensitivity: $10\text{mV} / ^\circ\text{C}$.

(19) OUTPUT A 10mV/°C connector

BNC connector monitoring the temperature determined by SENSOR A **(18)**, sensitivity: $10\text{mV} / ^\circ\text{C}$.

(21) COMMAND INPUT 10mV/°C connector

BNC connector to set the working temperature of the controller system by an external voltage signal. This input is scaled with the factor $10\text{mV} / ^\circ\text{C}$.

(22) GROUND / (23) Protective earth connectors

To avoid ground loops the internal ground of the system is floating, i.e. it is not connected to the protective earth of the line cable while the cabinet is always connected via the power supply cable (green / yellow wire). The system can be grounded by connecting plug **(22)** internal ground or **(23)** protective earth.

3.3. Rear Panel Elements

LINE VOLTAGE SELECTION: The selector for the line voltage and the connector for the power cord are located in a mains connection module on the rear panel of the instrument.

CAUTION: If operated with other line voltages the instrument may be damaged if the wrong line fuse is installed!

FUSE: The fuse is also integrated in the mains connection module. The line fuse must be 3.15 A slow (115 Volt) or 1.6 A slow(230 Volt). It must be replaced only by specified type (see above). Please disconnect mains power plug when replacing fuse.

3.4. Electronic Control and Protection Circuits

CONTROL LOOP

The sensor / thermometer, PI-controller, output power stage and Peltier element form a closed loop control system. The desired temperature signal is compared with the output signal obtained from the thermometer giving an error signal. This signal is amplified in the PI controller and transferred to the output stage where it is converted to a high-power output signal applied to the Peltier element.

ELECTRONIC PROTECTION CIRCUITS

Each system is equipped with two protection systems:

1. Sensor inputs: an electronic shut-off function disconnects the output if the sensor is disconnected, broken or short-circuited.
2. Output protection: the output current and voltage are limited electronically.

Important: The sensor used for the control must be in good thermal connection with the Peltier element, if not, unstable operation and damage may occur.

ALARM CIRCUIT

The internal thermometer (R2252 or PT 100 sensor) inputs are protected by the sensor alarm circuit (see above). If this thermometer is used as input device for the PI controller, the ALARM circuit disconnects the power output if the sensor is damaged or not connected. This state is indicated by the red ALARM LED. If the DIRECT mode or EXT. SENSOR mode is used the ALARM circuit is disabled.

ACCURACY

Measuring accuracy of the internal thermometer is 0.1 °C, controller accuracy is 0.5 °C or better (depending on the amount of heated solution).

3.5. Connection of Peltier Elements

The PTC-10 is designed to work with Peltier elements. Peltier elements have two different sides: one is the “active” side and the other is the “opposite” side (usually marked as “active” and “opposite” respectively). In order to work properly the Peltier elements have to be connected with right polarity to the PTC-10.

Quick installation:

- Connect the “active” side to the + pole (**13**, Figure 1)
- Connect the “opposite” side to the - pole (**14**, Figure 1)
- Mount the Peltier element on a heat sink (the “opposite” side facing the heat sink)

This is very important especially if you use the Peltier element for cooling, because in this mode the “opposite” side gets hot!!

Now it is ensured that the “active” side gets hot if the MODE switch (**5**, Figure 1) is set to HEAT and cold if the MODE switch (**5**, Figure 1) is set to COOL in DIRECT mode. The right polarity is also very important for all other operation modes (see chapter 3.6).

3.6. Modes of Operation

The system can be used in the following modes of operation:

DIRECT Mode

In DIRECT mode (no temperature control) the MODE switch (**5**, Figure 1) is switched to one of the two possible DIRECT positions:

DIRECT HEAT position sets the output voltage positive (referring to ground).

DIRECT COOL position sets the output voltage negative (referring to ground).

In both DIRECT modes the control unit is not active, i.e. the output voltage is preset directly at the DESIRED TEMP. °C control (**2**, Figure 1). With setting from 000 to 999 the output voltage increases from 0 V to +15 V (DIRECT HEAT) or 0 V to -15 V (DIRECT COOL). The ALARM circuit (see below) is disabled in this mode.

Note: In DIRECT COOL mode there will not occur any output voltage when the HEAT ONLY toggle switch is activated!

DIRECT HEAT and DIRECT COOL will work in this way only if the Peltier element is connected to the PTC-10 with right polarity!

HEATING / COOLING OPERATION in DIRECT mode

The PTC system is designed with bipolar outputs (0 V to ± 15 Volt DC). If a resistive load is used, the system can be used for heating purposes in all modes (CONTROL and DIRECT).

If a PELTIER device is connected to the output, the system can be used either for heating purposes or for cooling (“active” side of the Peltier device in contact with recording chamber). If a Peltier device is used for cooling purposes, the “opposite” side of the Peltier element must be connected to an adequate heat sink.

Caution: When using COOL DIRECT mode check the position of the HEAT ONLY toggle switch (position is also indicated by the red HEAT ONLY LED). In any case cooling function is only possible when this switch is not activated!

Internal SENSOR mode

In this mode the output voltage is controlled by the PI controller (PI [proportional-integral controller system] activated):

The SENSOR position selects the internal thermometer which use a small semiconductor or PT100 sensor. The measured temperature is displayed at the respective digital display unit (**3** or **7**, Figure 1). The selected sensor input (A or B) is connected to the controller and output stage.

If no sensor is connected or if the sensor is damaged or short circuited the internal shut-off unit disconnects the corresponding power output. This state is indicated by the red ALARM LED (**4** or **6**, Figure 1).

EXT. SENSOR mode

This mode can be used to connect an external thermometer. The calibration of the external input BNC (**17** , Figure 1) is 1 mV / °C. If this option is used the internal ALARM circuit is disabled.

Figure 2 gives an overview of the operation modes of the PTC-10.

3.7. Setting the *DESIRED TEMPERATURE*

There are two ways to set the *DESIRED TEMPERATURE*:

1. The easiest way is to use the digital potentiometer *DESIRED TEMP. / °C*. The temperature can be set from +03.0 °C to +45.0 °C, resolution: 0.1 °C. If the PTC-10 leaves this temperature window the internal shut-off unit disconnects the power output. This could be the case if the sensor is broken or short-circuited.
2. If the user wants to have external control (e.g. with a computer system) the *DESIRED TEMPERATURE* can be set using the *COMMAND INPUT 10mV / °C* connector (**10**, Figure 1). The *COMMAND INPUT* is scaled 10mV / °C, i.e. +370 mV at this connector would set the *DESIRED TEMPERATURE* to +37 °C.

Important: The set value of the temperature is always the sum of the setting at *DESIRED TEMP. / °C* potentiometer and the voltage at *COMMAND INPUT 10mV / °C* connector, i.e. if *DESIRED TEMP. / °C* is set to +25.0 °C and the voltage at *COMMAND INPUT 10mV / °C* is +150 mV the temperature will be set to +40 °C !!

4. Grounding

To avoid ground loops the internal ground of the system is floating, i.e. it is not connected to the protective earth of the line cable while the cabinet is always connected via the power supply cable (green / yellow wire). The system can be grounded by connecting plug **22**, Figure 1 (internal ground) or **23**, Figure 1 (protective earth).

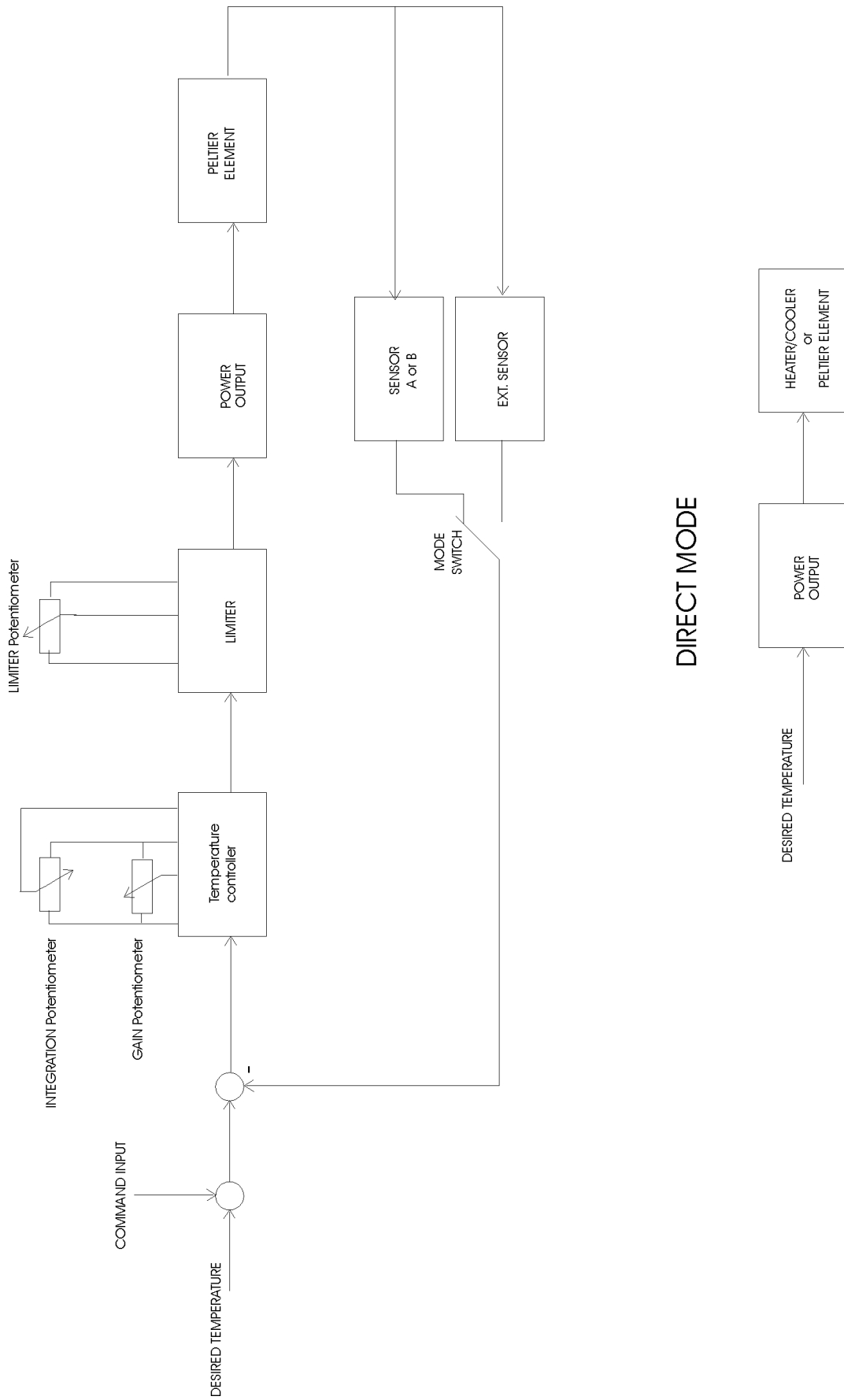
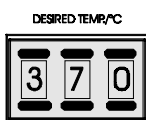


Figure 2: Block diagram of the PTC-10

5. Operating guide – Tuning procedure

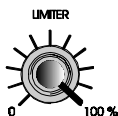
After unpacking the instrument please check the appropriate voltage at the voltage selector at the back panel. Also check that the sensor used for the control is in good thermal connection with the heating wire or the “active” side of the Peltier element and that the Peltier element is connected with right polarity (see chapter 3.5). In the following it is assumed that you use devices delivered by npj or ALA Scientific Instr. with 12V operating voltage. Please follow these instructions step by step to avoid problems in adjusting the instrument.

- Turn all potentiometers to the most left position
- switch the MODE selector to the position SENSOR A or B depending on which sensor is used as feedback temperature in the controller loop
- set the DESIRED TEMPERATURE to e.g. 37 °C



turn on the instrument and wait at least 15 minutes to warm up the instrument. The temperature display should show the actual temperature at the sensor

- turn the LIMITER to 100%



Note: If you use heating wires with 6V operating voltage turn the LIMITER to 50% to protect the wire from damage.

If the difference between the actual and the desired temperature is more than 10 °C the HEAT-LED will light up slightly.

- turn the GAIN to the third scale mark



The actual temperature at the sensor now approaches the desired temperature but will not reach 37 °C because the control loop is not yet well adjusted. The actual temperature will arrest at 1 to 2 °C below the desired temperature. Please wait until this steady state value is reached. This may last several minutes.

- Now turn on the INTEGRATION and set it approximately to the first scale mark. You will hear a “Click” if the INTEGRATION gets active.



The actual temperature at the sensor will now reach the desired temperature possibly after a small overshoot. Wait again until the steady state value is reached. If this value is not reached set the GAIN to higher levels until - in this example - 35 °C to 35.5 °C is reached.

- If the desired temperature is not reached first set the GAIN to a slightly higher level and then – if necessary – raise the INTEGRATION (see Figure 3).

Note: The speed of the control circuit (and therefore the time in which the actual temperature reaches the DESIRED TEMPERATURE) is highly dependent on the first settings of GAIN and INTEGRATION. Thus, when beginning to use the PTC-10 we recommend to try out several first settings of GAIN and INTEGRATION to find out which settings are best for your experimental conditions.

If you use a perfusion system and you are going to heat it is recommended to heat the solution approximately to the desired temperature **before** perfusing the bath either with a heating foil wrapped around the supplying tube (available from npi) or by heating up the supplying bowl.

As mentioned above it is very important that the sensor element and the heating / cooling element are in good thermal connection.

In Figure 3 the time course of temperature regulation of the PTC-10 is shown. As resistive load a bulb (12V, 21W) was used. The temperature sensor was fixed directly on the bulb and sensor and bulb were wrapped with foam. Starting temperature was 27,3 °C. Starting conditions were: LIMITER set to 0, GAIN set to 0, INTEGRATION off.

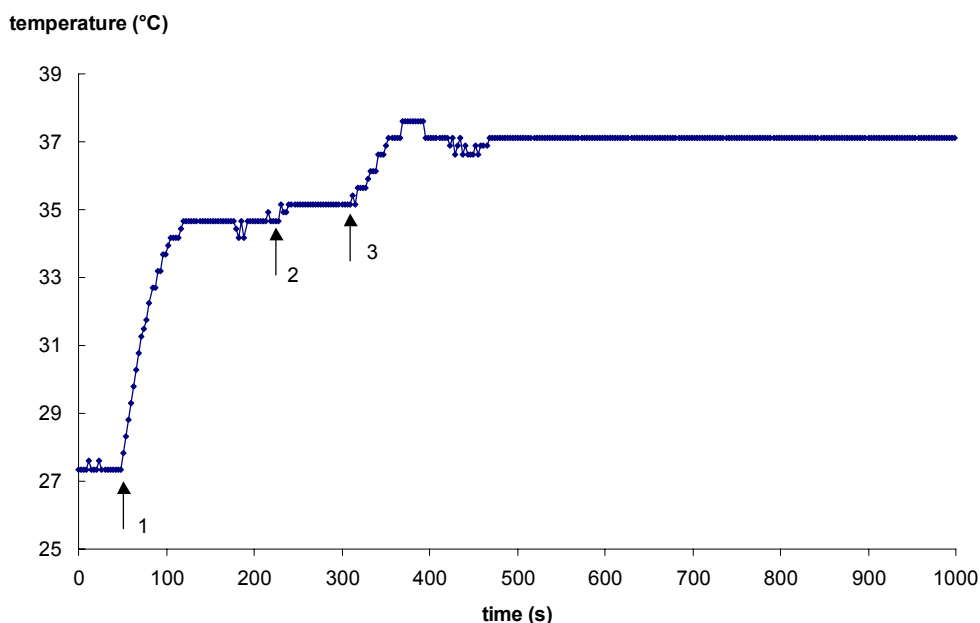


Figure 3: Time course of temperature regulation of the PTC-10.

- 1: LIMITER was set to 100%, GAIN was set to the third scale mark
- 2: GAIN was set to the fourth scale mark
- 3: INTEGRATION was turned on at a low level

5.1. PTC-10 and the HCMIS micro incubator

Connection

Connect the banana plugs to the POWER OUTPUT (13/14, Figure 1) and the plug of the sensor to SENSOR A or B (18 or 16, Figure 1) respectively.

Operation

Heating

Follow the steps as described above. With the HCMIS micro incubator from ALA Scientific Instr. it is likely that you have to use more gain in order to reach a steady state temperature of 35 °C to 36 °C without INTEGRATION. In that case increase the gain stepwise and wait in every step until the temperature reaches a steady state level of 35 °C to 36 °C and then turn on the INTEGRATION as described above (see also Figure 4).

Cooling

It is characteristic for Peltier elements that when they cool on one side the other side gets very hot. When cooling the upper side of the HCMIS gets hot and it must be ensured that the heat from the upper side is carried off. This is best done by using the fluid cooling system of the HCMIS. Without cooling the HCMIS with fluid it is not possible to reach temperatures below 20 °C.

Caution: When operating the HCMIS in cooling mode always use the fluid cooling system to avoid overheating and damage of the Peltier elements.

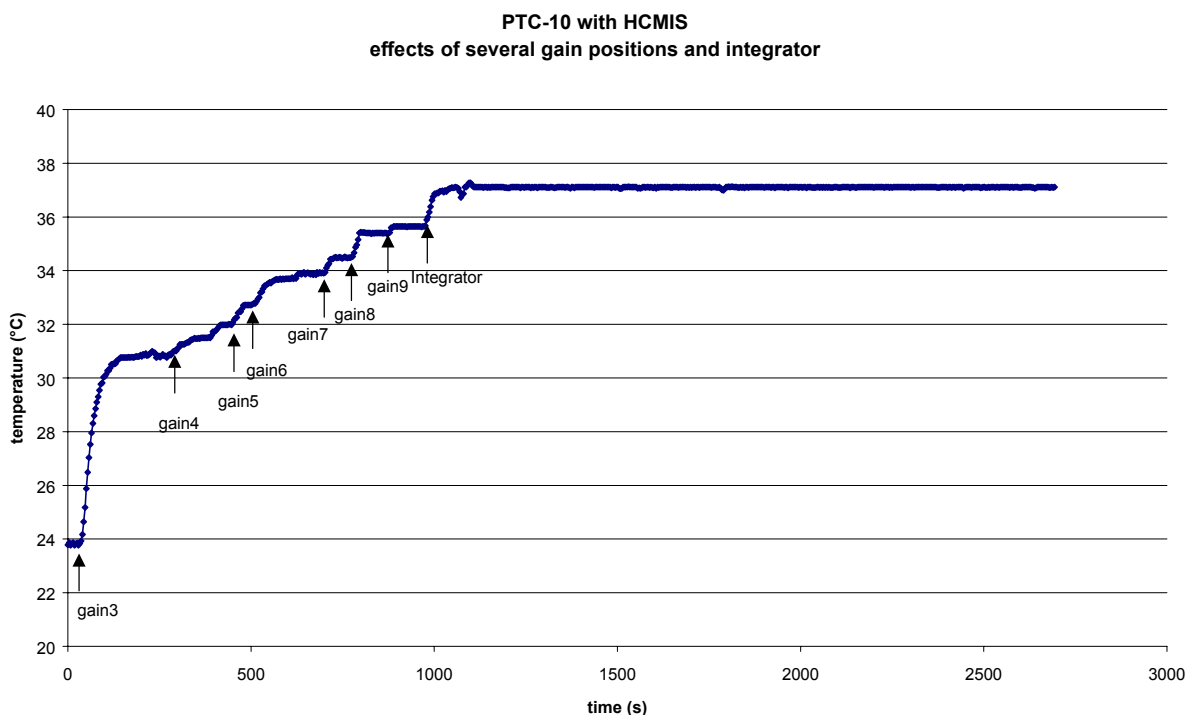


Figure 4: Time course of temperature regulation of the PTC-10, HCMIS micro incubator connected

6. Literature

Kettenmann, H. and R. Grantyn (eds.) Practical Electrophysiological Methods, Wiley-Liss, New York 1992

Froehr, F. and F. Ortttenburger Introduction to Electronic Control Engineering, Siemens AG, Berlin and Munich 1982

7. Technical Data

<u>Sensor input:</u>	for semiconductor 2252 Ω at 25 °C (standard) or platinum 100 Ω at 0 °C, accuracy typically 0.1 °C at 25 °C, with electronic protection
<u>Sensor input (EXT. Mode):</u>	1mV / °C
<u>ALARM and SHUTOFF:</u>	disconnects POWER OUTPUT if temperature is below +3 °C (not connected or broken sensor) or above +45 °C (short circuited sensor)
<u>Digital displays:</u>	3 1/2 digits, XX.X °C (temperature of SENSOR A or B) or XX.X V (voltage at power output)
<u>COMMAND INPUT:</u>	analog input, 10mV / °C, via BNC connector
<u>Set value control:</u>	digital control, range: 02.0 °C to 45.0 °C, XX.X °C or 0-100% of output voltage (DIRECT modes)
<u>Temperature OUTPUT (A, B):</u>	analog outputs, 10mV / °C, via BNC connector, output impedance: 250 Ω
<u>Power output:</u>	± 15 V / 5 A, short circuit protected, continuous DC
<u>Limiters:</u>	control for the output voltage with a linear range from 0 – 100 %
<u>Control:</u>	PI (proportional-integral) controller, accuracy typically ± 0.2 °C, gain range 10 - 10k, integration time 50 ms - 20 s (logarithmic scale)
<u>Measuring accuracy:</u>	0.1 °C at 25 °C
<u>Power requirements:</u>	115 / 230V AC, 60 / 50 Hz, fuse 3.15 / 1.6 A slow
<u>Dimensions:</u>	19" rackmount cabinet 19" (483 mm), 10" (250 mm), 3.5" (88 mm)