Electronic Instruments for the Life Sciences

made to measure

OPERATING INSTRUCTIONS AND SYSTEM DESCRIPTION FOR THE

MTC-20/2SD

TEMPERATURE CONTROL SYSTEM

VERSION 4.0
npi 2016

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1. Safety Regulations

<u>VERY IMPORTANT</u>: 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.

2. MTC-20/2SD Components

The following items are shipped with the MTC-20/2SD system:

✓ MTC-20/2SD desktop cabinet
✓ Power cord
✓ User manual

Optional accessories:

- Miniature temperature sensor
- Subminiature temperature sensor

Caution: The temperature sensors are very sensitive to mechanical stress, especially to bending. Therefore, they must be handled with great care to avoid breaking of the insulation!

- PT 100 temperature sensor
- Recording chambers
- ALA DIN connector cable assembly
- HCS heated chamber stage
- HPC-G Heated perfusion cube (ALA)
- Heated coil

3. MTC-20/2SD System

3.1. System Description

The MTC-20/2SD temperature control system is designed for heating purposes in electrophysiological experiments. The MTC-20/2SD system is housed in small desktop cabinet that can be placed close to the microscope, with built-in power supply and cooling elements for the power devices. The system guarantees low noise operation and has special protection features to prevent the preparation from damage.

The MTC-20/2SD incorporates two electronic thermometers for small semiconductor sensors (R2252, i.e. the sensor has a resistance of 2252 Ω at 25 °C), two digital temperature displays (XX.X °C), a set-point control with digital readout (XX.X °C), a PI (proportional-integral) controller with adjustable parameters, an output power control unit and a high-power output stage (DC, continuous operation) for resistive (i.e. heat only) loads with electronic protection circuits. The power output is short circuit protected, the output power is limited electronically. Maximal output voltage is approximately 12 V, the current is limited to 1 A.

The system can be connected to the thermistors / heating elements in two ways:
Using separate cables for the sensors and the heating element or
Using the ALA DIN cable assembly that connects both, sensors and heating elements

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

3.2. Description of the Front Panel

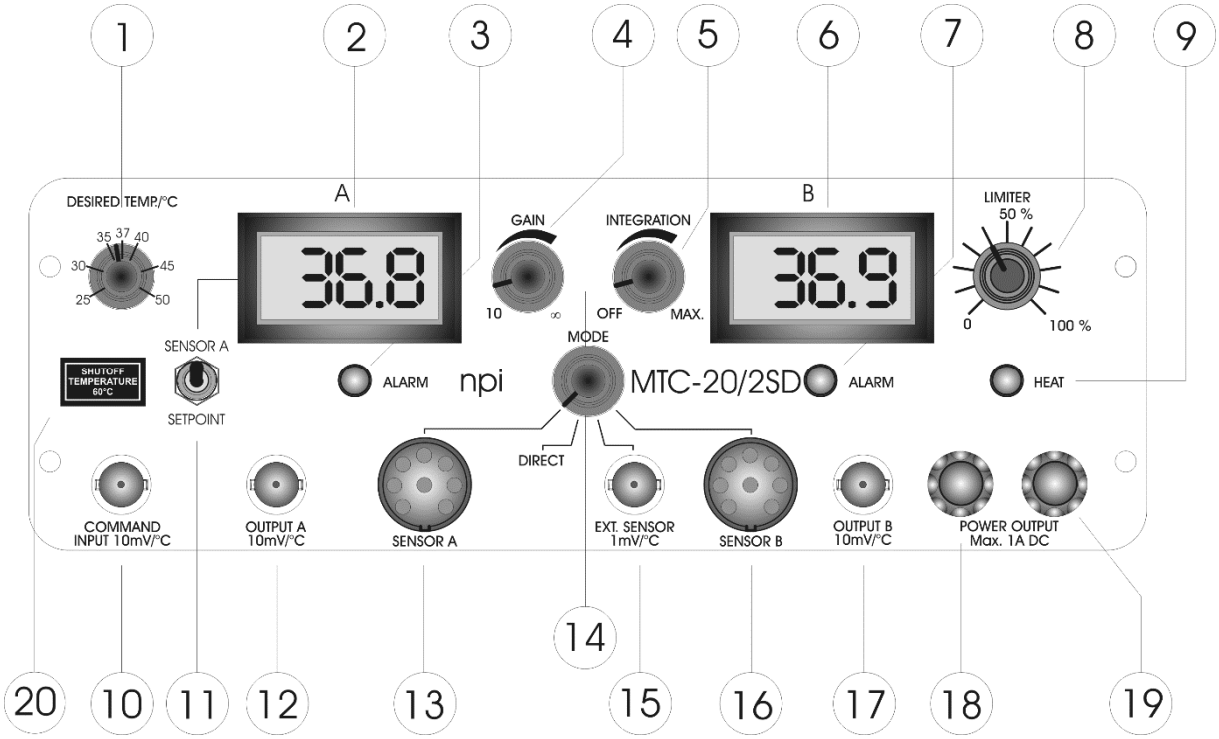


Figure 1: MTC-20/2SD front panel view

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**) **DESIRED TEMP./°C** potentiometer

Potentiometer to set the working temperature of the controller system. If the display mode switch (**11**) is in position SETPOINT the preset value is monitored on display A (**2**). Range: +25 °C….+50 °C.

(**2**) **Display A**

Digital display indicating the DESIRED TEMPERATURE, the temperature determined by SENSOR A or the voltage at the POWER OUTPUT connectors (18/19). The function is selected by the display mode switch (**11**).

(**3**) **ALARM** LED

This LED lights if temperature SENSOR A (**13**) is not connected, broken or short-circuited. The POWER OUTPUT (**18** / **19**) shuts down if this LED is on and the MODE switch (**14**) is set to SENSOR A.

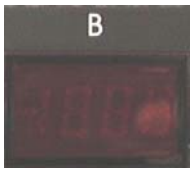
(4) GAIN potentiometer

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 ∞.

(5) INTEGRATION potentiometer

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

(6) Display B



Digital display showing the temperature determined by sensor B (**16**).

(**7**) **ALARM** LED

This LED lights if temperature SENSOR B (**16**) is not connected, broken or short-circuited. The POWER OUTPUT (**18** / **19**) shuts down if this LED is on and the MODE switch (**14**) is set to SENSOR B.

(8) LIMITER potentiometer

Potentiometer to set the voltage range of the POWER OUTPUT (**18** / **19**), 100% = 12 Volt.

(**9**) **HEAT** LED

This LED indicates the status of the POWER OUTPUT (**18** / **19**) (LED on = heating).

(10) 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 10mV / °C.

(11) SENSOR A / SETPOINT / PWR OUT switch (display mode switch)

Switch to select the mode of display A (**2**):

SENSOR A (upper position): the temperature determined by SENSOR A (**13**) is displayed (XX.X °C)

SETPOINT (middle position): the value preset at the DESIRED TEMPERATURE potentiometer (**1**) is displayed (XX.X °C)

PWR OUT ((lower position): the voltage at the POWER OUTPUT (**18**/**19**) is displayed.

(12) OUTPUT A 10mV/°C connector

BNC connector monitoring the temperature determined by SENSOR A (**13**), sensitivity: 10mV / °C.

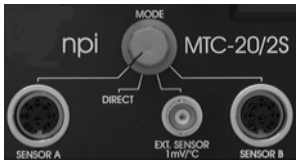
(13) SENSOR A connector

8-pole connector for temperature SENSOR A.

This connector also provides the POWER OUTPUT (**18** / **19**) for the heating unit (max. 12V DC and 1A) for devices with the ALA DIN connector cable assembly. (e.g. HPT-2A, see www.alascience.com).

(14) MODE switch

Switch to select the operation modes of the MTC-20/2SD. Four modes are available:



SENSOR A: the temperature determined by SENSOR A (**13**) is used for the control system

DIRECT: the voltage at the POWER OUTPUT (**18** / **19**) can be set directly from the LIMITER potentiometer (**8**) (0-12 V, no control)

EXT. SENSOR (EXTERN SENSOR): an external thermometer connected to BNC (**15**) (sensitivity 1mV/°C) can be used for the controller loop

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

(15) EXT. SENSOR 1mV/°C connector

BNC connector to connect external thermometer with a voltage output of 1mV/°C (see (**14**)).

(16) SENSOR B connector

8-pole connector for temperature SENSOR B.
This connector also provides the POWER OUTPUT (**18** / **19**) for the heating unit (max. 12V DC and 1A) for devices with the ALA DIN connector cable assembly. (e.g. HPT-2A, see www.alascience.com).

(17) OUTPUT B 10mV/°C connector

BNC connector monitoring the temperature determined by SENSOR B (**16**), sensitivity: 10mV / °C.

(18) / (19) POWER OUTPUT Max. 1A DC connectors

Banana jack connectors for the heating unit. This output supplies a maximum voltage of 12V DC and a maximum current of 1 A.
POWER OUTPUT is also available at the SENSOR A (**13**) and SENSOR B connectors (**16**) for devices with the ALA DIN cable assembly.

(20) SHUTOFF TEMPERATURE label

Label indicating the upper SHUTOFF TEMPERATURE (standard is 60 °C). If the sensor measures the indicated temperature or more the POWER OUTPUT is disabled.

3.3. Rear Panel Elements

POWER ON: The POWER ON push button turns on/off the power supply (115/ 230 V AC, 60 / 50 Hz). The selector for the line voltage and the connector for the power cord are located on the rear panel of the instrument.

FUSE: Line fuse: 0.8 A slow (115 V) or 0.4 A slow (230 V). It must be replaced only by specified type. Always disconnect mains power plug when replacing fuse.

***Caution**:* The instrument may be damaged if the wrong line fuse is installed, e.g. 0.4 A if the MTC-20/2SD is operated at 115 V!

GROUND: Banana jack providing system ground.
CHASSIS: Banana jack providing CHASSIS ground.

Note: System ground and CHASSIS ground are not connected.

3.4. Electronic Control and Protection Circuits

CONTROL LOOP
The sensor / thermometer, PI-controller, output power stage and heating 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 heating element (see also Figure 5).

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 heating wire. If not overheating and damage may occur.

ALARM circuit
The internal thermometer (R2252 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 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. Modes of Operation

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

DIRECT MODE:	output voltage is set directly by the LIMITER control.
Internal SENSOR mode:	output voltage is controlled by the PI controller using SENSOR A or SENSOR B.
EXT. SENSOR mode:	output voltage is controlled by the PI controller using an external thermometer.

DIRECT mode

DIRECT mode (no temperature control): the MODE switch (**14**, Figure 1) is set to the DIRECT position. The control unit is not active, i.e. the output voltage is preset directly at the LIMITER control (**8**, Figure 1). With the setting from 0% to 100% the output voltage increases linearly from 0 V to 12 V. The ALARM circuit (see below) is disabled in this mode.
The MTC-20/2SD is designed with an unipolar output. If a resistive load is used, the system can be used for heating purposes in all modes (SENSOR and DIRECT).

Internal SENSOR mode

In this mode the output voltage is controlled by the PI controller (PI [proportional-integral controller system] activated). The temperature signal which is used for the control unit is selected by the MODE switch.

- ❑ The SENSOR A or SENSOR B position selects one of the internal thermometers (SENSOR A or SENSOR B) which use a small semiconductor sensor. The measured temperature is shown at the respective digital display unit (**2** or **6**, Figure 1 respectively, XX.X °C).
- ❑ If no sensor is connected or if the sensor is damaged or short circuited the internal shut-off unit disconnects the power output. This state is indicated by the red ALARM LED (**3** or **7**, Figure 1 respectively) located just above the sensor connectors.

Caution: The temperature sensors are very sensitive to mechanical stress, especially to bending. Therefore, they must be handled with great care to avoid breaking of the insulation!

EXT. SENSOR mode

This mode can be used to connect an external thermometer. The calibration of the external input (SENS. INPUT BNC, (**15**, Figure 1)) is 1 mV / °C. If this option is used the internal ALARM circuit is disabled.

POWER OUTPUT is always available at POWER OUTPUT, SENSOR A and SENSOR B.

3.6. Setting the DESIRED TEMPERATURE

There are two ways to set the DESIRED TEMPERATURE:

1. The easiest way is to use the potentiometer DESIRED TEMP. / °C. The temperature can be set with this potentiometer from +25.0 °C to +45.0 °C. If the temperature exceeds +60 °C the internal shut-off unit disconnects the power output. This could be also 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) or to set the temperature to lower (<25 °C) or higher (>50 °C)values, 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 mains while the cabinet (CHASSIS) is always connected to protective earth (green / yellow wire).

5. Temperature sensors / Block diagram

5.1. DIN Connector

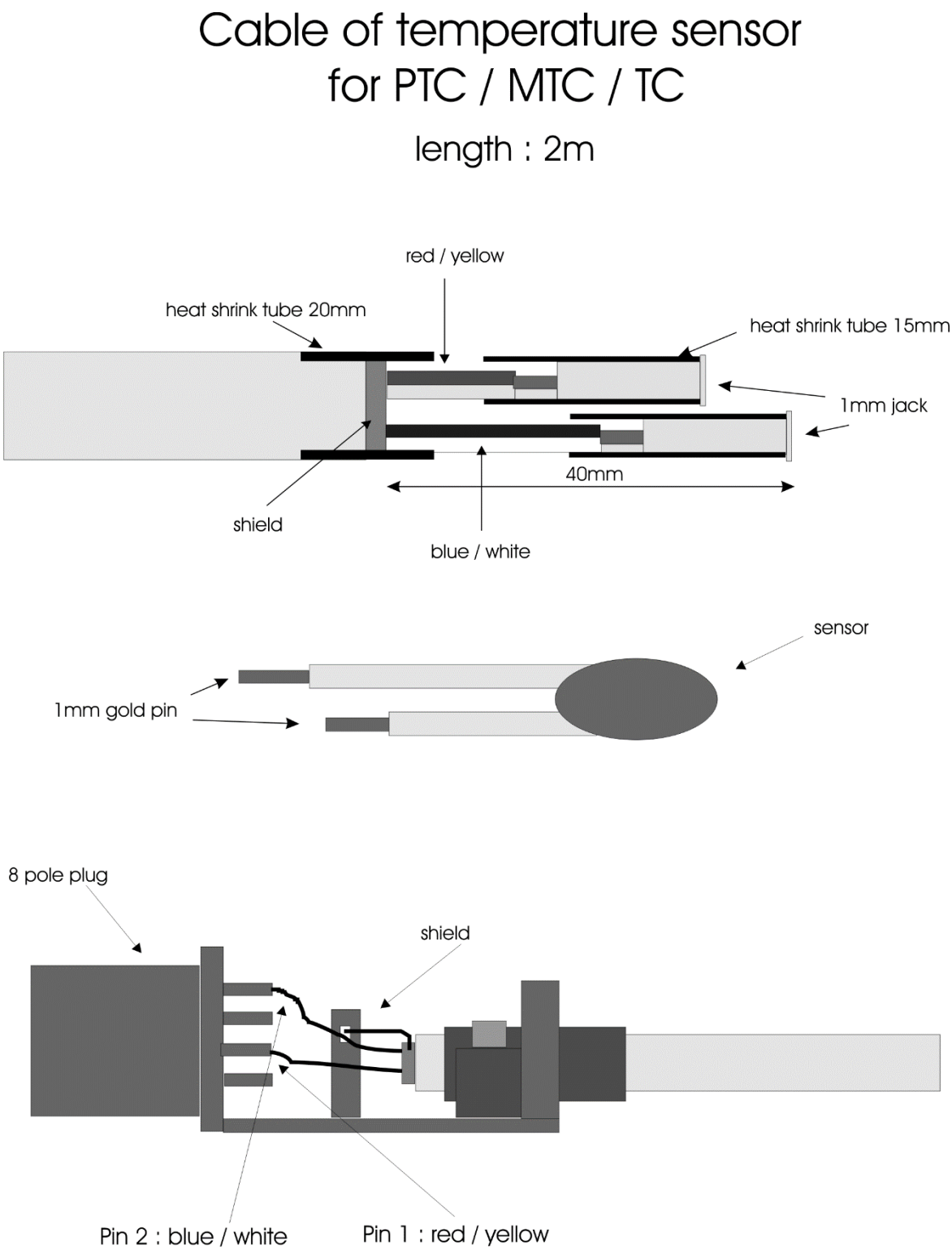


Figure 2: How to connect the temperature sensor

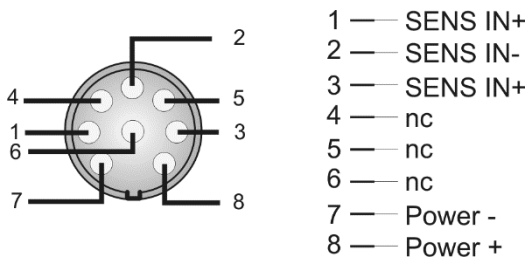


Figure 3: Connector pinout of the DIN connector (pins 1 and 3 are connected internally)

5.1. Available sensors

Figure 4: Temperature sensors and cable.

The sensors come with a connection cable (TS-CAB, see Figure 4, left) with a DIN connector on one end and two 1 mm connectors on the other end. The DIN connector is for connection to the SENSOR input at the front panel of the temperature controller. The 1 mm connector are for connection of the sensor, which is available as spare part.
There are two sensors available: the white TS-100S (Figure 4right, top) and the dark TS-200S (Figure 4 right, bottom).

Important: The TS-100S has a special coating that makes it mechanically stable and waterproof. The TS-200S is optimized for size. Its coating might get leaky after mechanical stress (e.g. bending of the wires).

Dimensions:

TS-100S: 2.5 mm x 6 mm
TS-200S: 0.8 mm x 6 mm

5.2. Block diagram

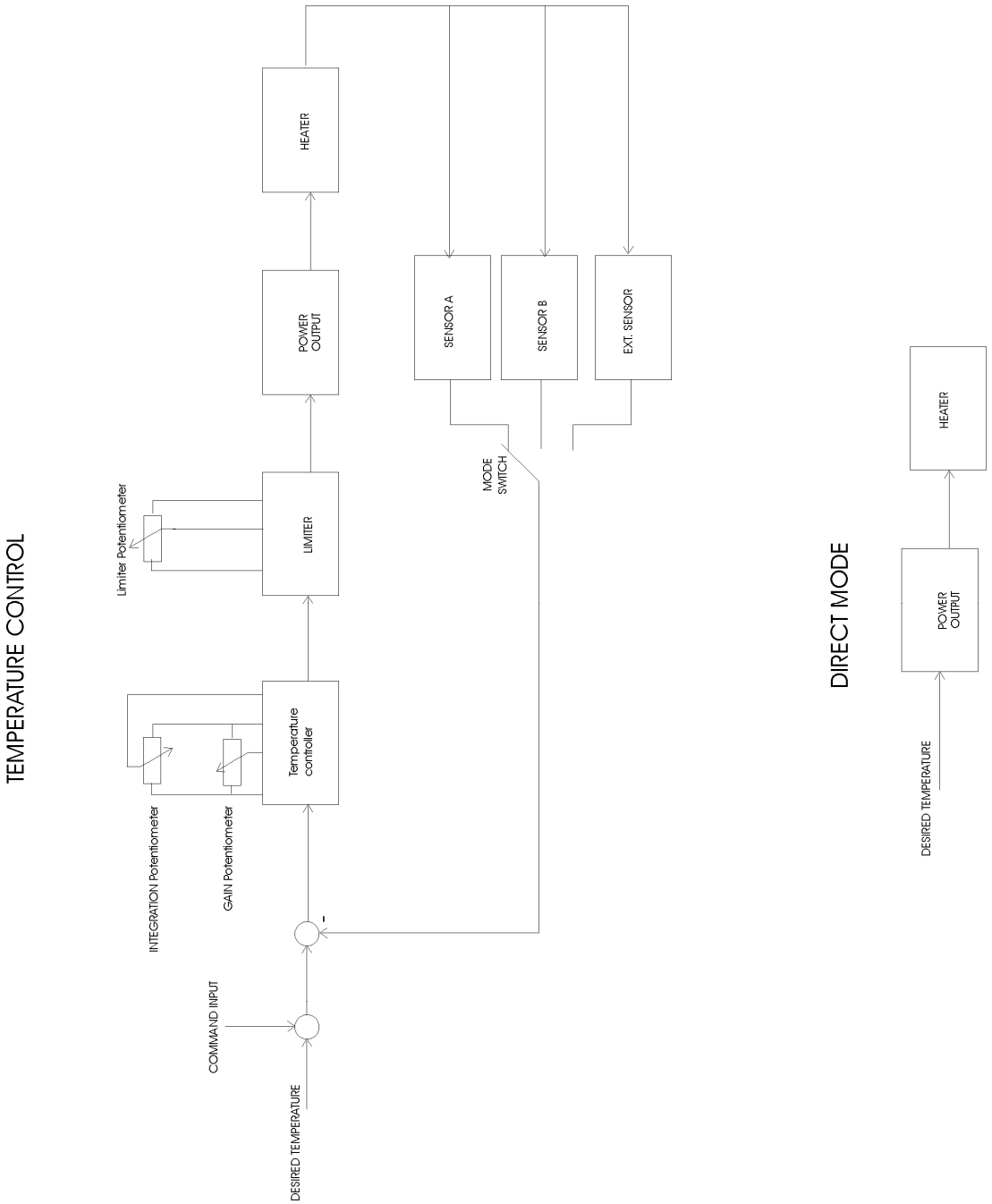


Figure 5: Block diagram of the MTC-20/2SD

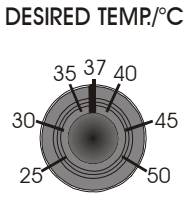
6. Operating Guide – Tuning Procedure

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.

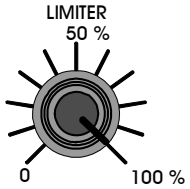
Important: Make sure that the SENSOR or the external SENSOR, respectively, and the heating device that is controlled by this SENSOR are using the same channel. Otherwise the heating device may be damaged due to overheating.

In the following it is assumed that you use heating devices delivered by npi or ALA Scientific Instruments. 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



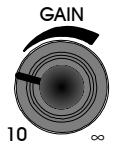
- turn on the MTC-20/2SD and wait at least 15 minutes to warm up the instrument. The temperature display should show the actual temperature at the sensor
- turn the LIMITER to 100%



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 a position as shown below



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 should arrest at 1 to 2 °C below the desired temperature. Please wait until this steady state value is reached.

This may last several minutes. 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 you don't get a steady state value, set the LIMITER to 80-90% (or 30-40%, respectively) and wait again.

Now turn on the INTEGRATION and set it to a low level

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 the desired temperature is not reached first set the GAIN to a slightly higher level and then – if necessary – raise the INTEGRATION

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 MTC-20/2SD 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 it is recommended to heat the solution approximately to the desired temperature **before** perfusing the bath either with a heated perfusion tube (HPT-2A, available from npi) or by heating up the supplying bowl.

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

In Figure 6 the time course of temperature regulation of the MTC-20/2SD is shown. As resistive load a bulb 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.

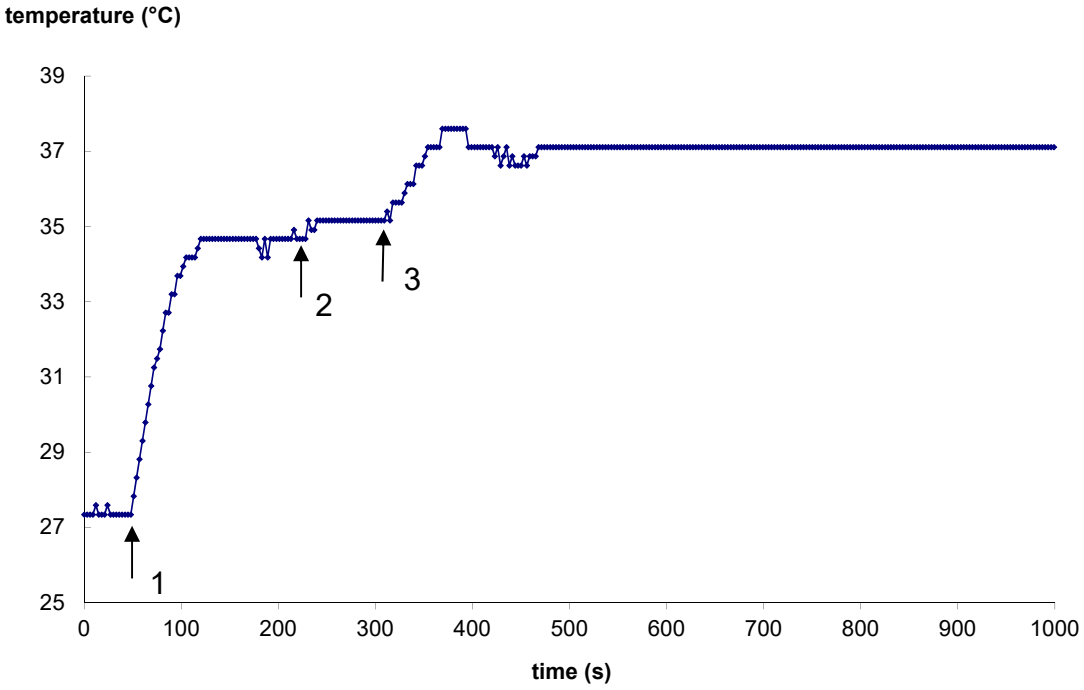


Figure 6: Time course of temperature regulation of the MTC-20/2SD.
1: LIMITER was set to 100%, GAIN was set to a low level
2: GAIN was set to a slightly higher value (about 10% of the whole scale)
3: INTEGRATION was turned on at a low level

6.1. Operation with HPT-2A Heated Perfusion Tube (discontinued)

For use with HPT-2A from ALA please follow these hints.

- ❑ Always use the LIMITER. Do not set the LIMITER to more than 40% for a longer time, since the HPT-2A will melt if operated at more than 5V. If in doubt, measure the output voltage using a voltmeter.
- ❑ Do not heat the HPT-2A without flow of solution. See also HPT-2A manual.

7. Literature

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

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

8. Technical Data

Sensor input:	for semiconductor 2252 Ω at 25 °C (standard), accuracy typically 0.1 °C at 25 °C, with electronic protection
Sensor input (EXT. Mode):	sensitivity: 1 mV/°C
ALARM and SHUTOFF:	disconnects POWER OUTPUT if temperature is below +3 °C (not connected or broken sensor) or above +60 °C (short circuited sensor)
Digital displays:	3 1/2 digits, XX.X °C (temperature of SENSOR A or B) or XX.X V (voltage at POWER OUTPUT)
COMMAND INPUT:	BNC connector, analog input, sensitivity. 10 mV/°C
Set value control:	potentiometer, range: up to 50.0 °C, XX.X °C
Temperature OUTPUT (A, B):	BNC connector, analog outputs, sensitivity. 10 mV/°C, output impedance: 250 Ω
POWER OUTPUT:	12 V / 1 A, short circuit protected, continuous DC
Limiter:	potentiometer for the maximum output voltage with a linear range from 0 – 100 %
Control:	PI (proportional-integral) controller, accuracy typically ±0.2 °C
GAIN:	potentiometer, logarithmic scale, range: 10-10k
INTEGRATION:	potentiometer, logarithmic scale, time range: 50 ms - 20 s
Measuring accuracy:	0.1 °C at 25 °C
Power requirements:	115V / 230V AC, 60 / 50 Hz, fuse 0.8A / 0.4A slow
Dimensions:	desktop cabinet, 246 mm, 260 mm, 90 mm