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TC^2_{bip} [R5]

Bipolar Temperature Controller

INSTRUCTION MANUAL

August, 1996 Rev June08

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INTRODUCTION

The **TC^2_{bip} Bipolar Temperature Controller, TH-1 thermistor probe** and **HI-25x Heaters** form a temperature control system that yields reliable and accurate temperature control in small experimental chambers used for studying acutely isolated or cultured cells. The **TC^2_{bip}** compares the voltage from the thermistor probe with an internal reference voltage set either by manual controls or by external programming. The difference between these two voltages (the error signal), is then used to generate appropriate power in the heater so as to maintain the chamber temperature at the reference temperature during changes in flow rate or ambient conditions. In general, when the reference temperature is increased in a step, the temperature in the experimental chamber overshoots before settling; the **TC^2_{bip}** works to minimize this overshoot, thereby protecting the cells from damage due to transient high temperatures. (The estimated temperature overshoot in response to a temperature jump of 10°C is approximately 2°C at the bottom surface of the **BT-1 Bath**). With proper adjustment of the controller parameters the temperature across a 0.6x1.0cm surface can be regulated within ±1°C for flow rates of zero to 2ml/min. The rate of rise of temperature depends principally on the experimental chamber volume. Typically rates of 1°C/sec can be expected with chamber volumes less than 0.25ml. The rate of decay of temperature depends on the experimental chamber design as well as the solution flow rate. For the **BT-1 Bath** decay rates range from approximately 30 secs at a flow rate of 2ml/min to 112 secs for a flow rate of 0.2ml/min. Further details of the performance of this type of system is described in Datyner, Gintant and Cohen (1985)†.

The **HI-25x** heater is a transparent Indium Tin Oxide (ITO) coated heater. The heater provides a uniform heat source approximately 0.12 [**HI-25T**]-0.25mm [**HI-25**] thick suitable for both conventional or inverted microscopes.

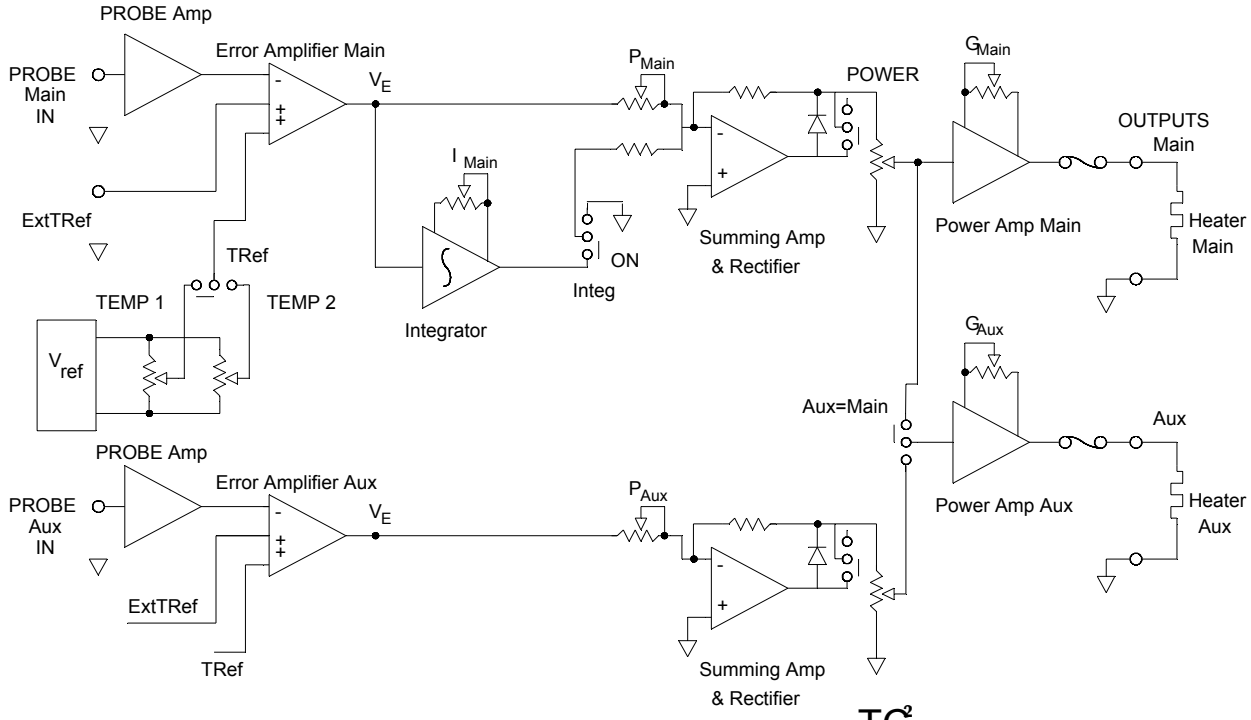
†Datyner N.B., Gintant G.A. & Cohen I.S. (1985) Versatile temperature controlled tissue bath for studies of isolated cells using an inverted microscope. Pfluügers Archiv 403, 318-323.

THEORY OF OPERATION

A block diagram of the temperature controller is shown below. The PROBE Amp voltage is fed to the Main Error Amplifier and compared with the reference voltage (corresponding to the reference temperature selected [TEMP 1, TEMP 2 plus ExtTRef]). The resulting amplified error signal (V_E) is fed directly to the Summing Amp and Rectifier and also to the Integrator. The magnitudes of the amplified error and integrated error signals are controlled by the settings of the P_{Main} and I_{Main} controls respectively to allow rapid changes in temperature with minimal overshoot. The amplified error signal is essential in maintaining the chamber temperature at the reference temperature during changes in flow rate, while the integrator enables zero steady-state temperature error to be maintained as it supplies a constant heater current in the absence of any temperature error. The Aux stage operates very similarly except that there is no integrator. The POWER control is common to both Main and Aux channels.

The Aux=Main switch allows the Aux amplifier to be a slave of the Main amplifier. The output in this case is scaled by the ratio of G_{Aux}/G_{Main}.

The third control channel is not shown but is very similar to the Aux channel except that it is a "heat only" channel while the outputs of the Main and Aux channels can go both negative and positive (ie. heating and cooling).

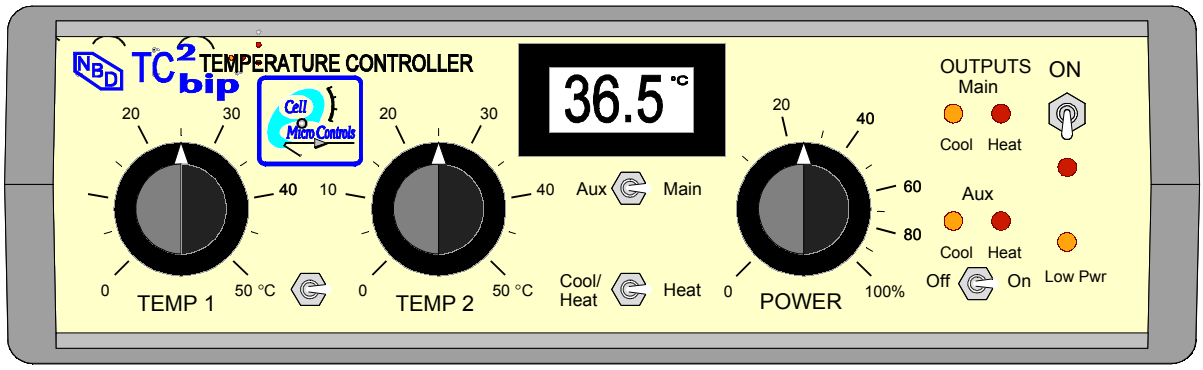


TC^2_{bip}

Bipolar Temperature Controller

CONTROLS, INDICATORS, INPUTS AND OUTPUTS

FRONT PANEL



TEMP 1

Reference temperature 1. The temperature controller uses this as the reference temperature when the TEMP 1,2 switch is set on TEMP 1.

TEMP 2

Reference temperature 2 (*see* TEMP 1).

TEMP 1,2 switch

Selects TEMP 1 or TEMP 2 as the reference temperature. This control allows reproducible switching between two preset reference temperatures. Jumpers can be set internally so that TEMP1 is used for Main and TEMP2 for Aux.

Aux/Main switch

Selects between display of Main probe temperature or Auxiliary probe temperature. **When probe is not connected or open circuit the display shows a 1 in the leftmost position.** In the central position the meter displays the temperature from the optional Ch3.

Cool/Heat Heat switch

When set to Cool/Heat outputs can go negative (for cooling) or positive (for heating). Use this setting with Peltier devices. The Heat setting should be used for resistive heaters, eg. **H-1x**, **HI-25x** or **HPRE2** pre-heater.

POWER

This control regulates the power available to OUTPUTS Main and Aux (and Ch3). During normal operation (ie. when there is solution in the experimental chamber) this control is set to the 100% position. When the chamber is being drained of solution or loaded with cells this control should be set at 0%. The OUTPUT LED's may glow even when the control is set to 0% since even on this setting a small amount of power is still supplied to the heaters. Reducing the available power to zero is preferable to switching the **TC^2_{bip}** off, since this avoids the possibility of temperature transients when the **TC^2_{bip}** is turned on. The POWER control can also be used to slow the rate of rise of temperature if needed (halving the available power will halve the rate of rise of temperature). Since it is essential to have sufficient power for steady state maintenance of temperature, the application of this method is limited. Where slow temperature changes are desired it is preferable to either raise the temperature manually using the TEMP 1,2 controls or use the Ext T Ref to program a slow ramp.

OUTPUTS Main, Aux

Main: the intensity of the LED reflects the voltage at the HEATER Main output for low voltages. As

the output voltage increases the brightness will reach a maximum. For most situations the LED will glow. **If the FUSE is blown or the DC In voltage is too low the LED will not light.**

Aux: *see* Main

Aux On/Off switch

This switch turns off the Aux OUTPUT. This may be useful in setting up the G_{Aux} or if you are using a simple pre-heater (ie. without a thermistor) and stop solution flow.

ON/OFF switch

This switch turns the temperature controller ON or OFF. The LED below the switch lights when there is sufficient voltage at the DC In (ie. greater than 10V).

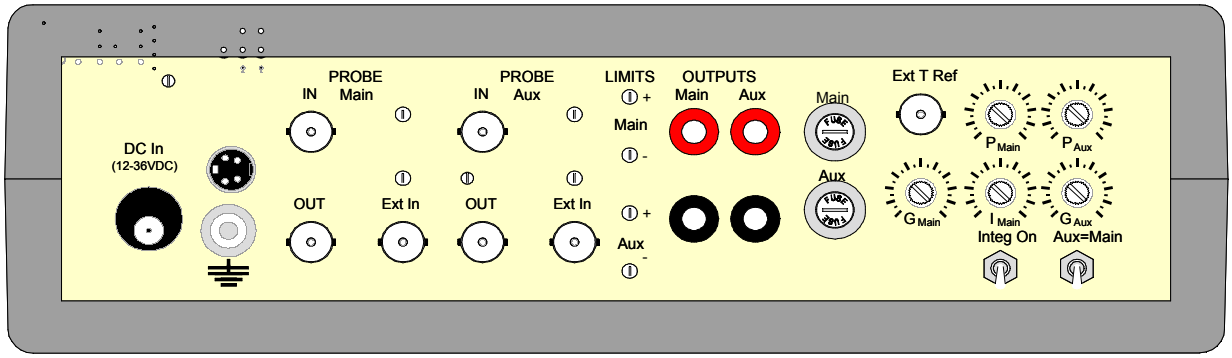
Lo Pwr

This LED lights when the DC In voltage is below about 10V. You should not use the **TC^2_{bip}** when this LED is lit as the operation may not be correct. For example probe temperatures may be incorrect or inappropriate output voltages may occur.

Buzzer

Inside the **TC^2_{bip}** there is a buzzer used to indicate that the output current is too high.

REAR PANEL



DC In

For most heat only situations an input of +12V (at 4 Amp max) will be used. For **H-1x** and **HI-25x** heaters typical currents are 0.5 Amps. For Peltier devices a 24V supply should be used although a 12V (or 13.8V since these are quite common) can be used with some devices including our **CH Cooling/Heating module**.

Ch 3 gain (option)

There is a small hole above the DC In socket near the top of the panel. This is the gain control for Ch3. In the minimum gain position the control is fully anticlockwise while maximum gain is when the control is fully clockwise.

Ch 3 Therm/Output (option)

The 4 pin DIN connector is compatible with heaters used with the ***m*TC micro-Temperature Controller**. These use a 10kΩ thermistor and a 5-15Ω resistance heater (see CHANNEL 3 Operation).

GROUND

The ground is the main ground for the **TC^2_{bip}** and connected to the negative side of the DC In socket. **The OUTPUTS negative terminals should NOT be connected to this ground.** This will short the output

amplifier and potentially cause damage to the amplifier.

PROBE Main

IN

This input accepts **TH-10Km** thermistor probes. The Span and Offset adjustments will have been set to match the thermistor characteristics. If you purchase the **TC^2_{bip}** with a **TH-1** thermistor probe the controller should have been adjusted for this probe. There should be a label on the rear indicating this. Keep in mind that if you change to another **TH-1** probe the **TC^2_{bip}** will have to be adjusted for this new probe. The PROBE input stage can be easily modified to accommodate other thermistor probes with different resistances and beta values. Please contact us if you want to use another type of probe.

OUT

This output can be used to monitor the probe temperature (eg. to log the temperature on a chart recorder or by computer). The Output voltage is given by:

$V_{OUT}(T)$ = 10mV[100mV* x T (in °C) where T is the probe temperature in °C. *Internal jumper.

Ext In

You can use other probe transducers provided the transducer output is 10mV/°C. This allows you to use some Sensortek thermocouple probes. When a voltage is applied to the Ext In the Ext In voltage is fed to the error amplifier in place of the output of the PROBE amplifier.

Span

The upper control allows the Span of the probe to be adjusted. Typically you will use 5°C and 45°C as calibration temperatures.

Offset

The lower control allows the Offset of the probe to be adjusted (see PROBE CALIBRATION).

PROBE Aux

IN

This input accepts 10kΩ interchangeable thermistor sensors such as those used in the **HPRE2 Pre-heater**. The PROBE input stage can be easily modified to accommodate other thermistor probes or sensors with different resistances and beta values. Please contact us if you want to use another type of probe.

T Offset

This control located between the PROBE IN and OUT on the Aux channel allows you to offset the temperature supplied to the error amplifier for the Aux error amplifier by ±6°C. For heating you would turn the control clockwise from its neutral (horizontal) position. This allows you to compensate for the fact that the Aux control uses only proportional gain and has no integrator to remove the steady-state error. Make sure the pre-heater temperature is always **below** the bath temperature.

OUT

This output can be used to monitor the probe temperature (eg. to log the temperature on a chart recorder or by computer). The Output voltage is given by:

$V_{OUT}(T)$ = 10mV[100mV*] x T (in °C) where T is the probe temperature in °C. *Internal jumper.

Ext In

You can use another probe transducer provided the transducer output is 10mV/°C. This allows you to use some Sensortek thermocouple probes. When a voltage is applied to the Ext In the Ext In voltage is fed to the error amplifier in place of the output of the PROBE amplifier.

LIMITS

Main

The + control can be adjusted to limit the maximum positive voltage at the OUTPUT Main.

The - control can be adjusted to limit the maximum negative voltage at the OUTPUT Main (for a Peltier

device).

Aux

The + control can be adjusted to limit the maximum positive voltage at the OUTPUT Aux.

The - control can be adjusted to limit the maximum negative voltage at the OUTPUT Aux (for a Peltier device).

OUTPUTS

Main: Output to Main heater or Peltier heater/cooler. **Neither output terminal can be grounded.**

Aux: Output to pre-heater or Peltier pre-heater/cooler. **Neither output terminal can be grounded.**

Ext T Ref

Can be used as an external temperature reference for the Main channel. The equivalent temperature is **added** to that set on the TEMP 1 or TEMP 2 control. The equivalent temperature of the Ext T Ref voltage is given by:-

$T = V_{ExtTRef} / 100mV$ where T is the equivalent temperature in °C

For example a 2.5V input to $V_{ExtTRef}$ is equivalent to 25°C. If the TEMP 1 control is set to 10°C and the TEMP1,2 switch is set to TEMP 1 the reference temperature is 35°C.

FUSES Main, Aux

Main: Fuse limiting output current for OUTPUT Main. The power amplifier current is internally limited to about 2 Amps so fuses should be less than or equal to 2Amps. For example if you have a heater where the current should be limited to 1 Amp substitute a 1 Amp fuse for the 2 Amp fuses that are supplied. Don't leave the outputs shorted for more than a few seconds. Do not use fuse values greater than 2 Amps (except for use with the **CH&CP1** Cooling/heating module where 4Amp fuses are used. The fuses are 2AG type.

Aux: Same as for Main but for OUTPUT Aux.

GAINS

P_{Main}

This control adjusts the amplification of the temperature error signal for the Main control channel (*see* TUNING PROCEDURE).

I_{Main}

This control adjusts the rate at which the temperature error signal for the Main control channel is integrated (*see* TUNING PROCEDURE).

G_{Main}

This control sets the output voltage span for the Main control channel. It is set according to the power supply voltage (*see* TUNING PROCEDURE).

P_{Aux}

This control adjusts the amplification of the temperature error signal for the Aux control channel (see TUNING PROCEDURE).

G_{Aux}

This control sets the output voltage span for the Aux control channel. It is set according to the power supply voltage (*see* TUNING PROCEDURE).

Integ On/Off

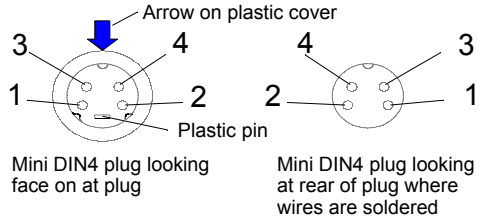
This switch turns the integrator for the Main control channel stage On or Off. During normal operation this switch is in the On position to eliminate steady-state temperature errors. The Off position is used in the TUNING PROCEDURE or where proportional control only is more appropriate (eg. for some Peltier devices).

Aux=Main switch

When set to the On position the Aux channel acts as a slave to the Main channel. In the Off position the

CHANNEL 3 OPERATION

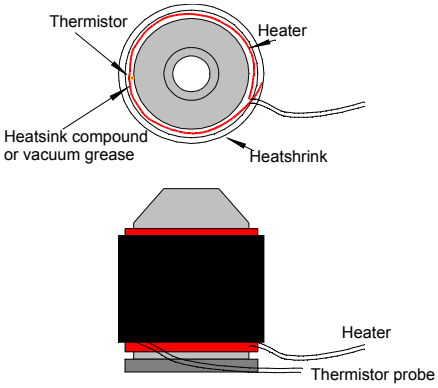
The **TC²bip** supports an optional 3rd "heat only" control channel **(TC2-Ch3 3rd Channel option)** intended for microscope lens heating for oil immersion microscopy or as an auxiliary heater for maintaining a secondary chamber at the same setpoint as the main tissue chamber. This could be used for extra dissociated cells. Compatible heaters should have a resistance from 5-15Ω. The thermistor should be a 10KΩ interchangeable thermistor such as the **TH-10Km Thermistor**. The figure below shows connections to the 4 pin MiniDIN plug if you wish to make your own heater assembly. The setpoint is normally derived from TEMP1,2 but can be set to come from TEMP1 or TEMP2 or from an optional 3rd potentiometer installed on the front panel.



1 & 2 Heater connections
3 & 4 Thermistor connections

The gain control for the third channel is located above the DC In socket near the top of the rear panel. To adjust the gain control rotate it fully clockwise and then monitor the heater temperature using an independent probe. If there are temperature oscillations rotate the gain control anticlockwise until they disappear.

There are several compatible heater assemblies that are also used for the **mTCII** micro-Temperature Controller, the **HLS-1P** and **HC-1P** heater assemblies shown below. **HLS-1P** is suitable for a lens heater. The heater can be wrapped around the lens and several heatshrink bands used to hold it in place. The thermistor probe should be held against the heater with a heatshrink band. The lens should be thermally isolated from the microscope turret if this is possible.

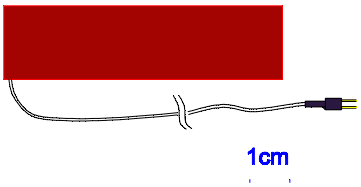


The 3rd channel output amplifier uses the rear panel of the **TC²bip** as a heatsink. The panel may get warm. If it feels hot then you are either using a heater with too low a resistance or the DC In is too high. Reduce DC In to the minimum necessary and use a heater with a higher resistance. The 3rd channel is internally fused with a 2Amp fuse.

HLS-1p Heater assembly - lens, silicon

Application

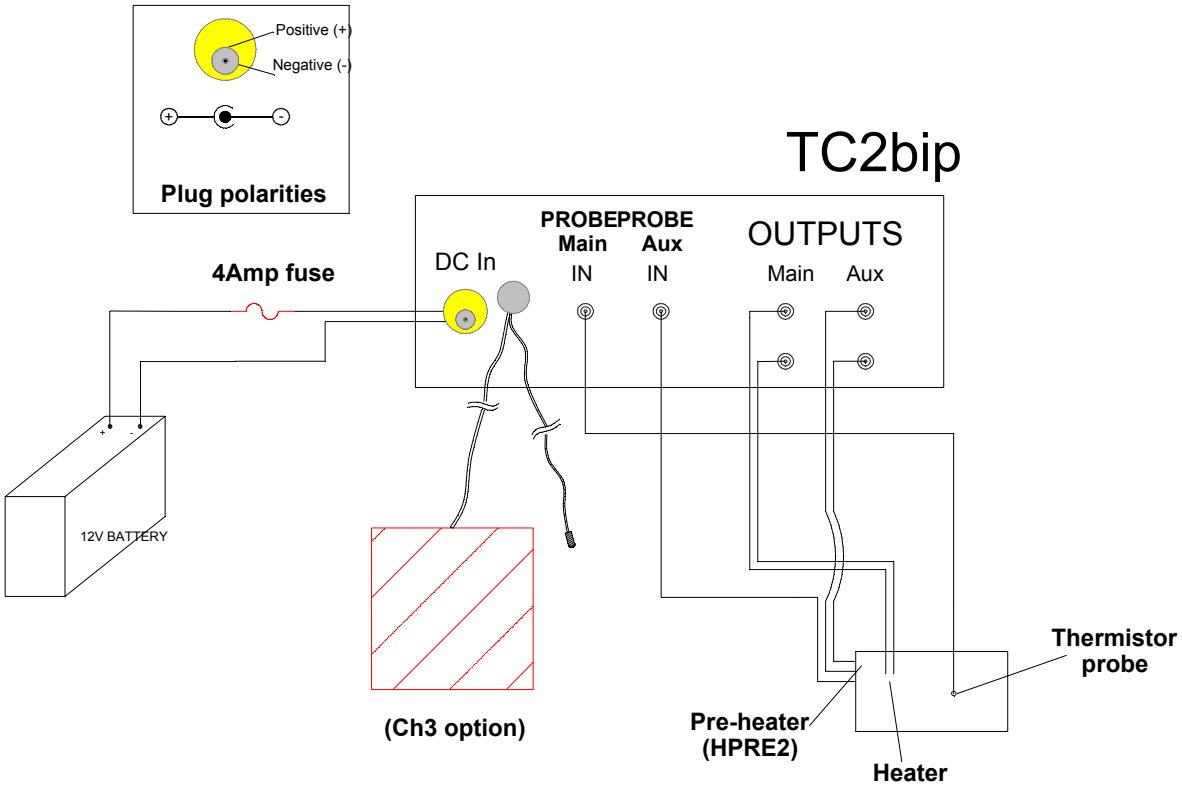
The **HLS-1P** can be used for heating a microscope lens. Attach to the lens according to the directions that come with the heater assembly.



- heater size 20x70x0.35mm thick
- thermistor as for **TH-10Km**
- max. operating temperature 100°C

ELECTRICAL CONNECTIONS

The electrical connections are illustrated below for a typical configuration of the **TC^2_{bip}**. You must use the power cable supplied with the **TC^2_{bip}**. This has a 5Amp circuit breaker in the lead. If you are making your own cable you must use either a circuit breaker or 4Amp fuse.



Typical connections

PROBE CALIBRATION (unit is delivered calibrated)

If you purchased the **TC^2_{bip}** along with accessories including the **TH-10Km, TH-2Km** or **TH-1 Thermistor probe** the **TC^2_{bip}** PROBE Main Span and Offset will have been adjusted to match the probe. If you purchase a replacement **TH-10Km** or **TH-2Km** you will not have to recalibrate the probe inputs. If you purchase a new **TH-1** probe **you will need to** adjust the Span and Offset controls so that the LCD temperature display will read the correct temperature (please call us for instructions on how to do this).

LIMITS Settings

The LIMIT adjustments allow you to limit the rate of rise (or fall for a Peltier device) of temperature by limiting the maximum or minimum voltage swing of the outputs.

An example taken from the application of the **HC-1 Heater** may better illustrate the use of the control.

Suppose you attach the **HC-1 Heater** to a 5cmx5cm Aluminium plate. This plate would have a thermal resistance (ΔT/Power) of about 16ºC/W. The plate would weigh about 25gms. You can estimate the rate of rise of temperature (˚C/sec) from $\beta = P_{max} / (c \,.\, m_{heated})$ where:-

P_{max} = max power input to heater

c = heat capacity of heated mass (for glass or Aluminium c≈0.8kJ/kg)

m_{heated} = mass heated by heater

If you are using a 12V supply and G_{Main} is set to 0 the maximum output is about 4.9V. This means that:-

$\beta=(4.9)^2/(800.0.025)=1.2$°C/sec.

The power required to increase the temperature of the plate by ΔT degrees is given by:

$P_{ss}=\Delta T/\theta$ θ in °C/W, T in °C and P in Watts.

Where θ is the thermal resistance of the plate and P_{ss} the steady state power. If ambient temperature is 25ºC then to maintain the plate at 35ºC would require 0.625W. This is much less than the maximum power available so we could reduce the maximum output voltage to for example 2V by reducing the +ve LIMIT. This would limit the rate of rise of temperature to about 0.2ºC/sec and reduce any temperature overshoots. There would still be ample power to maintain the heater at 35ºC.

G_{Main} and G_{Aux} settings

The G_{Main} and G_{Aux} controls adjust the voltage range of the output amplifier to allow for different resistance heaters (or Peltier elements). An example may help to explain. If you have a 12V DC In and set the G_{Main} control to 100% the OUTPUT range will be increased to -8 to 8V however decreasing the POWER control to 50% will **not** decrease the OUTPUT voltage from 8V. In other words the POWER control will no longer reduce the OUTPUT voltage in a "linear" fashion since internally the amplifiers will have reached a limiting value. You should keep with the values of G_{Main} recommended for DC In voltages and devices attached to the controller.

The settings of G_{Main} depends on the DC In voltage according to the following table:-

DC In Voltage	G_{Main} Setting (%)	OUTPUT range Volts
12V	0	-8.0 to 4.9V
24V	15	-13 to 8.4V
36V	100	-28 to 28V

The G_{Aux} value should be set as suggested in the TUNING PROCEDURE section. G_{Aux} performs the same function as G_{Main} but for the Aux control channel. If you do not have any information indicating that G_{Aux} should be set to a particular value then it should be set to be equal to the G_{Main} value.

Overcurrent protection

The **TC^2_{bip}** uses a microcontroller to detect the current in the Main and Aux channel power amplifier to protect them from overcurrent and short circuit conditions. However, **don't** deliberately overload or short the OUTPUTS. For most accessories you will never encounter the operation of the overcurrent protection. If you use the **CH Cooling/Heating module** you may need to adjust the maximum current using the POWER control. The **TC^2_{bip}** also detects the temperature of the power amplifier heatsinks and will shut down the power amplifer (ie. Main or Aux) whose heatsink is too hot. Overcurrent is indicated by both a buzzer and the OUTPUT LEDs flashing. **All** the output amplifiers are shut down even if only one channel is overloaded. If the current exceeds approx. 2.5Amps the buzzer will go on and the OUTPUT LEDs will flash. The output amplifiers are being shut off and then turned on very briefly (for about 10ms) to test the output amplifier current. You should reduce the current using the POWER control till the buzzer stops and the LEDs do not flash.

If the output current exceeds 3Amps even for brief periods you can damage the power amplifiers so you will first hear a series of beeps and the LED's will flash. After a 0.5sec delay you will see either 1,2,3 or 4 flashes of the LED's. The number of flashes indicates which amplifier is being overloaded (Main +ve, Main-ve, Aux +ve, Aux -ve respectively). The buzzer will then sound continuously for 10seconds. During this time you should shut off the **TC^2_{bip}** and try to work out what is shorting out the output amplifier. If you don't see anything wrong turn the POWER control to zero and turn the **TC^2_{bip}** on again. If the overcurrent is still there it will repeat the shut down cycle.

The power amplifier heatsink can overheat if you are using a heater with a very low resistance (eg. 3ohms). You should either use a higher resistance heater or reduce the voltage of the power supply. Overheating can also occur if you are using a high voltage power supply (eg. 36V) with a heater with a resistance in the normal range (5-15ohms). In this case you should use a lower power supply voltage. Typically with a usual 12-15V power supply overheating of the heatsink does not occur.

TUNING PROCEDURE

The **TC²bip** is delivered with the $P_{Main/Aux}$, I_{Main} and $G_{Main/Aux}$ set up for use with the **HI-xx** ITO Transparent heaters on the Main channel and **HPRE2** or **MPRE8** on the Aux channel. You should not have to change these settings. Below is a description of the controls and how to customize the adjustments for your own accessories or where you want to optimize the temperature performance.

On the Main control channel three controls P_{Main}, I_{Main} and G_{Main} influence the steady-state and transient performance of the temperature controller. For the Aux channel there are two controls P_{Aux} and G_{Aux}. The values they are set to depend on the thermal properties of the experimental and pre-heater chambers as well as on flow rates used. First G_{Main} is set depending on the DC In voltage. Then P_{Main} is approximately set and then I_{Main} and P_{Main} adjusted for optimum transient response. The **TC²bip** is shipped with P_{Main} set to 80%, I_{Main} set to 50%, G_{Main} set to 0 (for 12V supply). P_{Aux} is also set to 80% and G_{Aux} to 10% (to give G_{Aux}/G_{Main}=1.5). The Aux=Main switch is set to On. These settings are suitable if you are using the **BT-1** and simple capillary pre-heater. If you are using the **HPRE2 Pre-heater** then the Aux=Main switch should be set to Off. If you are using another bath design or want to optimize the transient performance then you should perform the tuning procedure below.

G_{Aux}/G_{Main} ratio

If you are using a simple pre-heater without a thermistor sensor then you will need to adjust the G_{Aux}/G_{Main} ratio. You will have the the Aux=Main switch is set to On. This sets the ratio of power supplied to the pre-heater versus the main heater. For this adjustment an independent thermistor probe is required to monitor the temperature at the inlet side of the experimental chamber. This test point should be on the long axis of the heater element approximately 5mm left of the center of the element (ie. in a spot corresponding to the bath thermistor but on the left hand side of the chamber).

1.Set initial control positions :

G_{Aux}=G_{Main}=0; P_{Main} at 80%, I_{Main} at 50%; Integ On; Aux=Main set to On.

Select TEMP 1 at 35°C; POWER at 100%

2. Adjust flow rate to a typical value that will be used in experiments.

3. Allow flow to stabilize and increase G_{Aux} until test point temperature matches that of the controller thermistor. For the **BT-1 Bath** and capillary pre-heater G_{Aux} should be about 10%.

4. Adjust the flow rate to the maximum that will be used and measure the temperature at the test point. Similarly, repeat for the lowest non-zero flow rate.

5. If the temperature at the test point in these two cases is low or high by more than 1°C adjust G_{Aux} appropriately and check the test point again for the temperature at the typical flow rate.

6. It is preferable to use the **smallest** value possible for G_{Aux} as this prevents oscillations of temperature caused by overheated solution exiting the pre-heater.

P_{Main}

1.Set initial control positions :

P_{Main} fully clockwise; Integ Off, TEMP 1 at 25°C and TEMP 2 at 35°C, select TEMP 2; POWER at 100%., Aux channel off (front panel switch).

2. Adjust flow rate to typical value that will be used in experiments.

3. Monitor the OUTPUT Main voltage with a storage scope chart recorder or DVM. **The chart recorder inputs must not be grounded.** For a scope use a **differential input** or **subtract** the voltage using the voltage subtraction feature available on most oscilloscopes.

4. With the control settings above there may be sustained oscillations in the heater voltage. If so rotate P_{Main} anti-clockwise until oscillations just disappear. This sets an upper limit on P_{Main}.

5. Repeatedly switch from TEMP 1 to TEMP 2, waiting for the temperature to settle and reducing P_{Main}

if there are significant oscillations in the OUTPUT Main voltage following the switch.

I_{Main}

1. Set initial control positions :

P_{Main} as determined above; I_{Main} fully anti-clockwise; Integ On; TEMP 1 at 25°C and TEMP 2 at 35°C and select TEMP 1; POWER at 100%

2. Switch between TEMP 1 and TEMP 2 and measure the rate of rise of temperature in experimental chamber (in °C/sec) using a storage scope or chart recorder plugged into the PROBE OUT.

3. Measure the OUTPUT Main output voltage when switched to TEMP 1 ($V_{1,s\text{-}s}$) and then the output voltage when switched to TEMP 2 ($V_{2,s\text{-}s}$). An initial value for I_{Main} is given by

$I_{Main} = \{100 - (\text{TEMP 2} - \text{TEMP 1})^2 / [\ .(V_{2,s\text{-}s} - V_{1,s\text{-}s})]\}$ %

= percent of the full-scale value

This gives an initial estimate for I_{Main}. From this value the optimum can be set by observing the temperature transient and increasing or decreasing I_{Main}. When the rise is too slow I_{Main} should be increased and vice versa.

P_{Aux}

You will only need to adjust P_{Aux} if you have the Aux=Main switch set to Off so that the two control channels are independent.

1.Set initial control positions :

P_{Aux} fully clockwise; TEMP 1 at 25°C and TEMP 2 at 35°C, select TEMP 2; POWER at 100%.

2. Adjust flow rate to typical value that will be used in experiments.

3. Monitor the OUTPUT Aux voltage with a storage scope chart recorder or DVM. **The chart recorder inputs must not be grounded.** For a scope use a **differential input** or **subtract** the voltage using the voltage subtraction feature available on most oscilloscopes.

4. With the control settings above there may be sustained oscillations in the heater voltage. If so rotate P_{Aux} anti-clockwise until oscillations just disappear. This sets an upper limit on P_{Aux}.

5. Repeatedly switch from TEMP 1 to TEMP 2, reducing P_{Aux} if there are significant oscillations in the OUTPUT Aux voltage following the switch.

G_{Aux}

If you are using the second control channel as a slave channel (ie. Aux=Main set to On) then adjust the G_{Aux}/G_{Main} ratio as described above. If you are using the **HPRE2 Pre-heater** set G_{Aux} at 10%.

TROUBLESHOOTING & TIPS

TC^2_{bip} doesn't work

Check the LED below the ON/OFF switch. This should be lit if there is power coming from the DC In socket. Check the Lo Pwr LED. If this is lit the input voltage is too low (<10V). You should charge the external battery or use a more suitable power supply.

Am I reading the correct temperature on the LCD display?

The **TC^2_{bip}** is normally set up to use the **TH-10Km Thermistor probe.** If you purchased a **TH-1 Thermistor probe** with the Temperature Controller the PROBE Main Span and Offset should have been adjusted to match the probe. Otherwise you will have to adjust these controls so that the LCD display shows the correct temperature (*see* PROBE CALIBRATION).

The OUTPUT LED's don't light and the probe temperature is not at the set point

Make sure the POWER control is not on 0%. Check the OUTPUT cables. It is unlikely that the FUSES have blown but check them just in case.

Can I use OUTPUT Aux as the main heater and OUTPUT Main as a pre-heater?

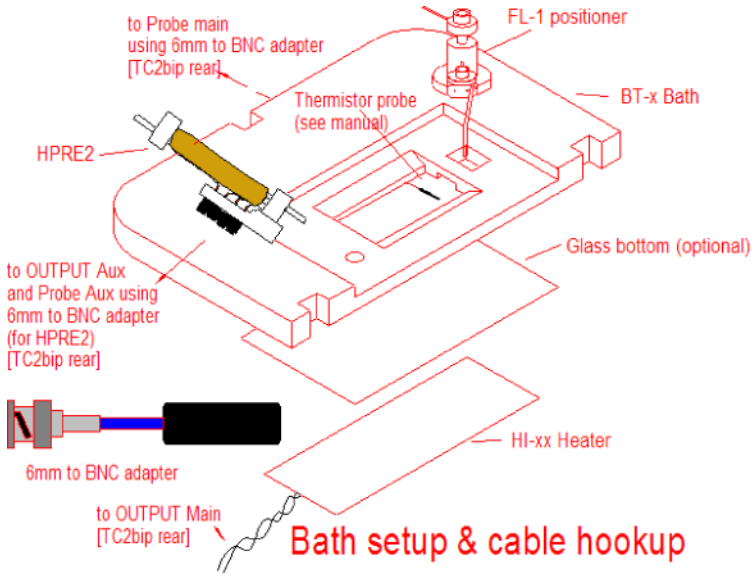
Yes. If you are using a pre-heater that requires the integrator then use the OUTPUT Main for the pre-heater and OUTPUT Aux for the main bath heater. You should set G_{Aux} to 0%.

Do I need the hypodermic tubing to protect the thermistor?

If you place cells on poly-l-lysine or other coated slides they may bump into the thermistor probe and eventually damage the insulation. Suitable tubing can be obtained by scoring regular hypodermic needles with the edge of a a small file and bending them to and fro with pliers.

Where does everything go?

Most researchers have their own methods for flowing solutions in and out of chambers and use of ground wires etc. Below is a guide for one way to setup the bath. For the inflow use a piece 1/32" ID 3/32" OD silicon



(#06411-60, Cole Parmer, Chicago IL 60648;ph: 800-323-4340) tubing to connect the HPRE2 to the stainless steel inlet. Keep the length of this tubing short (eg. 1cm) or the solution will cool down before entering the chamber.o the temperature control). If you purchased a tissue chamber you will have an aspirator and the tube to fit into the

FL-1 Miniature positioner. The tapped hole in the front left of the **BT-X** is intended to hold a ground wire in place. You can also make a simple block using a thick spacer (about 0.15" thick, 0.3" diam.) made of Delrin or Plexiglass. Make sure that solution cannot reach the solder joint between the silver wire and wire going back to the amplifier headstage.

Bath assembly

Details of the **BT-1xx Tissue chamber** construction are given with the bath. The chamber is normally attached to one of our microscope stage adapters but can also be attached to a stage using 3 thumbscrews in the three rectangular indents in the bath; 2 at the front and one at the rear. If you make your own stage adapter depending on the stage cutout and lenses you may find it necessary to raise the bath above the stage by about 1mm to provide clearance for the **H-24/25x Heaters**. This can be done using nylon washers placed between the bath and stage on the shafts of the thumbscrews.

Thermistor and heater placement

This is described in the instructions for the tissue chamber assembly.

HPRE2 Pre-heater

The **HPRE2 Pre-heater** allows more flexibility in the range of flow rates and provides improved stability of temperature control. The **HPRE2 Pre-heater** has a folded loop construction to heat solution over an extended "distance". This provides a slow transition in the temperature profile as solution comes out of the pre-heater which gives more stable temperature control when the sensing thermistor is located away from the outflow of the pre-heater. The built in thermistor sensor is used by the Aux channel to control the pre-heater temperature for a wide range of flow rates. The Aux=Main control should be set to Off.

USING HC-1 Heater with TC^2_{bip}

You should refer to the instructions that come with the **HC-1 Heater** for detailed guidance on the setup of the **HC-1 Heater** for use with culture dishes. This section provides information on hooking up the heater to the TC^2_{bip} and factors which influence the performance of the TC^2_{bip} and **HC-1** combination.

Electrical connections

The **HC-1** is normally plugged into the OUTPUT Main. The rest of the cabling is as indicated in the **ELECTRICAL CONNECTIONS** section.

Pre-heater

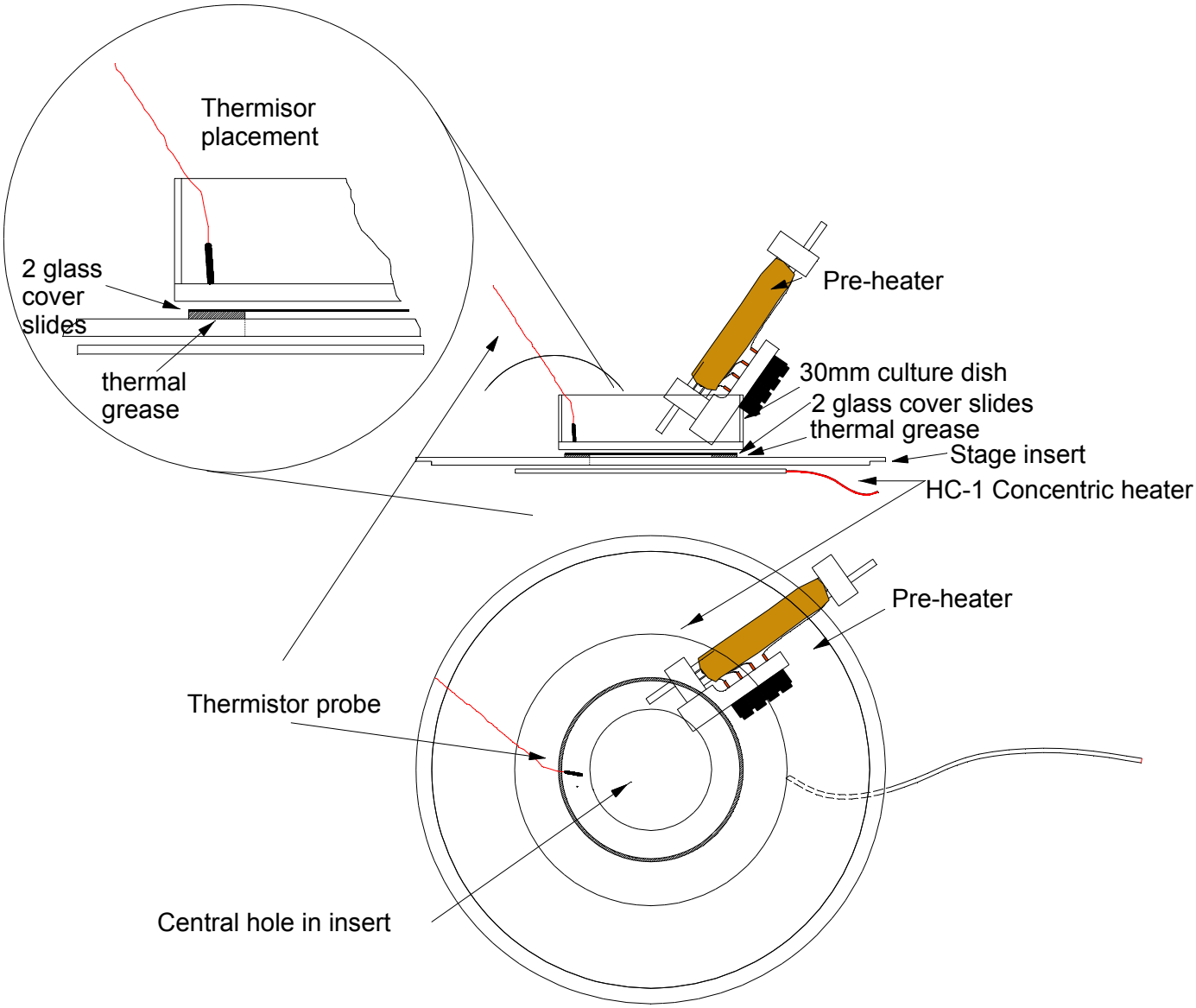
If you intend to flow solutions you should use the HPRE2 Pre-heater. The **HPRE2** provides flexible pre-heating arrangement when a wide range of flow is to be used. The pre-heater should be positioned as shown in the **Mechanical assembly** figure. You should experiment to achieve the most uniform temperature distribution when you are flowing solutions. It my be helpful to provide some kind of baffle in front of the pre-heater outlet or to point the pre-heater towards the rim of the culture dish to help in mixing the inflowing solution.

Thermistor position

The thermistor should be positioned so that it is just outside the central hole. Placing the thermistor at the center of the culture dish is not a good idea because of the delay in heat diffusing to the probe from the heater. This delay will destabilize the temperature control. You can also experiment with the thermistor position by using the **LTX Liquid crystal temperature sensor** material to measure the 2D temperature distribution.

Tuning Procedure

You should leave P_{Main} and I_{Main} in their shipped positions; P_{Main}: 80%, I_{Main}: 50%. Because the heating and cooling of the **HC-1 Heater** setup is much slower than with the **HI-25x Heaters** the settings on these controls do not greatly influence the performance of the TC^2_{bip}. If you are flowing solutions the G_{Aux}/G_{Main} ratio should be set to the minimum value possible such that solution leaving the pre-heater is approximately at the temperature being regulated (Ie. setpoint). Making the G_{Aux}/G_{Main} ratio too large will destabilize the control and there will be large oscillations. If you need to flow solutions at more than 1.5ml/min then you should use the **HPRE2** for pre-heating.



Notes on mechanical assembly:

1. See HC-1 Instructions for further details.
2. HC-1 is bonded to bottom of stage insert.
3. 2 round glass cover slides improve uniformity of temperature and allow for rim that is present on most plastic culture dishes. The slides are bonded together with optically clear glue. They are either glued to the insert using thermal epoxy or held with thermal grease.
4. The TH-1 Thermistor probe is placed towards the rim of the petri dish as indicated in the diagram.
5. Stage insert should be as small and light as possible and thermally isolated from the microscope stage (using plastic shims or similar thin insulators.
6. Pre-heater is made using a piece of capillary wrapped with RW-10 resistance wire (see separate Pre-heater instructions) or preferably use HPRE2 Pre-heater.

USING CH Cooling/Heating module with TC^2_{bip}

The **CH Cooling/Heating module** can be used with TC^2_{bip} but you will need to set the P_{Aux} and G_{Aux} settings appropriately. You should also refer to the instructions that come with the **CH Cooling/Heating module**.

Electrical connections

The **CH** is normally plugged into the OUTPUT Aux. The lead from the module that is connected to the negative side of the fan will be connected to the red banana socket. The lead from the positive side of the fan is connected to the black banana socket. This may mean that the color coding on the banana plugs attached to the **CH** may be opposite. If the connections are reversed the **CH** will heat when you expect it to cool. In this case just reverse the OUTPUT connections.

CH as a Pre-heater/cooler

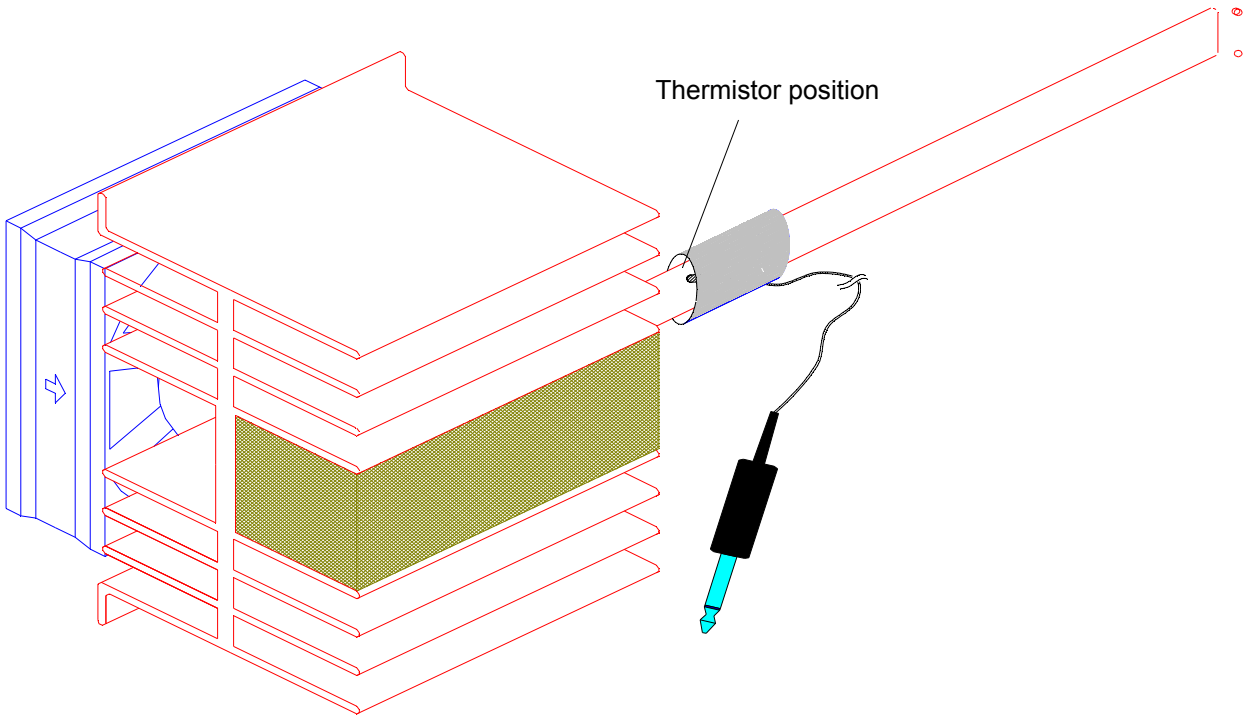
If you are using the **CH** as a pre-heater/cooler and are using a heater for the main chamber you should use set the Aux=Main switch to off since you will be separately controlling the **CH** with a **TH-10Km Thermistor probe** to sense the heatpipe temperature.

TH-10Km Thermistor position

The thermistor sensor should be positioned at the heatsink end of the heatpipe. It should be in good thermal contact with the heatpipe. We suggest coating the sensor with thermal grease (eg. Type Z9 Heat Sink Compound from GC Electronics) and using a piece of heatshrink to hold the sensor against the heatpipe.

Tuning Procedure

If you are using a 12V or 13.8V power supply you should set G_{Aux} to 40%.. P_{Aux} should be set between 20 and 40%. If you see sustained oscillations in the heatpipe temperature you should reduce P_{Aux}. Even when P_{Aux} is set to 0% there is significant gain in the feedback circuit. With P_{Aux} set to 0% you will have about 1-2°C error.



SPECIFICATIONS

Temp Ref Range: 0°C to 50°C

Output (Main & Aux)

Output current	max: 2.5Amps each channel
Output power	max: approx. 20W per channel
DC In:12V	max: -8V to +8V; 5-15Ω load
DC In:24V	max: -12V to +8V; 5Ω load
	max: -18V to +18V; 15Ω load
DC In:36V	max: -28V to +28V; 50Ω load

Ch 3 DC In:12-36V max: 8V 1.5Amp.

Suitable heaters: 3.5 to 50Ω resistance. eg. **HI-25x**, **H-1x**, **HC-1**.
For 50Ω heaters need >24V supply.

Suitable Peltier: 12V, 2A device.

Supply Voltage:

Resistive heater
12V at 4.0Amp max. Typ. 0.5 Amp. for **HI-25x, H-1x**.
36V at 1.4Amp max.

12V Peltier element
24V at 4.0Amp max.

Dimensions: 8.0 x 10.0 x 3.0 inches (LxWxH)

APPENDIX 1

Power supplies

You can purchase the **PS12V3** Power supply from us (for us in US and Canada) for the **TC2BIP**. This supply is suitable for setting up and microscopy and whole cell patch clamping. Below are alternative supplies for different applications. Please call use with any questions.

Below available in U.S. from Allied Electronics (800-433-5700 www.alliedelec.com) or Digikey (800-344-4539 www.digikey.com)

Suitable for patch clamping and microscopy

Digikey No. P174-ND Battery: Panasonic Model LCR12V17CP (12V 17AH Gel battery)

Digikey No. PATC-03-ND Charger: Patco Model 150 12V 1.5Amp (slow charger)

Digikey No. PATC-07-ND Charger cable: Patco Model 4020

Suitable for microscopy and some whole cell patch clamping (PS12V3)

Allied No. 575-5004 Power supply: Tripp PR 4.5 (13.8V 4.5Amp regulated power supply)

Suitable for CH& CP1 Heating/Cooling module (PS12V3)

Allied No. 575-5004 Power supply: Tripp PR 4.5 (13.8V 4.5Amp regulated power supply)

This power supply can be internally adjusted to supply 18V which provides optimum performance for the **CH&CP1** with the **TC2bip**.

We have provided a cable with the 5.5mm/2.1mm plug for the **TC2BIP** with an inline 5Amp circuit breaker in line with the 12V lead to protect against accidental shorts of the plug to a grounded line in a setup. **Please use this cable.** If the circuit breaker "pops" you will have to wait for about 30 seconds before resetting it. Find out why the short occurred first though.

If you have any problems please contact us at the numbers above or if you use email you can send us mail at info@cellmc.com.

APPENDIX 2

Internal jumper settings

This appendix describes the internal jumpers located on the main PCB of the **TC2BIP**. The jumper settings allow control over various functions of the **TC2BIP** switches.

Orientation

The **TC2BIP** should be oriented so that the front panel is facing you.

Case removal

Peel off the small square rubber buffers and unscrew the 4 screws holding the feet. Note the orientation of the feet for the tilt bail at the front of the **TC2BIP**. Gradually lift upper part of case away from lower part while at the same time holding down the front and rear panels with any spare fingers. The top of the case will come away and you have access to the **TC2BIP**.

Jumpers

J14 TOff1 [J15 TOff21]-Offset to Temp1 [Temp2] reference
Location-front left [Main] front right [Aux]
When jumpered offsets Temp1 [Temp2] reference by 10C.; default open

J12 Ref for Ch3
Location-front left
T1-reference from Temp1; T2-reference from Temp2 ; T3-reference from optional potentiometer
default T1.

J13 Add onto Temp1 reference
Location-front left
A3-add Temp3 (with optional pot) to Temp1; A2-add Temp2 to Temp1; 0-nothing added to Temp1
default 0.

J9 Aux channel reference
Location-front middle
T12-from Temp1, Temp2 switch; T2-from Temp2 control; default T12

J10 Cool/Heat lockout
Location-front right
Left position-Cool/heat switch enabled; right position switch disabled.; default disabled

J11 Aux=Main lockout
Location-middle middle
Lower position Aux and Main independent; upper position Aux depends on Main; default Aux and Main independent.

Case reassembly

Make sure the cables are not going to be in the way of the metal posts. This can happen on the left and right rear posts. If you crush the cables they may short and be damaged. Slide the case onto the front and rear panels (there are grooves to accommodate them) making sure the front and rear panel decals don't get damaged. If they catch on the edge of the groove use your nails to smooth then and use them like a shoe horn to make sure that the decals get into the groove. Once the box fits together screw on the feet using the 4 Phillips screws. Don't tighten the feet excessively as it is possible to crack the case. Put back the rubber buffers.

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