



**bmseed**  
— BioMedical —  
Sustainable Elastic Electronic Devices

## **Innovation in Neural Interface Technology**

# **OPERATING INSTRUCTIONS FOR THE TEMPERATURE CONTROLLER**

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## 1 Purpose of this Document and Disclaimer

The purpose of this document is to provide operating instructions for BMSEED's Temperature Controller to guide the user through hardware setup and use of the device in conjunction with BMSEED's Electrophysiology Interface Board (EIB) or a Plexon board. Only use the temperature controller to control the solution temperature in stretchable microelectrode arrays (sMEAs), stretchwells (sWs), or glass MEAs sold by BMSEED.

Further details about the electronics and operating that are beyond the scope of this manual can be found at:

<http://waterheatertimer.org/pdf/Inkbird-PID-0bk4.pdf>

## 2 User Requirements, Safety, Liability and Warranty

### 2.1 User Requirements

Only trained and qualified users should be allowed to work with the temperature controller. BMSEED LLC does not guarantee the accuracy of the measured data. A qualified user familiar with the operation of the temperature controller must assess the quality and accuracy of the obtained data using standard laboratory protocols.

Qualified users are those that:

- are familiar with the laboratory and work safety requirements to operate the controller
- have the professional knowledge and skills to use the controller
- have read this document prior to using the controller.

### 2.2 Safety

The following statements should be considered to avoid serious injury to those individuals performing the procedures and/or damage to the equipment:

#### WARNINGS

- After turning off the power and disconnecting the equipment power source, **wait at least 10 minutes** before touching any parts on or near the heating resistors (e.g. the heating resistors themselves, EIB/Plexon board, sMEA/glass MEA, movable MEASSuRE platform, etc.).



#### PRECAUTIONS

- The temperature controller's heating resistors may exceed a temperature of 60°C and the EIB/Plexon board may exceed a temperature of 50°C during operation.
- Some components become electrically charged when in operation.
- Only use the power supply provided by BMSEED with the temperature controller.
- Once the controller is turned on, the heating resistors heat rapidly to a high temperature in less than a minute. Never touch the heating resistors and use caution when touching the heated EIB/Plexon board when the controller is on.
- Do not make any connections to any internal circuitry. Only connections to designated connectors are allowed.
- Before turning on the temperature controller, check that all safety precautions have been followed, as well as the installation procedures.



Always follow OSHA rules when working with the product.  
Always follow the laboratory and other safety regulations issued by the state, municipality, and organization where the product is used.



For best results, always follow good laboratory practices.  
Do not use the product or its software for medical applications or on humans.


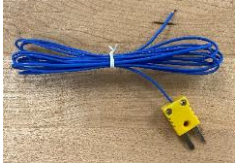







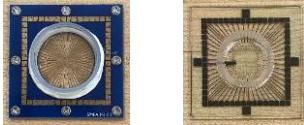

## **2.3 Liability and Warranty**

The Sales Agreement between BMSEED LLC and the customer will be provided upon delivery of the system.

BMSEED's liability and warranty in the event of damage to the product or injury of personnel is excluded when the product is: (i) operated outside its operating regime, (ii) incorrectly operated by the user, or (iii) tampered with in any way. Examples of such liability and warranty exclusions are, but not limited to:

- incorrect and inappropriate use of the product
- operating the product when safety and protective features are defective
- improper operation of the product
- unauthorized or inappropriate alteration or repair of the product
- water or other physical damages that occur after the product was delivered.

### 3 Materials and Equipment

Component	Image
temperature controller box	
thermocouple, <i>K-type</i>	
power cable, <i>DC</i>	
heating resistor cable	
heating resistors (x2)	
for EIB: M2x5 screws (x2)	
for EIB: M2 nuts (x2)	
for Plexon board: M3x5 screws (x2)	
BMSEED Electrophysiology Interface Board (EIB) or Plexon Board	 <p style="text-align: center;">EIB</p>
sMEA or glass MEA	 <p style="text-align: center;">sMEA      glass MEA</p>
infrared thermometer	

## 4 Equipment Setup

This section describes the equipment setup of BMSEED's Temperature Controller.



**Figure 1.** Temperature controller box **a)** front side and **b)** back side.



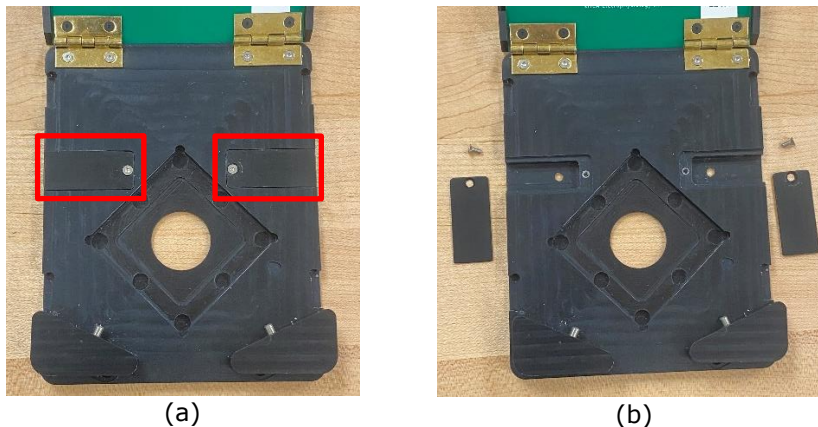
Before operating the tool, always make sure that the hardware components are set up and connected properly.

### 4.1 Connecting the Heating Resistors

First, connect the two heating resistor pieces to either the EIB or the Plexon board.

#### 4.1.1 to Electrophysiology Interface Board (EIB):

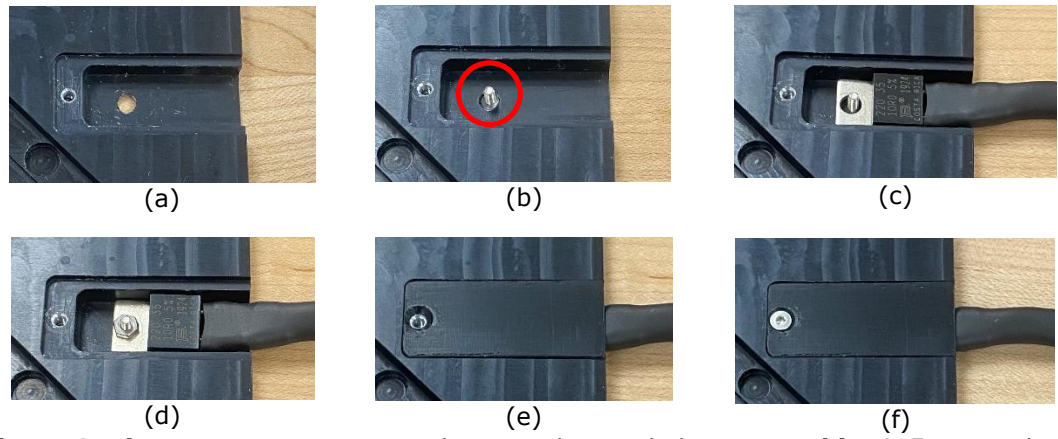
- a. Unscrew the two cover pieces from the bottom plate of the EIB using an Allen wrench (Fig. 2). Note: The cover pieces also use M2x5 screws.



**Figure 2.** Bottom plate of the EIB with the two cover pieces **a)** screwed on and **b)** unscrewed from the plate.

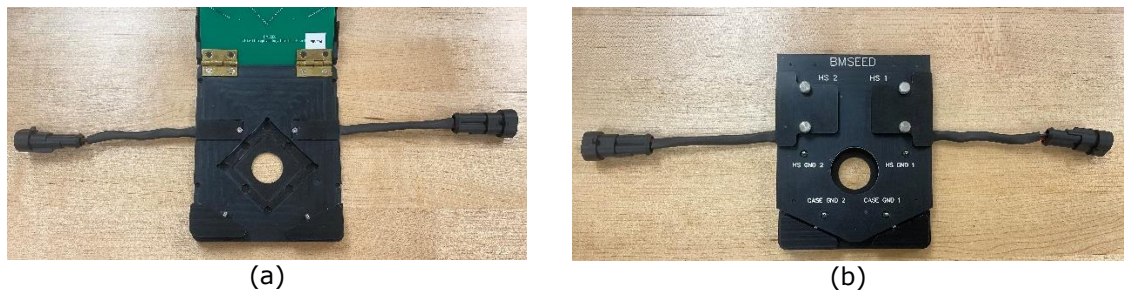
- b. After removing the cover pieces (Fig. 3a), place the M2x5 screws on the backside of the screw hole openings at the base of the board (Fig. 3b). The flat-head screws should be flush with the backside of the board.
- c. Place the heating resistors (flat side facing down) over the end of each screw (Fig. 3c).
- d. Use the M2 nuts to secure the heating resistors in place (Fig. 3d). Tighten the screws with an Allen Wrench so that the resistors make good contact with the board.
- e. Re-place the heating resistor cover pieces (counter-sink side facing up) over the secured heating resistors (Fig. 3e) and screw back in place with the Allen Wrench (Fig. 3f).





**Figure 3.** **a)** EIB cover piece removed to reveal screw hole opening. **b)** M2x5 screw placed through hole from backside of EIB. **c)** heating resistor placed over screw and **d)** secured with M2 nut. **e)** cover piece placed back over heating resistor and **f)** screwed in.

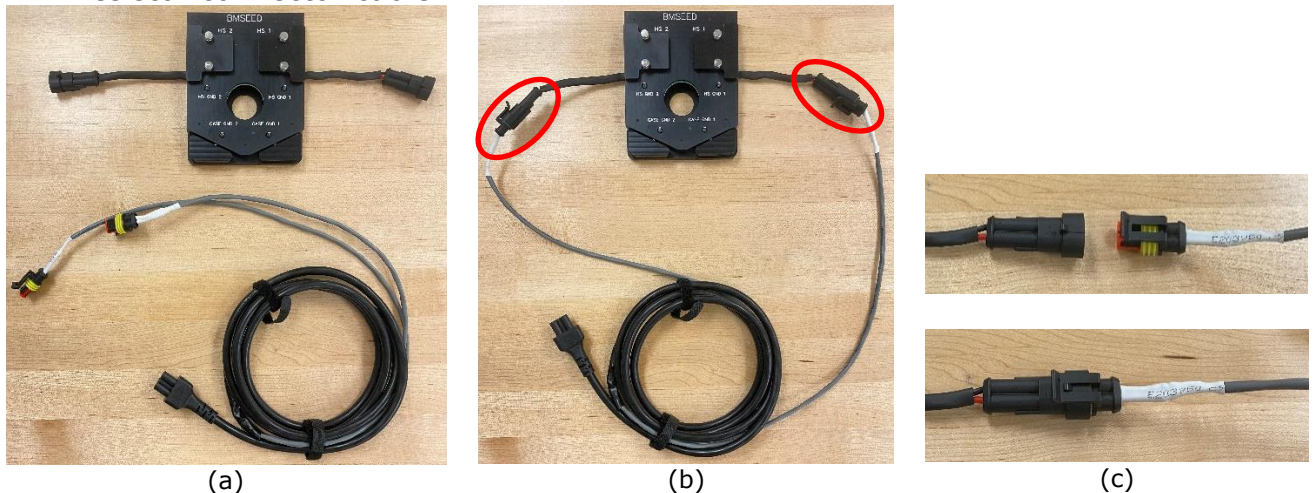
Fig. 4 shows the entire EIB with the heating resistors being connected.



**Figure 4.** EIB with two heating resistors secured to the bottom plate; **a)** lid open, **b)** lid closed.

### 4.1.2 Connecting Heating Resistor Cable

- a. Attach the two connector ends of the heating resistor cable (Fig. 7a) to the connectors on the heating resistors (Fig. 7b+c). In the correct orientation, the notch on the heating resistor connector snaps with the clamp on the heating resistor connector cable.



**Figure 7.** **a)** Heating resistor cable and EIB with heating resistors, **b)** connected. **c)** More zoomed in view of connectors.

- b. Connect the other end of the heating resistor cable to the backside of the temperature controller box, labeled "HEATER" (Fig. 8).

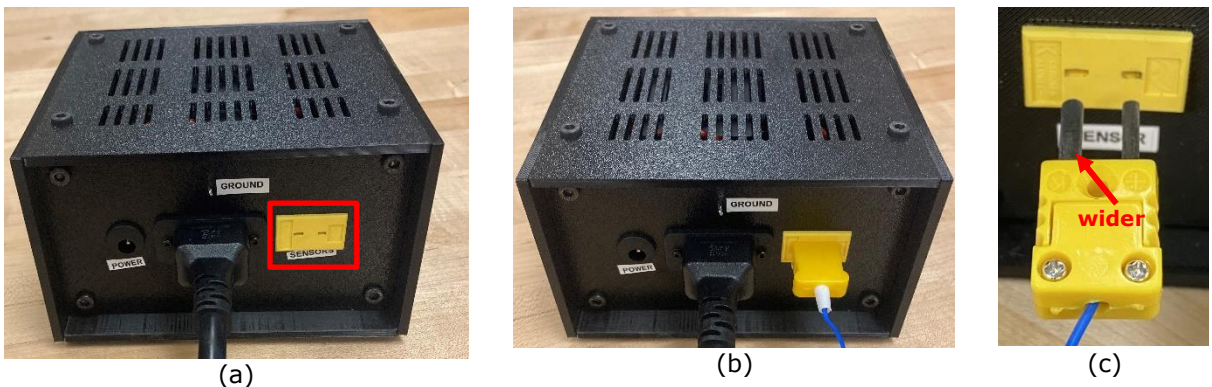


**Figure 8. a)** backside of temperature controller box with heating resistor connector in the center, labeled "HEATER". **b)** heating resistor cable plugged into temperature controller box.

## 4.2 Connecting the Thermocouple

- a. Connect the thermocouple to the backside of the temperature controller box, labelled "SENSOR".

Note: One of the thermocouple prongs of the thermocouple connector is wider than the other. Ensure that the prong sizes line up correctly in the connector.



**Figure 9. a)** backside of temperature controller box with thermocouple connector labeled "SENSOR". **b)** thermocouple plugged into temperature controller box. **c)** different sized thermocouple prongs: thinner (*right*) and wider (*left*).

- b. Insert the other end of the thermocouple (the sensor) completely inside the small hole at the front of the EIB or Plexon board (until the sensor hits the back of the hole).

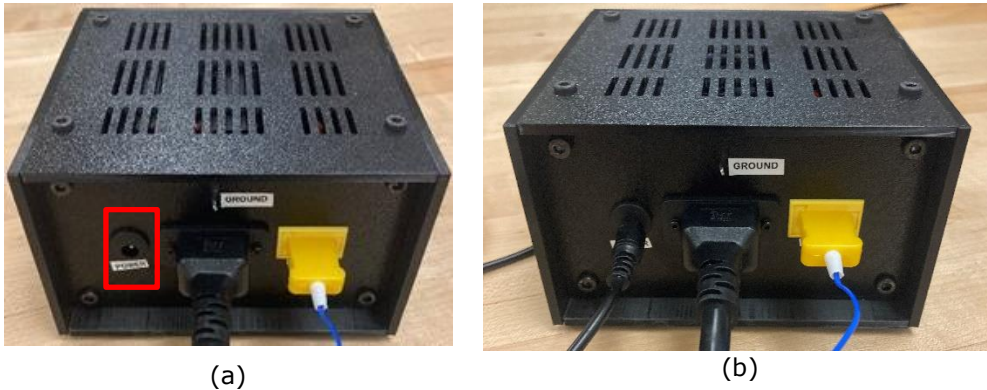


**Figure 10.** Thermocouple sensor end inserted into hole on bottom plate of EIB



### 4.3 Connecting the Power Cable

- a. Connect the power cable to the backside of the temperature controller box, labeled "POWER".



**Figure 11. a)** backside of temperature controller box with power connector labeled "POWER". **b)** power cable plugged into temperature controller box.

- b. Connect the other end of the cable to an electrical outlet.
- c. To turn on the temperature controller, press the button on the front panel of the temperature controller, labeled "ON/OFF". The LED and controller screen will turn on.



**Figure 12. a)** front panel of temperature controller with on/off switch labelled "ON/OFF". **b)** temperature controller turned on after pressing the on/off button.

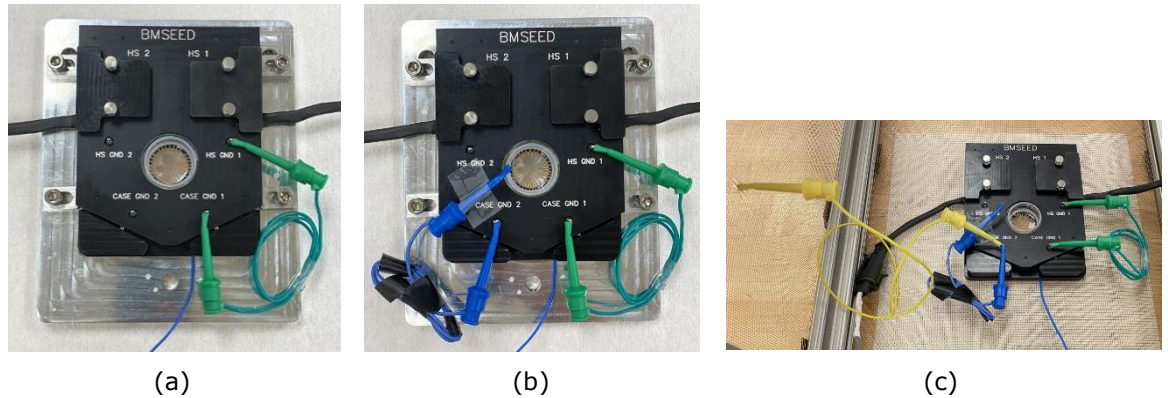
### 4.4 Grounding

For recording electrophysiological activity while using the temperature controller, the controller needs to be properly grounded. The following steps will outline proper grounding to eliminate the most recording noise.

**Note:** For best grounding, use a Faraday cage or cover the EIB/Plexon board completely in Aluminum foil. In the following steps, a Faraday cage is used.

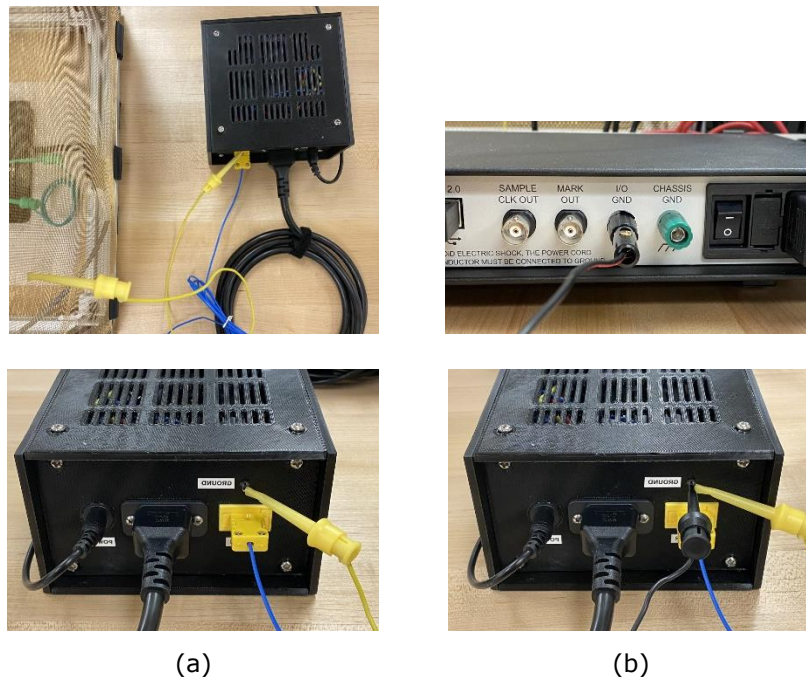
- a. Ground the EIB or Plexon board following the guidelines in the BMSEED Electrophysiology Manual:
  - 1) **EIB:**
    - i. Connect one of the "HS GND" pins to one of the "CASE GND" pins of the EIB using hook clips (Fig. 13a, **green wire**).
    - ii. Connect one of the "CASE GND" OR "HS GND" pins of the EIB to the Pt counter electrode. Place the Pt counter electrode into the solution in the sMEA well (Fig. 13b, **blue wire**).

- iii. Place the EIB inside of the Faraday cage and connect one of the "CASE GND" OR "HS GND" pins of the EIB to the Faraday cage (Fig. 13c, **yellow wire**).



**Figure 13.** Grounding the EIB with **a)** "HS GND" and "CASE GND" pins shorted, **b)** Pt counter electrode connected to "CASE GND" pin, and **c)** "CASE GND" pin connected to the Faraday cage.

- 2) **Plexon Board:** Connect one of the "Ground" pins on the Plexon board to the Faraday cage.
- b. Ground the temperature controller box using the following steps:
- 1) Connect the "GROUND" pin on the backside of the temperature controller box to the Faraday cage (Fig. 14a, **yellow wire**).
  - 2) Connect the "GROUND" pin on the backside of the temperature controller box to the "I/O GND" on the backside of the Intan controller (Fig. 14b, **black wire**).



**Figure 14.** Grounding the temperature controller box with **a)** "GROUND" pin connected to the Faraday cage and **b)** "GROUND" pin connected to the Intan "I/O GND".

## 5 Operating the Temperature Controller

Once turned on, the temperature controller will begin to deliver heat to the heating resistors. If the set temperature needs to be changed, the user must adjust it immediately after turning on the controller.

### 5.1 Temperature Controller Panel



**Figure 13.** Temperature controller screen with labeled values.

### 5.2 Adjusting the Temperature Setting

Immediately after turning on the temperature controller, change the temperature setting to the desired setpoint for the board and the MEA being used.

**Note:** The temperature controller directly controls the temperature of the board (EIB or Plexon), not the solution inside the well. The temperatures below are the Temperature Controller settings that correspond to the desired solution temperature.

Desired Solution Temperature (°C)	Temperature Controller Setting (°C)	
	sMEA	glass MEA
35.0	<b>44.1</b>	<b>44.3</b>
36.0	<b>45.7</b>	<b>46.1</b>
<b>37.0</b>	<b>47.2</b>	<b>48.0</b>
38.0	<b>48.8</b>	<b>49.9</b>

**Table 1.** Temperature controller settings for desired solution temperatures (35-38°C) using the EIB with an sMEA or glass MEA.

- a. To change the temperature setpoint, press the "up" arrow once to enter the "temperature setting mode". Note: The green decimal point will begin to flash in temperature setting mode.



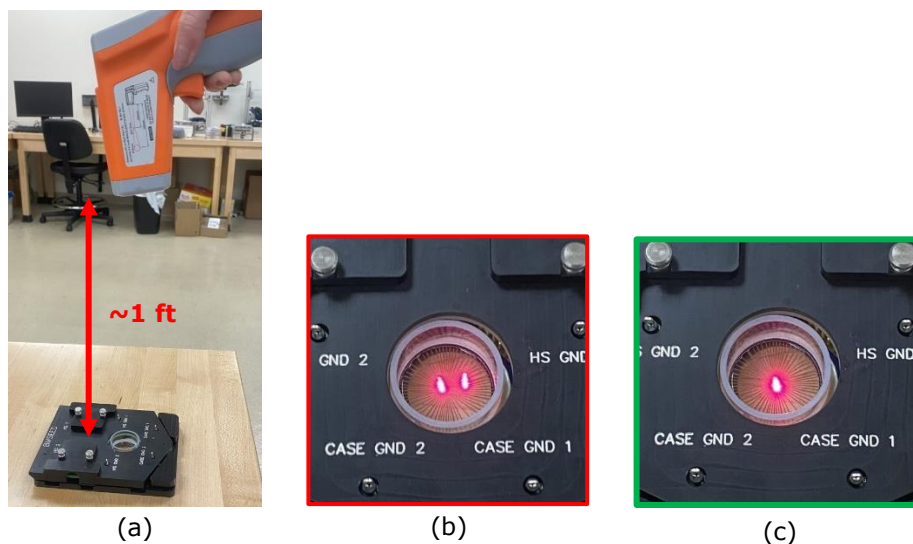
**Figure 14.** Press the “up” arrow once to enter temperature setting mode.

- b. In temperature setting mode, change the temperature by pressing:
  - i. “up” arrow = increases temperature
  - ii. “down” arrow = decreases temperature
  - iii. “left” arrow = moves decimal that is changed with the up and down arrows
  - iv. “SET” button = sets the temperature, exits temperature setting mode (decimal stops flashing)

### 5.3 Measuring Solution Temperature with Infrared Thermometer

The temperature controller controls the temperature of the board itself (EIB or Plexon). To ensure that the solution temperature is  $\sim 37^{\circ}\text{C}$ , the infrared thermometer allows a contactless measurement of the solution temperature.

- a. Aim the infrared thermometer directly at the solution from a distance of about one foot (Fig. 15a).
- b. Hold the trigger of the infrared (IR) thermometer down until the two red laser dots appear (Fig. 15b). Move the infrared thermometer closer or further from the solution until the two dots are joined together (Fig. 15c). Read the temperature in the well by holding the IR thermometer directly above the culture well at the distance where the red laser dots are joined (14.17” or 36cm). This gives a more accurate temperature reading.



**Figure 15. a)** infrared thermometer pointed at solution from a foot away. **b)** two red laser dots that combine into **c)** one red laser dot, which gives the most accurate reading.



## 5.4 Electrophysiology Recordings

When taking electrophysiology recordings with the Intan Controller while using the Temperature Controller, you must **switch off** the Temperature Controller (press the white "ON/OFF" button) for the duration of the recording. This will reduce any recording noise caused by current flowing through the heating resistors (a rapidly-changing magnetic field).

The Temperature Controller can remain off for **up to 3 minutes for sMEAs** and **up to 2 minutes for glass MEAs** before the solution temperature **drops by 1.0°C** (i.e. the solution temperature will drop by 1.0°C every 3 minutes for sMEAs and every 2 minutes for glass MEAs).

## 6 References

PID Controller ICT-106 User Manual (Version 1.0):

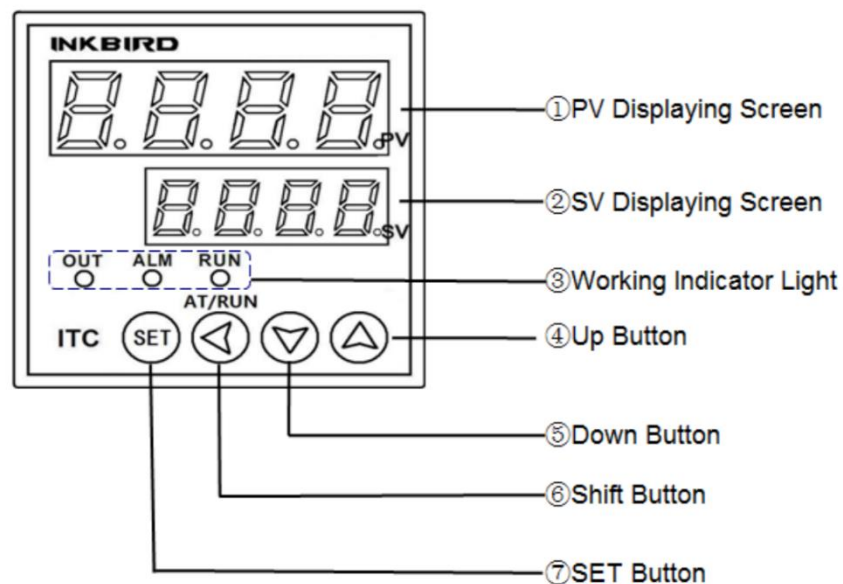
<http://waterheatertimer.org/pdf/Inkbird-PID-0bk4.pdf>

## 7 Appendix

### 7.1 PID Controller: Basic Operating Instructions

This section describes the basic functions of the PID controller that controls the temperature controller. This information can also be found in the PID Temperature Controller ITC-106 User Manual (Version 1.0).

#### 7.1.1 Panel Instruction



**Figure A.** PID controller labels from manufacturer.

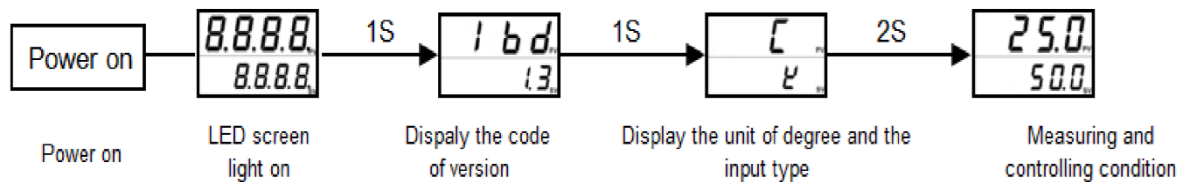
- 1) **PV Displaying Screen:** Displaying the measured value or the setting parameters.
  - This is the actual measured temperature of the Plexon board or EIB that is read by the thermocouple sensor end.

- 2) **SV Displaying Screen:** Displaying the setting value or the set parameters readout.
  - This is the temperature that the user sets for the Plexon board or EIB to reach over time; remains constant until the user changes it.
- 3) **Working Indicator Light:**
  - OUT:** Control Output Indicator (a clicking noise will be heard as this light turns on and off during temperature control)
  - ALM:** Alarm Output Indicator
  - RUN:** Manual Operation Indicator

The user should only see the OUT indicator light turning on and off during operation, indicating that the heating resistors are delivering heat when the light is on.
- 4) **UP Button:** Pressing the up button once will initiate the changing the temperature setting (indicated by a flashing decimal point); pressing the up button additional times will increase the value; holding the button will rapidly increase the value.
- 5) **DOWN Button:** When setting the temperature value, pressing the down button will decrease the value; holding the button will rapidly decrease the value.
- 6) **SHIFT Button:** When setting the temperature value, pressing the shift button will switch to the required value position, or decimal place.
- 7) **SET Button:** Holding the SET button for 3s will enter the parameters settings mode. The PID controller will already have the required settings for temperature control, as set by BMSEED.

### 7.1.2 Boot Screen Display

When the temperature controller is turned on, the PID controller screen will follow the above screen displays during startup. These settings were preset by BMSEED.



**Figure B.** PID controller startup displays (preset by BMSEED).

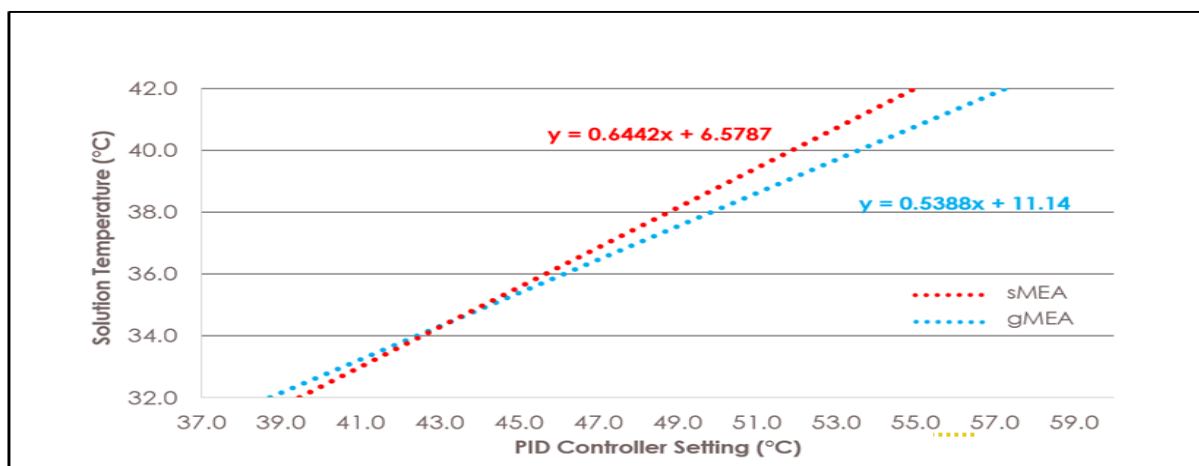
### 7.1.3 Error Display

If the user encounters an error display, which is indicated by the phrase "orAL" displayed in the SV reading, check that the three external cables are properly connected to the temperature controller box or contact BMSEED for further assistance. The error could mean a faulty wire connection within the controller enclosure, a faulty sensor, etc.

## 7.2 Temperature Profiles

The temperature controller maintains the temperature of the interface board which connects the glass or stretchable MEAs to the Intan controller. The temperature of the medium in the well is not the same as the temperature of the interface board. The plots below show the relationship between the temperature of the medium in the culture well and the interface board (Plexon and BMSEED) for glass and stretchable MEAs as well as for different numbers of support PCBs to reduce the distance between the MEAs and the pogo pins of the board.

### 7.2.37.2.1 EIB



**Figure C.** Temperature profiles for the EIB and two different MEA types (sMEA v. gMEA). Used to calculate **Table 1** values. All with 1 support PCB.

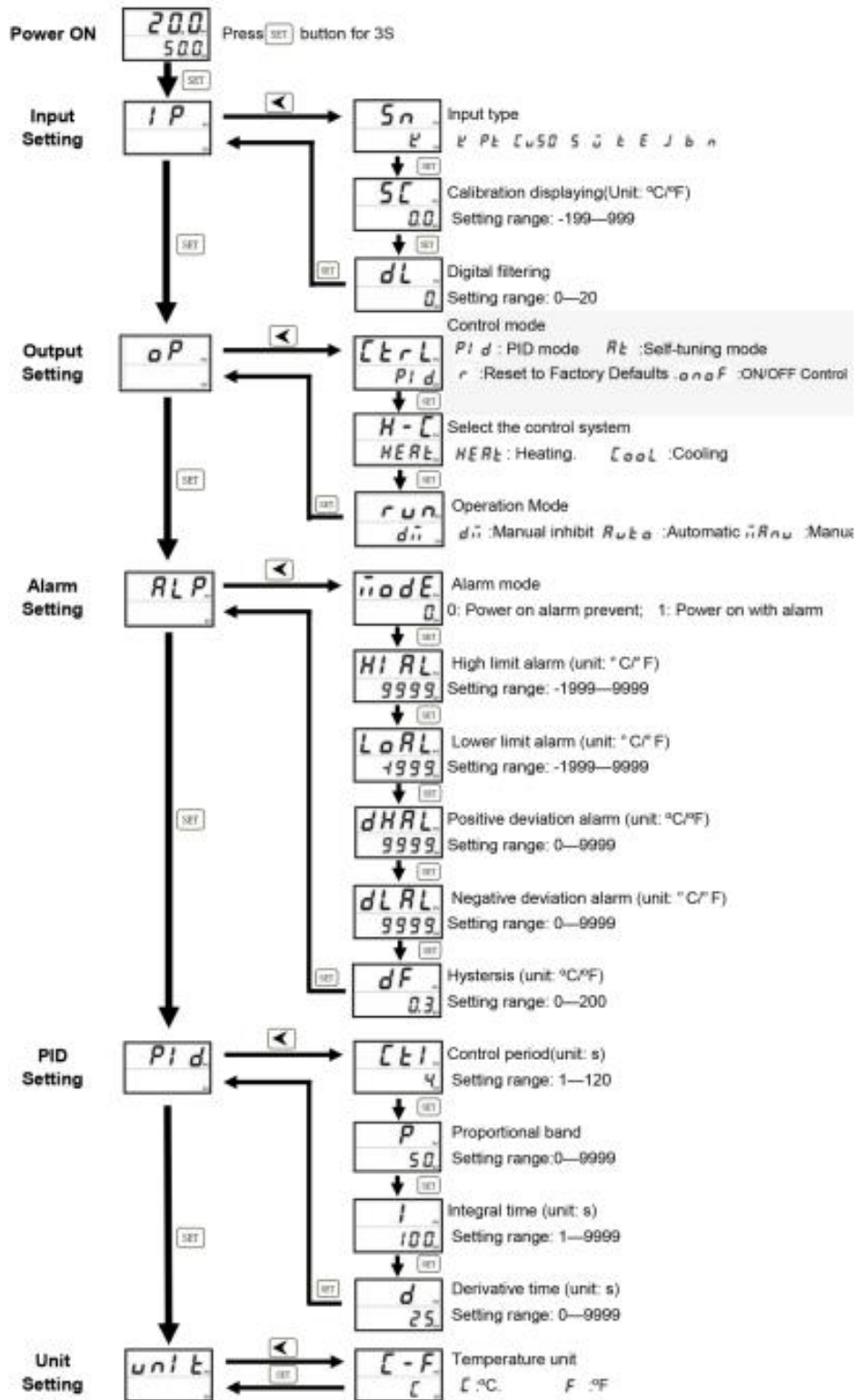
### 7.2.2 # Support PCBs

Note, the number of support PCBs used may affect the temperature curve [FLA1] (i.e. more support PCBs might require a higher temperature setting to reach the desired solution temperature). The temperature curve in Section 7.2.1 was created using **1 support PCB**.

## 7.3 PID Controller: Setup Flow Chart

The controller is set up for a K-type thermocouple sensor, and additional inputs are not required by the user. However, the user has the option to change several parameters of the controller, such as the type of thermocouple and the PID control parameters.

## Setup Flow Chart





The default settings for the BMSEED Temperature Controller are as follows:

**GREEN** = default controller value

**RED** = new BMSEED value

Setting	Parameter	Value
Input Setting (IP)	Sn	<b>y</b>
	SC	<b>0.0</b>
	dL	<b>0</b>
Output Setting (oP)	Ctrl	<b>PId</b>
	H-C	<b>HEAt</b>
	run	<b>dM</b>
Alarm Setting (ALP)	ModE	<b>0</b>
	HiAL	<b>9999</b>
	LoAL	<b>-1999</b>
	dHAL	<b>9999</b>
	dLAL	<b>9999</b>
	dF	<b>0.3</b>
PID Setting (PId)	Ctl	<b>4</b>
	P	<b>800</b>
	I	<b>100</b>
	d	<b>25</b>
Unit Setting (unIt)	C-F	<b>C</b>

The table below shows a list of sensors that can be used in conjunction with the temperature controller.

Sensor Type	Input	Code	Measuring Range	
Platinum Resistor	Pt100	<i>Pt</i>	-200~600 (°C)	-300~1100(°F)
	Cu50	<i>Cu50</i>	-50~150 (°C)	-100~300(°F)
Thermocouple	K	<i>K</i>	-50~1300 (°C)	-100~2300(°F)
	S	<i>S</i>	-50~1700 (°C)	-100~3000(°F)
	Wre	<i>Wre</i>	0~2300 (°C)	0~4000(°F)
	T	<i>T</i>	-200~400 (°C)	-300~750(°F)
	E	<i>E</i>	0~1000 (°C)	0~1800(°F)
	J	<i>J</i>	0~1000 (°C)	0~1800(°F)
	B	<i>b</i>	0~1800 (°C)	0~3200(°F)
	N	<i>n</i>	0~1000 (°C)	0~1800(°F)