Team 512 Operations Manual

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FAMU-FSU College of Engineering

Team 512 Operations Manual

Project Overview

The damage from natural disasters, such as hurricanes, can impact lives long after the storm has passed. Families rebuilding after a storm should not need to worry about having their lifesaving medication. Medical organizations have found the lack of refrigeration to keep insulin, and other medicine, cool as a leading cause of death following hurricanes. Therefore, we developed a cooling system for these medications without grid power.

To keep these medications usable, they need to be between 2°C - 8°C according to their storage instructions. An everyday cooler can meet this range, but only for a few hours without an added cooling source. A generator or extremely large battery could power a refrigerator but would not be practical for the public. Thus, because of the lack of a grid power, using the least power is just as crucial as cooling. With this in mind, we found that a thermoelectric unit (TEC) is the best way to keep the internal temperature of the cooler in the goal range. A mix of stored battery and solar energy powers our TEC. This will keep the medicine in range until power returns.

After trying many ideas, our final design uses a simple cooler body with an attached TEC unit, added insulation, and three airtight locking drawers. These drawers both protect and contain each vial separately within the cooler. Our design gives the user peace of mind in times of a natural disaster. It not only spares users the cost of replacing medicine, but also prevents medical emergencies, and saves lives.

Module Description

Our medicine cooler design consists of three major functionalities: to produce power, convert electrical power into cooling power, and store medication within the device. Power production is achieved through a photovoltaic power system that harnesses irradiance from the sun to produce and store electrical energy within the design. To achieve this, three main components are required within the power generation system: the solar panel, deep-cycle battery, and solar charge controller. A simple wiring diagram is included below in Figure 1 with the components mentioned and their connection to the TEC.

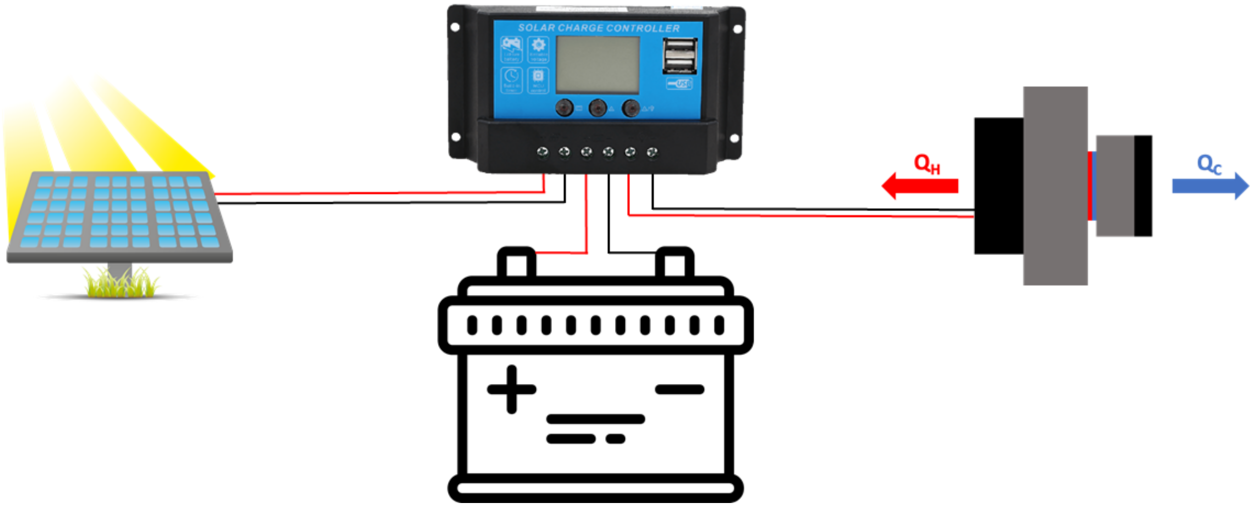


Figure 1: Figure 1: Simple Wiring Diagram

The solar panel produces electrical power for the system. Therefore, design restrictions in terms of voltage are imposed by solar panel selection on the rest of the power system. As a result, a 12V panel is selected as this nominal value best correlates with commonly available solar charge controllers and deep cycle batteries.

The deep cycle lead-acid battery stores energy for the system. This is extremely important as sufficient energy must be available in times when weather conditions do not permit solar energy production, such as cloudy days or during the night. The battery is selected to be 12V to match the nominal voltage from the solar panel.

The solar charge controller essentially acts as the brain of the solar power system. It controls which component the power flows to while preventing backflow and damage to the system. The charge controller always prioritizes the TEC, and thus will direct power differently dependent on the weather conditions. On a sunny day, when the solar panel is producing lots of power, the charge controller will direct the necessary portion of power to the TEC and dump the remaining amount into the battery for charging purposes. If weather conditions only permit the panel to produce a small amount of power, it will prioritize the TEC and draw additional power from the battery if necessary. If conditions prohibit solar production, such as at night, the charge controller will draw power from the deep cycle battery to the TEC while preventing backflow into the solar panel. The charge controller also operates at 12V, therefore ensuring all components match in terms of nominal voltage. To connect the components together, 10-gauge wire is used to provide adequate thickness for withstanding the maximum current flow through the solar power generation system.

Of paramount importance to the success of the device is ensuring that the medication within is kept within viable refrigerated ranges. As a result, it is critical to convert the generated electrical energy into thermal cooling. This is accomplished through thermoelectric cooling. Thermoelectric modules (TEC) take advantage of the Peltier effect, where passing current through alternating semiconductors creates a significant temperature differential, thus producing a hot and cold side. If enough current is passed through the device, sufficiently cold temperatures can be generated to produce refrigeration conditions. The TEC consists of five main components, and a simplified schematic is presented below in Figure 2.

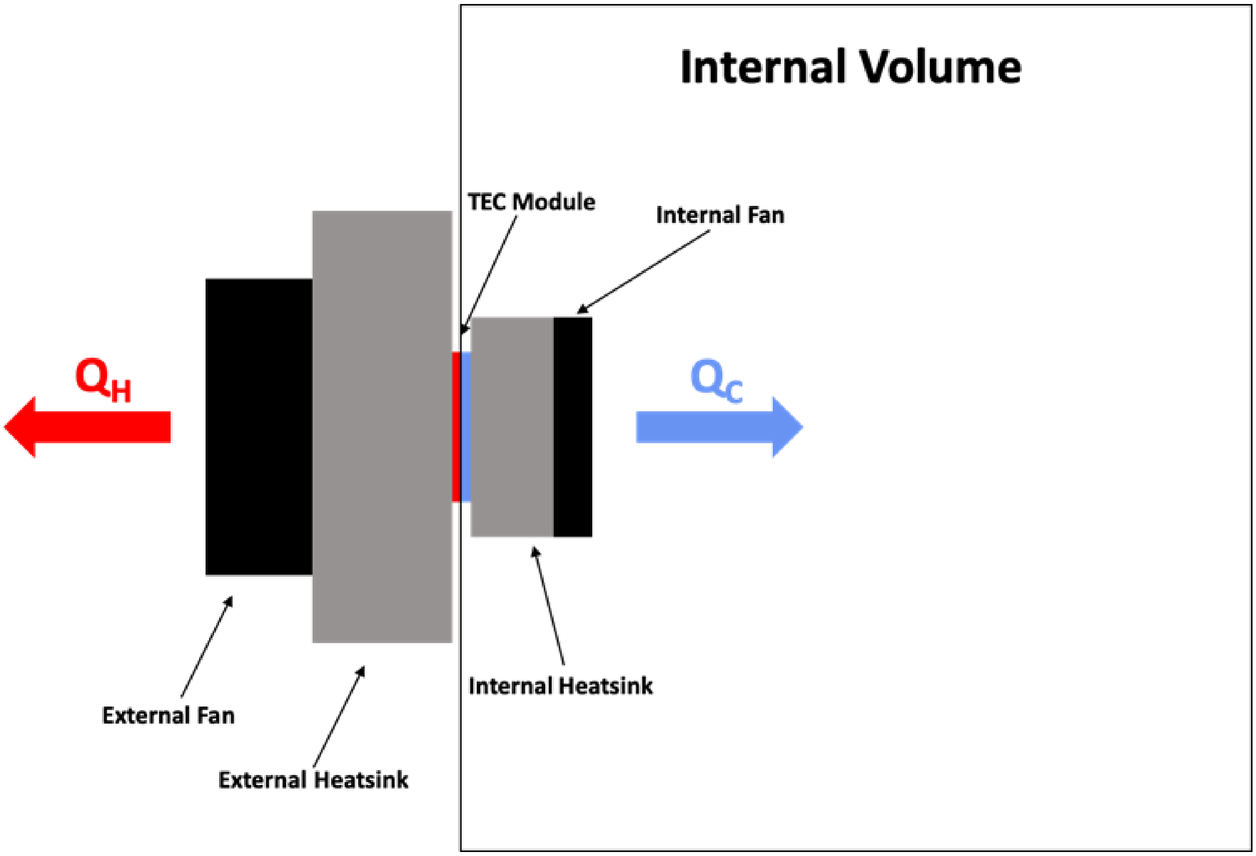


Figure 2: Thermoelectric Module Schematic DiagramFigure 2: Thermoelectric Module Schematic Diagram

The TEC module is responsible for creating the temperature differential when power supplied through the solar power system is applied. However, without modification, the TEC module alone is unable to sustain cold temperatures as it lacks the ability to dissipate heat from the hot side of the module. As a result, an external heatsink and fan are included to draw heat from the module and effectively disperse it to the environment. It is also evident that a smaller heat sink and fan are included in the internal region of the cooler. This ensures that air flow evenly distributes within the body of the cooler and a relatively constant temperature exists within the cooler cavity.

The storage components of our device consist of a store-bought cooler and 3D printed drawers, which work in tandem to protect and insulate the medication while keeping them near the cooling source. The cooler used during testing is the Igloo Legend 6-can 5 qt cooler, seen below in Figure 3.

Figure 3: Igloo Legend 6-can 5 qt cooler

The cooler has interior dimensions of roughly 8.5” x 6.5” x 6” and exterior dimensions of 11” x 8” x 7.5”. Additionally, the internal volume was reduced by roughly 66% with the addition of expanding insulation foam. The insulation was added in a way such that one side of the cooler was left without added insulation, allowing ample space for the TEC to fit. This was done so that the TEC could be in the closest proximity to the temperature sensor. The expanding insulation foam used was Loctite Tite Foam, but there are many similar products on the market that could be used as well. Solid foam rubber sheets were also added to the cooler around the closures and holes for the sensors and TEC.

The drawers were designed to extract the medication from inside the cooler individually without exposing the others to warmer exterior air, while providing structural support and protection. The CAD for the drawers, which can be seen below in Figures 4, 5, and 6, were made on Creo 5 and rapidly prototyped using the 3D printers at the FSU Innovation Hub. Two prototypes were made that were half the intended final length but of the same scale as the final product drawers. However, due to the closure of the Innovation Hub from the COVID-19 outbreak, the three final full-size drawers were never printed. Should they have been made, three holes would have been cut in the side of the cooler for the three drawer assemblies to be inserted. While this would involve removing some of the added insulation inside the cooler, the team planned to add back whatever insulation was removed so that the internal volume was roughly the same.

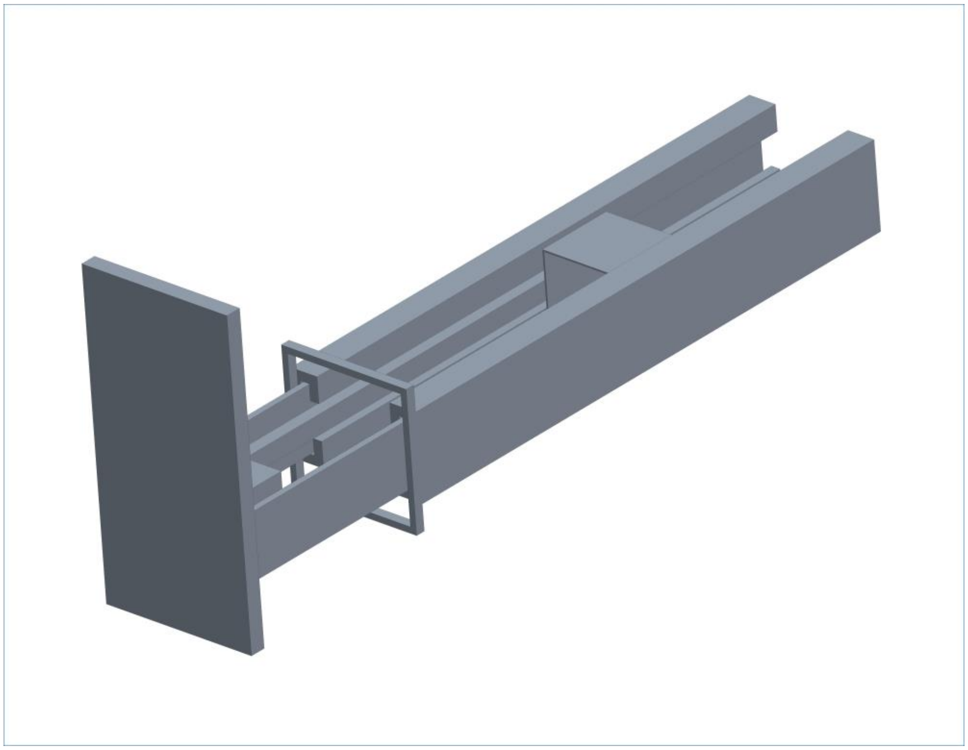


Figure 4: Isometric Back View of Medication Drawer

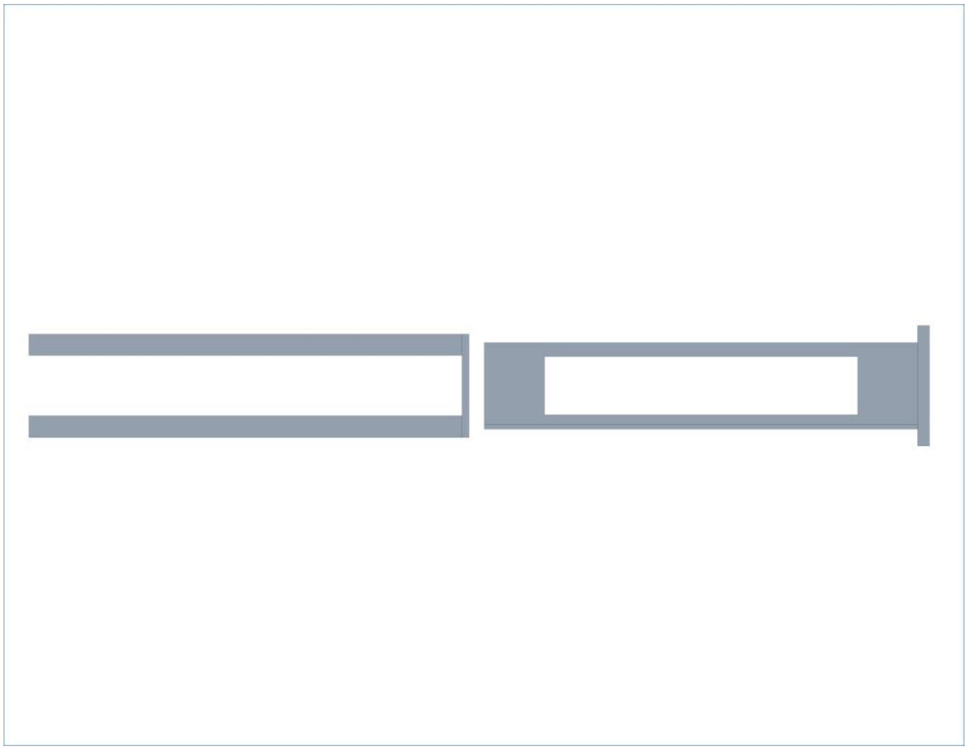


Figure 5: Bottom/Top View of Medication Drawer

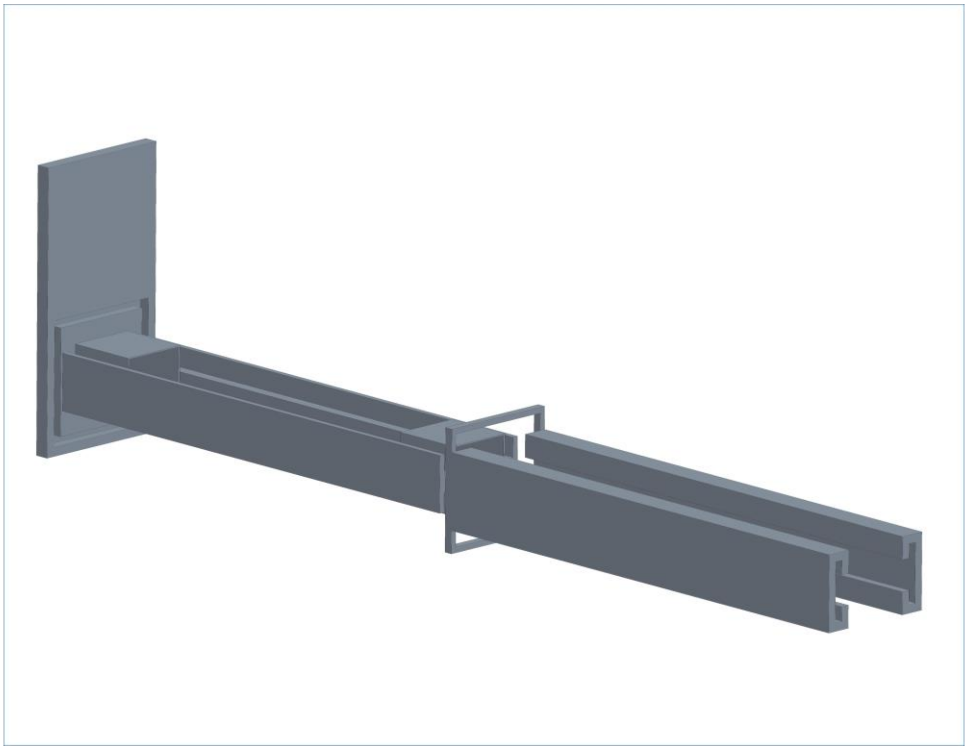


Figure 6: Isometric Front View of Medication Drawer

Integration

The integration of the components, as it stands, involves the TEC and other small electrical components and the Igloo 6-can 5 qt cooler with added insulation, visible in Fig. 7. This setup is what was used for nearly all the testing done by our team. Although we were unable to finish the assembly of our final prototype, we had all of the components sourced and were ready to purchase; but unfortunately, were unable to purchase these components before the university moved all classes online and closed the College of Engineering. With that being said, the initial prototype was able to satisfy the targets and metrics established in terms of cooling. As a result, it forms a sufficient model to base the operations manual on and supports the validation of the design.

Figure 7: Testing of the Prototype

Operation

When providing the initial set up, the first thing to consider is the wiring of the system. From the solar charge controller, the leads are first supplied to the temperature controller to provide a temperature reading, as well as implement an automation aspect. Figure 8 below represents the electrical schematic for the solar charge controller, temperature controller, and output leads.

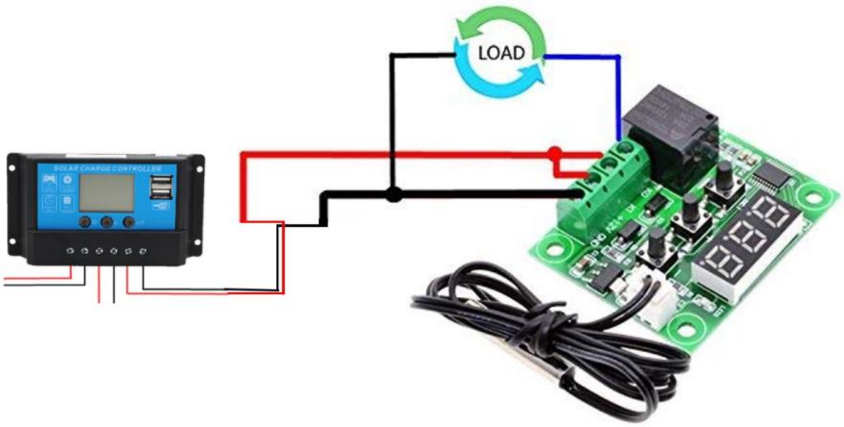


Figure 8: Electrical Schematic for Solar Charge Controller, Temperature Controller, and Output Leads

In this case, the load represents the remaining portion of the "cooler" side, encompassing the two fans and the TEC module. Based on the leads from the temperature controller going to the load, configure the wires in such a way that there are 3 parallel branches. The first two branches will simply connect to the positive and negative leads of the external and internal fans, insuring they are both receiving their rated voltage of 12V. The third branch will be connected to the TEC module, only after it is run through a Buck step down voltage regulator. This allows all of the electronic components to be running through the same size power source, but providing the module a much lower voltage, and thus more efficient current. Figure 9 below demonstrates the wiring schematic for the Buck converter.

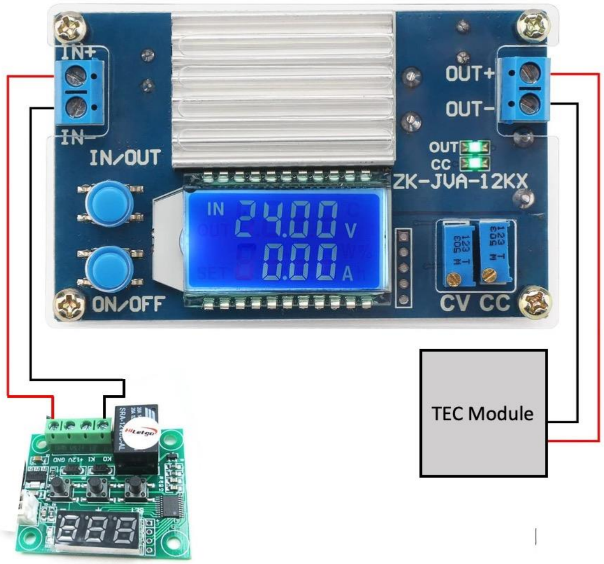


Figure 9: Wiring Schematic for Buck Converter

While utilizing the control voltage option, adjust the output voltage to the TEC down to 4V. This setting will minimize the power consumed while providing enough cooling power to the system. Figure 10 below represents the wiring schematic for the entire cooler system.

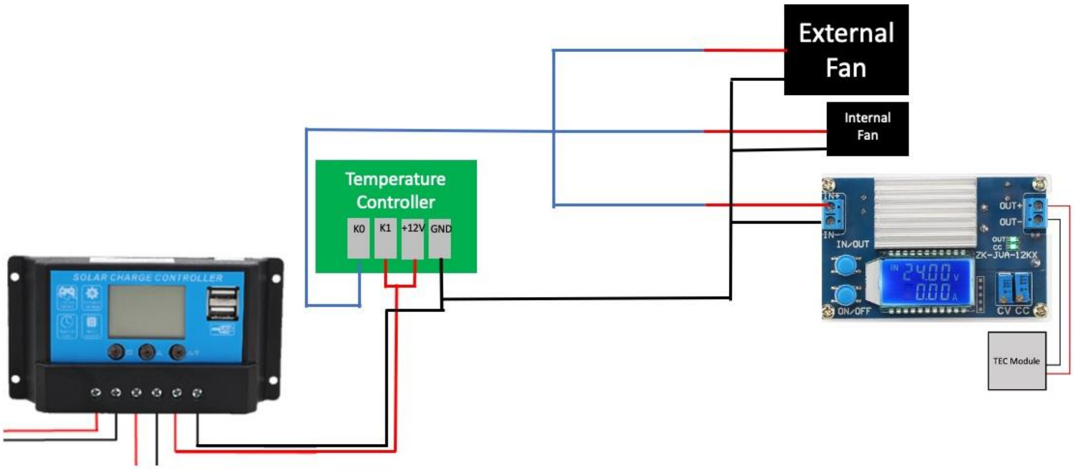


Figure 10: Wiring Schematic for Cooler System

Troubleshooting

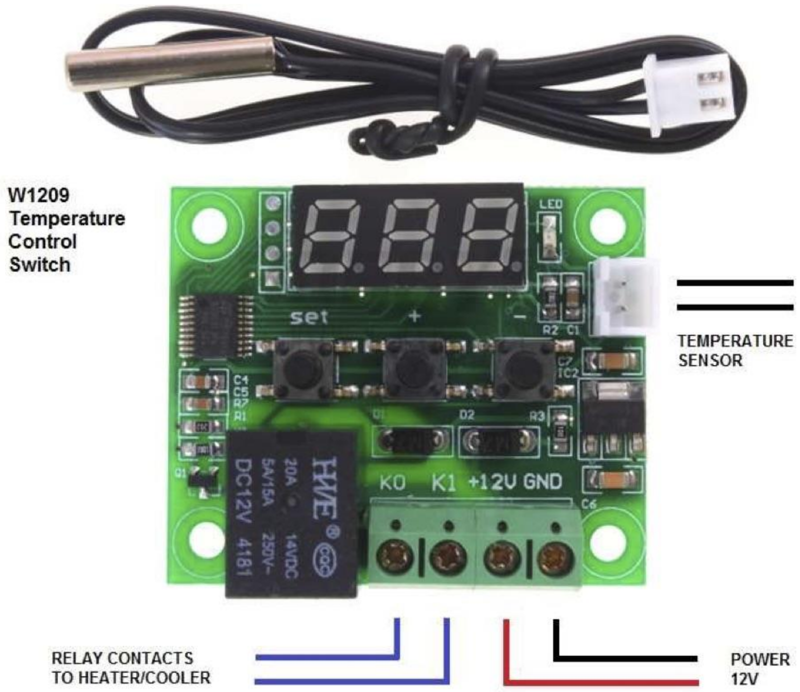
Throughout testing of the module, two situations occurred where troubleshooting was necessary to run the device. The first and by far most prevalent was loose wire connections. Since the team was unable to finish the prototype before the closure, many leads were not soldered to form solid connections. As a result, screw connection ports were used as attachment points which allow wire slippage when transporting the device. Before operation of the prototype, the user should confirm that all electrical leads are firmly in place. If any are found to be disconnected, simply use an appropriately sized Philips head screwdriver to reattach the wires.

Testing of the device indicates that 4V of step-down voltage is adequate to keep the cooler within range while minimizing power consumption. However, if the temperature of the device exceeds the refrigeration range for any reason, the voltage regulator acts as a controllable safeguard that can inject more electrical power through the TEC module and thus increase the cooling capability of the system. To do this, rotate the CV dial with a small flat head screwdriver to increase the step-down voltage applied to the module, which is clearly displayed on the LED screen. This will cause the internal cooler temperature to decrease. However, this comes at an expense since more power is drawn from the solar power generation system and thus will drain the battery faster.

Appendix

A.1 Temperature Controller Manual

W1209 Temperature Control Switch



DESCRIPTION:

The W1209 is an incredibly low cost yet highly functional thermostat controller. With this module you can intelligently control power to most types of electrical device based on the temperature sensed by the included high accuracy NTC temperature sensor. Although this module has an embedded microcontroller no programming knowledge is required. 3 tactile switches allow for configuring various parameters including on & off trigger temperatures. The on board relay can switch up to a maximum of 240V AC at 5A or 14V DC at 10A. The current temperature is displayed in degrees Centigrade via its 3 digit seven segment display and the current relay state by an on board LED.

SPECIFICATION:

Temperature Control Range: -50 ~ 110 C
Resolution at -9.9 to 99.9: 0.1 C
Resolution at all other temperatures: 1 C
Measurement Accuracy: 0.1 C
Control Accuracy: 0.1 C
Refresh Rate: 0.5 Seconds
Input Power (DC): 12V
Measuring Inputs: NTC (10K 0.5%)
Waterproof Sensor: 0.5M
Output: 1 Channel Relay Output, Capacity: 10A

Power Consumption
Static Current: <=35mA
Current: <=65mA

Environmental Requirements
Temperature: -10 ~ 60 C
Humidity: 20-85%

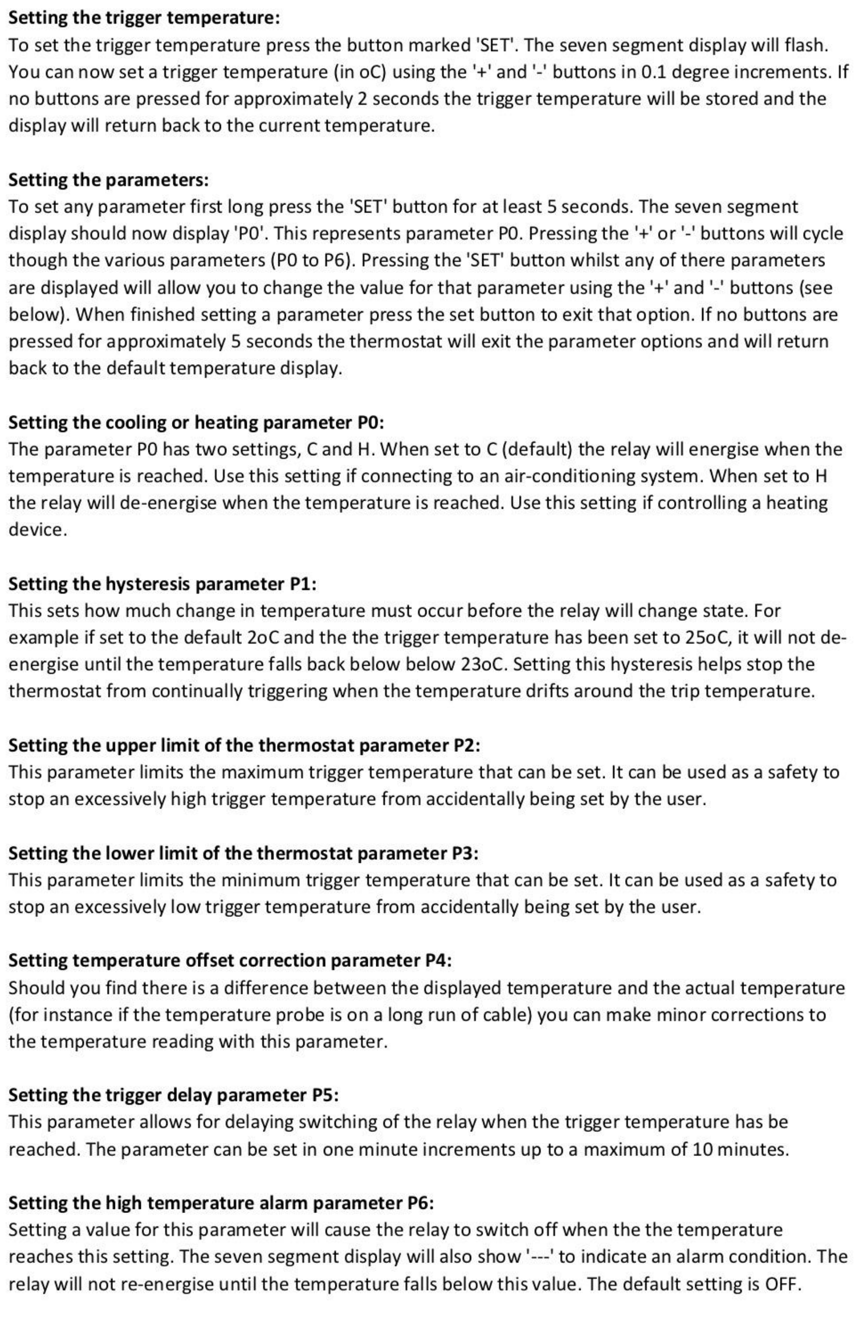
Dimensions
48mm x 40mm x 14mm

Settings Chart
Long press the "SET" button to activate the menu.

Code Description Range Default Value
P0 Heat C/H C
P1 Backlash Set 0.1-15 2
P2 Upper Limit 110 110
P3 Lower Limit -50 -50
P4 Correction -7.0 ~ 7.0 0
P5 Delay Start Time 0-10 mins 0
P6 High Temperature Alarm 0-110 OFF

Long pressing +- will reset all values to their default

Displaying the current temperature:
The thermostat will display the current temperature in oC by default. When in any other mode making no input for approximately 5 seconds will cause the thermostat to return to this default display.



Setting the trigger temperature:
To set the trigger temperature press the button marked 'SET'. The seven segment display will flash. You can now set a trigger temperature (in oC) using the '+' and '-' buttons in 0.1 degree increments. If no buttons are pressed for approximately 2 seconds the trigger temperature will be stored and the display will return back to the current temperature.

Setting the parameters:
To set any parameter first long press the 'SET' button for at least 5 seconds. The seven segment display should now display 'P0'. This represents parameter P0. Pressing the '+' or '-' buttons will cycle though the various parameters (P0 to P6). Pressing the 'SET' button whilst any of there parameters are displayed will allow you to change the value for that parameter using the '+' and '-' buttons (see below). When finished setting a parameter press the set button to exit that option. If no buttons are pressed for approximately 5 seconds the thermostat will exit the parameter options and will return back to the default temperature display.

Setting the cooling or heating parameter P0:
The parameter P0 has two settings, C and H. When set to C (default) the relay will energise when the temperature is reached. Use this setting if connecting to an air-conditioning system. When set to H the relay will de-energise when the temperature is reached. Use this setting if controlling a heating device.

Setting the hysteresis parameter P1:
This sets how much change in temperature must occur before the relay will change state. For example if set to the default 2oC and the the trigger temperature has been set to 25oC, it will not de-energise until the temperature falls back below below 23oC. Setting this hysteresis helps stop the thermostat from continually triggering when the temperature drifts around the trip temperature.

Setting the upper limit of the thermostat parameter P2:
This parameter limits the maximum trigger temperature that can be set. It can be used as a safety to stop an excessively high trigger temperature from accidentally being set by the user.

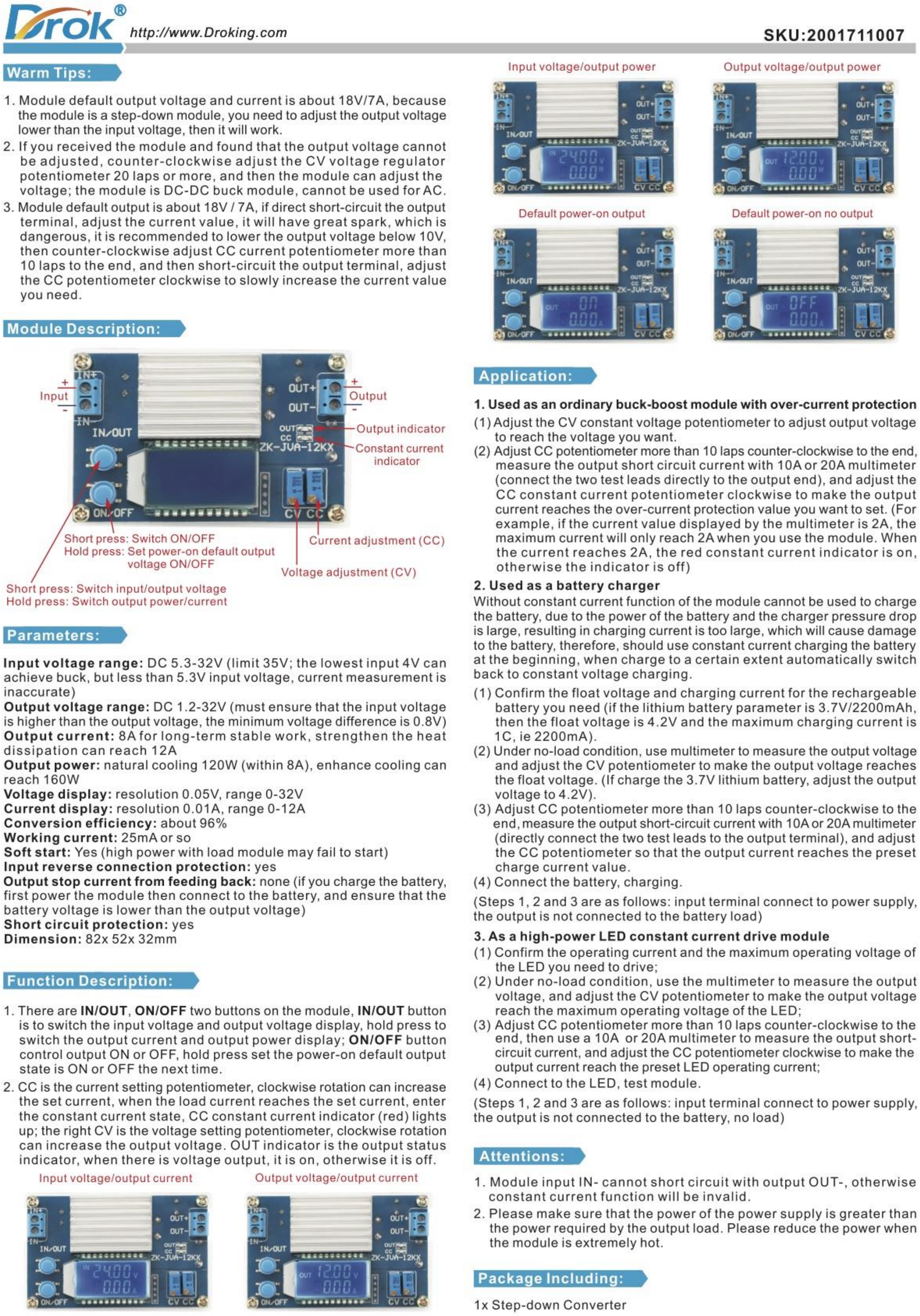
Setting the lower limit of the thermostat parameter P3:
This parameter limits the minimum trigger temperature that can be set. It can be used as a safety to stop an excessively low trigger temperature from accidentally being set by the user.

Setting temperature offset correction parameter P4:
Should you find there is a difference between the displayed temperature and the actual temperature (for instance if the temperature probe is on a long run of cable) you can make minor corrections to the temperature reading with this parameter.

Setting the trigger delay parameter P5:
This parameter allows for delaying switching of the relay when the trigger temperature has be reached. The parameter can be set in one minute increments up to a maximum of 10 minutes.

Setting the high temperature alarm parameter P6:
Setting a value for this parameter will cause the relay to switch off when the the temperature reaches this setting. The seven segment display will also show '---' to indicate an alarm condition. The relay will not re-energise until the temperature falls below this value. The default setting is OFF.

A.2 Buck Step Down Manual



http://www.Droking.com

SKU:2001711007

Warm Tips:

1. Module default output voltage and current is about 18V/7A, because the module is a step-down module, you need to adjust the output voltage lower than the input voltage, then it will work.
2. If you received the module and found that the output voltage cannot be adjusted, counter-clockwise adjust the CV voltage regulator potentiometer 20 laps or more, and then the module can adjust the voltage; the module is DC-DC buck module, cannot be used for AC.
3. Module default output is about 18V / 7A, if direct short-circuit the output terminal, adjust the current value, it will have great spark, which is dangerous, it is recommended to lower the output voltage below 10V, then counter-clockwise adjust CC current potentiometer more than 10 laps to the end, and then short-circuit the output terminal, adjust the CC potentiometer clockwise to slowly increase the current value you need.

Module Description:

Parameters:

Input voltage range: DC 5.3-32V (limit 35V; the lowest input 4V can achieve buck, but less than 5.3V input voltage, current measurement is inaccurate)
Output voltage range: DC 1.2-32V (must ensure that the input voltage is higher than the output voltage, the minimum voltage difference is 0.8V)
Output current: 8A for long-term stable work, strengthen the heat dissipation can reach 12A
Output power: natural cooling 120W (within 8A), enhance cooling can reach 160W
Voltage display: resolution 0.05V, range 0-32V
Current display: resolution 0.01A, range 0-12A
Conversion efficiency: about 96%
Working current: 25mA or so
Soft start: Yes (high power with load module may fail to start)
Input reverse connection protection: yes
Output stop current from feeding back: none (if you charge the battery, first power the module then connect to the battery, and ensure that the battery voltage is lower than the output voltage)
Short circuit protection: yes
Dimension: 82x 52x 32mm

Function Description:

1. There are **IN/OUT**, **ON/OFF** two buttons on the module, **IN/OUT** button is to switch the input voltage and output voltage display, hold press to switch the output current and output power display; **ON/OFF** button control output ON or OFF, hold press set the power-on default output state is ON or OFF the next time.
2. CC is the current setting potentiometer, clockwise rotation can increase the set current, when the load current reaches the set current, enter the constant current state, CC constant current indicator (red) lights up; the right CV is the voltage setting potentiometer, clockwise rotation can increase the output voltage. OUT indicator is the output status indicator, when there is voltage output, it is on, otherwise it is off.

Input voltage/output current

Output voltage/output current

Input voltage/output power

Output voltage/output power

Default power-on output

Default power-on no output

Application:

1. Used as an ordinary buck-boost module with over-current protection

(1) Adjust the CV constant voltage potentiometer to adjust output voltage to reach the voltage you want.
(2) Adjust CC potentiometer more than 10 laps counter-clockwise to the end, measure the output short circuit current with 10A or 20A multimeter (connect the two test leads directly to the output end), and adjust the CC constant current potentiometer clockwise to make the output current reaches the over-current protection value you want to set. (For example, if the current value displayed by the multimeter is 2A, the maximum current will only reach 2A when you use the module. When the current reaches 2A, the red constant current indicator is on, otherwise the indicator is off)

2. Used as a battery charger

Without constant current function of the module cannot be used to charge the battery, due to the power of the battery and the charger pressure drop is large, resulting in charging current is too large, which will cause damage to the battery, therefore, should use constant current charging the battery at the beginning, when charge to a certain extent automatically switch back to constant voltage charging.

(1) Confirm the float voltage and charging current for the rechargeable battery you need (if the lithium battery parameter is 3.7V/2200mAh, then the float voltage is 4.2V and the maximum charging current is 1C, ie 2200mA).
(2) Under no-load condition, use multimeter to measure the output voltage and adjust the CV potentiometer to make the output voltage reaches the float voltage. (If charge the 3.7V lithium battery, adjust the output voltage to 4.2V).
(3) Adjust CC potentiometer more than 10 laps counter-clockwise to the end, measure the output short-circuit current with 10A or 20A multimeter (directly connect the two test leads to the output terminal), and adjust the CC potentiometer so that the output current reaches the preset charge current value.
(4) Connect the battery, charging.

(Steps 1, 2 and 3 are as follows: input terminal connect to power supply, the output is not connected to the battery load)

3. As a high-power LED constant current drive module

(1) Confirm the operating current and the maximum operating voltage of the LED you need to drive;
(2) Under no-load condition, use the multimeter to measure the output voltage, and adjust the CV potentiometer to make the output voltage reach the maximum operating voltage of the LED;
(3) Adjust CC potentiometer more than 10 laps counter-clockwise to the end, then use a 10A or 20A multimeter to measure the output short-circuit current, and adjust the CC potentiometer clockwise to make the output current reach the preset LED operating current;
(4) Connect to the LED, test module.

(Steps 1, 2 and 3 are as follows: input terminal connect to power supply, the output is not connected to the battery, no load)

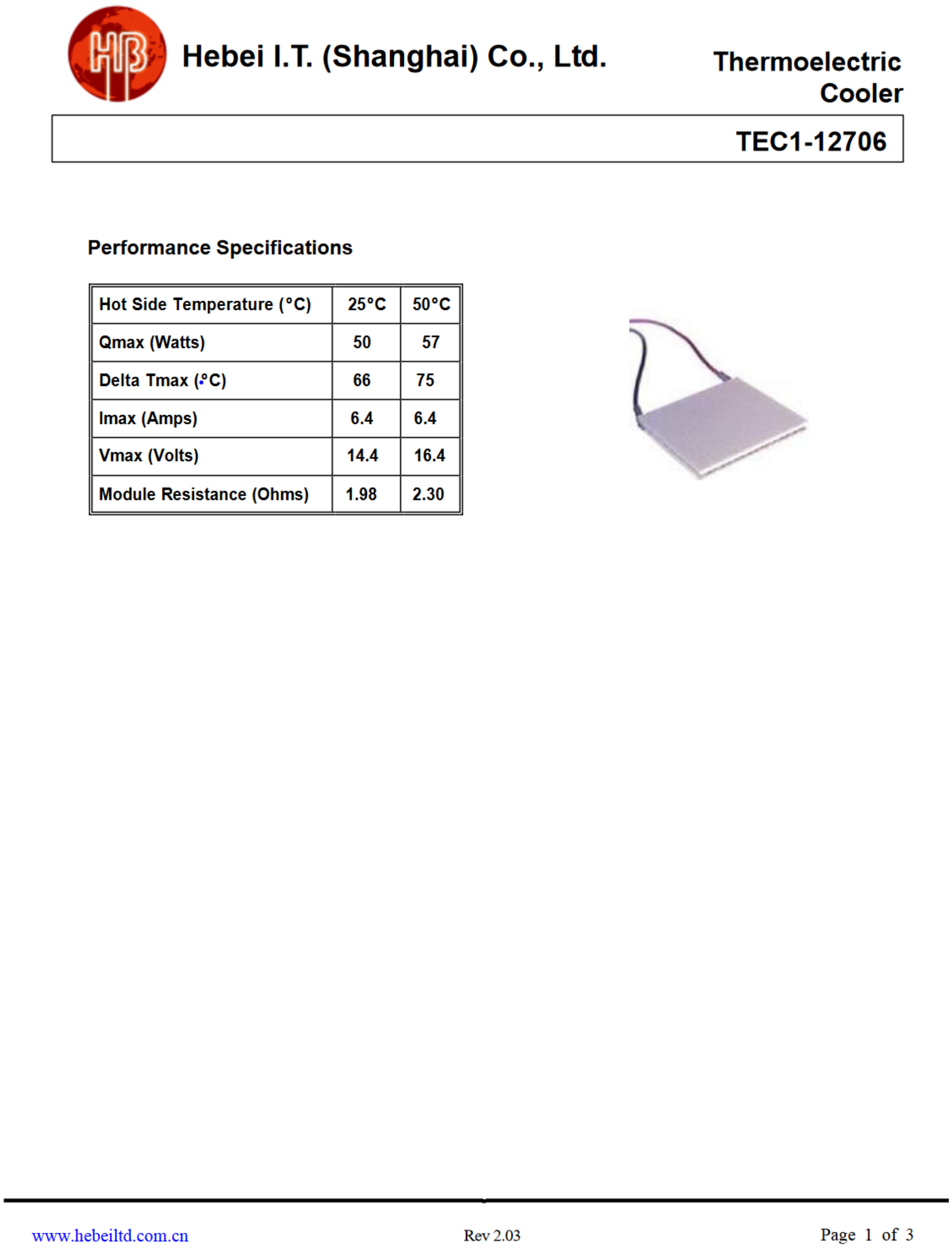
Attentions:

1. Module input IN- cannot short circuit with output OUT-, otherwise constant current function will be invalid.
2. Please make sure that the power of the power supply is greater than the power required by the output load. Please reduce the power when the module is extremely hot.

Package Including:

1x Step-down Converter

A.3 Thermoelectric Cooler (TEC1-12706) Datasheets



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Thermoelectric Cooler

TEC1-12706

Performance Specifications

Hot Side Temperature (°C)	25°C	50°C
Qmax (Watts)	50	57
Delta Tmax (°C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

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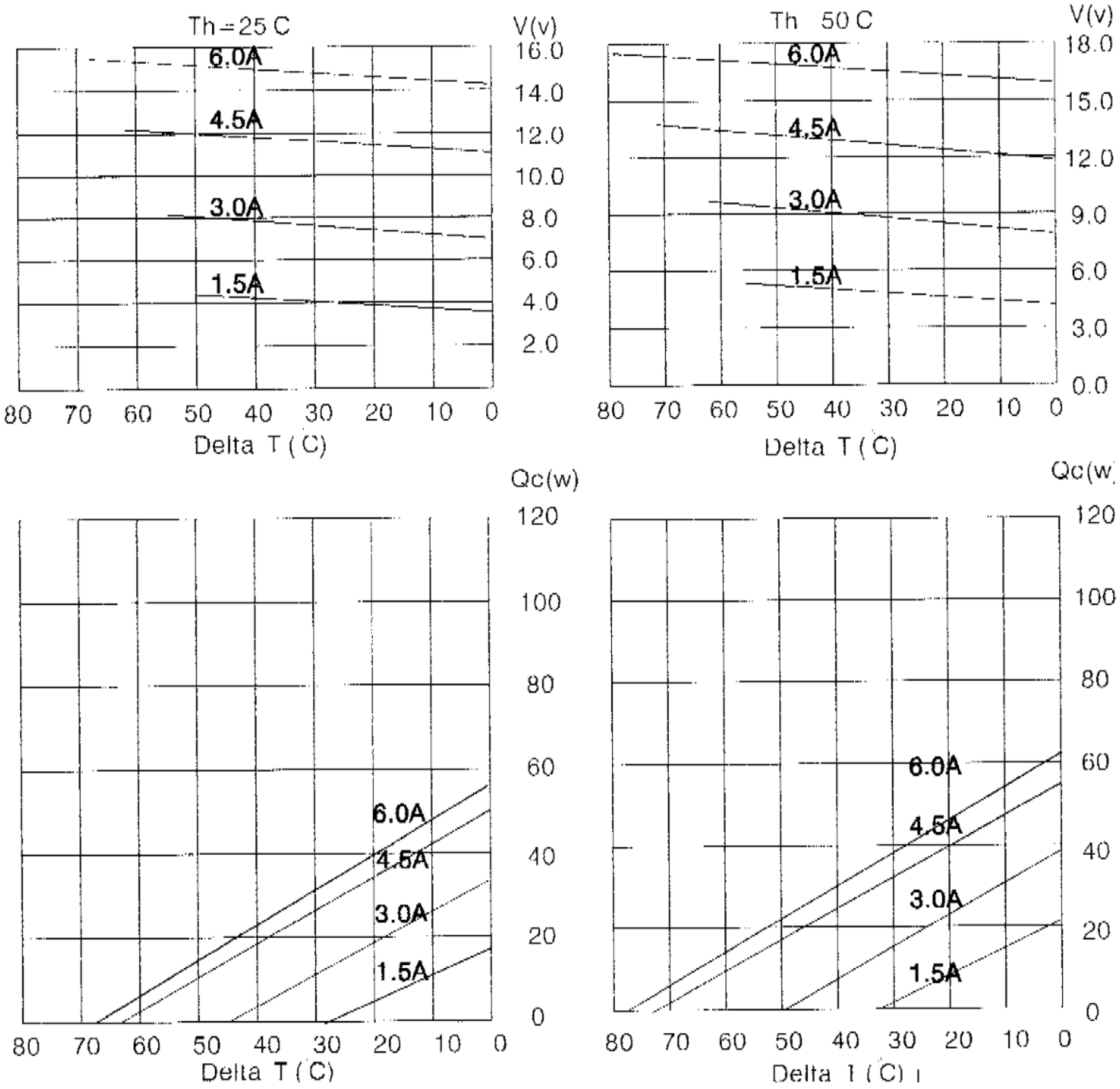
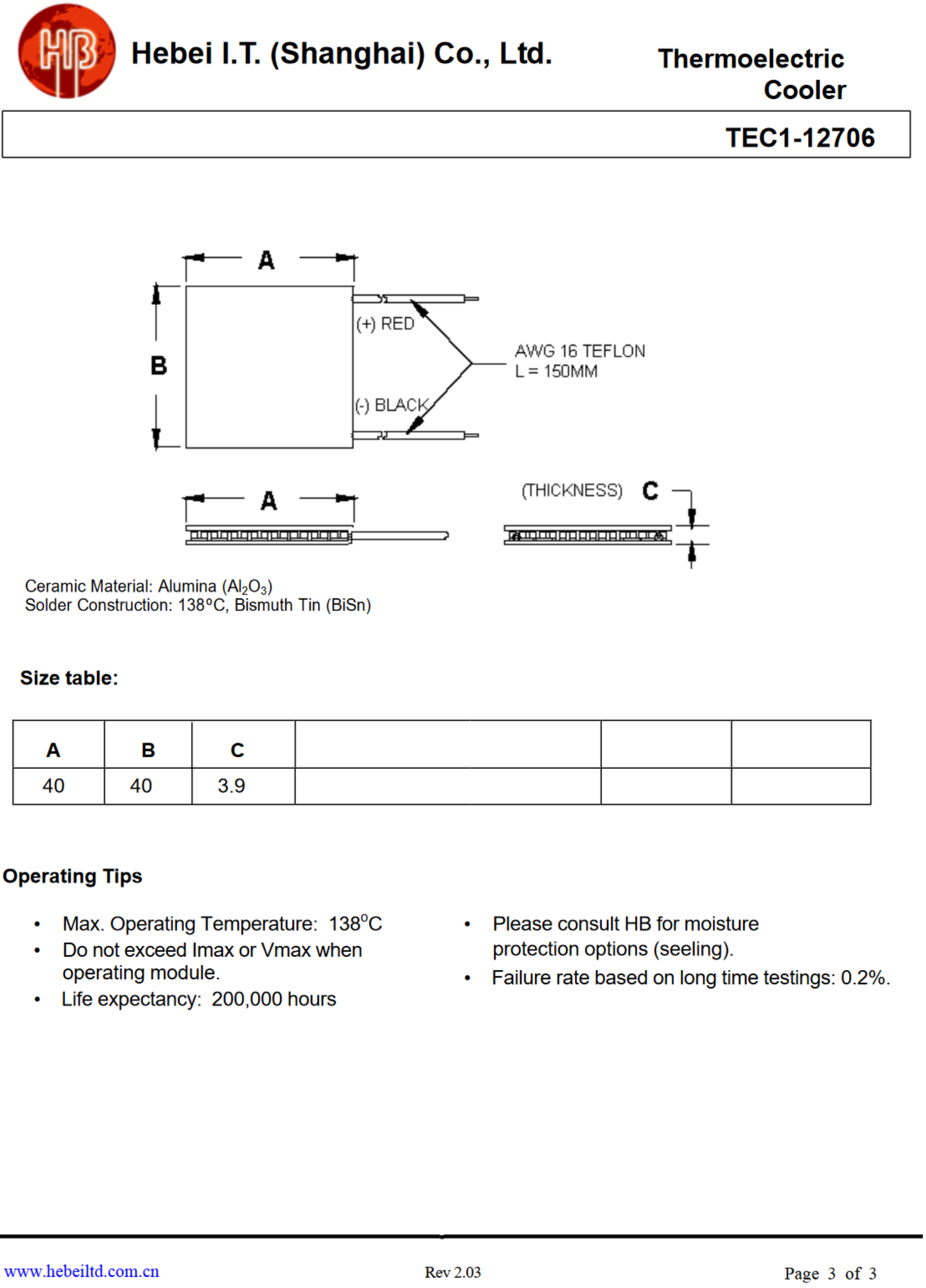
Thermoelectric Cooler

TEC1-12706

Performance curves:





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Thermoelectric Cooler

TEC1-12706

Ceramic Material: Alumina (Al_2O_3)
Solder Construction: 138°C, Bismuth Tin (BiSn)

Size table:

A	B	C			
40	40	3.9			

Operating Tips

- Max. Operating Temperature: 138°C
- Do not exceed Imax or Vmax when operating module.
- Life expectancy: 200,000 hours
- Please consult HB for moisture protection options (seeling).
- Failure rate based on long time testings: 0.2%.

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A.4 Dropbox Link to Files Related to CAD Model

https://www.dropbox.com/sh/9hlrh0ealq9nkzt/AAASFbL3ENvsu_jYzTx_BATYa?dl=0

Please note, the CAD files were updated to reflect the conduction setup which we were planning to implement but were unable to. However, the CAD for the drawers are still inside the folder and are unchanged. The positioning of the TEC and the other various holes on the cooler are different in the most recent CAD but would only require a few changes to revert to. If you have any questions, please contact the production engineer Timothy Willms at tjm15m@my.fsu.edu. The naming convention for all the files is very simple and straight forward.

A.4 Dropbox Link to Testing Data

https://www.dropbox.com/sh/ibkddng13fnamho/AAABYSdq8ikVcgSZcxj-L8Qba?dl=0

The following data was obtained through multiple tests of the prototype previously mentioned. Initial tests were used to determine the appropriate mode of heat transfer within the cooler, most effective means of dissipating thermal energy from the hot side of TEC module to the environment, and initial estimates of cooling time and reheating time within the cooler. After selecting convective cooling for the initial prototype and verifying that it would reach the required temperature range, the group identified methods to reduce the power consumption of the device. Therefore, multiple trials were conducted using a voltage regulator to reduce the voltage through the TEC module. The group was able to identify that a step-down voltage from 12V to 4V significantly decreased the power consumed while maintaining the required temperature range over a 5-day trial. If you have any questions, please contact the thermal process engineer Matthew Israel at mi16e@my.fsu.edu or the energy systems engineer Tyler White at tpw16@my.fsu.edu.