Report: Temperature Regulator Fridge Using On-Off Controller

1. Introduction

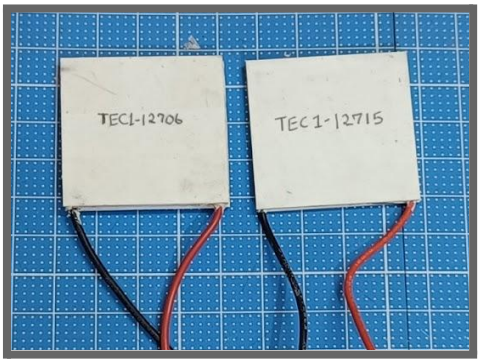
This technical report aims to provide a detailed guide for constructing a cost-effective DIY mini fridge using a Peltier chip and an on-off control mechanism for temperature regulation. The proposed design utilises readily available components and offers a compact and energy-efficient solution for cooling small spaces or storing perishable items. The temperature regulator fridge is an essential appliance commonly used in households, restaurants, and various other settings to maintain a consistent temperature for food, medicine or skincare products preservation. The on-off controller is a simple yet effective control mechanism that switches the fridge's cooling system on and off based on predefined temperature thresholds.

2. Components and Materials

The temperature regulator fridge consists of several key components that work together to maintain the desired temperature.To construct the DIY mini fridge, the following components and materials are required:

2.1 Peltier chip:

A Peltier chip, also known as a thermoelectric cooler, is a semiconductor device that can transfer heat from one side to the other when an electrical current is applied. For this particular project I used two peltier chips Tec1-12706 and Tec1-12715, with rated voltage at 12 Volts and maximum current load at 6 amps and 15 amps respectively. The reason to use two chips is to achieve a higher temperature range on the colder side by stacking the two peltier chips together.

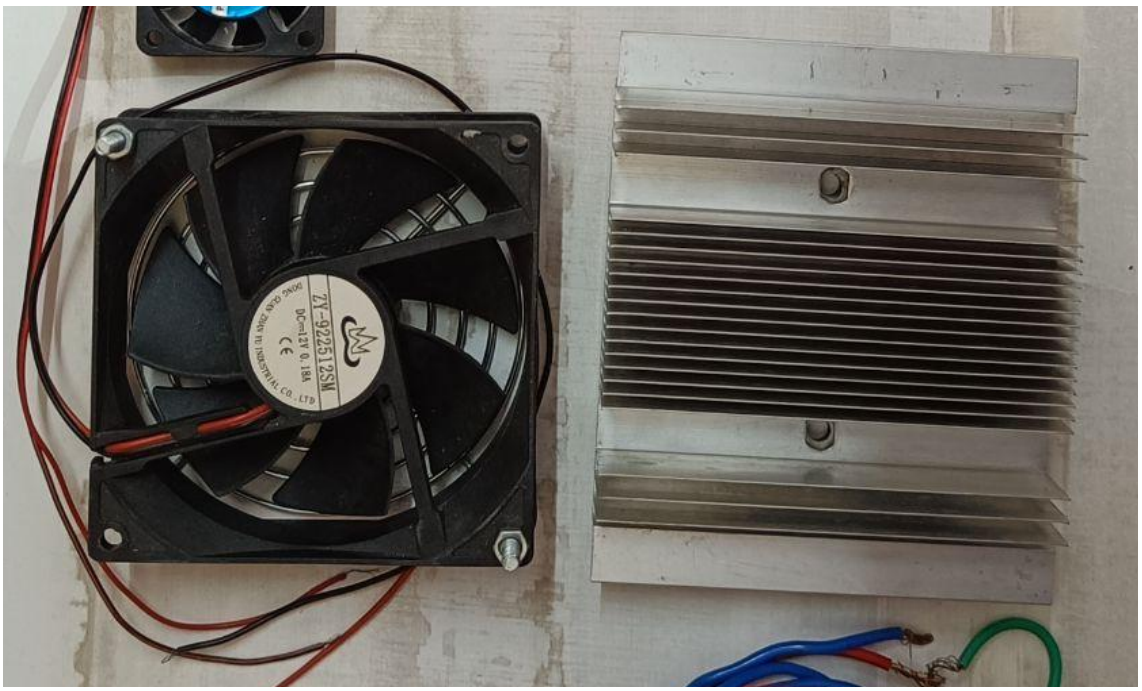


2.2 Cooling System:

The cooling system is responsible for regulating the temperature inside the fridge. It usually consists of a compressor, condenser, evaporator, and refrigerant in a conventional fridge. Since we are using peltier chips in his project, the hot side becomes well… extremely hot. Why is that a problem? Because the higher the temperature is on the hot side, the lesser the cooling power of the chip. For example, at the same power rating the minimum temperature achieved on the cold side would be only a mere 10℃ for a maximum temperature of 50℃ on the hot side. However we can achieve subzero temperatures(-4℃ to -6℃) if the hot side is kept under 40℃. The cooling system comprises heat/cold sinks, fans, coolant(water), water pump and radiator to dissipate heat.

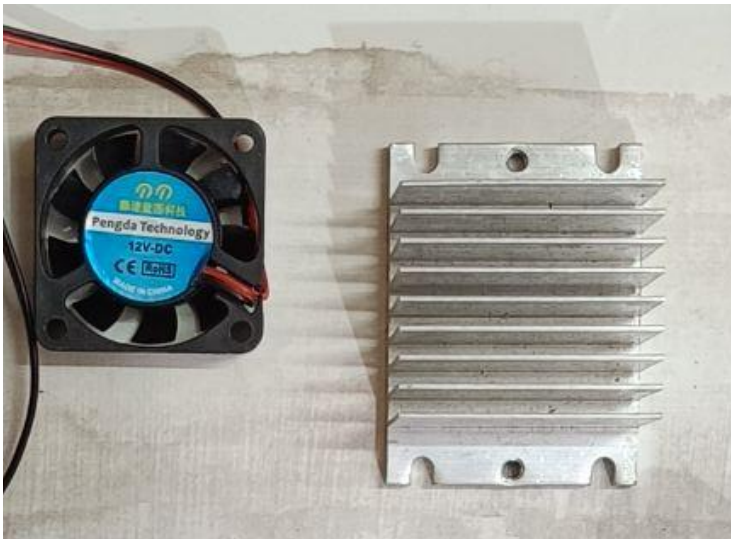
2.2.1 Heatsink and fan:

A heat sink with a fan is needed to dissipate the heat generated by the Peltier chip. The fan for the heat sink used has 9*9*2 cm 12V 0.18A rated cooling fan. The heat sink is an aluminium type with corrugated fins on one side for heat dissipation, where the fan is placed and placing the hot side of the peltier chip on the other side.



2.2.3 Coldsink and fan:

For better air circulation inside the fridge, a cold sink with a fan is placed on the cold side of the peltier chip

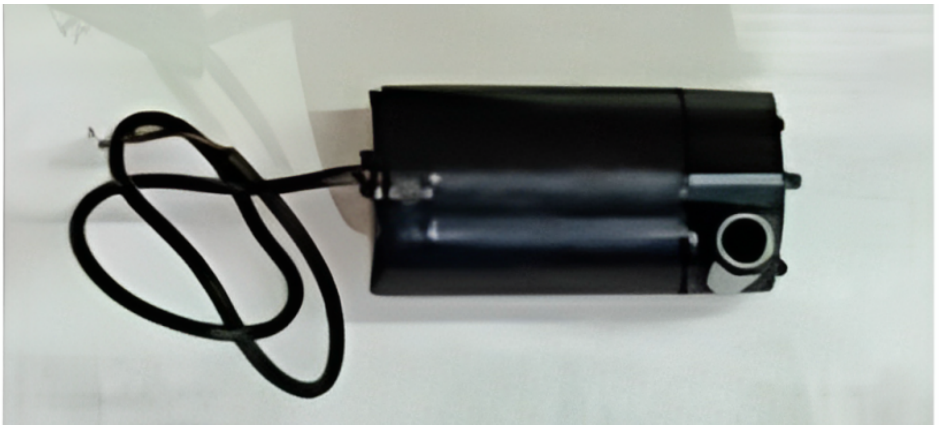


2.2.4 Water Cooling Block and Pipe:

A 4*4*1.5 cm water cooling aluminium block is placed on the hot side of the peltier chip to quickly absorb the heat into the coolant (water).

2.2.5 Water Pump:

A 12 V rated water pump is used to circulate the coolant(water) from the heat source to the radiator and back



2.2.6 Radiator:

To dissipate the heat absorbed into the coolant, a radiator to quickly expel heat is required, an old CPU radiator is used for this project.

2.3 Temperature and Humidity Sensor:

A temperature sensor, such as a thermistor, to measure the internal temperature of the mini fridge along with the humidity conditions.

2.4 Power supply:

The power supply provides the necessary electrical energy to run the fridge's components, including the cooling system and the controller. A suitable power supply capable of providing the required voltage and current to operate the Peltier chip and the cooling system.

Total power consumption is 12 V * (current rating of peltier chips + DC Pump + Fans + Controller)
= 12V* (15 + 6 + 2 + 0.18 + 0.5 + 0.15)

≅ 12V * 25 A

Maximum Power Output : 12 Volt 25 Amp

2.5 Insulating materials:

Insulating material, such as foam or Styrofoam, to create the walls of the mini fridge.

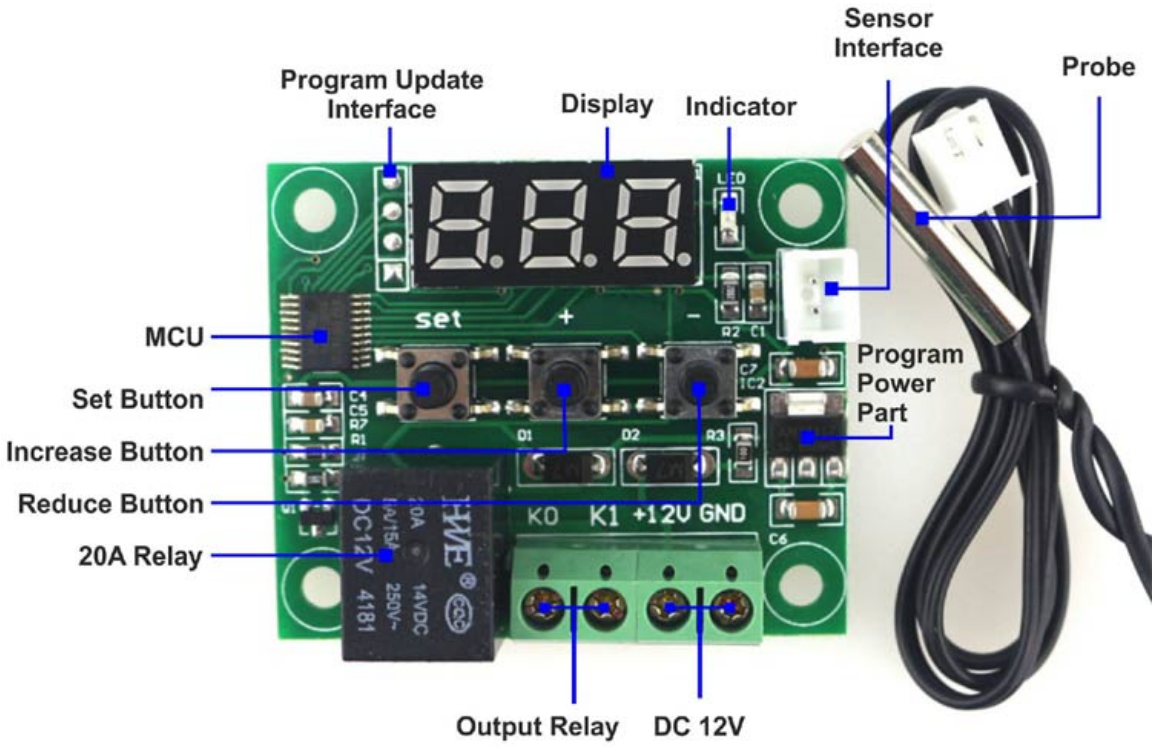
2.6 Miscellaneous tools:

Soldering iron, wires, screws, nuts, pipes, adhesives and basic hand tools for assembly.

2.7. On-Off Controller: W1209

The on-off controller, also known as a bang-bang controller, is a basic control strategy widely employed in temperature regulation systems. It operates by comparing the measured temperature against a desired setpoint and then either activating or deactivating the fridge's cooling system based on the predefined temperature thresholds.
The temperature sensor, typically a thermistor or a thermocouple, measures the current temperature inside the fridge. It converts the temperature into an electrical signal that can be interpreted by the control system. The controller is responsible for processing the temperature data received from the sensor and determining whether to activate or deactivate the cooling system. In the case of the on-off controller, it compares the measured temperature against the setpoint and sends a control signal to the cooling system accordingly. The controller used for this project is w1209. This section mentions some of the specifications of the W1209 Thermostat sensor module:

- Temperature control range: -50 to 110 degree C
- Measurement accuracy: 0.1 Degree C
- Input Voltage: 12V DC
- Refresh rate: 0.5 Seconds
- Output: 1 Channel Relay Output 240V AC/ 12V DC
- Relay current Capacity: 10A



Connections to a W1209 Temperature Control Switch [Source]

3. Construction Steps:

After gathering all key components it is time to construct the fridge

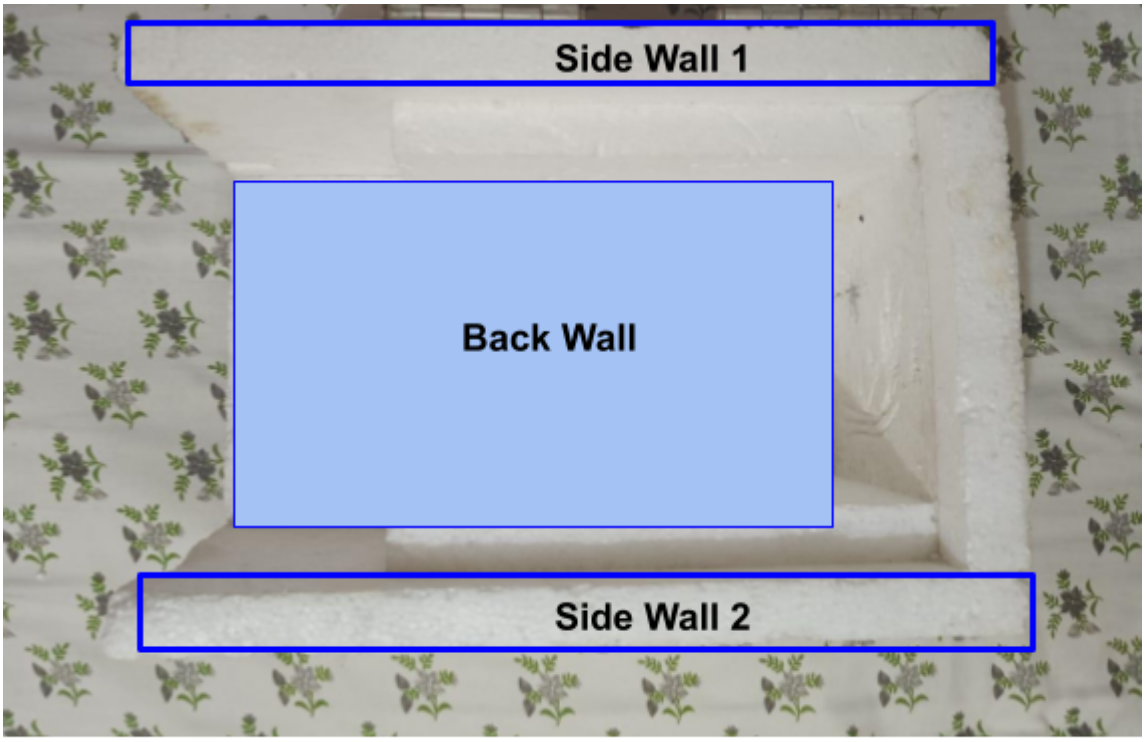
3.1. Building the Cooling Chamber

1. Starting with bigger pieces, cut five pieces , two for side walls, one for back wall and one for door and the bottom.

   You can use these dimensions as guidelines (in cm):

   Sheet thickness: 2.5

   Side wall: 18*40
   Back wall: 20*40

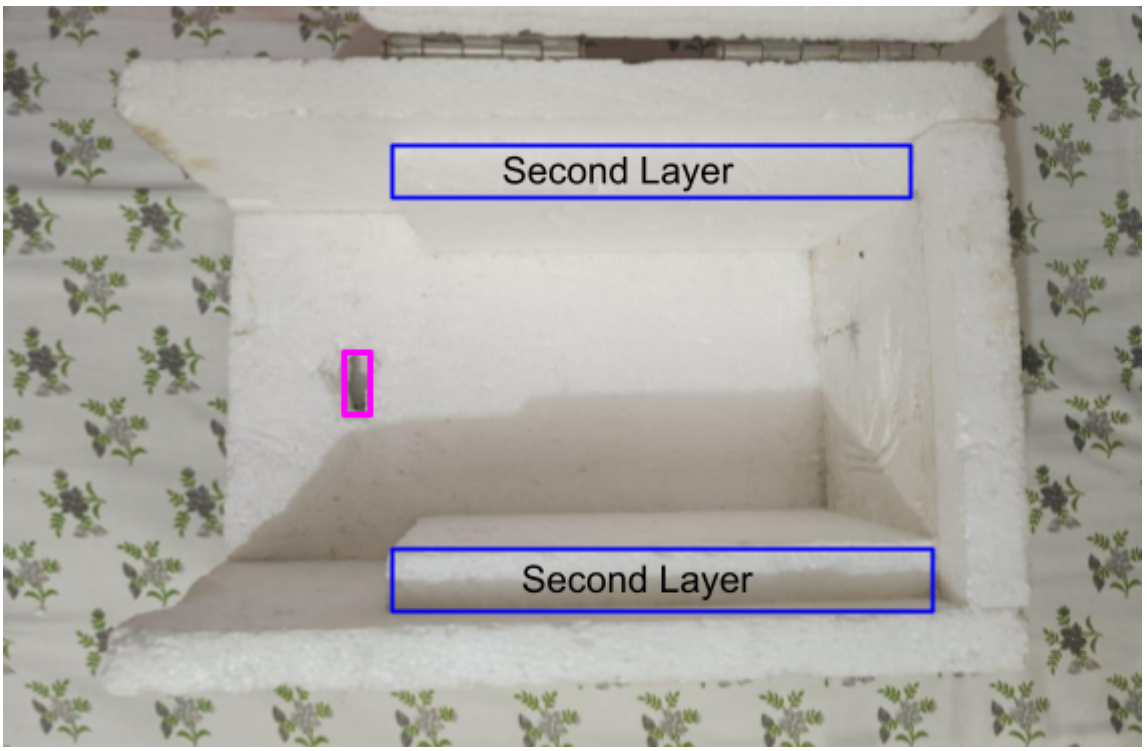


Top platform: 20.5 *15 (On Left)
Front wall: 10* 25 (On Right)

2. Begin by cutting the styrofoam or thermocol to the suitable size using a hot Knife or extremely sharp cutter.
3. Cut out holes in the top platform and front wall for mounting the cooling module and the temperature sensor

4. Line the inside of the mini fridge with another layer of styrofoam , to minimise heat exchange with the surroundings. Also cut holes in the back wall for adjusting wiring and pipe.

   Side Wall Second layer: 22*21.5



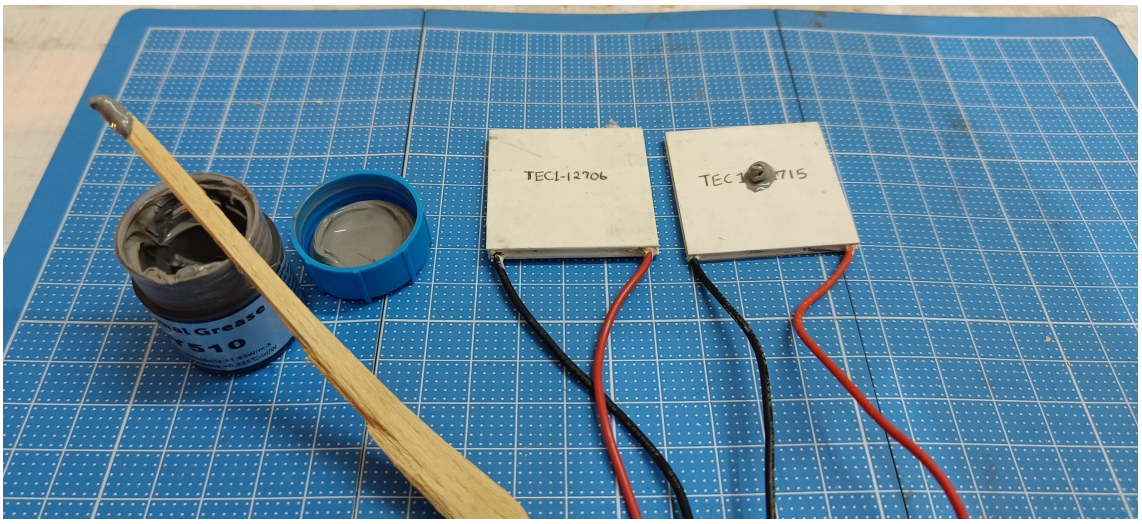
5. Create a door for the mini fridge using insulating material and attach it securely to the box with the help of hinges

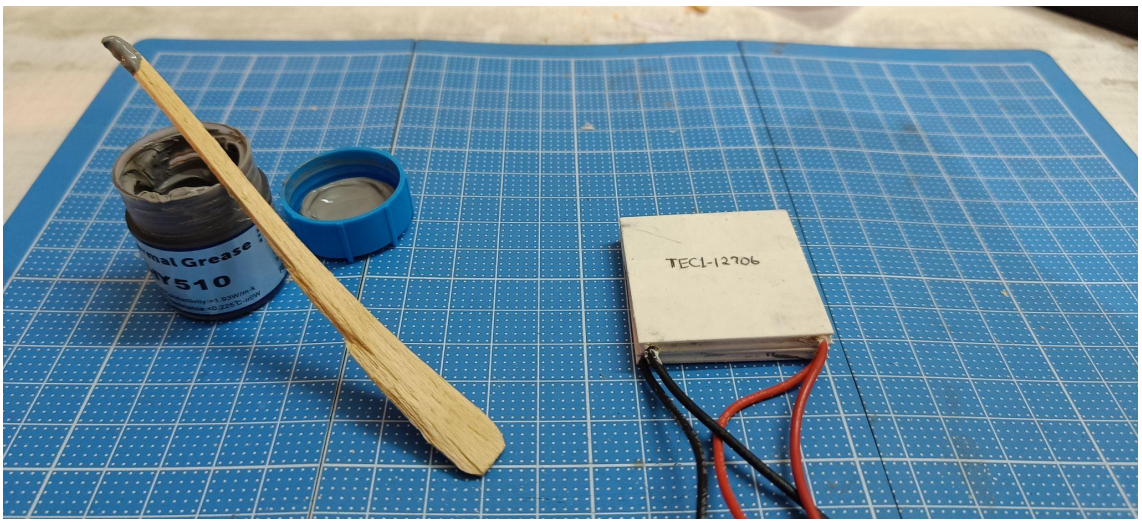
   Door : 25* 25
   Door Second layer: 21.5*19

6. Place the top platform inside the chamber, don't attach the front wall yet

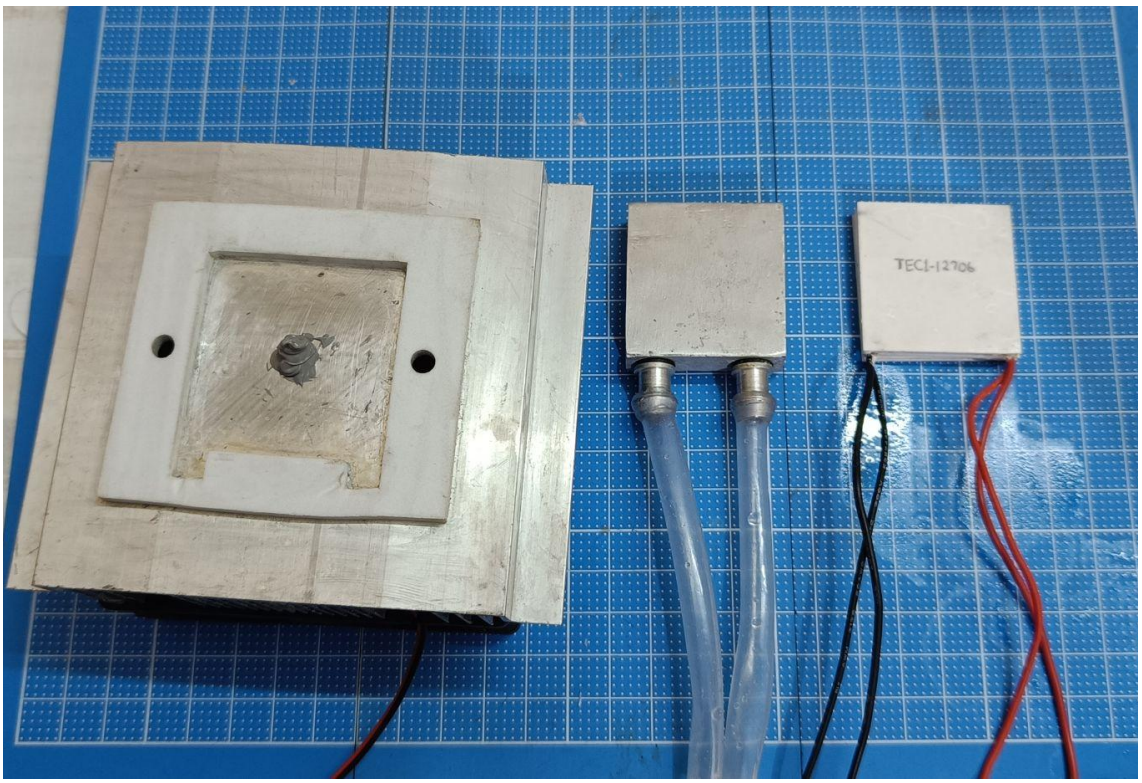
3.2. Assembly of the Cooling Module

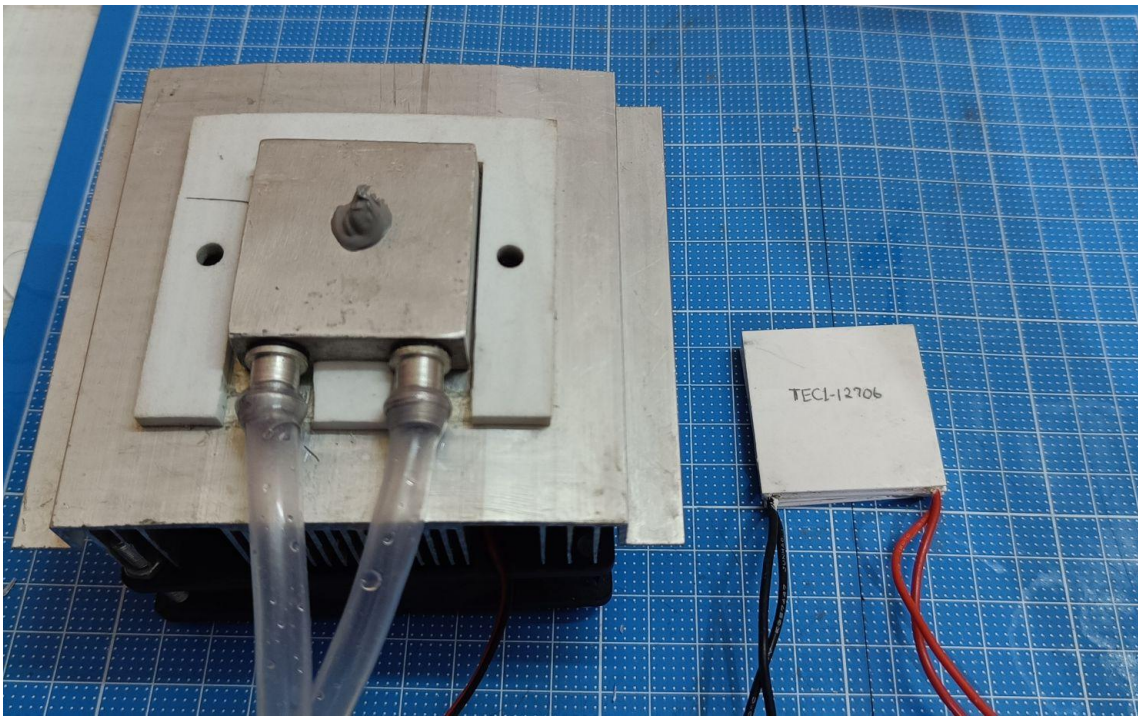
1. Start by stacking the two peltier chips together with the help of thermal paste

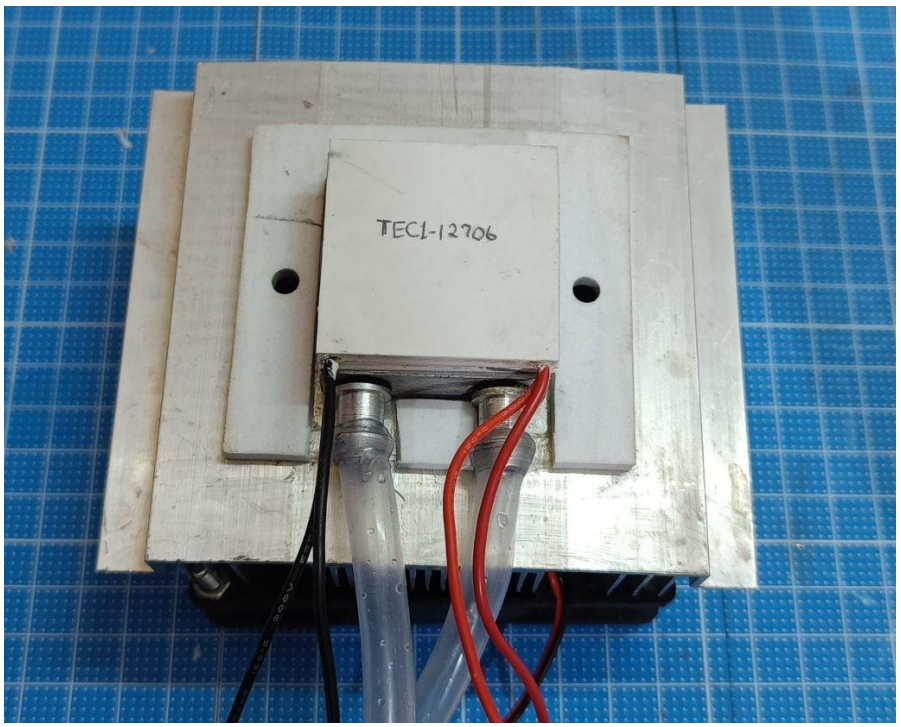




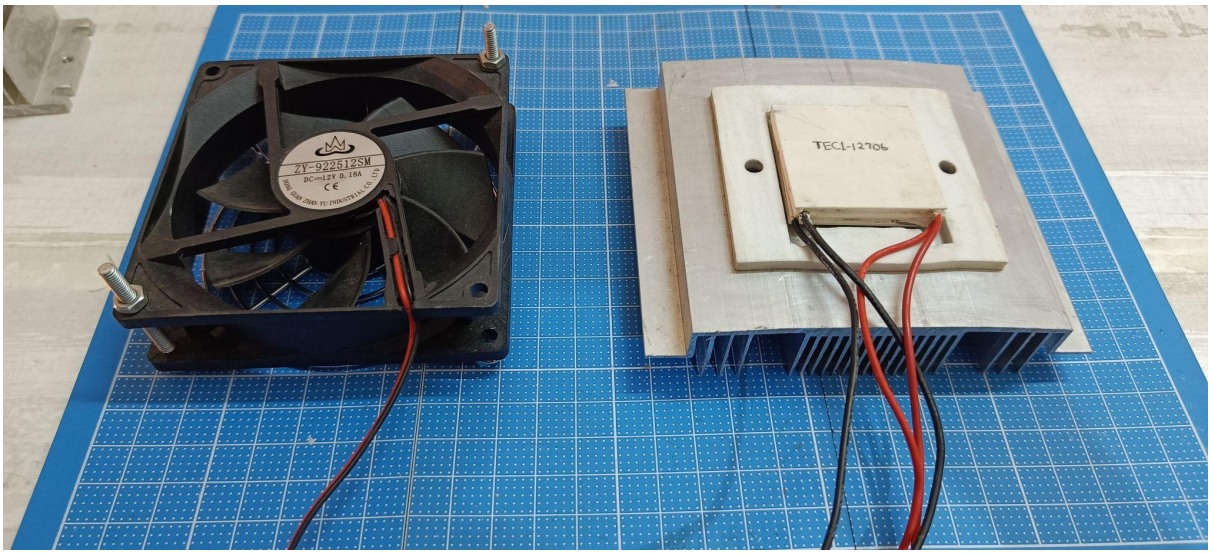
2. Attach the heat sink to the hot side of the Peltier chip using thermal adhesive or a thermal paste, or sandwich the water cooling block between the heatsink and the peltier chip

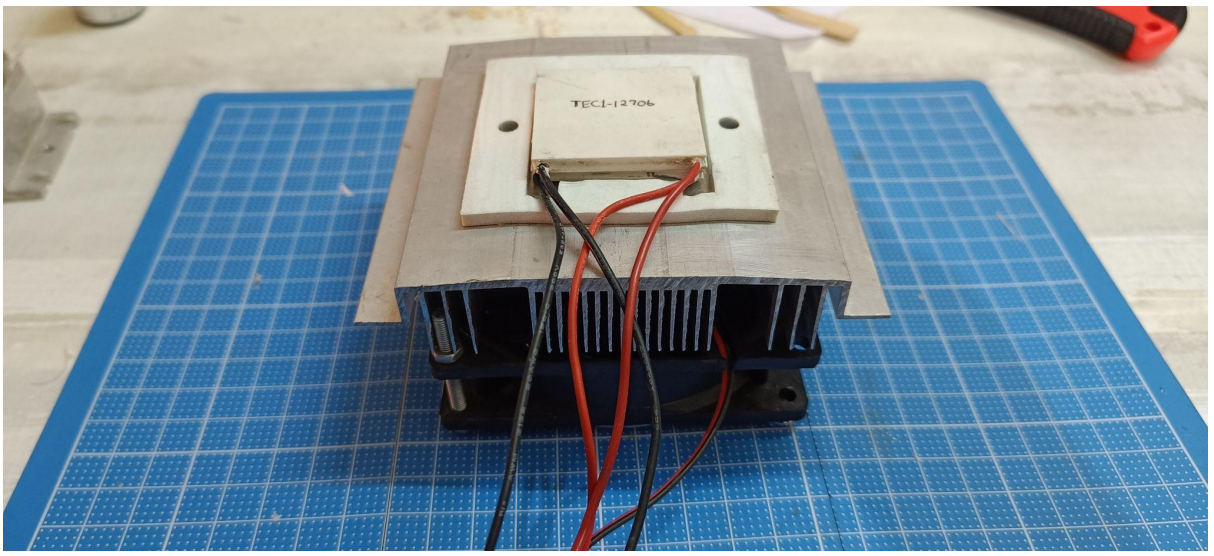

TEC1-12706


TEC1-12706



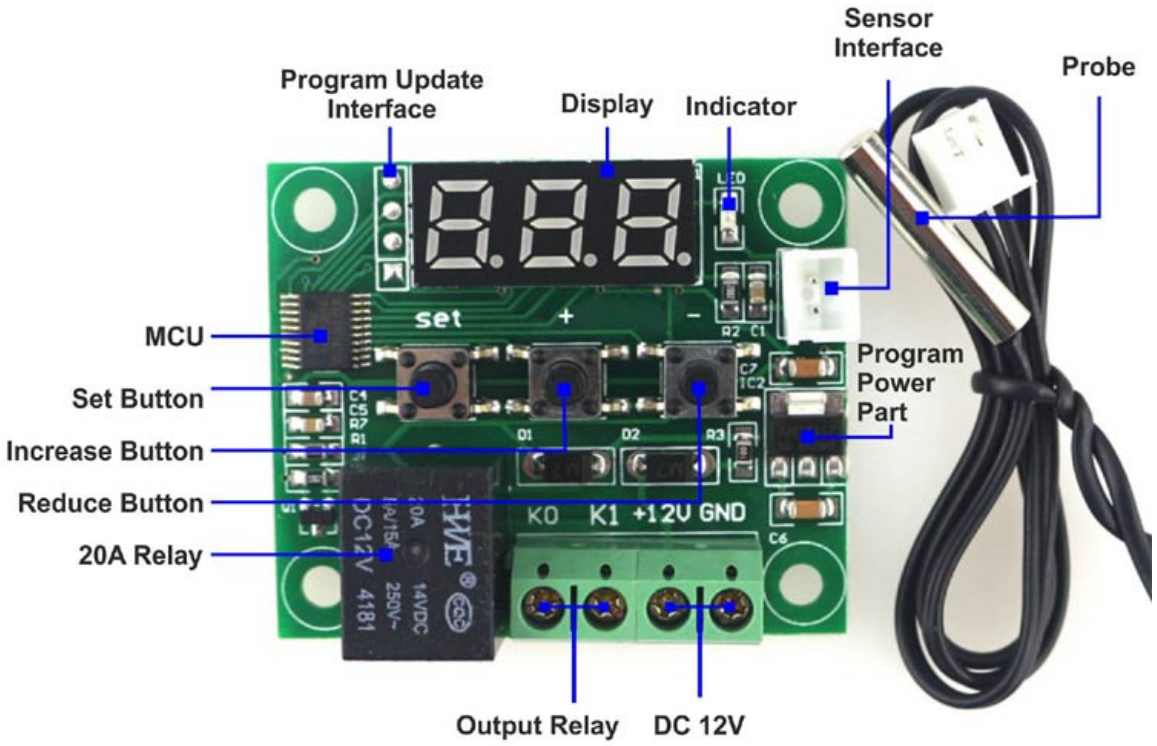
3. Install the cooling fan on the opposite side of the heat sink to enhance heat dissipation.





4. Mount the Peltier chip with the heat sink onto the top platform , ensuring good thermal contact with the cooling chamber.

3.3 Wiring and Connection



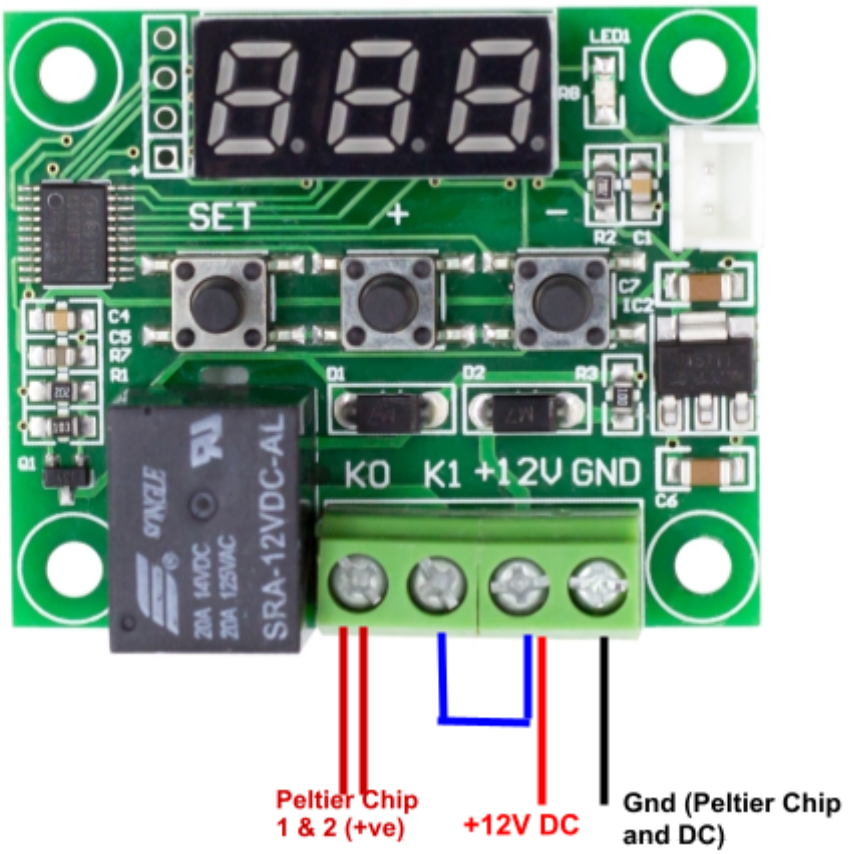
1. Connect power supply to the Controller :

   Positive (red wire) -> +12V
   Negative (black wire) -> GND

2. Connect the positive and negative terminals of the two Peltier chips in parallel to the controller as shown:

   Positive terminal (red wire) -> K0
   Negative terminal (black wire) -> GND

3. Connect K1 with +12V
4. Attach the probe to the sensor interface



5. Connect one pipe from the aluminium cooling block to one outlet of the radiator. Connect the other outlet of the radiator to the outlet of the DC water pump, finally connect the second outlet of the pump with the cooling block with a third pipe forming a closed loop for circulation of water.

6. Next connect the 12V DC pump directly with the power supply without passing it through the controller as the chips need to be regulated even if the controller's relay is turned off

7. Similarly connect both fans directly to the 12 V DC power supply

3.4. Programming the Controller

To ensure the safety of the system I have put the limit to the maximum temperature that the coolant/water can achieve before the system is turned off; 45C. To set the temperature for heat regulation of the water cooling system on a WX 1209 On-Off controller, follow these step-by-step instructions:

1. Ensure that the probe is dipped in the water
2. Locate the temperature control settings on the WX 1209 controller. It usually consists of a display screen and three buttons for navigation and adjustment.
3. Turn on the power to the controller.
4. The display screen should now show the current temperature or a default value. Take note of this value as a reference.
5. Look for the button or combination of buttons that allow you to enter the temperature setup mode. It should be labelled "Set," "Setup," or "Temperature." Refer to the user manual of the WX 1209 controller if you are unsure about the specific button(s) to press.
6. Once in the setup mode, the display may start blinking or show a specific symbol indicating that you can now adjust the temperature.
7. Use the navigation buttons, typically labelled as "+" and "-," to increase or decrease the temperature value displayed on the screen. Keep pressing the appropriate button until you reach the desired heat threshold temperature.
8. Press the "Set" button to confirm the chosen temperature.
9. After confirming the temperature setting, the display may stop blinking, indicating that the temperature has been successfully set.
10. Finally, verify that the temperature value displayed on the screen matches the desired heat threshold temperature you selected. If it does, you have successfully set the temperature for cooling on the WX 1209 On-Off controller.
11. To ensure accurate temperature control, it is important to place the temperature sensor of the controller in the appropriate location where it can measure the temperature accurately. Refer to the user manual for guidance on sensor placement.

4. Testing and Optimization

1. Power up the DIY mini fridge and monitor the temperature inside the cooling chamber with the temperature and humidity sensor.
2. Verify that the on-off control system effectively regulates the temperature, cycling the Peltier chip and cooling system on and off as needed.
3. Optimize the control algorithm and temperature thresholds for improved performance, ensuring temperature stability within an acceptable range.

4. Operation of the On-Off Controller

The on-off controller operates based on a hysteresis band, which defines a temperature range within which the controller switches the cooling system on or off. This hysteresis band is determined by two thresholds: an upper threshold (T_1) and a lower threshold (T_2).

4.1 Cooling Activation:

When the measured temperature exceeds the upper threshold (T_1), the controller sends a signal to activate the cooling system. The cooling system starts circulating the coolant, causing the temperature to decrease.

4.2 Cooling Deactivation:

Once the temperature drops below the lower threshold (T_2), the controller sends a signal to deactivate the cooling system. The cooling system stops operating, allowing the temperature to rise.

5. Advantages and Limitations of On-Off Controller

The on-off controller offers several advantages, including:

1. Simplicity: The on-off controller is a straightforward control mechanism that is easy to implement and understand.
2. Cost-Effectiveness: It is a cost-effective solution as it requires minimal hardware and is less complex than other control strategies.
3. Energy Efficiency: By activating the cooling system only when necessary, the on-off controller can help conserve energy.

However, the on-off controller also has limitations, such as:

1. Temperature Oscillations: Due to the hysteresis band, the on-off controller may cause temperature oscillations around the setpoint, leading to slight temperature variations inside the fridge.
2. Limited Precision: The on-off controller lacks precision as it only operates in two states (on or off) and does not allow for fine-tuning of the cooling system.

5. Conclusion

By following the outlined steps and using readily available components, it is possible to construct a cost-effective DIY mini fridge using a Peltier chip and an on-off control

mechanism for temperature regulation. The final product offers a compact and energy-efficient cooling solution for small spaces or storing perishable items. However, it is important to note that the cooling capacity of the DIY mini fridge may be limited compared to commercial refrigerators, and careful consideration should be given to the application and intended usage. The temperature regulator fridge using an on-off controller is a reliable and cost-effective solution for maintaining desired temperatures. While it may not offer the same precision as more advanced control strategies, it fulfills the basic requirements for most applications. The simplicity and energy efficiency of the on-off controller make it a popular choice in various settings where precise temperature control is not critical.