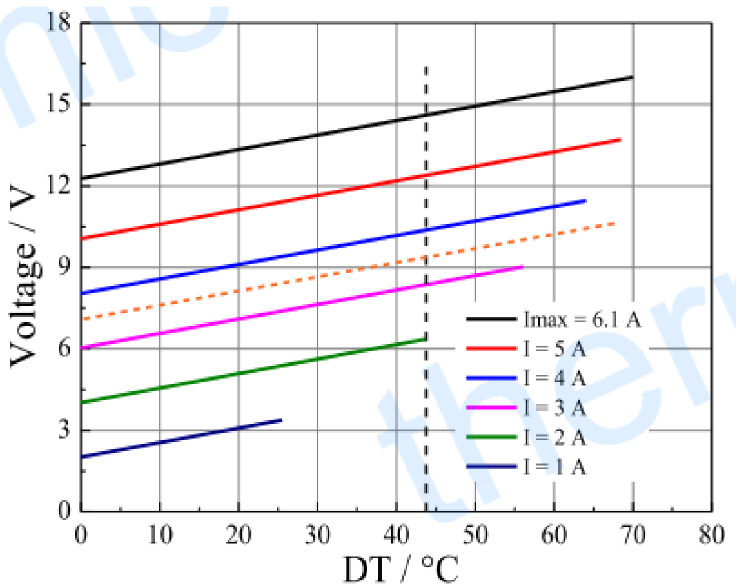
Responsable	IFIBIO “Houssay” UBA-CONICET	Ticket #
Dr. Esteban Valverde	**Peltier-based cooling system for microtome machine**	20200102
Start date: 02/01/2020		**End date: 28/01/2020**

This project seeks to develop and manufacture a device capable of freezing biological samples in the stage of a microtome. The making of slices of biological samples of a few microns thickness for subsequent histological processing can be achieved by different cutting systems, mainly cryostats, vibratoms and microtomes. The latter are the most commonly used in pathology laboratories. To achieve the necessary resistance for cutting, biological samples must be embedded in support materials (traditionally paraffin), a laborious procedure that requires several hours of work and that in many cases alters the ability to perform stains on the samples. An efficient and fast alternative is to freeze the sample on the cutting stage of the microtome. This technique, freezing microtome cutting, is widely used in neuroscience research and other related fields, as well as in the processing of intrasurgical samples (for example, to determine the malignancy of a tumor during exploratory surgery). The systems available for freezing samples in the microtome are inefficient and require consumables that are difficult to store (dry ice, CO2 tubes). This project seeks to develop and manufacture a device capable of freezing biological samples in a few minutes directly on the cutting stage of a microtome from the use of a thermoelectric module more commonly called a Peltier cell.

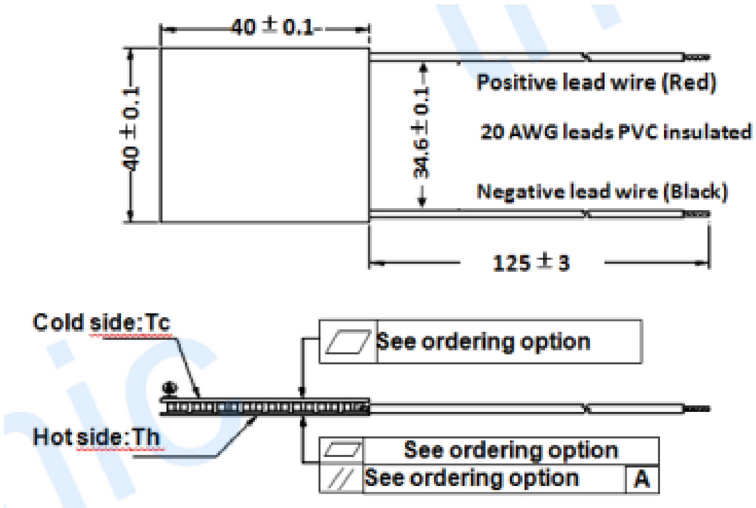
Service Order Development

The present development aims to replace the control system of the "cooling device for the histology microtome", according to the PDE 2019 of Juan Belforte, which is based on a Peltier cell, model TEC1-12706. The system currently in use is considered technologically obsolete and at risk of failure, which would leave researchers without a cooling system control device.

Consequently, I am developing a new device to replace the old one, to control the same Peltier cell. At 27°C the Peltier cell has the following characteristic curve



Where DT represents the temperature difference between the hot and cold sides of the cell. The cell is as follows

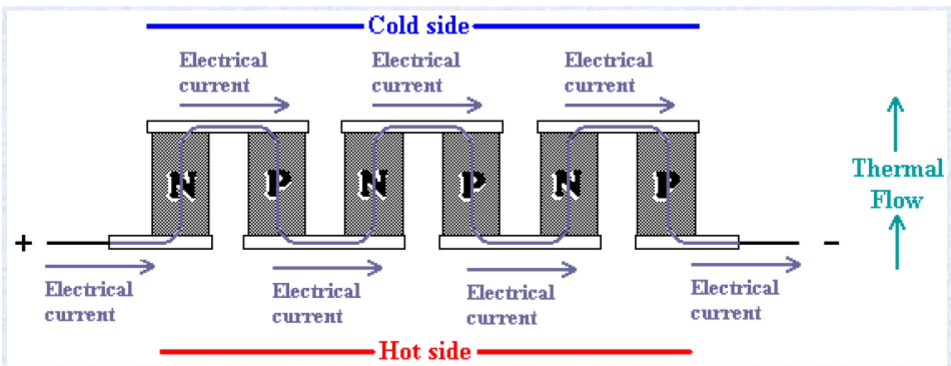


The technical characteristics are as follows

Peformance Specification Sheet

Th(°C)	27	50	Hot side temperature at environment: dry air, N_2
DT_{max}(°C)	70	79	Temperature Difference between cold and hot side of the module when cooling capacity is zero at cold side
U_{max}(Voltage)	16.0	17.2	Voltage applied to the module at DT_{max}
I_{max}(amps)	6.1	6.1	DC current through the modules at DT_{max}
Q_{Cmax}(Watts)	61.4	66.7	Cooling capacity at cold side of the module under DT=0 °C
AC resistance(ohms)	2.0	2.2	The module resistance is tested under AC
Tolerance (%)	± 10		For thermal and electricity parameters

The principle of operation of the cell is based on semiconductors configured according to the figure below, in which the circulation of current through each junction of different metals causes a temperature gradient so that one side emits heat and the other absorbs it.



The Peltier cell shows in its data sheet the thermal gradient it generates, in this case up to 40°C between the hot and cold side, so it is necessary to "cool" the hot side, by means of a cooling system that can be a heat sink, or a cold or icy water circulation system. if you want to have a cold side with negative temperatures. In this way, temperatures in the order of -25 to -30°C can be reached on the cold side of the cell.

Considerando que el sistema actual de enfriamiento consta de un sistema de circulación de agua con hielo, alcanzando un balance térmico de temperatura de aprox. 4 – 10°C, el lado frío del sistema llega hasta los -15 a -30°C aprox. En este caso, según la curva anterior, se precisa una tensión de 12Vdc y una corriente máxima de 4Amp aprox. En consecuencia, el sistema de control debe ser capaz de entregar estos niveles de potencia requeridos.

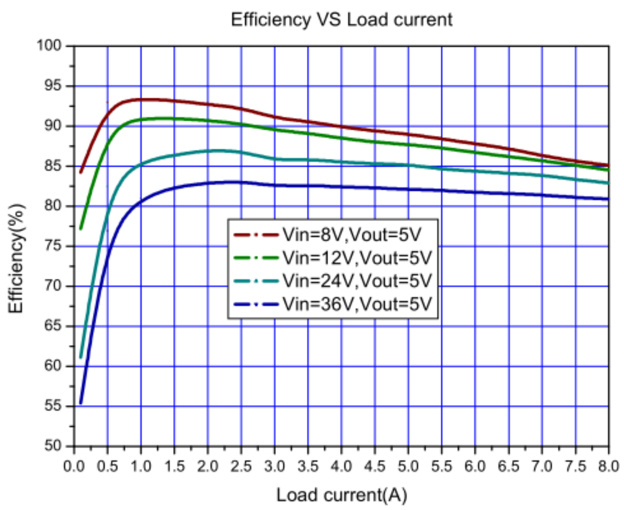
It should be noted that the maximum current and voltage supported by the cell are 6Amp and 16Vdc approx. So, the control system must be limited to these maximum values for cell protection.

It was decided to design the control system based on three commercial and easily replaceable modules, taking into account the technical specifications of the cell and these modules.

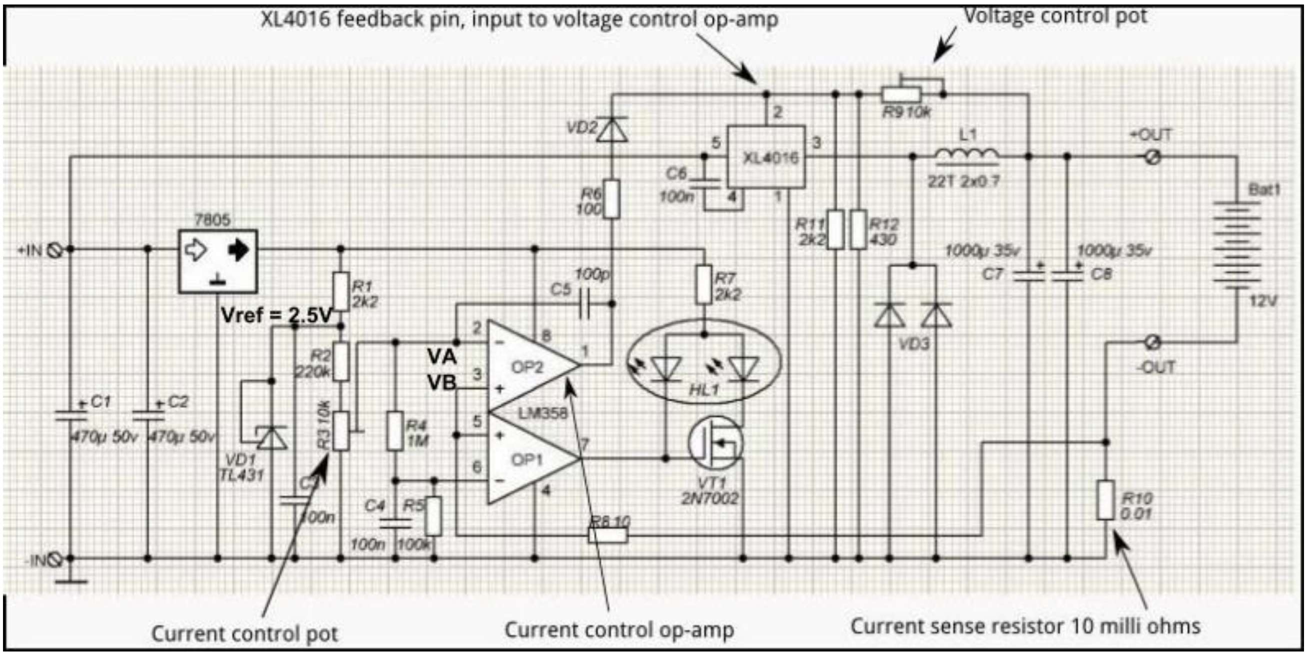
Modelo	Descripción	Costo aprox.
XL4016	8 – 40 Vin Output Regulator, 1.25 – 36 Vout, 0 – 8Amp	USD 12.00
WX-DC2416	Power supply switching 110 – 220 VAC, 24Vdc output, 6Amp	USD 26.00
W1209	Census and temperature control module	USD 4.00
Adicionales	LM7812 Regulator, IC, Miscellaneous Capacitors, 12Vdc Fan, 220VAC Cable, Key Ignition, 5Amp Fuse & Holder, PC Source Type Enclosure	USD 10.00
TEC1-12706	Additional Peltier Cell	USD 5.00
		USD 57.00

XL4016 Output Regulator

The XL4016 module is a DC-DC buck converter, based on a PWM at 180KHz, capable of delivering up to 8Amp output. The output voltage varies between 1.25 – 36Vdc, for a supply voltage of 8 – 40Vdc. The system has an efficiency of around 90% for the specifications required by the Peltier cell.



The schematic circuit of the XL4016 module is as follows



The circuit is based on the XL4016 DC-DC converter. It is also observed that there is a current control, through an LM358 that compares the current measured in R10, with respect to a reference made up of TL431 and various resistors. By means of the R3 preset, the output current can be limited.

The output voltage is regulated by the R9 preset, so that the output current depends on the load. When the output current exceeds the value set by R3, the converter, through the system fed back by the LM358, turns off the 4016 regulator, which turns back on almost immediately, when the current that is registered is below the one that was limited (because the regulator is off). The effect is that the on-off time of the regulator is set by the current that was limited at R3, and the output voltage varies according to the load. Consequently, the complete module operates at regulated voltage and if the current set at R3 is reached, it starts operating at regulated current, floating the output voltage.

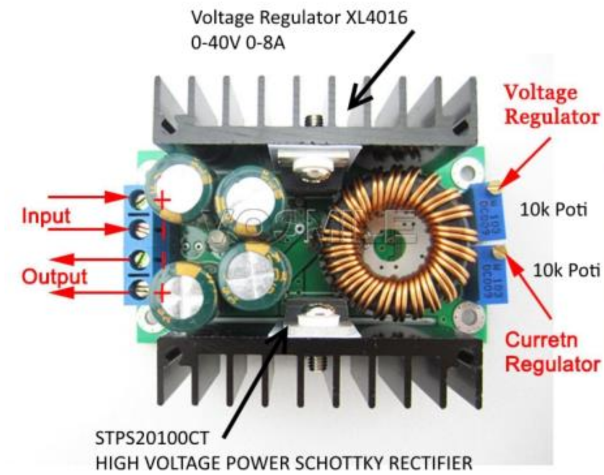
Consequently, it was decided to set the limit current at 4.5Amp as the maximum allowable value, since at 4Amp it was observed that it was sufficient for the Peltier cell to reach the required temperatures. As the cell will work at a maximum nominal value of 4Amp, the complete module will always operate as a regulated voltage unless an unforeseen event occurs (cell failure, connecting an unforeseen cell, etc.) that exceeds that current, and consequently the output current is limited to 4.5Amp. However, as an additional protection, a 5Amp fuse is placed at the outlet to prevent the case of a short circuit at the output of the system.

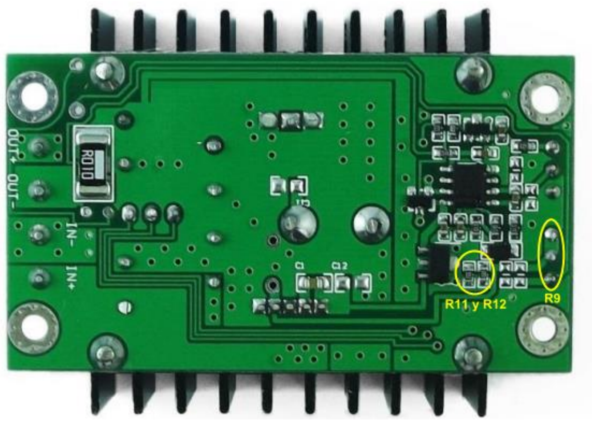
To limit the output current, proceed as follows. Turn the R3 current all the way clockwise. Connect a load of 2.66E – 100W, to ensure 4.5Amp at 12Vdc. Regulate the output voltage to 12Vdc and then decrease the current limiting, turning R3 counter-clockwise until the output voltage starts to decrease. Leave at that point.

On the other hand, the maximum output voltage should not exceed 16Vdc and the regulator delivers up to 36Vdc. It is then necessary to modify the circuit values to limit the maximum output voltage. From the circuit it is observed that the output voltage is equal to

Vout = 1.25 * [1+R9/(R11//R12)] = 1.25 * [1 + 0-10K / (2k2//430)] = 1.25 * [1 + 0-10K / 359.69] = 1.25 – 36V

To limit the output voltage, R9 is changed to a 10K panel potentiometer, R11 is left to open circuit, and R12 = 1K. Consequently, the maximum output voltage will be 13.75V. This value is higher than the maximum working rating of the Peltier cell and is below the maximum allowable value of the cell before it is forced to be destroyed.

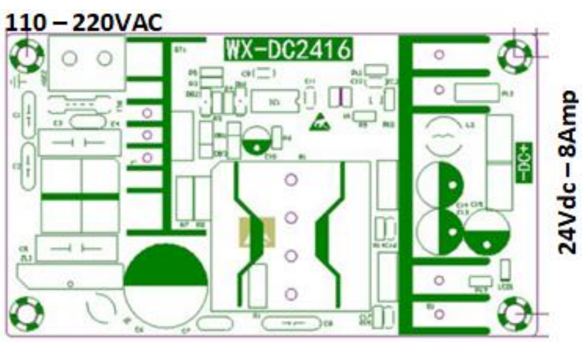




In the previous figure, you can see the connection of the XL4016 regulator and the lower side of the circuit, in order to locate the resistors and the preset whose values must be modified.

Switching Power Supply

The XL4016 module is powered by an input of 4 – 40Vdc, and 6Amp approx. Consequently, a device is required that allows it to be connected to the 220VAC power supply. The WX-DC2416 module is a commercial 100 – 220VAC, 24Vdc 8Amp output switching source that can be used for this application. It has protection against over voltage, and short circuit at the output.



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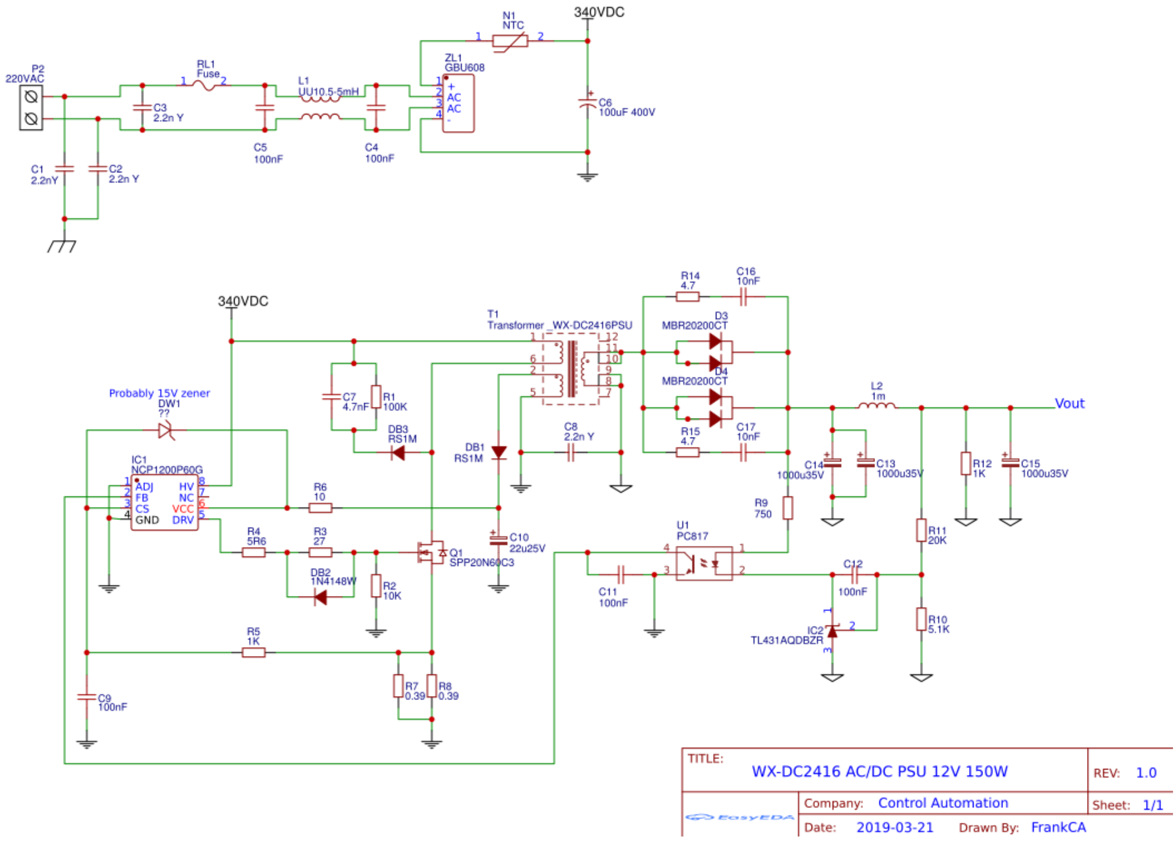
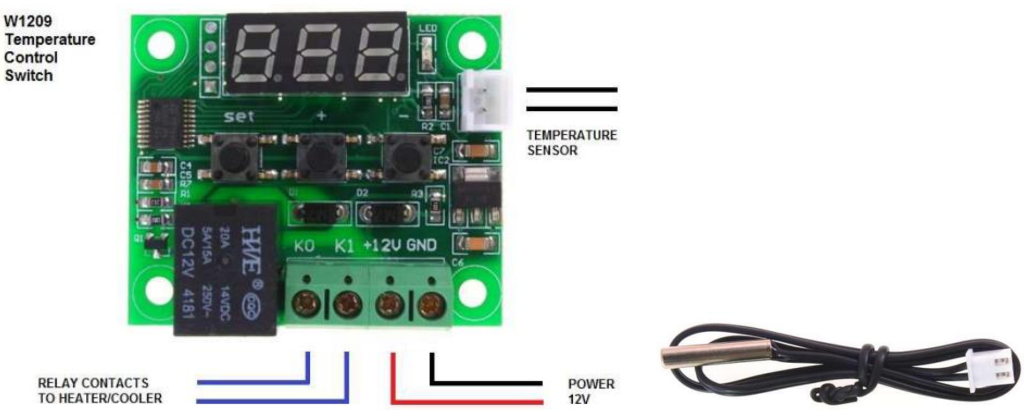


Census and temperature control module

In addition, the W1209 module is used as an option, which is a programmable temperature measurement system that, through a relay, can be connected to the XL4016 module to have the temperature of the Peltier cell controlled. In the first instance, it will only be used as a digital thermometer, leaving the temperature control system as an option in the future if required. The reason this module includes programmable temperature control is because of the just described and the low cost of the module. The module is as follows



While the sensor cable is very short, an extension cord was adapted up to almost 1mt long. The system is powered by 12Vdc.

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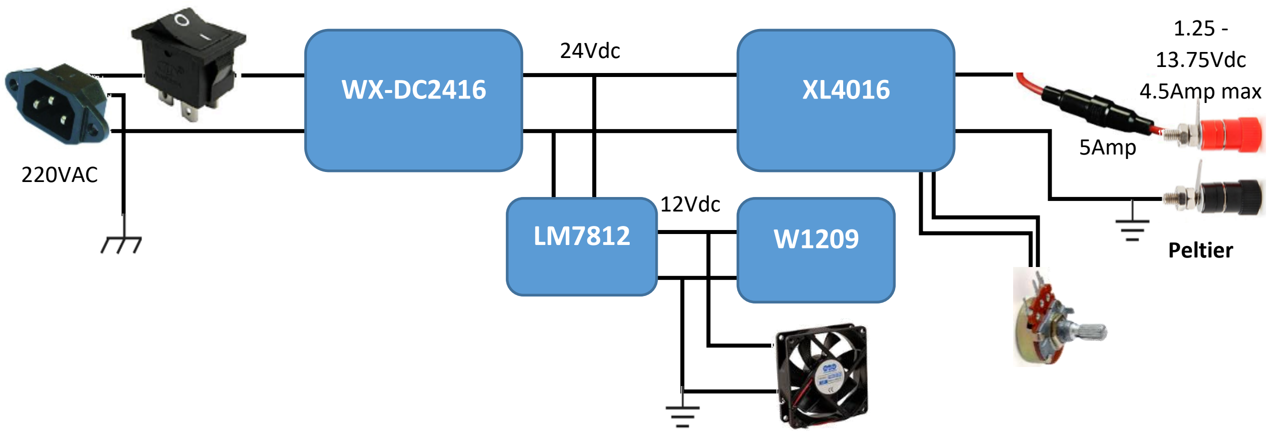
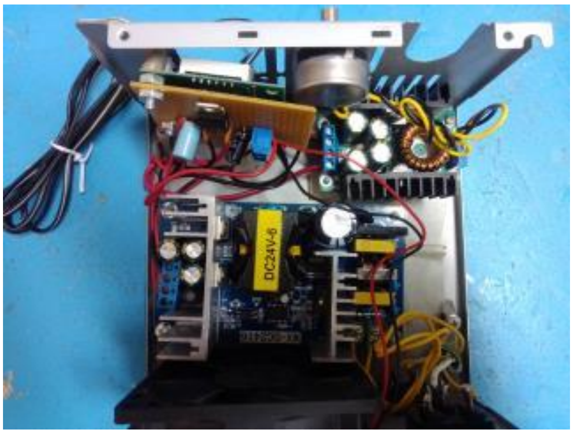
In order to power the temperature module and the addition of an additional fan to dissipate the heat generated by the WX-DC2416 and XL4016 modules, a simple 12Vdc output and 24Vdc input module is developed from an LM7812 voltage regulator and a pair of 25V electrolytic and 0.1uF ceramic capacitors.

Assembling the system

The entire system is mounted on a PC source, taking advantage of 220VAC interlock, ignition key and 12Vdc fan. The full wiring diagram is as follows





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Heat exchanger (the one found in the GNS microtome)

A metal block will be used on which the peltier will be mounted. The higher temperature side of the peltier will be in direct contact with the block, using silicone grease or Kafuter K-5202 thermal glue, to improve thermal conductivity.

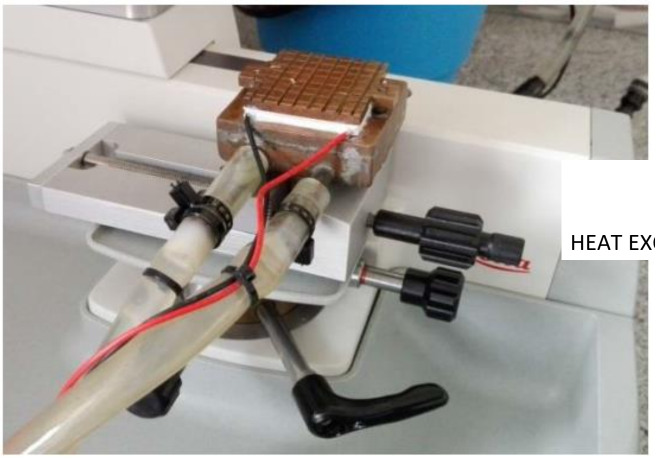
Water previously cooled in ice is circulated internally to the metal block with the help of a submersible pump, which is placed inside a container with cold water. The pump will activate whenever the peltier is energized.

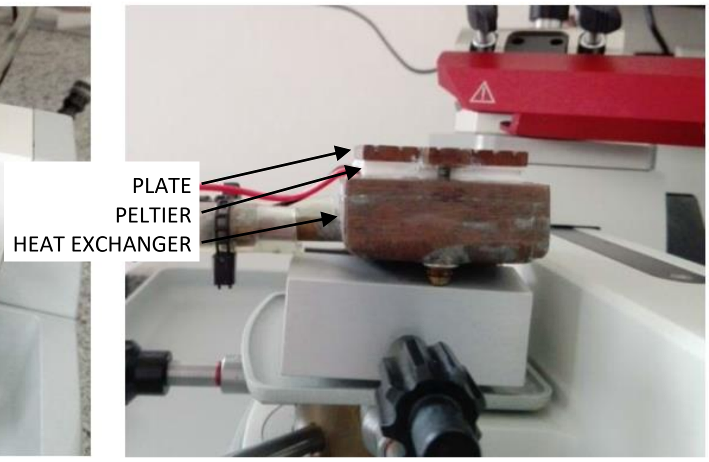
The metal heat exchanger essentially consists of a solid block of aluminium or brass, with parallel faces with internal ducts made by machining. The specific dimensions and shapes will depend on each particular application (microtome), which will not exceed the pre-established maximums for peltier selection.

The ducts between the heat exchanger and the container with the coolant are carried out by means of flexible silicone hoses.

Whenever the current regulator energizes the peltier, an auxiliary relay will automatically connect the power to the submersible pump, which is powered by the 220VAC supply voltage. The pump will be connected directly to the enclosure containing the peltier current regulator, thus preventing accidental disconnection.

A plastic box with a capacity of approximately 10 liters is used as a container. The submersible pump to be used is the one used in fish tanks, as they provide us with the necessary flow rate (30 liters per minute) to produce cooling on the hot side of the peltier.





The following figure shows the machining system of the platen – peltier – heat exchanger. It is observed that the hot side of the peltier cell is attached to the heat exchanger to remove heat and allow the cold side, which is attached to the stage, to cool. It should be remembered that the peltier cell produces a temperature difference between the two sides, so the more heat that is removed from the hot side, the greater the cold that is obtained from the side of the platen.

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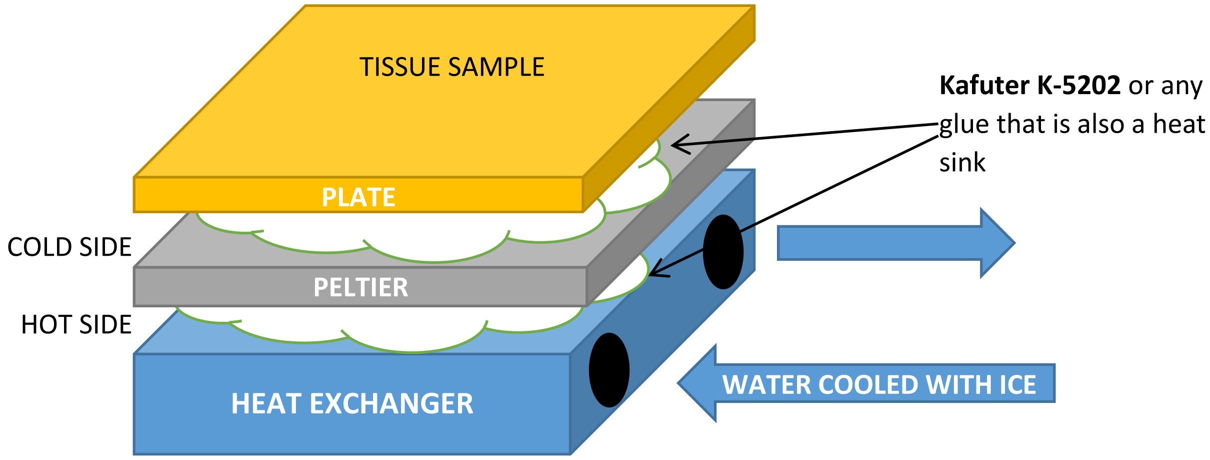

In the following figure you can see the diagram of the cooling system