*Nové metody a postupy v oblasti přístrojové techniky, automatického řízení a informatiky*
*Ústav přístrojové a řídicí techniky ČVUT v Praze*
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# ZAŘÍZENÍ PRO PÁJENÍ V PARÁCH S PELTIEROVÝMI ČLÁNKY

# Device for Vzpour Phase Soldering with Peltier Heaters

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***Abstrakt***: A system using peltier heater is provided for vapour phase soldering of components on PCB, system with increasing heating and cooling speed of the components and PCB lands that are to be soldered together. Vapour phase soldering (VPS) uses the latent heat of liquid vaporization to provide heat for soldering. This latent heat is released as the vapour of the inert liquid condenses on components and PCB lands. The peak soldering temperature is the boiling temperature of the inert liquid at atmospheric pressure.

***Key words***: Vapour Phase Soldering, Solder Paste, Peltier Elements

## 1. Introduction

Soldering is a process of joining metallic surfaces with solder, without the melting of the base materials. The two metallic parts are joined by a molten filler metal. Vapour phase soldering (VPS), also known as condensation soldering, has gone through changes in popularity. It was the process of choice in the early 1980s [1]. VPS uses the latent heat of liquid vaporization to provide heat for soldering. This latent heat is released as the vapour of the inert liquid condenses on component leads and PCB lands. In VPS, the liquid produces a dense, saturated vapour that displaces air and moisture. The temperature of the saturated vapour zone is the same as the boiling point of the vapour phase liquid. This fluid does not have any known environmental concerns. The peak soldering temperature is the boiling temperature of the inert liquid at atmospheric pressure. VPS does heats uniformly, and no part on the board (irrespective of its geometry) exceeds the fluid-boiling temperature. The process is suitable for soldering odd-shaped parts, flexible circuits, pins, and connectors, as well as for reflowing tin/lead and lead-free surface mount package leads. As VPS is heating uniformly the components and board, the components can not be overheated (the maximal achievable temperature is the temperature of the vapour). This prevents component and board damage by high temperature and can lead to higher reliability of the soldered device.

## 2. Requirements of the device

A solder reflow process follows an optimized temperature profile to prevent the board from experiencing high thermal stresses while it is undergoing reflow. A typical reflow temperature profile would consist of the following steps:

- Preheat, which consists of gradually ramping up the temperature to the preheat zone temperature at which the solvents will be evaporated from the solder paste;
- Flux Activation, which consists of bringing the dehydrated solder paste to a temperature at which it is chemically activated, allowing it to react with and remove surface oxides and contaminants;
- Actual Reflow, which consists of ramping up the temperature to the point at which the solder alloy content of the solder paste melts, causing the solder to sufficiently wet the interconnection surfaces of both the SMD's and the board and form the required solder fillet between the two; the peak reflow temperature should be significantly higher than the solder alloy's melting point to ensure good wetting, but not so high that damage to the components is caused; and
- Cold down, which consists of ramping down the temperature at optimum speed (fast enough to form small grains that lead to higher fatigue resistance, but slow enough to prevent thermo-mechanical damage to the components) until the solder becomes solid again, forming good metallurgical bonds between the components and the board.

The reflow temperatures required by Pb-free board assemblies are higher than those required by non-Pb-free boards, mainly because Pb-free solders generally have higher melting temperatures than Pb-Sn solders. As such, the optimization of the reflow profile is more critical in Pb-free assemblies with regard to preventing the occurrence of package cracking in the surface mount components on the board [2].

Table 1 Requirements of device

| Profile feature | PB-free Assembly |
|---|---|
| Average ram up rate | $3C^0$/ second max |
| Preheat<br>Temperature Mn ($t_{smin}$)<br>Temperature Mmax ($t_{smax}$)<br>Time (Tmin to tmax) | <br>$150^0$C<br>$200^0$C<br>60-180 second |
| Time maintained aboard<br>Temperature (lt)<br>Time (lt) | <br>$220^o$C<br>60-150 second |
| Time Peak temperature (tp) | 20-40 second |
| Ramp-Down rate | $6^0$C/ second max |
| Time from $6^0$C to peak | 8 minute max |

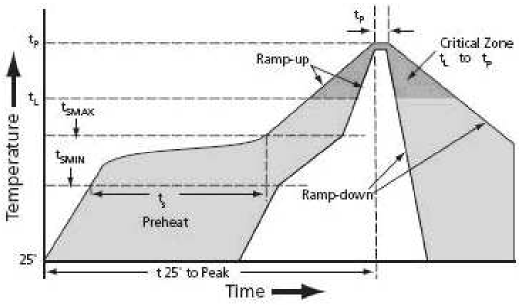


*Fig. 1 Lead free reflow profile*

## 3. Automated soldering device with resistence heater

The major parts of this oven are the Soldering Tank, Main frame, Electric Heater, Temperature Sensor, Temperature Indicator, Cooling Device, and Controller. This project concentrated to design and to manufacture the device consisting of these parts above except the cooling device.

*Fig 2 Real device picture*

## 4. Test results with resistive heating

The cooling was done by adding some specific amount of cool liquid to the tank. First we added 100ml liquid and then 150ml of the liquid. The results with this type of cooling are shown in figure 4.

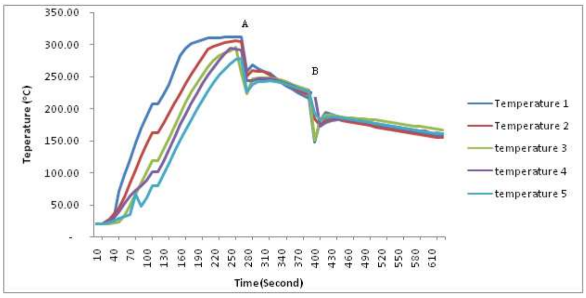


*Fig. 3 Temperature graphs. A is the first time cooling, B is the second time cooling*

Soldering device with resistance heater increases quickly the temperature of the liquid to the peak temperature. It is easy to built device. But for this device it is difficult to control the increase of temperature as there is a large amount of accumulated energy even when the hearer is switched off. The increase of temperature caused by this thermal inertia is clearly seen in the measured temperature profile. The biggest problem however of this type of construction is the necessity to have a separate device for cooling. For this reasons, we abandoned resistive heating and designed the device with Peltier elements.

## 5. Soldering device with peltier heater

Peltier element is a thermoelectric element consisting of semiconductor materials paired to accomplish heating or cooling processes as a result of peltier effect. If a voltage is placed on a Peltier element, one side is cooled and the opposite side simultaneously heats up. Simply by reversing the polarity of the supply voltage, the hot and cold sites of the Peltier element can be swapped [4].

Peltier element can be used in single or cascade combination. The elements are arranged to fit the needs. In this project, the elements are interconnected in series and parallel constructing a cascading layer of peltier element. Each element and combination in any layer need to be controlled precisely regarding the temperature curve.

## 6. Structure of soldering device with Peltier heater

This soldering device uses HB TEC1-12710. This device uses 5 layers peltier. As we keep the temperature on the bottom layer equal environment so the average delta T on 1 layer is:

$(220-20)/5= 40^{o}\,C$

The current for each layer is controlled independently.

Table: 2 Peltier HB TEC1-12710

| Performance Specifications | | |
|---|---|---|
| Hot Side Temperature (ºC) | 25ºC | 50ºC |
| Qmax (Watts) | 85 | 96 |
| Delta Tmax (ºC) | 66 | 75 |
| Imax (Amps) | 10.5 | 10.5 |
| Vmax (Volts) | 15.2 | 17.4 |
| Module Resistance (Ohms) | 1.08 | 1.24 |
| | | |

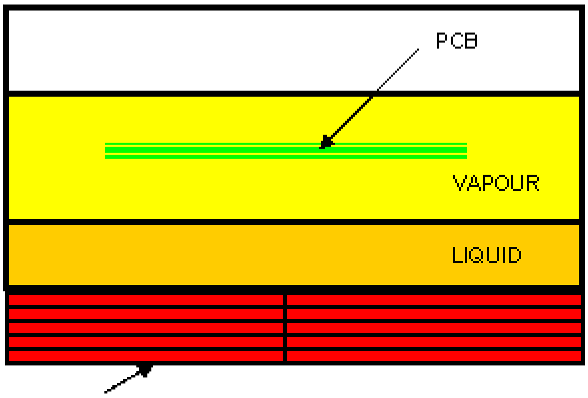


*Fig. 4 Structure soldering device with peltier heater*

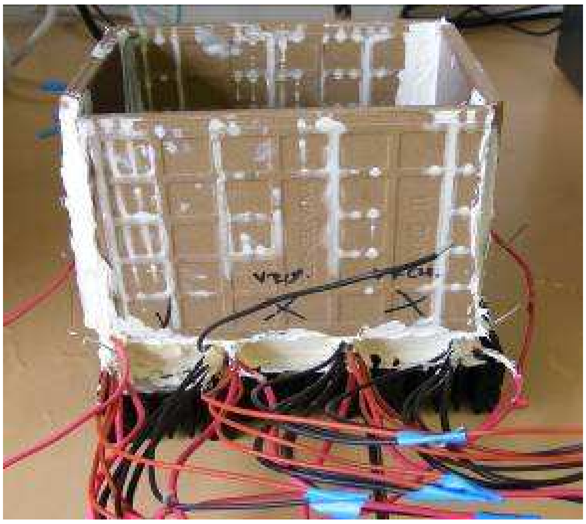

*Fig. 5 Real device picture*

## 7. Test results

We ran the test with 5mm thick liquid, the average current was from 10A to 12A, and then the current was reversed at the peak temperature to start cooling.

Control of the current was independent for each layer. During liquid heating, the current was increased from the bottom layer to the top layer, during cooling down of the liquid; the current was decreased from bottom layer to the top layer. The measured results are shown in figure 11. As the used peltier elements had endurance only to 230°C, the measurement was stopped at temperature around 170°C.

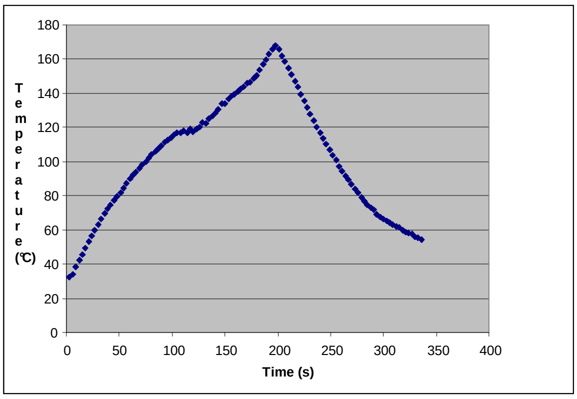


*Fig 6 Temperature profile*

## 8. Conclusions

Soldering device with peltier heater solves the problem of resistance heater (high temperature inertia). As it can be seen from the obtained temperature profile, this construction is able to achieve very rapid heating and cooling of the liquid. As this device is supposed to be used for soldering in laboratory or small development team environments, the necessity is to have the soldering process as fast as possible but by maintaining the components manufacturers recommended reflow process. By controlling the peltier elements currents, it is easy to control the temperature profile. But, the biggest advantage of this type of construction is the removal of the temperature inertia and of the second necessary device used only for cooling. On the other hand, compared to resistive heating, as the peltier elements are more expensive, the price of the device is higher. Also, high temperature peltier elements are not easily available yet today. According to manufacturer information's, some of them are developing high temperature elements capable to endure up to 250°C, some have them already available. Our goal for the near future is to test these high temperature types and to get the device operational for lead free soldering process with temperatures up to 240°C.

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