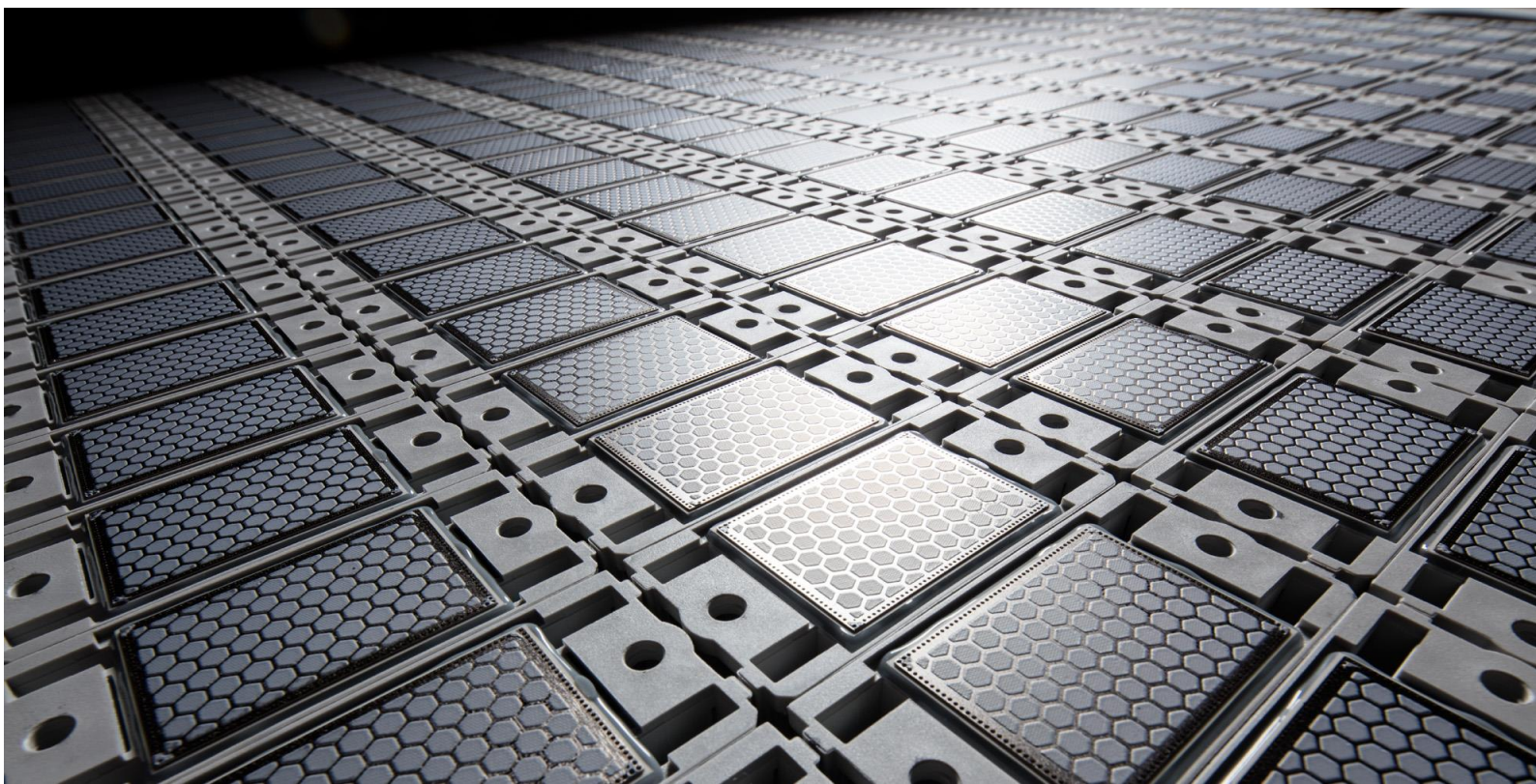


# Power modules with phase-change material



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## Revision History

<b>Date</b>	<b>Revision Level</b>	<b>Description</b>	<b>Page Number(s)</b>
July 2012	1	First release	9 pages
April 2016	2	Added module constructions	12 pages
May 2019	3	Added allowed PCM layer damages section Temperature stability	13 pages
November 2020	4	Added PTM6000; storage conditions; imprint pattern	15 pages

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## 1 Abstract

There are several advantages to using phase-change material (PCM) rather than conventional thermal grease as thermal interface material (TIM) between the power module and heatsink. Vincotech offers modules with a layer of pre-applied PCM. The thermal interface material is applied in a layer with uniform thickness by a screen- or stencil printing process. This document describes the benefits of this phase-change material and provides tips on handling modules.

## 2 Introduction

Heat has to be transferred from the module to the heatsink and thermal interface material is a necessary evil that gets the job done. However, thermal resistance increases if the layer is too thin or thick. Vincotech has addressed this issue by supporting modules with a pre-applied layer of phase-change material. The module's size and technology determine the layer's thickness.

The phase-change material is solid at room temperature, so it requires no special care during transportation, handling and application. Because of its thixotropic consistency, the material softens but does not flow when heated during soldering. The surface needs protection only if the power module's phase-change material comes into contact with other objects during or directly after soldering, for example, the soldering oven's carpet. The printing process is precise, thereby maximizing heat-transfer capability.

The customer is spared the task of applying thermal interface material, thereby saving time and reducing the failure risk.

### 3 The phase-change material

Vincotech uses Loctite PSX-P7 and Honeywell PTM6000 phase-change material. They have the advantage that it can be applied by screen or stencil printing. It is fluid during the application and dries out over time and temperature. Once the phase-change material solidifies, the module may be handled like any conventional module. Key benefits include:

- Faster, easier module mounting
- Optimum thickness of the thermal interface material
- Improved  $R_{th}$  and reduced risk of DBC cracking
- Streamlined production; no need for screen-printing facilities
- Automated screen printing for utmost reliability
- No risk of smearing thermal paste; material is solid at room temperature
- Standard solder profile applicable (e.g. J-STD-001, J-STD-003)
- Compatible with Press-fit pins

The table below lists the phase-change material's physical and thermal properties. Please refer to the manufacturer's datasheet for more details.

<b>Loctite PSX-P7 (Loctite TCP 4000 Pm)</b>		
Parameter	Value	Unit
Specific gravity	2	g/cm <sup>2</sup>
Thermal conductivity	3.4	W/m*K
Phase-change temperature	45	°C
Continuous operation temperature limit	105	°C
Viscosity above phase-change temperature	Thixotropic	
Color	Grey	

*Table 1: Physical and thermal properties of Loctite PSX-P7*

<b>Honeywell PTM6000</b>		
Parameter	Value	Unit
Specific gravity	2.3	g/cm <sup>2</sup>
Thermal conductivity	4.4	W/m*K
Phase-change temperature	45	°C
Continuous operation temperature limit	150	°C
Viscosity above phase-change temperature	Thixotropic	
Color	Grey	

*Table 2: Physical and thermal properties of Honeywell PTM6000*

## 4 Vincotech modules with pre-applied PCM

Vincotech offers modules with a pre-applied layer of phase-change material as indicated on the specific product detail page on the website. All modules are UL-listed; therefore modules with phase-change material are also UL-approved. They come in a standard blister box with a protective lid.

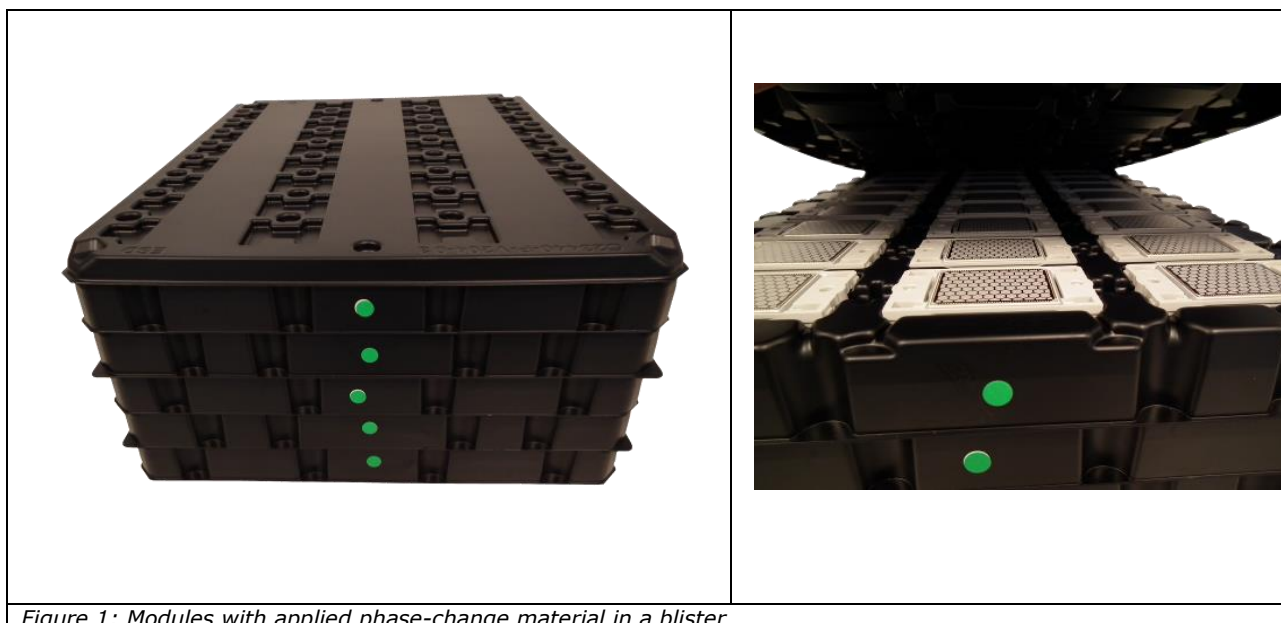


Figure 1: Modules with applied phase-change material in a blister

Modules must be stored in blister boxes under the following conditions:

- Temperature:  $5\text{ }^{\circ}\text{C} < T < 40\text{ }^{\circ}\text{C}$
- Relative humidity:  $10\text{ \%} < rH < 85\text{ \%}$

The shelf-life of the applied TIM is 1 year. After the expiration the TIM have to be removed and reapplied before the module installed into the application. It is recommended to use the modules according to the FIFO method.

This compound was subjected to a battery of tests to verify its reliability.



Test	Test parameters	Acceptance criteria
<b>Temperature cycle</b> IEC 60068-2-14	-40°C (30min); +150°C (30min); 100 cycles; max. paste thickness	No ceramic cracking is allowed
R <sub>th</sub> measurement + <b>High temperature storage</b> IEC 60749-6 + R <sub>th</sub> measurement	1000h; @T <sub>operation</sub> temperature limit	R <sub>th</sub> increment <20%
R <sub>th</sub> measurement + <b>High temperature high humidity storage</b> IEC 60749-42 + R <sub>th</sub> measurement	1000h; @Ts=85°;@Rh=85%;	R <sub>th</sub> increment <20%
<b>Power cycles min.</b> EN 60749-34	$\Delta T=70^{\circ}\text{C}$ ; T <sub>vj</sub> =150°C; ton=2min	Min 20k cycles R <sub>th</sub> increment <20%
<b>Paste distribution</b>	Screw down the module with minimal paste thickness acc. to HI	Proper paste distribution (see Section 9)
<i>Table 3: Qualification procedure for TIM</i>		

All modules had phase-change material applied and were mounted vertically to an aluminum heatsink for these tests.

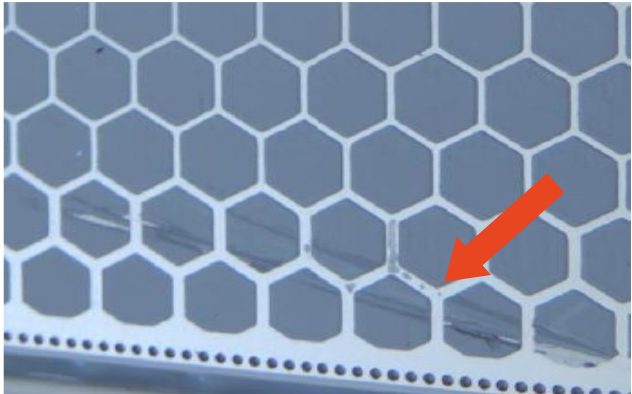
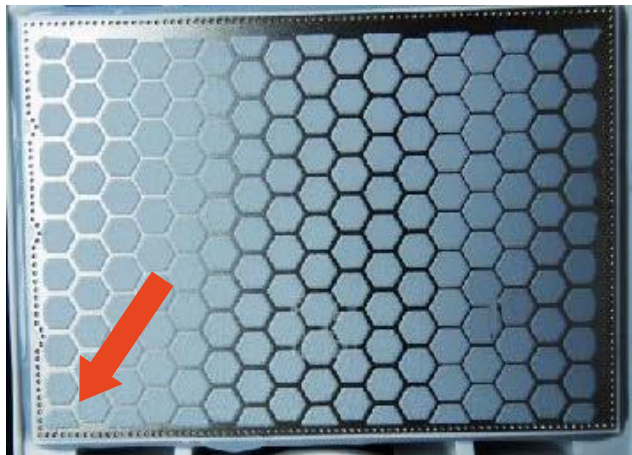
The recommended PCM pattern may be downloaded from Vincotech's website under the specific product detail page.




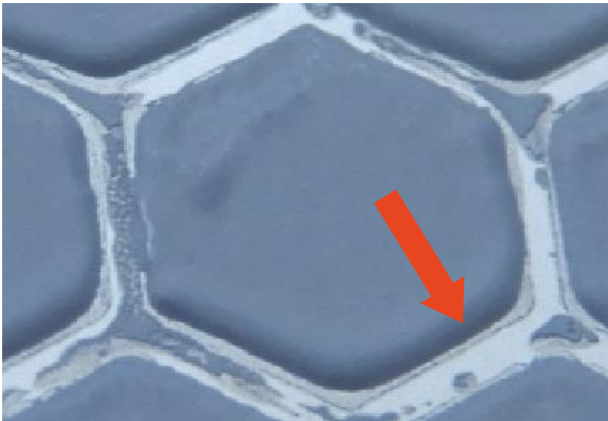
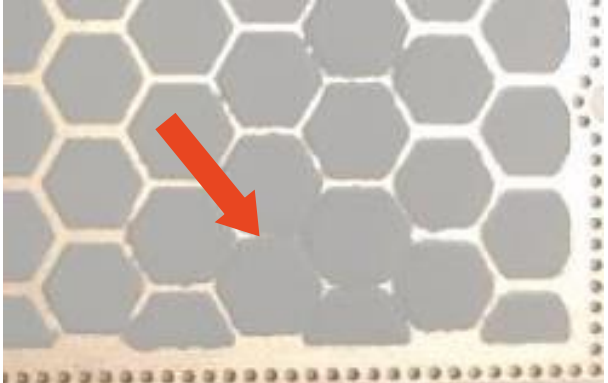
Figure 2: Pattern after screen printing

## 5 Allowed deviations of PCM layer

During handling deviations may occur. These deviation of the Phase-Change Material (PCM) layer has no negative influence on the thermal performance or the expected lifetime of the material and module, also no impact on the assembly of modules.

<p><b>Scratches</b></p> <p>Where a portion of the material is dislocated can be tolerated, if the width of one scratch does not exceed the distance of the honeycombs.</p>	 <p>Acceptable scratch with material dislocation</p>
<p><b>Shifted pattern</b></p> <p>X and Y shift of the pattern maximum up to the line of dimples on the bottom copper side of DCB.</p>	 <p>Shifted pattern</p>



<p><b>Foreign material in PCM</b></p> <p>Cloth fiber allowed.</p> <p>Hard materials not exceeding 70% of the TIM thickness.</p>	 <p>Foreign material in PCM</p>
<p><b>Ridge on honeycomb</b></p> <p>A local height maximum on a single honeycomb. Upon contact with surface the ridges are pushed down easy as the PCM material is soft and malleable even at room temperature.</p>	 <p>Ridge on honeycomb</p>
<p><b>Paste between honeycomb / honeycomb flow together</b></p>	 <p>Honeycomb flow together</p>

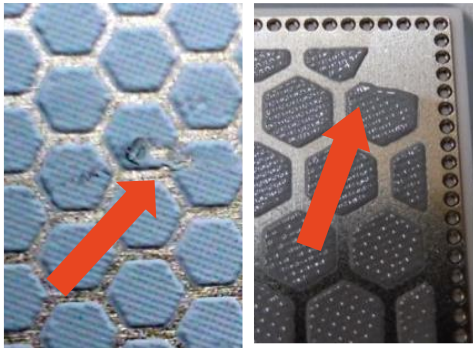
<p><b>Incomplete honeycomb</b></p> <p>It only can be accepted if no more than 1/2 of a single honeycomb is missing.</p>	 <p>Incomplete honeycomb</p>
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Figure 3: Examples of allowed deviations of PCM layer

Any of the deviation listed in the table is allowed in any combinations and multiple occurrence.

In any case the pre-applied PCM is damaged, there is no proper way to repair it. The module should be returned to Vincotech and/or a new layer of thermal interface material has to be applied.

## 6 Mounting / assembly

The module can be mounted to the heatsink after it has been soldered or pressed in. The procedure is the same as the standard mounting process described in the housing specifications or handling instructions, apart from one major difference: Screws to the heatsink can be fastened and tightened in a single step. The phase-change material is solid at room temperature, so screws can be tightened immediately without having to give the material any relaxation time.

Pictured below is a module with melted phase-change material assembled to an inspection block.

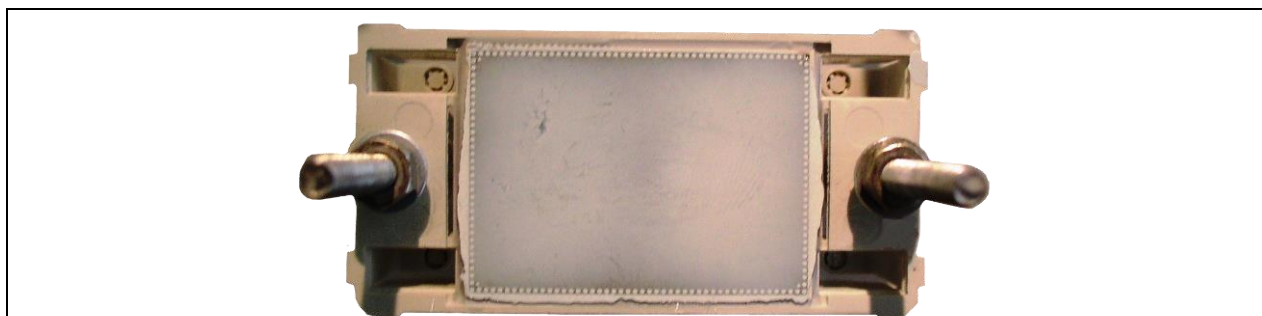


Figure 4: Module assembled to an inspection block

Please refer to each module's handling instructions to learn more about the heatsink properties, mounting and handling.

## 7 Operation

Upon initial start-up, the  $R_{th}$  between the junction and the heatsink of a system without soft material will be 10 % to 15 % higher than that of an operating system; that is, a system where the module is operating a temperature higher than 45 °C and the phase-change material has attained its ultimate thickness. The higher  $R_{th}$  is not a problem because the heatsink temperature is below 45 °C to 50 °C, a state at which chips cannot overheat. Time-to-melt is a function of temperature and the speed of temperature change. The material will not flow unless heat and force are applied.

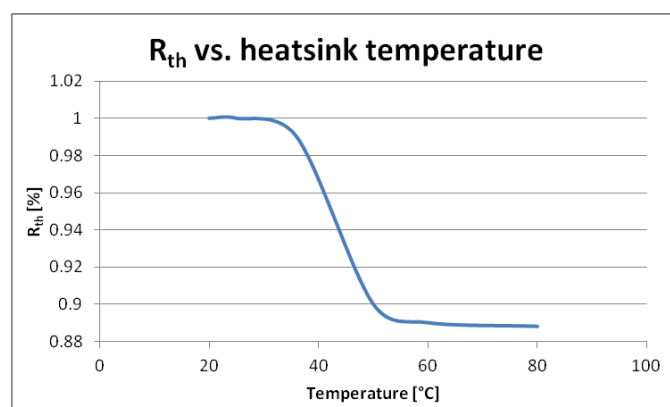


Figure 5: Thermal resistance versus heatsink temperature

Once the module has been mounted, the system should be heated up (e.g. during the system's burn-in test) while leaving enough time for the phase-change material to melt. If the temperature of the PCM exceeds 45 °C, the material will melt, fill gaps and after a short time provide an optimal thermal connection between the module and heatsink. Screws do not have to be tightened again.

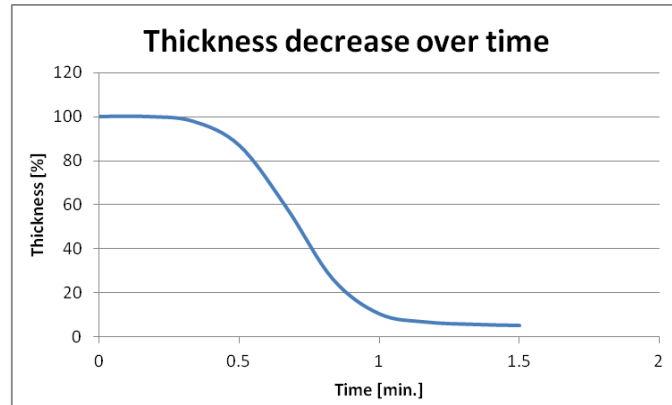


Figure 6: Decrease in thickness over time

The above curve shows how thickness decreases as the heatsink temperature increases at a rate of 15 K/min. with the temperature starting at 35 °C. The force applied to the phase-change material was around 100 kPa, which is below the flow modules' pressure handling capability and therefore leaves a margin for safety.

The phase-change material returns to its solid state when the temperature drops below 45 °C. This means the material's phase changes every time it reaches 45 °C.

## 8 Disassembly / reuse

No special care has to be taken when removing the module from the heatsink. Simply loosen the screws and use a knife to lift the module from the heatsink. Standard isopropyl or other alcohol with similar properties may be used to clean the back of the module and the heatsink. A non-woven antistatic microfiber cloth is best for this purpose. It is not advisable to reuse the module without cleaning it first.

The picture below shows a disassembled module that had been in operation and its heatsink print.

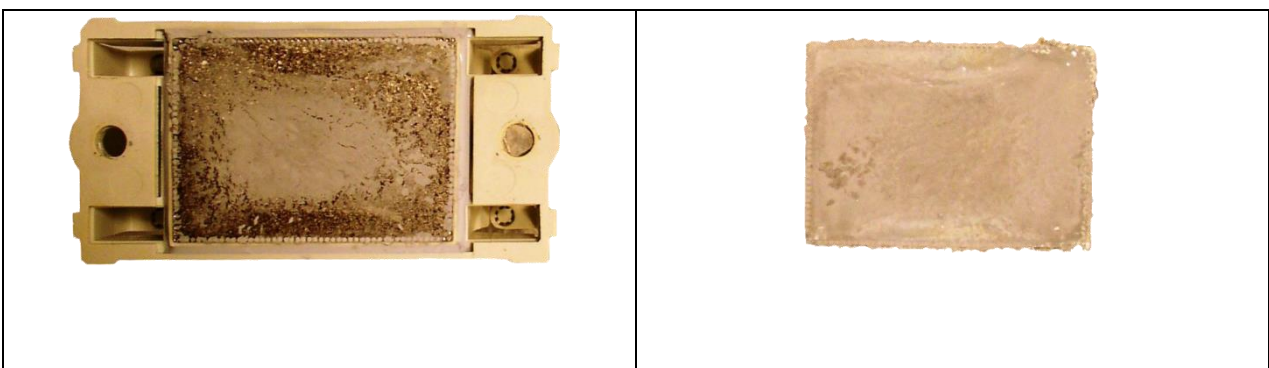


Figure 7: Disassembled module and its heatsink print

Standard thermal grease or phase-change material described above can be applied before the module is remounted.

## 9 Evaluation of imprint pattern

- Mount the module to the heat sink according to the specifications described in the Handling Instruction.
- Perform 4 thermal cycles on the module in order to give possibility to the thermal interface material to melt, spread and distribute under the module. During the thermal cycles the TIM should achieve 80 °C at the hot cycle and 20 °C at the cold cycle. The cycles dwell time should be 20 minutes.
- Dismount the module by releasing the screws and carefully remove it from the heat sink.
- Check the imprint pattern on the module backside surface and the heat sink top surface as well.


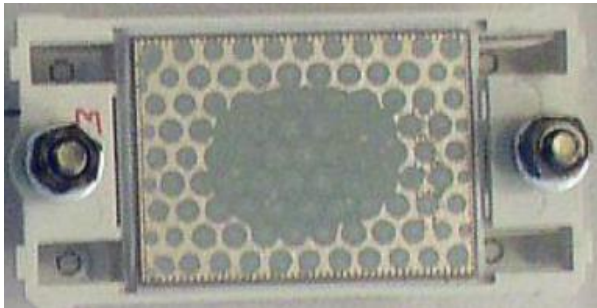


Acceptable imprint deviations	Non-acceptable imprint deviations
	
	

Figure 8: Imprint deviations



The acceptable imprint deviations supposed to totally disappear and the distribution of the TIM material improves after further thermal cycles. When the imprint pattern shows insufficient interconnection between the module and the heat sink, it is mostly related to some deviation to the heat sink surface specification. (see in Handling Instruction)

## 10 Labeling and marking

All Vincotech modules come in a carton. The suffixes on the label indicates that it contains modules with pre-applied phase-change material:

- -/3/ - Loctite PSX-P7
- -/7/ - Honeywell PTM6000



Figure 9: Label on carton

The part number printed on the module does not indicate that these modules come with phase-change material pre-applied.

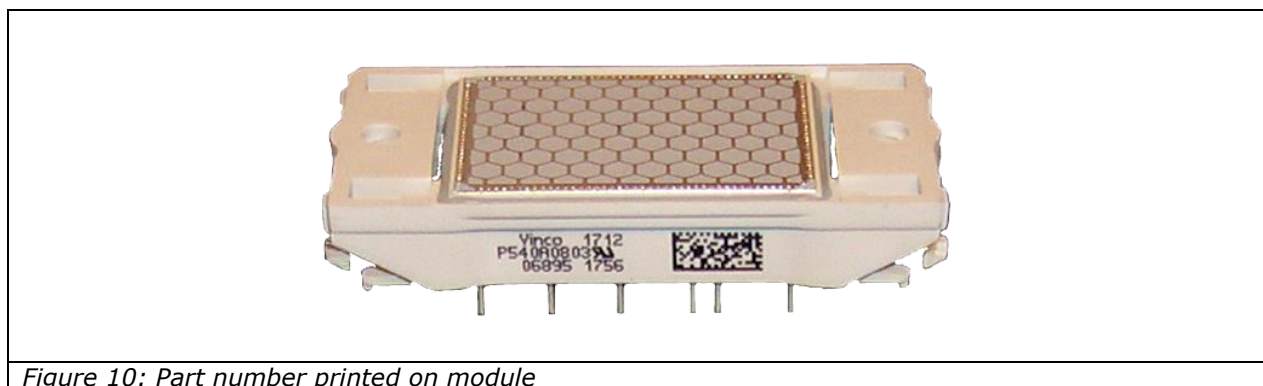


Figure 10: Part number printed on module

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The “03” prefix to the RoHS indicates that this module is in revision status 03, and has no bearing on whether or not it comes with pre-applied phase-change material.

## 11 Conclusion

Vincotech offers modules with pre-applied phase-change material. This PCM is applied in a screen-printing process that leaves an optimum and always consistent layer thickness. This phase-change material is thixotropic and therefore will not flow without the application of pressure. Standard soldering profiles may be used. A lid or a foil can prevent the phase-change material’s surface from coming into contact with the soldering oven’s carpet.

Power modules with Press-fit pins and phase-change material are compatible. Please refer to the module’s handling instructions to learn more about this.