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Characterization of Electronic Cooling Solution and Thermal Interface Material using Thermal Test Vehicle

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INTRODUCTION:

Increasing the power density of chips with small footprints requires to cool down device within the expected range of temperature. Otherwise it can cause chips to malfunction or to burn under extreme condition. This scenario poses challenges to the performance and reliability of cooling solutions like Heatsink, Liquid Cooling, Heat pipe etc. (combined with Thermal Interface Material).

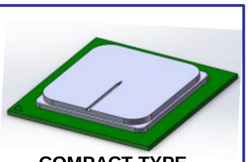
APPROACH:

To qualify and characterize these cooling solutions, a dummy chip is required to act as a heat source. Our goal is to create a package which mimics the actual chip to be tested. This would give us an idea on the thermal performance of customer chip under different test condition.

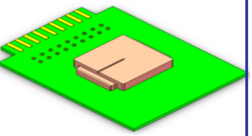
Thermal Test Vehicle (TTV) is the best tool to use in this case. It consists of two main elements:
1-Highly doped resistors which act as a heater to power up the chip.
2-Thermal sensors with Diodes to sense and measure the temperature.

There are two different types of Thermal Test Vehicle available; one is Compact type and another one is Configurable type.
Pros/Cons of Compact TTV: Small in size with Heating power limited up-to 2 digits. No option to measure Junction Temperature.
Pros/Cons of Configurable TTV: Bigger in size with Heating power up-to 3 digits. Configurable to generate different heat flux. Measurement option is available for Junction Temperature, if calibrated properly.

Thermal Test Vehicle

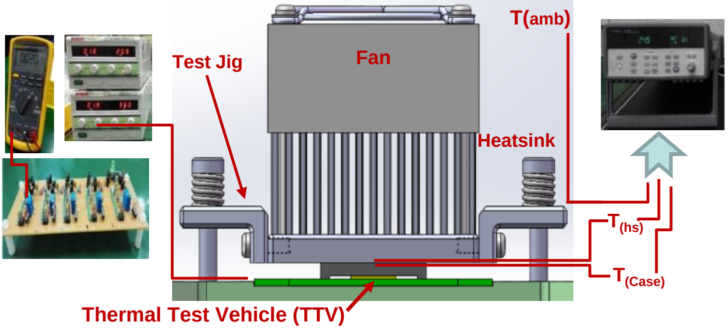


COMPACT TYPE
(LOW POWER)



CONFIGURABLE TYPE
(LOW/HIGH POWER)

Test Setup for Thermal Characterization



CALIBRATION FOR THERMAL TEST VEHICLE (TTV):

It is recommended to calibrate Thermal Test Vehicle prior to test. A controlled environment test chamber is required to calibrate TTV over a range of temperature. Two common methods use to calibrate TTV are:

1- Four (4)-wire Resistance Calibration

2- Diode Calibration

COOLING SOLUTION CHARACTERIZATION:

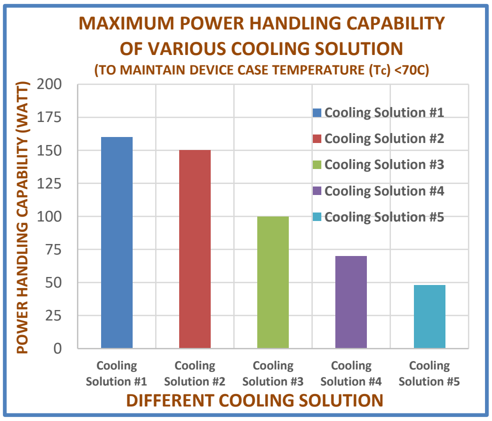
To characterize a cooling solution (example a fan heatsink), the solution is placed onto the surface of the TTV. Power is applied to the TTV to heat up to a certain required level with proper set-up (example with Compression Jig). The surface of the 'package metal casing' and 'Heatsink base' are to be attached with a thermocouple for measurement of temperature. To calculate the thermal resistance of the cooling solution used, measure the heatsink to ambient temperature difference and divide by the power applied.

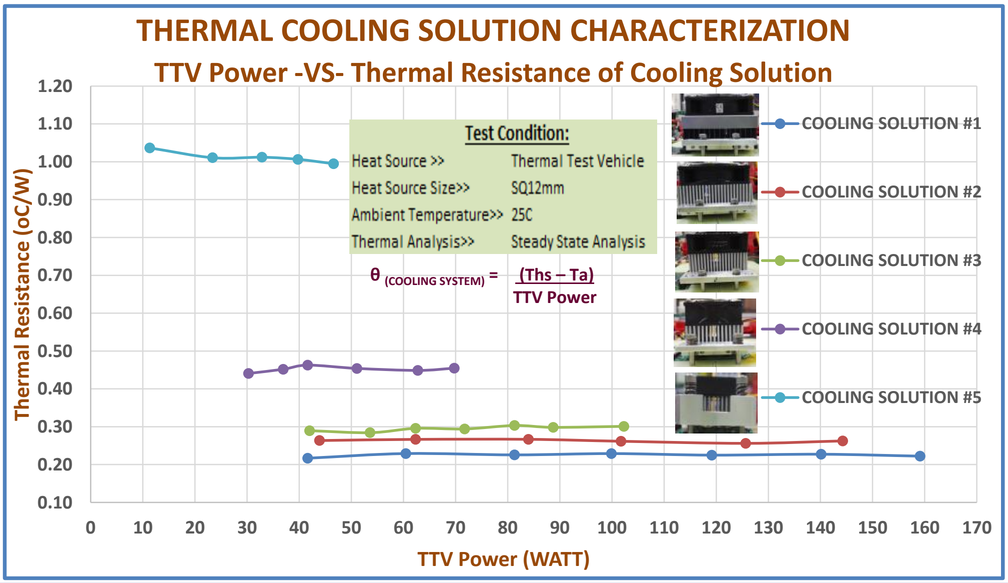
Using this method, you can estimate:

- Thermal Resistance of cooling solution
- Power handling capability of cooling solution to maintain maximum allowable temperature at device case or junction.

The graph on the right shows Power Handling Capability of cooling solution to maintain device case temperature at <70^{o}C.

The graph below shows thermal resistance of different cooling solution over a range of power applied.



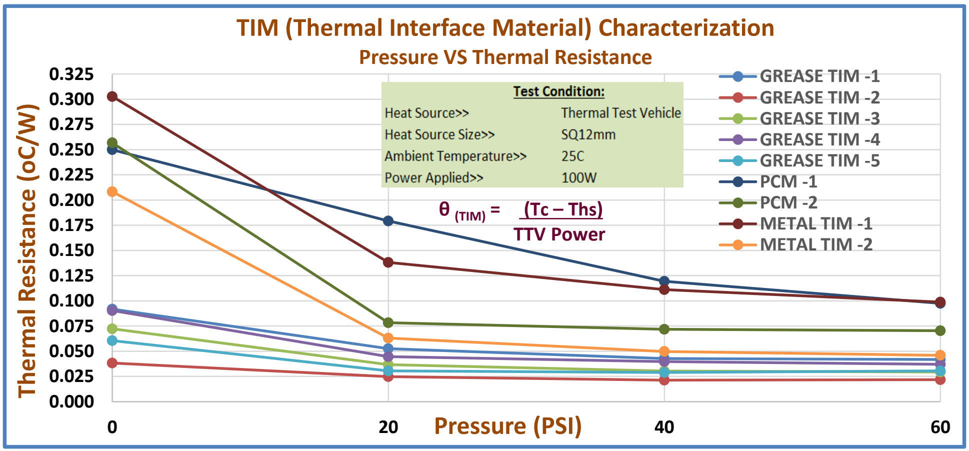


THERMAL INTERFACE MATERIAL (TIM) CHARACTERIZATION

TIM is placed between the TTV surface and the cooling solution, where the temperature is measured by connecting a thermocouple at the bottom of the cooling solution and heat spreader. Calculate the temperature difference and divide by power, will evaluate TIM thermal resistance for that specific pressure. It is recommended to refer to the TIM datasheet to check how much pressure/force is required to get optimum performance.

Below result is shown for reference. The Chart concludes:

- That by applying proper compression on TIM, performance can be optimized.
- TIM selection would be more easier if tested on the same platform under same test condition.



TIM TYPE	Thermal Resistance (C/W) of TIM at Different Pressure			
	No Pressure	20 PSI	40 PSI	60 PSI
GREASE TIM -1	0.092	0.053	0.043	0.042
GREASE TIM -2	0.038	0.025	0.021	0.022
GREASE TIM -3	0.072	0.037	0.030	0.029
GREASE TIM -4	0.090	0.045	0.040	0.037
GREASE TIM -5	0.060	0.030	0.029	0.030
METAL TIM -1	0.303	0.138	0.111	0.099
METAL TIM -2	0.208	0.063	0.050	0.046
PCM -1	0.250	0.179	0.119	0.097
PCM -2	0.257	0.078	0.072	0.070

CONCLUSION:

- Thermal Test Vehicle is an inexpensive way to estimate the thermal performance of your cooling solution/system .
- Dedicated test chips coupled with validated models can be used to understand temperature distribution and heat transfer characteristics.
- Measurements and simulation models are compared to see offset differences.
- The value of the test chip and validation will become even more evident as more experiments are performed on the samples. If tested properly, you are ready to produce a COOLING SOLUTION AT THE RIGHT TIME, AND AT THE RIGHT COST!