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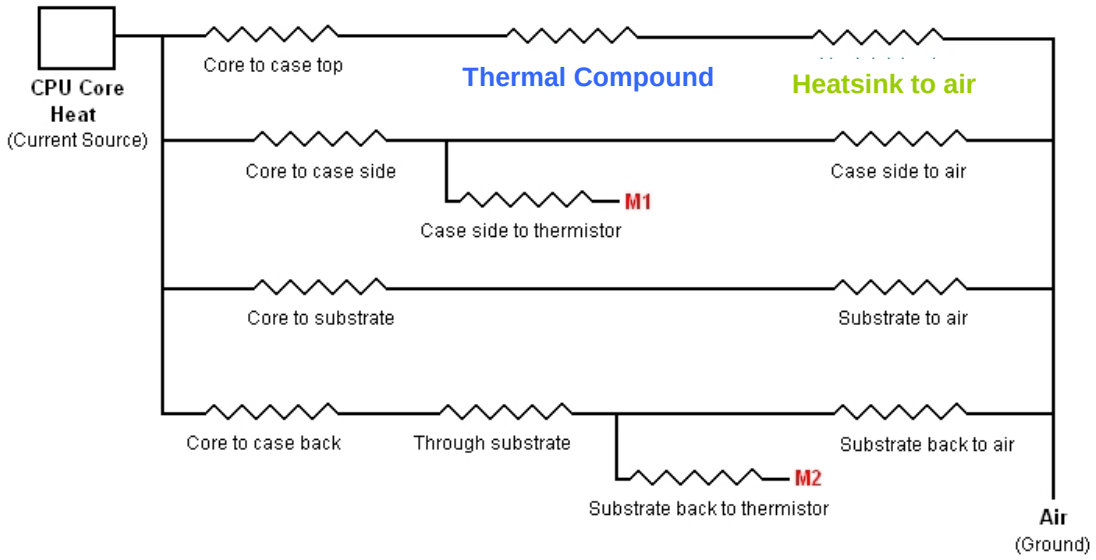
Technical Papers and Publications

Why Many Thermal Measurements Are Not Valid

A common mistake when attempting to measure the effectiveness of a thermal compound or heatsink is the assumption that the primary thermal path…through the case top, through the thermal compound, through the heatsink and to the air…is the only heat path. In fact, there are multiple paths available to the CPU heat. For simplicity, these multiple paths can be illustrated as an electrical circuit with the CPU as the current source, the air as ground, and each component of a path as a resistor.



Many people, including many review sites, attempt to measure and quantify a **Thermal compound** change or **heatsink** change by measuring the side of the CPU case, **M1**, or the back of the CPU case, **M2**. Both these measurement points are in secondary heat paths and are between components that present unknown thermal resistances. While measurements at these points may change some due to changes in the primary heat path, the degree of change will not necessarily be proportional to the actual amount of change in the primary path.

(**M1** and **M2** are also not located in isothermal environments that introduce additional potential for severe measurement error.)

When the primary heatsink path resistance is changed at a constant heat load, the CPU temperature changes because the overall resistance has changed, and it would seem logical that the thermistor temperature at **M1** or **M2** should also

change. But the heat flows in all paths change as a consequence of the resistance change in the primary path, so the thermistor heat path gets a different heat flow while the resistance of that heat path does not change. But for the thermistor temperature to change as much as the CPU temperature changed, the heat flow in that path would have to be the same as before since the temperature drop from CPU to thermistor equals resistance*heat flow, (C/W)*W. Physics and algebra tell us that the thermistor temperature change should not be expected to be the same as the CPU temperature change. Modern Intel CPUs incorporate an internal thermal diode that can be read by a few select motherboards. While this diode and the motherboard circuits are not calibrated and therefore may not display the actual temperature, the error is constant. (I.e. 30 is actually 34, 40 is actually 44, 45 is actually 49.) Since the design goal of a thermal solution is to keep the CPU core within allowable temperatures, Intel's internal diode is the only valid means of comparison between different **heatsinks**, or **thermal compounds**. The diode and motherboard may lie a bit about the actual temperature, but they will tell the same lie every time. So when a **compound** or **heatsink** change results in a 5-degree CPU temperature change you will see a 5-degree change. (Measurements at points M1 or M2 may only show a 1 degree change or a 4 degree change, or no change; it is impossible to predict since the thermal resistances of the preceding and following components in the secondary paths are unknown and the changes to the heat flow of the secondary paths when the primary path's resistance is changed cannot be accurately determined.)