A printed circuit board (PCB) is defined as an item which, "mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate." (definition courtesy of Wikipedia). PCBs may be single- or double-sided, and may have multiple layers. Some have components embedded to allow for complex and advanced circuitry (Figure 1).

Figure 1. An advanced PCB with embedded components visible (Source).

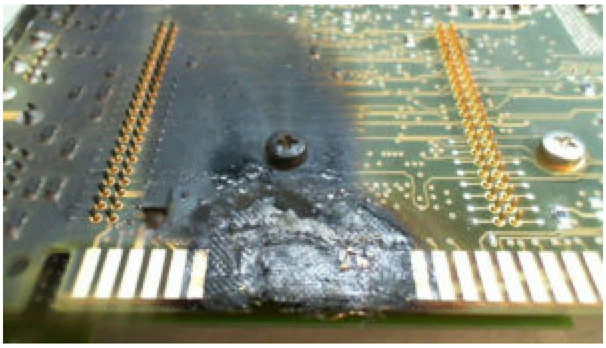


Figure 2. A PCB with a visible failure, caused by overheating. Such a failure can be due to poor thermal management (Source).

Importance of Thermal Conductivity with Printed

Circuit Boards

Heat management is crucial for PCB performance, reliability, and longevity. Inadequate heat management may lead to delamination, damage, or device failure (Figure 2). Thermal conductivity plays a vital role in heat management, and thus it is a key parameter for PCB design. The C-Therm Trident thermal conductivity platform is a useful tool in obtaining rapid, precise, and accurate measurements of PCB component thermal conductivity.

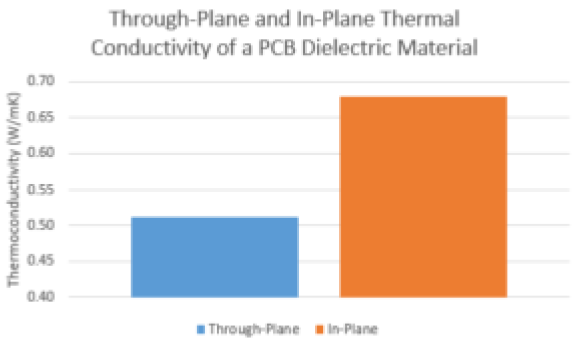
Here, we detail how the C-Therm Technologies TCi sensor may be used to aid in PCB heat management design. This application note comes with a special foreword by Doug Brooks, a PCB design expert, regular contributor to industry publications such as PCB Design 007, and owner of UltraCAD Design, Inc:

For the last 25 years I have owned a printed circuit board (PCB) design service bureau. The "hot" topic in PCB design is high-speed signal integrity. But on another front, PCB designers may be interested in how hot (literally) an individual PCB trace becomes. Trace temperature is directly related to reliability. In the extreme, a trace that is too hot can melt the solder or cause a board to delaminate. But generally we want trace temperatures to be a lot lower than that. For very high reliability applications (e.g. manned space, medical, etc.) we may want to design very conservatively. For consumer products we can be a little more aggressive. For applications in a hot desert (think war time) we may want to know how much heat we have to dissipate through some external means. The trace reaches a stable temperature when the heating of the trace equals the cooling of the trace. The heating of the trace is caused by the I^2R (power) drop across the trace. The cooling of the trace is primarily the result of conduction through the dielectric (board material), and secondarily through convection and radiation. It is only in the last 10 years that the industry has recognized the importance of the dielectric in the trace cooling process. The important material property in trace heating is the resistivity of the trace material (typically copper foil or plating.) Although the *actual* resistivity of a trace is subject to some discussion in the industry, most estimates are that it is between that of pure copper (1.7 µOhm-cm), and about 2.1 µOhm-cm. The important material property in trace cooling is the thermal conductivity (W/mK) in the x,y plane and in the z axis. This can vary significantly between material offerings and even between manufacturers for the same material specification. Moreover, not all manufacturers provide a thermal conductivity specification, particularly in the z-axis. The C-Therm Thermal Conductivity Analyzer can be an important tool in measuring the thermal conductivity of a board material or in verifying that a manufacturer's product meets specification. For more information about the relationships between PCB trace current/temperature see the series of five papers posted at www.ultracad.com (with at least two more coming in future months.)

Douglas Brooks, PresidentUltraCAD Design, Inc. www.ultracad.com

Case Highlight: Testing the Thermal Conductivity of an FR4 PCB Dielectric Material

Samples of an FR4-type PCB dielectric material were obtained as pale yellow rectangular prisms and used as provided. Thermal conductivity was measured using a C-Therm Modified Transient Plane Source (MTPS) technique.



In-plane thermal conductivity of an FR4-type PCB dielectric material

The MTPS technique employs a patented Guard Ring technology which results in a one-directional heat flow and, thus, thermal conductivity measurement. This enables easy measurement of anisotropic materials by positioning the sensor along different surfaces of a material to obtain direct measurement of the thermal conductivity anisotropy.

Through-plane thermal conductivity data was obtained for three samples with three tests of fifteen measurements each. The mean of the three samples was taken and reported as the through-plane thermal conductivity. In all tests, the relative standard deviation was <1%, and across the three samples, the relative standard error was 0.7%. The in-plane thermal conductivity of the bulk material was measured with three tests of five measurements each. Relative standard deviation was 0.6% across three tests for in-plane thermal conductivity.

This work illustrates the importance of obtaining thermal conductivity data along all relevant material axes in the case of materials with anisotropic thermal conductivity – in this case, measuring only the through-plane value would lead to a significant underestimation of the effective thermal conductivity of the PCB dielectric material.