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MATERIALS

Material Selection for Digital Design

by Barry Olney, page 12

Environmental Effects on High-Frequency Material Properties

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PCBs can be subjected to a variety of environmental conditions, which can cause changes in the material and alter how a PCB operates. For those who are less familiar with circuit material properties, there is often an unrealistic expectation that material shouldn't change electrical performance when subjected to different environments. Actually, all circuit materials will change some properties when evaluated within a changing environment. Some properties may change more than others and some materials may have more change than others, but they all do change.

The materials formulated for use in high-frequency PCB applications are formulated so that critical electrical properties have minimal change when subjected to a changing environment. In the material development process, it is always a juggling act to allow some properties to change more so other properties will change less. All engineers typically struggle with difficult tradeoffs on just about any complex engineering task, and it is no different when formulating circuit materials.

One material property which is often overlooked until a field unit failure demands attention is TCDk (thermal coefficient of dielectric constant). This property is innate to all circuit materials; however, materials not formulated for high-frequency applications often have an extremely poor TCDk. Conversely, high-frequency laminates are formulated to have good

ENVIRONMENTAL EFFECTS ON HIGH-FREQUENCY MATERIAL PROPERTIES *continues*

TCDk properties and as a general statement, a good value would be 50 ppm/°C or less and this value would be an absolute value in the mathematical sense. Of course, the closer the material is to zero for TCDk the better.

The comment about a field failure attracting attention to TCDk is valid, because unaware engineers may fine-tune the application in a controlled environment, such as a lab, only to find that it will change electrical performance as the unit goes through normal temperature cycling in the field. TCDk describes how much the material will change dielectric constant with a change in temperature; the TCDk value varies among the different types of high-frequency PCB materials. In general, PTFE-based laminates have excellent electrical performance for loss but suffer from high (poor) TCDk. This is one reason why some PTFE laminates are filled. With the proper filler, the TCDk can be adjusted to a good, low level. For example, a nearly pure PTFE laminate may have a TCDk value of 200 ppm/°C whereas a PTFE laminate with ceramic filler can have a TCDk of 20 ppm/°C.

Satellite applications are sensitive to TCDk. The change in temperature which the PCB is subjected too can be extreme and if the dielectric constant (Dk) changes significantly, the PCB will not operate in the manner for which it was designed. A common material used in satellite applications for its consistent and low TCDk is the Rogers TMM laminate. However, as mentioned earlier, in the formulation process of a material, there are many tradeoffs. The TMM materials are excellent for TCDk properties, but require extra attention during the PCB fabrication process. A good understanding of the PCB manufacturing properties helps fabricators adjust their processing conditions, allowing them to manufacture a robust circuit using these materials.

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Another material property to consider which is related to change in operating environment is TCDf, the temperature coefficient of dissipation factor. This is the property of a laminate where the Df changes with a change in temperature. In many applications, the TCDk is much more important than TCDf but there are some designs which are more sensitive to TCDf. Typically, TCDf is important in PCB configurations where it is critical that loss performance remains consistent. As with TCDk, the TCDf property is often very different when comparing one type of high-frequency circuit material to another.

In general, the materials with high Df values typically have a higher TCDf. As another real-life example, a nearly pure PTFE laminate has a very low Df of about 0.0009 and the TCDf is also low at 20 ppm/°C, as compared to a ceramic filled hydrocarbon laminate where the Df is about 0.004 and has a TCDf of about 50 ppm/°C. Even though 50 ppm/°C is not considered bad, the difference between these material TCDf properties is more than double.

If a designer is not familiar with material attributes, ensuring consistent electrical performance of high-frequency PCBs can be more complicated than expected. Due to this concern, it is always recommended that the designer consult their high-frequency materials manufacturer for advice on proper materials when considering a new design. **PCBDESIGN**

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