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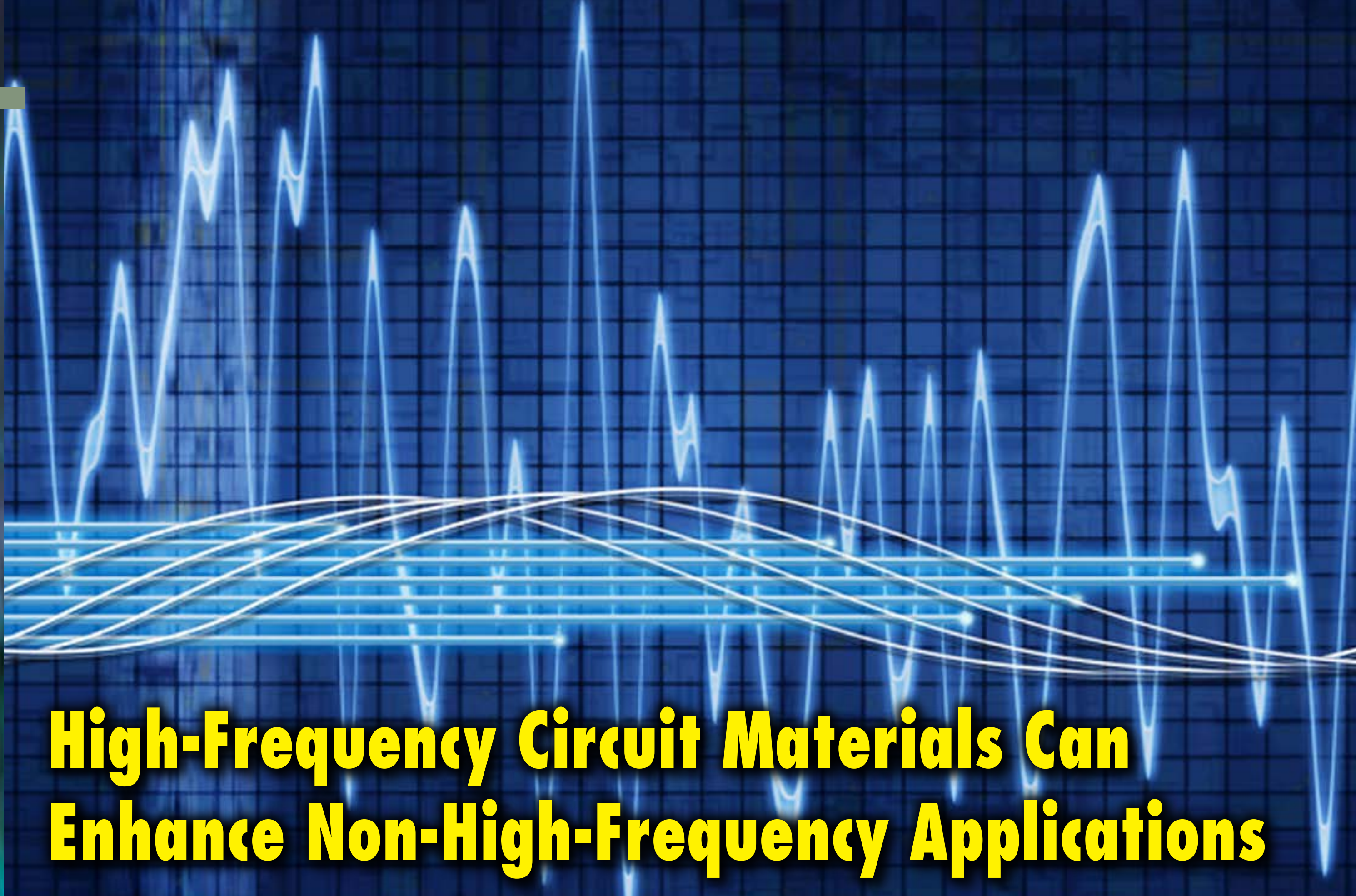

High-Frequency Circuit Materials Can Enhance Non-High-Frequency Applications

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SUMMARY: Creative circuit material selection can greatly benefit some applications that initially might not be associated with those materials. High-frequency circuit laminates feature a number of properties that work well beyond their targeted high-frequency uses.

Circuit materials are available in many varieties, each with unique qualities, benefits, and shortcomings. Flexible circuit materials, for example, offer key properties that are unlike those of rigid circuit board materials. The materials are typically selected for applications based on those properties, even though it can sometimes be advantageous to consider a circuit material associated with one set of applications, for an application where it might not normally be used. For example, high-frequency circuit materials are usually used for radio frequency (RF) circuits, such as wireless communications products, but they can also benefit a great number of lower frequency circuits, such as control and monitoring applications.

One example is a monitoring circuit in a temperature-humidity-controlled electronic product, in which the initial circuit material choice might be FR-4 circuit material. The monitoring circuit will operate at a relatively low temperature, about 300 MHz, and will require tightly controlled impedance to be effective. FR-4 material is attractive because of its low cost, but circuitry fabricated on it was found to exhibit widely variable impedance values during cycling of a temperature-humidity test unit. These changes in impedance were found to be due to one of the FR-4 materials' properties: excessive moisture absorption. Water has a dielectric constant of about 70. When the FR-4 circuit material absorbs water, the moisture content is enough to significantly change the dielectric constant of the circuit material—and the impedance of circuits fabricated on it. In contrast, circuit materials formulated for high-frequency applications exhibit very low moisture absorption, whether used in high-frequency applications or in an application such as this monitoring circuit. In this particular case, the use of a high-frequency circuit material for a low-frequency application can reap impressive performance benefits.

In some cases, the way a circuit is built can have as much bearing on the choice of circuit material as the ways in which the circuit will be used. Multilayer circuit constructions can place challenging physical demands on circuit materials, such as the use of multiple solder reflow cycles. In another application example, circuit material was needed for a high-layer-count circuit board. This construction consisted of 26 circuit layers, with four sequential laminations. Not only was robust circuit material needed for the fabrication process, but to also survive the 6x lead-free-solder reflow cycles for qualification. Of course, for such a multilayer construction, the selection of a low-cost circuit material such as FR-4 can be appealing. But a circuit fabricator who attempted to build this multilayer circuit ran into problems with either the sequential lamination or the multiple solder cycles when using certain circuit materials. These problems were solved through the use of nominally high-frequency circuit materials. Some materials, which are hydrocarbon-based, ceramic-filled circuit materials associated with high-frequency applications, are characterized by rugged thermal properties, such as high glass transition temperature (Tg), high decomposition temperature (Td), and good coefficient of thermal expansion (CTE), which enables them to handle the multiple lead-free soldering cycles of this example application.

Satellites use high-frequency signals, but they also rely on many circuits that are not at high frequencies. One of these circuits is for a deployment arm, which requires a flexible circuit with tightly controlled impedance, even with temperature cycling. Many circuit materials that are geared for lower frequency applications can suffer large shifts in impedance as temperature changes, if the dielectric constant of the material changes with temperature. This circuit material property is known as the temperature coefficient of dielectric constant (TcDk), with higher values indicating greater changes of dielectric constant (and impedance) with temperature. Many common circuit materials have TcDk values in the range of 300 to 400 ppm/°C, which can be a concern for circuits requiring tightly controlled impedance in environments with significantly changing temperatures. In contrast, some high-frequency circuit materials exhibit TcDk values in the range of 30 ppm/°C or less, which translates into very little shift in circuit material dielectric constant with changes in temperature.

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Although the satellite deployment arm is not a high-frequency application, there are benefits to using a high-frequency circuit material with low TcDk value, especially in this application where the impedance must be tightly controlled even with temperature cycling. This example application also required a flexible circuit material, and various high-frequency circuit materials with non-woven-glass reinforcement have shown good performance and reliability in flexible circuit applications. Such a high-frequency laminate should be relatively thin, with the proper copper type, and some non-woven-glass-reinforced polytetrafluoroethylene (PTFE) circuit materials have shown to be a good fit for flexible-circuit applications.

Another application example that might initially be designed around FR-4 circuit material is a 10-MHz high-power divider module. While such a low operating frequency might not normally suggest the use of high-frequency circuit materials, burn-in evaluation of a test circuit revealed some heat transfer problems in using FR-4. When the 10-MHz divider was fabricated on FR-4 and subjected to burn-in testing, the heat transfer from the module to the heat sink, with heat flow through the FR-4 circuit material, was not adequate. The key circuit material property of concern in this case is thermal conductivity: a circuit material with higher thermal conductivity than the FR-4 would transfer heat from the power divider module to the heat sink more efficiently, keeping the circuit cooler. FR-4 circuit materials provide typical thermal conductivity values from 0.20 to 0.25 W/m/K, so that better heat transfer can be achieved by choosing a circuit material with higher thermal conductivity values. As an example, ceramic-filled, high-frequency circuit laminates offer thermal conductivity values in the range of 0.5 to 0.7 W/m/K, or better than twice the thermal conductivity of FR-4. For this application example, the choice of a ceramic-filled, high-frequency circuit material can ensure greatly enhanced heat flow performance for the high-power divider module.

These examples are generic, but meant to illustrate that creative circuit material selection can greatly benefit some applications that might not initially be associated with those materials. High-frequency circuit laminates feature a number of properties that work well beyond their targeted high-frequency uses, and your high-frequency circuit materials supplier can provide valuable guidance when considering materials for new applications. **PCB**

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