This is a topic I have written about a few times, most recently in my August 2017 column, and with good reason. The answer, “it depends,” typically annoys engineers; fortunately, there is a list of items that can help the PCB designer answer the question of when to transition from FR-4 to high-frequency materials.

The bottom line is that FR-4 materials have been around a long time, and they work well within their formulated range. The same can be said for high-frequency circuit materials, which are also thought of as low-loss materials. However, there is a definite gray area that can muddy the waters when a designer is weighing a possible decision to switch from FR-4 to low-loss materials. High-frequency materials also have inherent properties that can benefit some applications that are not related to high frequencies or low loss. The material property differences between FR-4 and high-frequency materials is critical for the designer to understand when considering the use of either material.

It may be a good idea to compare properties of FR-4 to a commonly used high-frequency material. The low-loss material to be considered here is the RO4835 laminate. The FR-4 material that will be examined is a higher-quality, high-Tg FR-4 material. This comparison is mostly meant to trigger a designer’s thought process; there are admittedly exceptions with
these materials and the properties mentioned. Following is my subjective rating as a list of material properties for this comparison in Table 1.

The first item, Dk control (control of dielectric constant property), is very well controlled for high-frequency materials and not so well controlled for FR-4. For applications at lower frequencies, the lack of Dk control is often not a concern, but there are exceptions. Even lower-frequency circuits sometimes need well controlled impedance and having Dk that is tightly controlled can be advantageous for getting better yields with a controlled-impedance board.

Having good control of the Df property for low-frequency applications is typically not a concern. However, when the designer is considering FR-4 for an application where insertion loss is a concern, the inconsistency of FR-4 may preclude the designer from understanding the true limits of that material.

Circuit fabrication can impact the cost of the circuit as well as the consistency of different circuit properties. FR-4 materials are defined very well in the PCB fabrication process and are typically not a concern. The high-frequency material chosen for this example is defined well in the PCB fabrication process, but there are different parameters which must be used for fabricating with this material, and these parameters can make the circuit fabrication costlier.

Because the same FR-4 substrates are often manufactured differently at different manufacturing sites, this can certainly impact the thickness control of the substrate. The lot-to-lot (or within lot) variation of thickness control is typically much worse for FR-4 than for high-frequency materials. But thickness control of the substrate is extremely important to high-frequency designs. High-frequency materials are tightly controlled in the manufacturing process to provide consistent substrate thickness tolerance, because this tolerance has a direct impact on critical high-frequency circuit functions such as impedance, phase response, bandwidth and insertion loss. High-frequency materials with their tightly controlled thickness tolerance help improve yields for controlled-impedance boards, which leads to cost savings.

Moisture absorption is another important aspect to ensure consistent high-frequency performance, which is well defined in the formulation of most high-frequency circuit materials. Moisture absorption for a low-frequency application may or may not be important. In some cases, having a low moisture-absorbing material in a dynamic operating environment may not be an electrical concern. However, it could be a reliability concern. There are low-frequency applications that have no issues with electrical performance, but still utilize a high-frequency circuit material to avoid issues with moisture absorption.

Several applications have a board-mounted chip or device, which generates heat during normal operation. Using high-frequency materials with higher thermal conductivity can minimize thermal management concerns. The typical FR-4 material has a thermal conductivity property of about 0.25 W/m/K as compared to RO4835, which has a thermal conductivity of 0.62 W/m/K. This is a difference of more than 2X, which can certainly have a positive impact on thermal management.

Even with low-frequency circuits, when electrical consistency is required, the thermal coefficient of Dk (TCDk) must be considered. In a nutshell, TCDk is a measurement of how much the Dk of the substrate will change, given a change in temperature. FR-4 materials are not formulated with this property in mind and because of that, it is not uncommon for these

<table>
<thead>
<tr>
<th>Property</th>
<th>FR-4</th>
<th>High-frequency Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dk control</td>
<td>poor</td>
<td>good</td>
</tr>
<tr>
<td>Df control</td>
<td>poor</td>
<td>good</td>
</tr>
<tr>
<td>Circuit fabrication</td>
<td>excellent</td>
<td>moderate</td>
</tr>
<tr>
<td>Thickness control</td>
<td>moderate</td>
<td>good</td>
</tr>
<tr>
<td>Moisture absorption</td>
<td>moderate</td>
<td>excellent</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>poor</td>
<td>excellent</td>
</tr>
<tr>
<td>TCDk</td>
<td>poor</td>
<td>excellent</td>
</tr>
</tbody>
</table>

Table 1: A subjective rating of material properties.
materials to have TCDk values of more than 300 ppm/°C. The general rule of thumb in the high-frequency industry is that the TCDk should not be greater than 50 ppm/°C, which is the TCDk value for the RO4835 laminate.

Aside from the previously mentioned concerns, the tradeoffs between FR-4 and high-frequency materials often comes down to insertion loss differences. Some tricks can be done to get FR-4 to provide better loss performance at higher frequencies. One is to have the FR-4 laminate use a very smooth copper. The surface of the copper that is of concern is the copper surface roughness at the copper-substrate interface. Smooth copper at this interface will reduce the conductor loss, which is a component of the overall insertion loss. Also, if the FR-4 substrate is relatively thin, the conductor effects will be more significant, and the smooth copper will help improve insertion loss. The poor dissipation factor (Df) for FR-4 is really a big issue for insertion loss. In general, a high-Tg FR-4 substrate usually has Df values of 0.015 to 0.025 when tested at 1 GHz, as compared to the high-frequency material in these comparisons, which has a Df value of about 0.0025 at 1 GHz.

Whether or not FR-4 is acceptable for insertion loss will need to be addressed by the PCB designer who is familiar with the limits of the loss budget. Remember that when dealing with the gray area between FR-4 and high-frequency laminates, another choice is available: mid-loss materials. These materials typically have a Df value of 0.005 to 0.015 at 1 GHz and their laminate costs are usually closer to the cost of high-frequency materials costs than FR-4. The Rogers Kappa 438 laminate is considered a mid-loss material. It has a lot of the properties of high-frequency laminates, but it also has a Dk value that is closely matched to FR-4, with a much lower Df than FR-4 that is not as good as that of the RO4835 laminate.

When it’s time to move from FR-4 to a high-frequency material, keep in mind that you always have options.

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**Smart Homes Open New Approaches and Business Models for Healthcare Delivery**

As healthcare shifts to proactive care, a huge market is opening for automation products that can help deliver health and wellness services through smart homes. The ubiquity of broadband connectivity, development of smart sensors, and the decreasing costs of devices have already made it possible to offer aging-in-place, chronic disease management, and post-acute care services in smart homes. However, digital health vendors are striving to take telehealth to the next level by developing solutions that will allow caregivers to check on the health of all the residents of the house, not just the patient’s, monitor diet and nutrition, environment, and be integrable with existing and newer systems.

“Patients are conscious of their health and want to be involved in the wellness and disease management,” said Sowmya Rajagopalan, global program director, Transformational Health. “With consumerization of healthcare, enabling patients to clinically manage their disease at home has been of crucial importance for care providers and OEMs today as they have made this a reality with the launch of innovation in design, devices, services, and solutions.”

Frost & Sullivan’s recent analysis, Vision 2025—Healthcare in the Smart Home, examines the concept of a smart home delivering healthcare. It segments resident profiles and lists the individual needs that are relevant to healthcare delivery in the home.

Source: Frost & Sullivan