Advanced Circuit Materials
High Frequency Laminates and Flexible Circuit Materials

QUESTION:

In which way can the use of RO4350™ High Frequency materials benefit my high speed digital design?

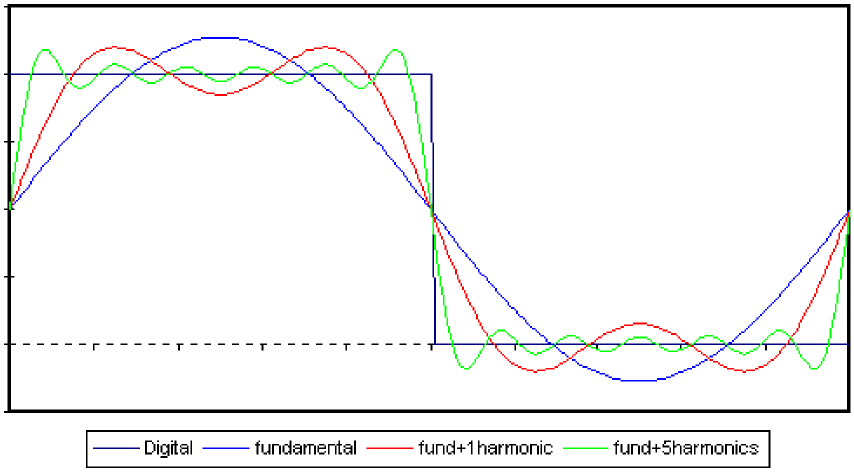
ANSWER:

In order to understand how a digital signal can be affected by the parameters of the circuit board laminate that it travels on, we need to first breakdown the different components of the signal. Using Fourier transformation, we can obtain how a digital signal (square wave) can be represented by a series of sinusoids. This representation can be performed by first finding the signal fundamental and then adding the various harmonics as needed. The equation below represents such transformation;

$$G(t) = \frac{4}{pi}\left(\sin(2wt) + \frac{1}{3}\sin(3wt) + \frac{1}{5}\sin(5wt) + \frac{1}{7}\sin(7wt) + \frac{1}{9}\sin(9wt) + \frac{1}{11}\sin(11wt)\right)$$

where w=2pif (f being the frequency of the signal).

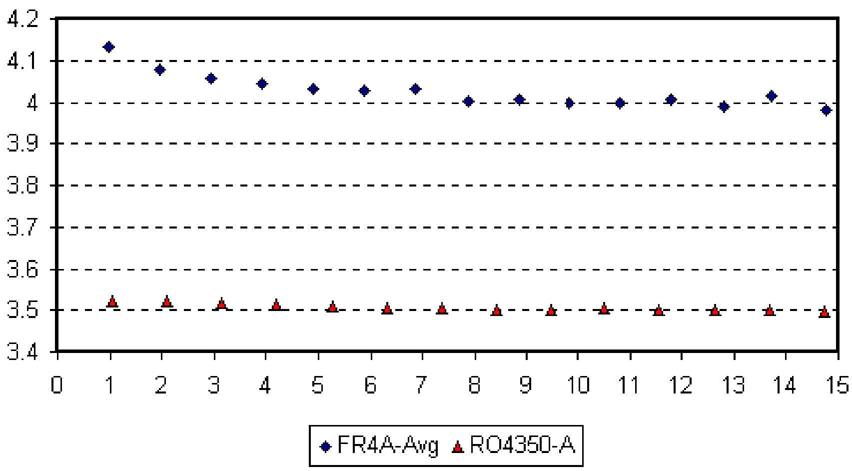
A digital signal of speed N bps is plotted against the fundamental (N/2 Hz), fundamental plus one harmonic and the fundamental plus 5 harmonics to provide a visual representation in Graph 1.



Graph 1. Sinusoidal representation digital signals

The total signal is made up of various signals having frequencies that are multiples of the fundamental (3w, 5w, 7w, 9w and 11w times). This is an important factor because as signal speeds start approaching RF frequencies (500 MHz and higher), the various harmonic signals will behave differently.

A signal traveling through a circuit board has a velocity that is dependent on the dielectric constant of the material , $v = \frac{c}{\sqrt{\text{Eeff}}}$ where c is the speed of light (3.0×10^8 m/sec) and Eeff is the effective dielectric constant of the medium. In the case of multilayer constructions, the effective dielectric constant is the dielectric constant of the material, while for double sided constructions it is somewhere in the 1/2Er <Eeff< Er range. This is due to the non-homogenous medium that exists between the PCB material and air. If the dielectric constant of the material changes versus frequency, then the fundamental and each harmonic will have different velocities. At the output, these signals will arrive at different times and not add up in phase, causing distortion of the square wave. Dielectric constant for FR4 and RO4350 material is plotted against frequency in Graph 2. The RO4350 material shows excellent stability as a function of frequency while FR4 demonstrates a noticeable change below 5 GHz.



Graph 2. Dielectric Constant vs. Frequency (GHz) tested via Long Stripline test method

A second factor that can affect signal integrity is circuit loss. Overall loss is mainly made up of material and conductor components. Both of these losses increase with frequency. Each harmonic, because it is operating at a different frequency, will be attenuated according to that frequency of operation. Testing of FR4 at 1 MHz provides values of 0.02 for dissipation factor while RO4350 tested at 10 GHz is 0.004. Calculating the overall signal attenuation for 0.020" 50 Ohm material, Table 1 quantifies the difference in signal output after traveling 10" on both RO4350 material and FR4 (double sided board). Overall increased loss in FR4 will add to the distortion of the pulse as it travels through the PCB.

Frequency, MHz	RO4350	FR4
100	98.0	96.5
300	95.7	91.5
500	93.7	87.1
700	91.9	83.0
900	90.3	79.2
1100	88.8	75.7

Table 1. Calculated attenuation at output of 10" long 50 Ohm impedance microstrip line on 0.020"

High frequency materials were initially designed to service the RF/microwave market because of the tight dielectric constant control, frequency stability and low material loss. As digital applications keep increasing in signal speeds, it is becoming evident that the materials available in the past, like FR4, can no longer provide the circuit performance needed for successful designs. The use of materials suited for high frequency use likeRO4350 laminates, can resolve the signal integrity problems being encountered by today’s high speed digital designers.

RO4350™ laminates are part of Rogers RO4000® family of high frequency materials.
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