John Coonrod
Dean Hattula

Rogers Corporation, Advanced Circuit Materials Division
john.Coonrod@rogerscorp.com

Biography:
John Coonrod is a Market Development Engineer for Rogers Corporation, Advanced Circuit Materials Division. John has been involved with the Printed Circuit Board industry for 24 years. About half of this time was spent in the Flexible Printed Circuit Board industry doing circuit design, applications, processing and materials engineering. John has also supported the High Frequency Rigid Printed Circuit Board materials made by Rogers for the past 10 years in regards to circuit fabrication, application support and electrical characterization studies of these materials. John holds a degree from Arizona State University in Bachelor of Science, Electrical Engineering.

Title:
New Developments in PCB Laminates

Executive Summary
There are many issues to consider when developing a new circuit material for the PCB industry. It is a given assumption that the new material must be compatible to standard PCB fabrication processes and that by itself is a daunting task. The desired properties of new materials today are also to be robust in multiple lamination cycles, repeated lead free solder reflow cycles, multilayer capable and have consistent electrical performance.

This paper outlines a new material which meets the needs mentioned and is also halogen free, very robust to thermal cycling and is a consistent mid loss material.

Theta® circuit materials (TH) is a new material and in this study it was compared to many other materials in the industry. Since there was no known material with the same properties, a direct comparison was not available. Comparison to industry known good materials for different properties were used for this study.

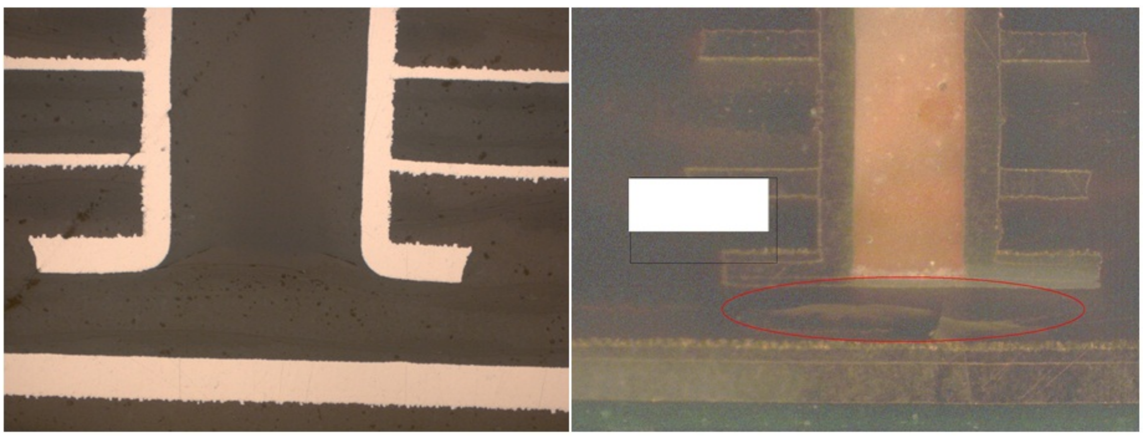
A solder float test was done with several materials, at 288C and the results shown below.

Material	Halogen Free	Cycle without delamination @ 288°C
TH	Yes	>10
Comp1	No	2
High Tg FR-4	No	5
Comp3	No	4
Comp2	No	8

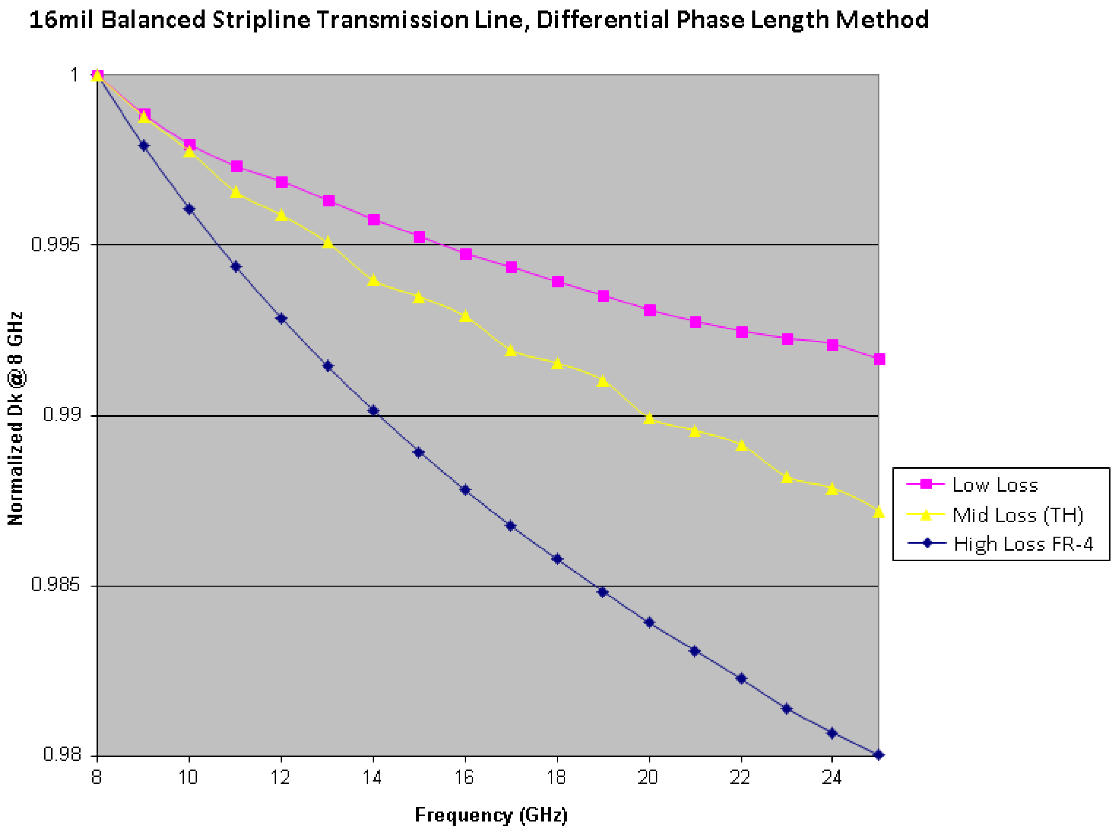
A challenging test vehicle was built and evaluated for several thermal properties. The multilayer board was a 28 layer carrier class router line card and the thermal results follow.

TMA Thermal Analysis	Results
Tg	185.4°C
CTE, alpha1	55.02°C
CTE, alpha2	260.4°C
CTE, 50-260°C	2.63%
T260	> 30 minutes

Another test of thermal process stability is the eyebrow crack test. This is done on a multilayer with several layers of stacked via's. When exposing the circuit to 288°C solder float, a circuit with good thermally robust material will typically withstand 3X cycles and the TH materials were good after 6X cycles. The pictures below shows the circuit made with the TH materials on the left, after passing 6X soldering cycles and another circuit to the right with different materials which failed after 3X cycles.



The electrical performance is also important and especially for high speed digital applications. In those applications dispersion can be important. Dispersion is how much the dielectric constant of the material will change with a change in frequency. The following graph shows dispersion curves of three materials.



Lastly the insertion loss or total loss of the circuit can be very important for new high speed digital applications. The following graph shows comparisons of three different materials, regarding insertion loss vs. frequency.

New Development in PCB Laminates

Dean Hattula, John Coonrod
Rogers Corporation
Advanced Circuit Materials Division

New Developments in PCB Laminates

Overview

PCB laminate properties

Thermal stability

Electrical performance

Summary

PCB Laminate Properties

Challenges of developing new PCB laminate technology

New laminates must conform to current PCB expectations

Must be:

- **Dimensionally stable (predictable scaling)**
- **Drill and route friendly (drill life, smear, speed/feed)**
- **Plated through hole compatible (desmear, prep)**
- **Reasonable lamination cycle (time, temperature, pressure)**
- **Multilayer capable**
- **Survive soldering**

PCB Laminate Properties

Ideally, all the previous PCB expectations and:

- **High layer count, Multilayer**
- **Sequential lamination capable**
- **Pass multiple lead-free soldering cycles**
- **Robust micro-via's**
- **Good CAF, IST and HATS performance**

Besides all of the previous demands, an ideal new material should have:

- **Halogen Free flame retardancy**
- **Good electrical performance**

....this is a lot to expect from one PCB material

PCB Laminate Properties

This material does exist:

Rogers Corporation's Theta® circuit materials (TH)

This material appears to be unique at this time

Due to the uniqueness, it is difficult for comparisons

This paper compares TH to other well know PCB materials

As a group, these comparative materials have attributes which can be used to verify thermal stability and electrical performance

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PCB Laminate Properties

Basic description of PCB materials used in this study:

Material ID	*Material description*
TH	Halogen free flame retardant, mid loss, thermally stable
Comp1	Standard flame retardant, mid loss, used extensively
High Tg FR-4	Standard flame retardant, high loss, used extensively
Comp2	Standard flame retardant, mid loss, thermally stable
Comp3	Standard flame retardant, mid loss, thermally stable

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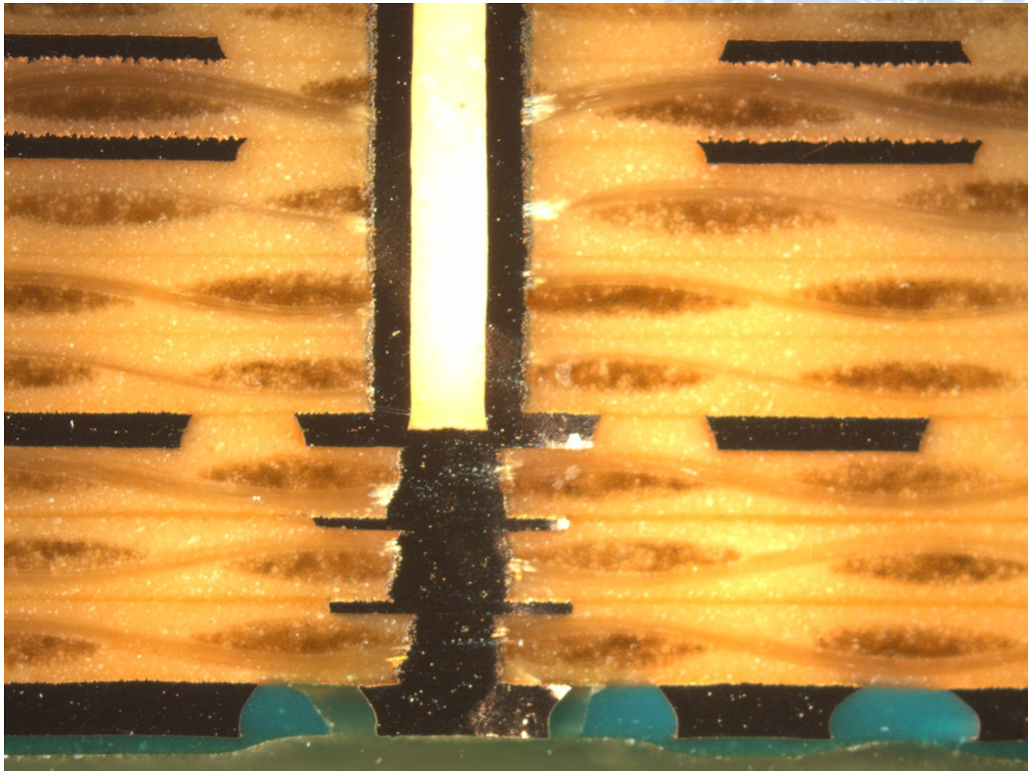
Thermal Stability

Material thermal properties:
- **Tg (glass transition temperature)**
- **CTE (coefficient of thermal expansion)**

Stacked-via's multilayer TH material after 10X lead-free solder reflow cycles



Circuit testing:
- **Multiple lead-free solder reflow testing**
- **288°C solder float testing**
- **Eyebrow crack testing**

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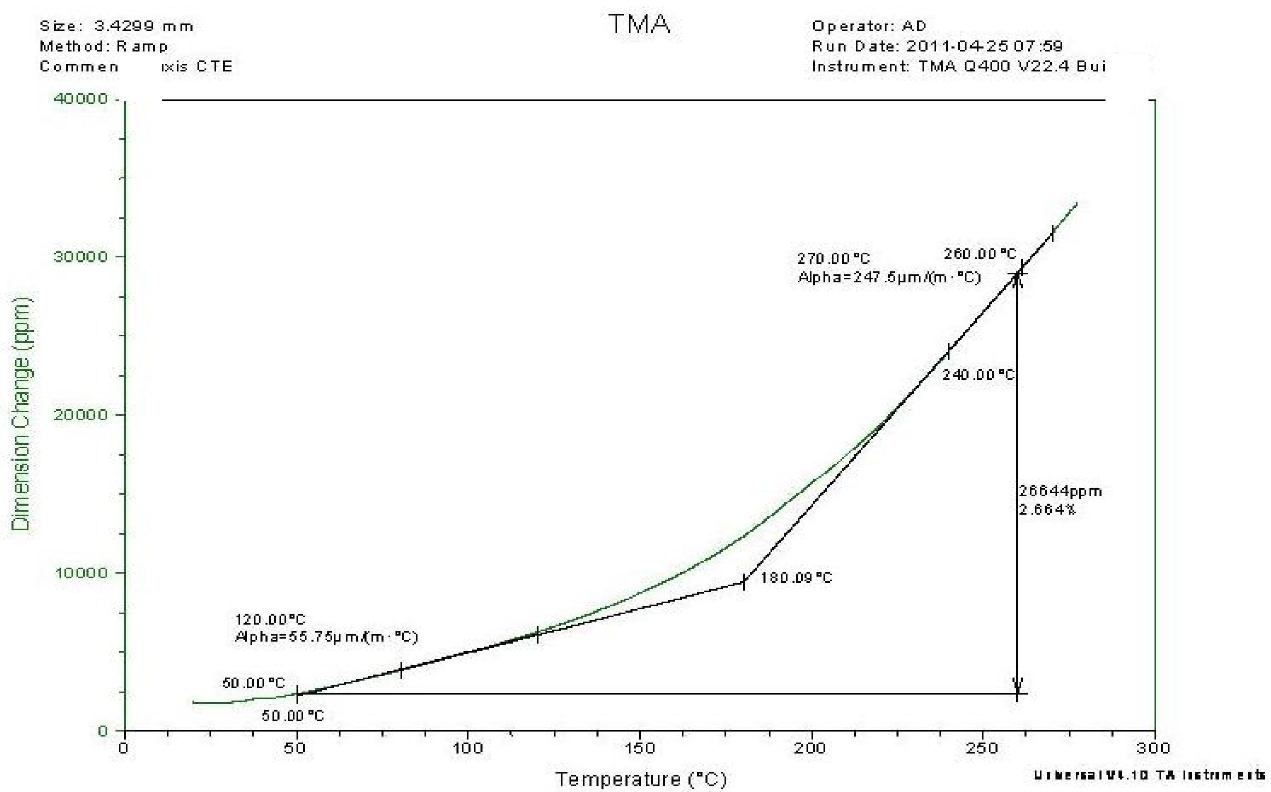
Thermal Stability

Material thermal properties:

- **Tg**
- **CTE below the Tg (alpha1) and Tg above Tg (alpha2)**
- **TMA curve displays comprehensive thermal performance**

TMA curve for the TH material



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Thermal Stability

Material thermal properties:

Material	*Tg(°C)*	*Td(°C)*	*CTE*
TH	180	390	50 ppm/°C
Comp1	210	350	70 ppm/°C
High Tg FR-4	170	300	3.9%
Comp2	200	360	55 ppm/°C
Comp3	176	360	35 ppm/°C

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Thermal Stability

288°C Solder float testing results of 3 copper layer pth stripline circuits

Material	*Halogen Free*	*Cycles without Delamination @ 288°C*
TH	Yes	>10
Comp1	No	2
High Tg FR-4	No	5
Comp2	No	4
Comp3	No	8

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Thermal Stability

Multilayer PCB thermal analysis results:

- **Carrier class router line card test vehicle**
- **28 layer PCB using 2oz copper planes and 3.68mm (0.145”) thick**
- **Circuit fabricated using TH materials**

TMA Thermal Analysis	*Results*
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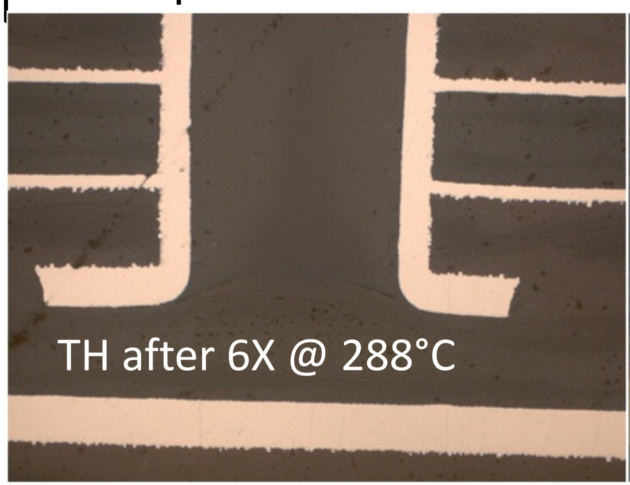
Thermal Stability

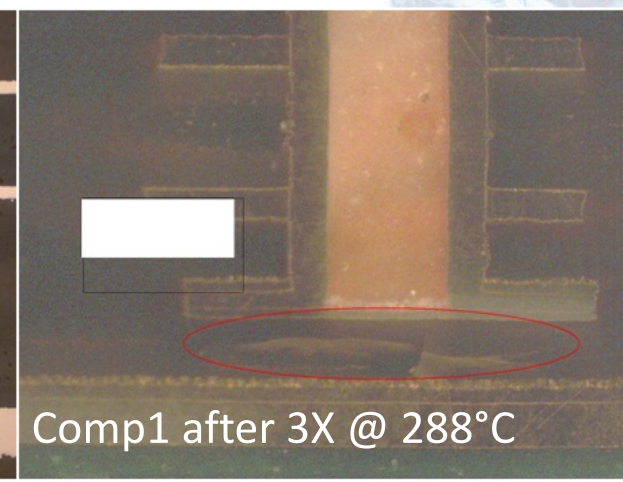
Eyebrow Crack testing

Used for thermal testing of complex via structures, stacked micro-vias

288°C solder float testing is difficult to pass one cycle for this test

Material	*Cycles to delamination @ 288°C*
TH	>6
Comp1	3





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Electrical Performance

Dielectric constant of PCB materials (Dk) decreases with frequency

Some materials decrease more than others over a range of frequencies

The change in Dk vs. frequency is called dispersion

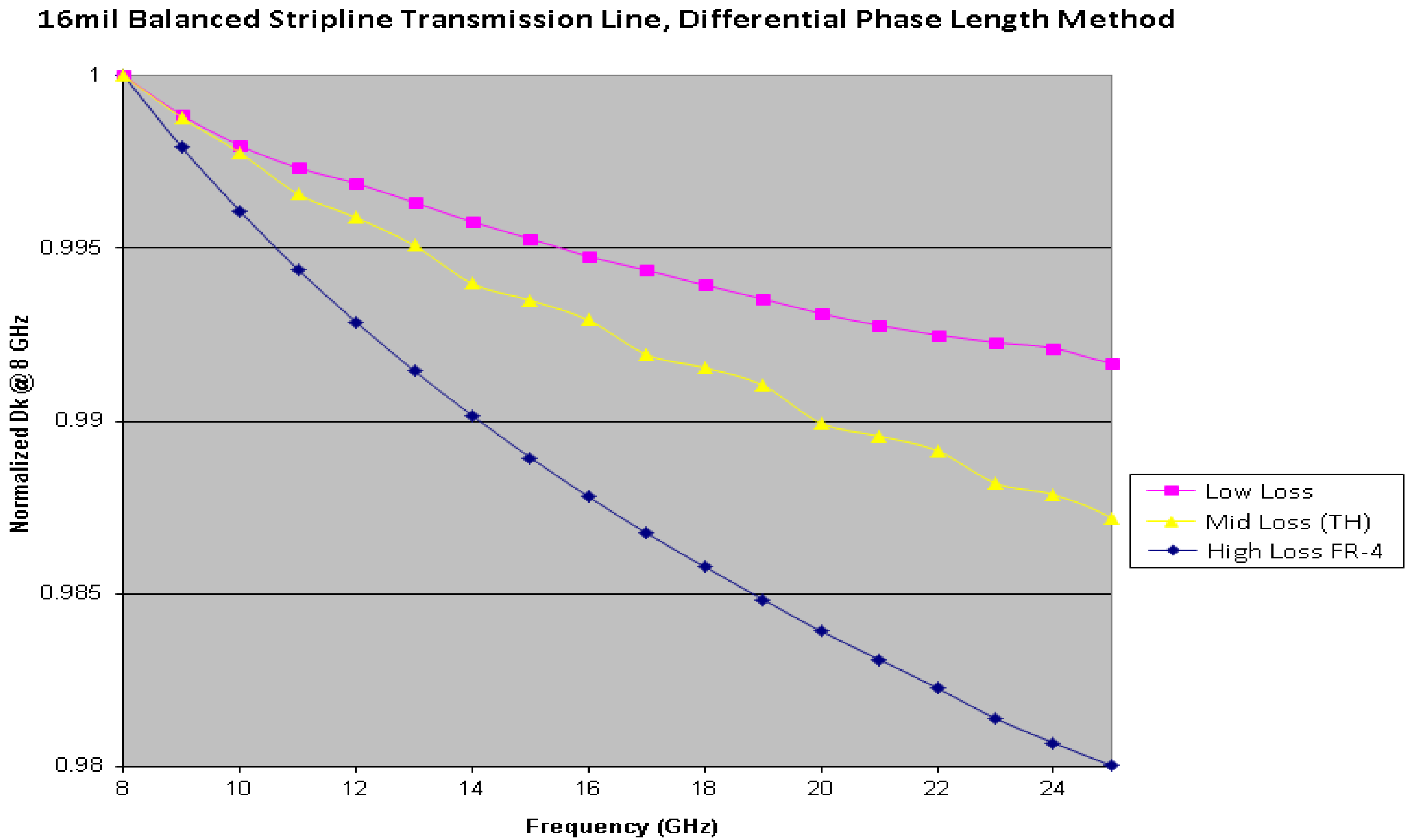
Dispersion can contribute to pulse broadening and narrowing of eye diagrams for digital waveforms

Materials with low dispersion are desired in high speed digital applications

New Developments in PCB Laminates

Electrical Performance

Dispersion comparisons



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Electrical Performance

Insertion loss is the total loss of RF energy for a circuit

Dissipation factor (Df) is a component of insertion loss

In general, the Df of PCB materials will increase with higher frequency

Some materials' Df increases more with frequency than other materials

Digital pulse amplitude is reduced with an increase in Df

It is desired to have low Df over a range of frequencies for high speed digital applications

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New Developments in PCB Laminates

Summary

Theta® circuit materials (TH):

- **Appear to be unique at this time**
- **Meet PCB material and circuit fabrication expectations**
- **Are halogen free flame retardant**
- **Have been shown to be thermally stable**
- **Demonstrated good electrical performance**

New Developments in PCB Laminates

Thank You